NON-NEUTRALIZING QUANTITY IN WORD-INITIAL CONSONANTS: ARTICULATORY EVIDENCE

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ABSTRACT

Stops in Swiss German dialects contrast in quantity in all word positions. As in most languages with consonant quantity contrast, geminate stops are produced with significantly longer CD than singletons in an intersonorant context. This holds word- and phrase-medially: e.g. [on**i** **tt**oːsə] 'without roar' vs. [on**i** **t**oːsə] 'without can'. Aspiration and voicing play no role in differentiating this contrast. Consequently, phrase-initially no CD cue distinguishes geminate from singleton stops. But do speakers utilize articulatory means to maintain the contrast in the absence of acoustic cues? In this study we investigated word-initial alveolar stops, focusing on their articulatory and acoustic properties in one phrase-initial and two phrase-medial contexts using EPG. Our results are twofold. First, CD and duration measures of contact of the articulators mirror each other within a phrase: after vowel-final and obstruent-final words geminates are longer than singletons. Second, phrase-initially, the contact data unequivocally establish a quantity distinction. This means that – even without acoustic CD cues for perception – geminates are articulated with substantially longer oral closure than singletons.

Keywords: word-initial geminate stops, phrase-initial, acoustic and articulatory correlates, EPG.

1. INTRODUCTION

In this investigation we look at the acoustic as well as articulatory properties of Swiss German word-initial voiceless geminate and singleton alveolar stops in different phrasal contexts. Earlier acoustic work (e.g. [3]) showed that the word-initial contrast was neutralized when the preceding word ended in an obstruent (cf. Table 1). Conversely, geminates had clearly longer CDs than singletons when the preceding word ended in a sonorant. Of course, phrase-initially, the acoustic CD measure was not available. The main question we ask here is whether in natural speech speakers make an articulatory distinction between phrase-initial geminates and singletons. A pilot EPG study reported in [4] had shown that this is the case and that phrase-medially the quantity distinction was neutralized in articulation in an obstruent context while it was maintained in a sonorant context. However, the data came from a single speaker, and the carrier sentences used were not ideal because they could potentially have had a phrase break at the crucial point of interest ([i ha elf __ ksaitt] 'I said eleven __'; [i ha t͡svai __ ksaitt] I said two __'). Our study avoided this by putting the target words with initial geminates and singletons inside a prepositional phrase where the connection to the preceding preposition was prosodically fairly tight. In normal speech, a prepositional phrase always constitutes a single phonological phrase.

By combining the articulatory and acoustic facts in this study, we expect that, within a phrase, the articulatory EPG measures go hand-in-hand with the acoustic CD measures. That is, if the preposition preceding the stop-initial word ends in a vowel, geminate values are longer; if the preceding word ends in an obstruent, geminate and singleton values are indistinguishable. However, in absolute phrase-initial position with no segmental context preceding, we expect that geminates have a longer oral closure than singletons in spite of the fact that CD information is missing.

2. METHOD

2.1. Test phrases and recording procedure

The sounds under investigation are the word-initial alveolar stops /tt t/. In our 60 target items (consisting of minimal and near-minimal pairs), these stops occurred in regular nouns in two different prosodic environments: (a) at the beginning of a phrase (henceforth *isolation context*) and (b) within a phrase. The phrase-medial condition had two segmental contexts: in the first the preceding word ended in an obstruent (henceforth *C context*), while

in the second the preceding word ended in a vowel (henceforth *V context*). Thus, each noun occurred in three distinct contexts: isolation, consonantal, and vocalic (Table 1).

Phrase-initial environment		
Ø /**tt**o:sə/	'roar'	*isolation context*
Ø /**t**o:sə/	'can'	
Phrase-medial environment		
/nɔ**x**/ /**tt**o:sə/	'after roar'	*C context*
/nɔ**x**/ /**t**o:sə/	'after can'	
/on**i**/ /**tt**o:sə/	'without roar'	*V context*
/on**i**/ /**t**o:sə/	'without can'	

Table 1: Prosodic and segmental contexts

In order to have a point of comparison and to make sure that whatever effect we would get is not due to unfamiliarity with the acrylic plate in the mouths of the speakers, we also recorded 42 nouns in which the alveolar stops /tt t/ contrast word-medially between vowels (e.g. /k͡xø:**tt**ər/ 'mutt', /k͡xø:**t**ər/ 'lure'). The full set of items presented to the speakers consisted of two thirds target words and one third fillers. All items had two syllables and carried main stress on the first.

Our subjects were given the custom-fitted palates a few weeks before the day of the recording in order for them to get used to talking as uninhibitedly and naturally as possible with this device in place. Also, they had at least 15 minutes "warm-up" time before the recording itself.

