Devoicing of phonologically voiced stops in European Portuguese – a comparative production and perception study

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Previous studies on European Portuguese (EP) (Lousada et al. 2010; Pape & Jesus 2011) have shown that phonologically voiced stops often do not have a discernible burst, and thus hinder the perceptual system to extract VOT cues. Further, recent studies showed that, in contrast to other Romance languages (Shih et al. 1999), EP has a considerable percentage of devoicing of phonologically voiced consonants (Jesus & Shadle 2003; Pape & Jesus 2011). However, the time characteristics and actual distribution of the devoicing behaviour are not known yet.

The present study explores the behaviour of devoicing in production and the importance and interplay of voicing maintenance and duration cues for stop perception *in absence of a facilitating burst*. We conducted a comparative production and perception experiment. The production study aimed to (1) examine the actual voicing behaviour of voiced vs. voiceless stops, (2) shed light to the time-variant devoicing behaviour of phonologically voiced velar stops /g/, and (3) extract the language-dependent temporal cues like vowel durations, stop durations and voicing maintenance during stop closure. These parameters are then used to conduct the perception experiment to examine the effects of these different factors on voicing identification.

For the production study, we recorded 6 native EP speakers (acoustics and EGG; same dialectal region – setentrionais/durinses-beirões) who produced CVCV clusters consisting of velar stops /k g/ in four *vowel contexts* /i e o a/ in two different *consonant positions* (intervocalic *initial* and *medial* position) with identical speech rate (9 repetitions). We manually labelled the preceding and following vowel durations and stop durations. Further, we computed a time-dependent *voicing profile* consisting in 10 consecutive points spread evenly throughout the stop closure.

For the perception study, we recorded 32 native EP listeners from the same dialectal region. The speech material generated for the perceptual experiments (extensively described in Pape et al. 2012) consisted of biomechanically modelled stimuli acoustically synthesized with a parametric model of the vocal tract and a three-mass vocal fold model. We aimed to examine three different factors for the perception of stop voicing: *consonant duration*; *contextual vowel duration*; *voicing maintenance*. From all different levels of the three continua (3x3x7) we constructed a forced choice identification experiment where the listener had to identify each stimulus (/g/ or /k/). Further, we conducted a discrimination experiment to test for the listeners' ability to distinguish the voicing maintenance continuum.

For the production study, we found that devoicing of phonologically voiced velar stops was very high for all EP speakers, with higher devoicing for stops associated with open *vowels* (see figure 1). There was no significant difference on *consonant position*. *Devoicing* occurred very early during stop production and was maintained throughout the complete stop closure.

For the perception study, we found that all factors (*vowel duration, stop duration, voicing maintenance*) were significant for the listeners' decision whether the stimuli were judged voiced or voiceless. Further, we could show that perception of voicing in EP is strongly dependent on the ambiguity of duration values, with higher influence of the *stop voicing maintenance* cue for stimuli with ambiguous duration values (see Figure 2). The results of the discrimination experiment showed that nearly all EP listeners are able to distinguish voicing maintenance differences above certain thresholds.

A strong devoicing behaviour (production experiments) for all EP velar stops resulted in an increased perceptual sensitivity for the perceptual cue *voicing maintenance*.

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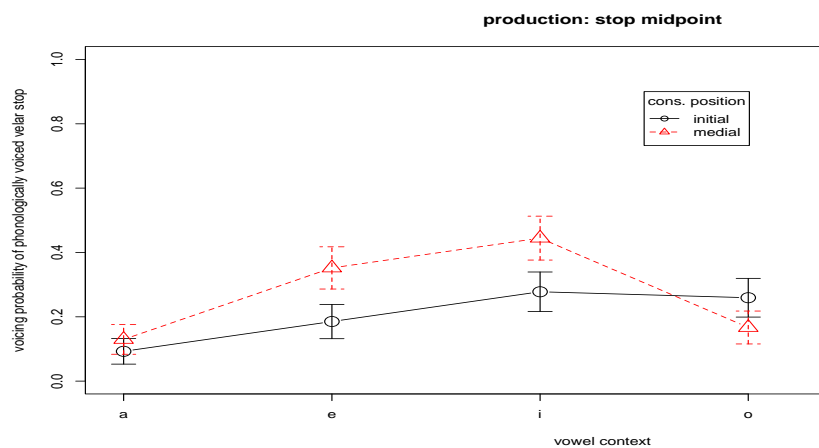
Figure 1: *Production study: voicing probability at the stop acoustic midpoint split by contextual vowel identity (x-axis) and consonantal position.*
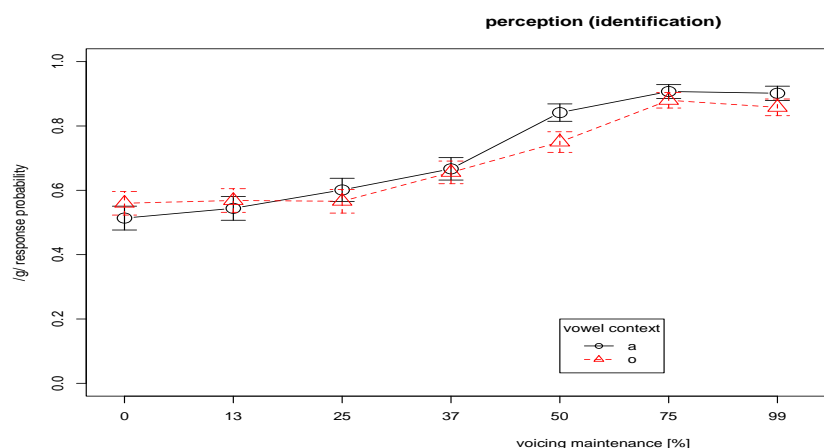

Figure 2: *Perception study: Probability of the listeners' "stop in stimulus is voiced" decision versus voicing maintenance during stop closure (x-axis) for stimuli with ambiguous duration values (vowel duration = 100 ms; stop duration = 125 ms).*