

Glottalisation as a consequence of rhythmic structure? A study of different speech styles in Polish and German.

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Several phonetically oriented studies have reported a huge variability in the acoustic realisation of glottal stops and glottalisations. The inter- and intra-speaker variability has been observed in a number of languages and shown to be dependent on several parameters such as: phrasal position, accented vs. unaccented syllable, segmental context, speech rate, dialect, speaker's gender and others (cf. e.g.: Kohler (1994), Pierrehumbert (1994), Redi and Shattuck-Hufnagel (2001)).

The present work examines glottal marking, i.e. glottal stops and glottalisations of word-initial vowels in Polish and German; languages that differ with respect to their rhythmic structure and stress system (see below). We analyse two different speech styles: spontaneous and 'prepared' speech. The presence of glottal stops and glottalisations is studied depending on word accent, phrasal position and the following vowel. A question is posed as to what extent is glottal marking dependent on rhythmic structure of a given language.

Our material consisted of a spontaneous speech dataset comprising a) Polish task-oriented dialogues and b) recordings of spontaneous dialogues in German. We analysed word-initial vowels of four storytellers in the German corpus and four instruction givers in the Polish corpus. In total, 409 tokens were analysed in German (ca. 20 min.) and 141 in Polish (ca. 20 min) dialogues. We also investigated samples of 'prepared' speeches given by four German and four Polish prominent speakers (ca. 40 min. recording time for each language). 481 items in Polish and 885 items in German were analysed.

Rhythmic and phrasal structure was annotated using the Rhythm and Pitch system (Breen et al., 2010), largely theory-independent and based on perceptual native judgements. It allows for a more straightforward comparison of glottal marking between both languages in the context of prosodic structure. Minor phrasal boundaries were delimited and rhythmic prominences were marked in all datasets. The RaP minor phrase boundary is defined as a minimally perceptible disjuncture. It approximately corresponds to the ToBI break index '3' (Breen et al., 2010). Experts identified all rhythmically stressed vowels resulting in an annotation of rhythmic stress intervals (RSI). In the 'glottalisation phenomena' stage, word-initial vowels were identified and examined for the presence of (i) glottal stops, (ii) glottalisation, and (iii) vowels produced without any glottal marking.

We decided to analyse rhythmic structure independently since descriptions of especially Polish rhythmic strategies found in the literature are often impressionistic or inconclusive. The variability in style also warranted a direct analysis of rhythm. In order to characterise rhythmic structure a method based on coupled oscillators as described in O'Dell and Nieminen (2009) was used. Coupling strength between the stress and syllabic oscillator was estimated empirically by a) measuring the durations of RSIs, b) counting the number of syllables comprising the RSIs, c) estimating intercept and slope coefficients by means of linear regression with the number of syllables as predictors of RSI duration, d) calculating the coupling strength $r = a/b$ where a is the intercept and b is the slope. When a stronger tendency to regularise RSIs exists (stress oscillator dominates), syllables adapt more in duration in order to accommodate stress-timing and r is greater than 1. For syllable timing: $r < 1$. In this case, RSI duration variability depends more on the syllable count within a RSI; it increases vis a vis syllable count more cumulatively.

We obtained the following results:

1. In German, glottal marking occurs significantly more often (63.5%) than in Polish (41.6%; $p < .001$). Logistic regression with a multinomial dependent variable (no marking, glottalisation, glottal stop) was

used for analysis. The type of glottal marking in German and Polish is discourse dependent (both at $p < .001$). In particular, the glottal stop is produced more often in German prepared speeches than in dialogue (DE Speech 29% vs. DE Dialogue 10%). Glottalisation on the other hand, is used more frequently in spontaneous speech (DE Dialogue 62% vs. DE Speech 30.4%). In Polish, the glottal stop was more prevalent in speeches (PL Speech 22.6% vs. PL Dialogue 12%) while glottalisation was approximately equally frequent in both styles (PL Speech 29% vs. Dialogue 32%).

2. Polish and German differ with respect to the marking of unstressed vowels. Whereas in both languages (and both styles) the majority of stressed vowels are more often marked than unstressed, it is German that also relatively often marks unstressed syllables (ca. 59.5% of all unstressed word-initial syllables, while in Polish only 31%). In Polish however, the effect of stress is weaker than in German. Logistic regression with a binomial dependent variable (glottally marked vs. unmarked) showed that glottal marking in German is 3.3 times ($\exp \beta$) more likely to occur in a stressed syllable ($p < .001$) than in an unstressed one (1.7 in Polish, $p < .04$).
3. Another difference pertains to the glottal marking of phrase position. In both languages, the phrase-initial position is more often glottalised than the phrase-medial position ($p < .001$ for both Polish and German). However, binomial logistic regression showed that in Polish the effect is stronger: in Polish it is 2 ($\exp \beta$), while in German 1.5 ($\exp \beta$) times more likely that an initial position will be glottalised compared to a medial position (see also: Rodgers (1999)).
4. Finally, it could be shown that in both languages glottal marking is strongly dependent on the very nature (i.e. tongue height) of the marked vowel itself. Low vowels are more frequently glottalised than non-low vowels. This holds for both languages and both styles ($p < .001$ for both languages, PL: 72.6% of all low vowels, 41.85% mid, 29.7% high; DE: 82% of all low, 59% mid, 50.65% high).
5. Results of rhythmical structure analysis are as follows: the stress cycle dominates very strongly in German speeches (for speeches $r = 2$, $p < .001$). Polish speeches are also 'stress-timed' ($r = 1.35$, $p < .001$) however less than German speeches. In dialogues, Polish rhythmic structure is syllable-timed ($r = .81$, $p < .001$), German stays within a stress-timed range ($r = 1.8$, $p < .001$).

Our results suggest that glottalisation might depend on the type of timing structure in the studied language (cf. also Bissiri et al. 2011). German, with foot timing, mobile stress and relatively more variable syllable durations than Polish, marks initial-word boundaries very frequently. Polish in turn, with more even syllable durations and predictable penultimate stress does not mark the stress position and word-initial boundary but rather the phrase-initial boundary. While words are extra marked in German in order to facilitate rhythmic grouping, Polish uses glottalisation more sparingly, mainly to indicate a new phrase.

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