We recorded four female Swiss German speakers, aged between 27 to 42 years. They were prompted with the items in sets of the three different contexts on a computer screen, from which they read the phrases or individual words out aloud. After a short break the sets were read a second time. The EPG and audio signals were recorded onto the computer directly.

For the subsequent analyses we were able to use a total of 1671 tokens. 1385 had initial geminates and singletons (693; 692), 286 had medial ones (146; 140). Since we needed both the EPG and the audio data combined, we discarded tokens in which either of them was not usable. For example, for the sets in the isolation context, the subjects were asked to start with the mouth slightly open and the tongue not touching the palate such that the first contact of the articulators corresponded to the beginning of the word. In quite a number of cases this instruction was not met, and thus the EPG data was lost for our purpose. Also, tokens were not considered for analysis if there were hesitations, pauses, and/or external noise interferences at the crucial points of interest.

2.2. Electropalatography (EPG)

In the articulatory part of the study we were interested in how articulation of word-initial long and short voiceless stops changes as a function of their preceding context. The measure we used was the duration of contact during the constriction of the consonants between the two main articulators, namely the tip of the tongue and the anterior portion of the hard palate. To obtain these contact duration measures we used the electropalatography (EPG) system WinEPG (Articulate Instruments Ltd, Edinburgh, UK). In this system, 62 electrodes, embedded in a thin custom-fitted acrylic palate, are scanned for tongue-to-palate information at a sampling interval of 10ms. Simultaneously, the audio signal was recorded at a sampling rate of 48kHz via a Sennheiser MKH20P48 microphone. Data analysis of the articulatory duration measure was done with the Articulate Assistant software (Version 1.12), while analysis of the acoustic duration measure was done with the Multi Speech software (Kay Elemetrics, Version 2.2).

2.3. Measurement

For the analysis we annotated the EPG and audio files of our tokens such that the articulatory and acoustic duration measures could be extracted and statistically analyzed.

2.3.1. Articulatory parameter

The articulatory annotations were done with the Articulate Assistant software. The annotation marked the interval between the first and last EPG frames in which 80% or more of the electrodes in the front two rows indicated contact of the articulators. We call this measure the *duration of maximum contact* (DMC) (cf. [4]).

2.3.2. Acoustic parameters

In the Multi Speech software two measures were annotated in the audio signal. The first was CD. With the help of spectrograms, *Tag 1* was set at the offset of the waveform pattern of the preceding sound, *Tag 2* at the closure release. These annotations were made for the tokens in the phrase-medial contexts and for the ones with medial contrast. In the phrase-initial context *Tag 1* could not be set because there was no preceding sound.

The second acoustic measure, *voice onset time* (VOT), which we here restrict to designate the interval between the stop release (*Tag 2*) and the beginning of the regular waveform pattern (i.e. voicing) of the following vowel (*Tag 3*), corresponds to what Mikuteit & Reetz [6] have called the *after closure time* (ACT). Although CD is the most relevant cue also cross-linguistically, we include VOT as a measure because it has been shown to play a role in some languages with a quantity contrast (e.g. Cypriot Greek [8], Turkish [5]).

2.4. Statistical analysis

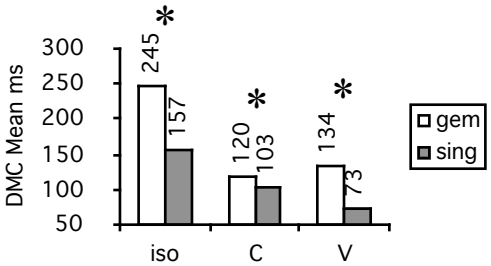
An ANOVA was performed for the words with initial and medial contrast separately (using the statistical software suit JMP; SAS Institute, 2003; Mac version 5.0.1.2) with the following factors: *speaker* (as random factor), *quantity* (singleton, geminate), and *condition* (vocalic, consonantal, isolation) in a Standard Least Square design using the Restricted Maximum Likelihood (REML) estimation. The dependent variables were *duration of maximum contact* (DMC), *CD* and *VOT*. Significance was computed at the 5% level, asterisks in the graphs and after the probability values indicate significant value differences.

3. Results

3.1. Articulatory parameter: DMC

For the DMC measure there were main effects for *quantity*, $F(1, 1370)=819.52$, $p <.0001$*, and for *condition*, $F(2, 1370)=1021.86$, $p <.0001$*. Articulator contact was 55ms longer for geminates (166ms) than for singletons (111ms). It was longest in the isolation context (201ms), shorter in the consonant context (111ms) and shortest in the vowel context (103ms). A post-hoc test revealed that geminate contact was significantly longer in all three contexts (Figure 1; Table 2).

Figure 1: DMC Least Square Means (ms) for *quantity* within *context*.



		LSM	diff	p
iso	gem	245	88	<.0001*
	sing	157		
C	gem	120	17	<.0001*
	sing	103		
V	gem	134	61	<.0001*
	sing	73		

Table 2: DMC Least Square Means (ms), difference (ms), and probability values for geminates and singletons in the three contexts.

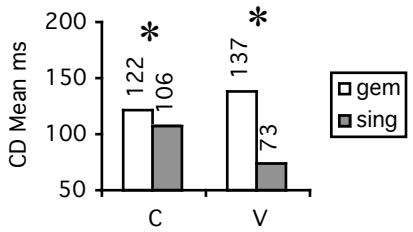
Also, the difference between geminates and singletons was significantly smaller in the C context as compared to both the V and isolation context (Prob>F <.0001*).

In comparison with the DMC values for word-medial geminates and singletons (195ms; 64ms), the initial contrast in the V context spanned a smaller range. In addition, the ratio of geminates to singletons was roughly 2:1, rather than 3:1. However, the difference displayed the same statistical level of significance for both value sets.

3.2. Acoustic parameters: CD and VOT

Like for DMC, there were main effects for the CD measure for *quantity*, $F(1, 931)=1297.3$, $p <.0001$, and for *condition*, $F(1, 931)=63.0$, $p <.0001$. CD was 40ms longer for geminates (130ms) than for singletons (90ms). In the C context (114ms), CDs were 9ms longer than in the V context (105ms). *Quantity* and *condition* interacted significantly: geminates had longer CDs than singletons both in C and V context (Figure 2; Table 3). Moreover, like for DMC again, the difference between geminates and singletons was significantly smaller in the C than in the V context (Prob>F <.0001*).

Figure 2: CD Least Square Means (ms) for *quantity* within *context*.



		LSM	diff	p
C	gem	122	16	<.0001*
	sing	106		
V	gem	137	64	<.0001*
	sing	73		

Table 3: CD Least Square Means (ms), difference (ms), and probability values for geminates and singletons in the two contexts.

The comparison to the CD values of medial geminates and singletons (196ms; 65ms) was virtually the same as in the articulatory data.

With respect to VOT, *quantity* and *condition* did not correlate, i.e. geminate and singleton VOT measures did not differ significantly within each context (Table 4).

		LSM	*diff*	*p*
iso	gem	19.8	0.9	0.0823
	sing	20.5		
C	gem	18.1	1.1	0.0547
	sing	17.0		
V	gem	19.3	0.7	0.2013
	sing	20.0		

Table 4: VOT Least Square Means (ms), difference (ms), and probability values for geminates and singletons in the three contexts.

There also was no main effect for *quantity*, $F(1, 1370)=0.14$, $p = 0.7075$, but there was an effect for *condition*, $F(2, 1370)=25.90$, $p <.0001$. VOTs overall were significantly shorter in the C context (17.6ms) than in both the V (19.7ms) and isolation (20.2ms) context (both $p <.0001$).

4. Discussion

The two central hypotheses we were entertaining were that (a) closure duration (and *not* VOT) and, therefore, articulator contact are the crucial acoustic and articulatory cues signaling the phrase-initial and word-initial geminate- singleton contrast, and (b) phrase-initial geminates would maintain longer contact although the acoustic correlate of closure duration was unavailable. These hypotheses were confirmed. First, VOT did not differ for geminates and singletons in any of the contexts. Thus, VOT is not used to make the phonological quantity contrast. This has been a consistent finding in all previous studies (cf. [3, 4, 7]). Second, in phrase-initial environment, where CD was not available, both stop types were articulated twice as long as in the vocalic context, with geminates showing significantly longer linguapalatal contact than singletons. Such articulatory strengthening in prosodically higher positions was also found for Korean in [2]. But what is most interesting for our purposes is the fact that geminates and singletons are so clearly distinguished (see Figure 1) when the main acoustic factor, CD, is missing. This finding confirms the pilot results in [4]. Third, in phrase-medial environments, the articulatory measure of oral closure corresponded to the acoustic measure of CD. As was found in [1, 3, 4], in the V context, geminates were double the length of singletons.

Furthermore, we had also anticipated a neutralization of the DMC and CD contrast in the C context. But here we found that the quantity contrast was not completely neutralized. Previous studies ([3, 4]) did not find any articulatory or acoustic length differences for geminates and singletons in this context. The magnitude of the difference, though, is far less and statistically significantly smaller than where a clear distinction was made: geminates were articulated longer by only 16%, vs. 81% in isolation and 56% in V context. It is rather questionable whether this small difference in absolute terms is still enough for the phonological contrast to be recoverable perceptually.

5. Conclusion

Our results showed articulatory maintenance of the quantity contrast in all contexts tested. Most strikingly, the voiceless geminates were distinctly longer than singletons even in phrase-initial context. Whether this articulatory difference can be exploited in perception is subject of further investigation.

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