Title: Analysis of open quotient in Voiced Fricative production using EGG

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Introduction: Electroglottography (EGG) is a common method for providing noninvasive measurements of glottal activity. The object of this study was to characterise EGG based parameters, specifically the open quotient (OQ), during fricative production, and during the phones preceding and following the fricative in a carrier phrase. With the OQ measures we aim to quantitatively establish if the relatively weak voicing during the fricative production may be differentiated from the stronger voicing of the contextual vowel. Our long term goal is to understand the mechanisms by which voicing is initiated and maintained as a guide to improving strategies for initiating and maintaining voicing in patients with laryngeal impairment such as unilateral vocal fold paralysis (UVFP) (Pinho, Jesus, & Barney, 2009).

Methods: Data were collected from two adult female (JG and HV) and two adult male (LJ and RS) speakers of EP. None had reported speech, language or hearing disorders, and all had normal vocal qualities. They were assessed by an experienced Speech and Language Therapist using a standardised evaluation protocol (Jesus, et al., 2009). Speakers were recorded producing 51 utterances, including 9 isolated words containing the EP voiced fricatives /v, z, Z/, in initial, medial and final word position, and the same 9 words embedded in 51 different carrier sentences, that presented a variety of consonantal (taps, laterals, stops and nasals) and vocalic (close, open front and back vowels) contexts in real EP sentences (only vowel-fricative-vowel sequences were analysed). To analyse the EGG signal we built Matlab scripts based on the open source software "MOQ *interface*" (Henrich, Alessandro, Doval, & Castellengo, 2004; Henrich, Gendrot, Michaud, & Tuan, 2005). We used the method "DEGG DECOM", reported as the one that presented the best results compared to OQ measurements derived from the inverse-filtered glottal flow (Henrich, et al., 2004). These functions, developed for the singing voice (Henrich, et al., 2004), assume a quasi-periodic signal and were therefore considered to be more suitable for voiced fricative analysis.

To characterise the fricatives in terms of their production mechanisms, we analysed the OQ derived from the EGG signal during the steady state of the fricative and of the adjacent vowels. The strategy used to correlate and extract information from these different modes of speech production was based on average values calculated for the OQ within phone1 (vowel), phone2 (fricative) and phone3 (vowel).

Results: We calculated for each phone (1, 2 and 3) the average of the OQ values derived from EGG-DEGG. In cases where the peaks do not stand out clearly and the OQ cannot be calculated reliably, it does not make sense to talk of an OQ at all (Henrich, et al., 2005). Therefore, zero and nonsense OQ values (e.g., fundamental frequency derived from EGG, with values equal or greater than 400Hz) were not included in subsequent analysis. For both female and male data, an increase in the OQ values during fricative production (phone2) was observed when compared to OQ values from the adjacent vowels (phone1 and phone3), as shown in Table 1.

Table 1. Mean ± std (standard deviation) absolute values of OQ.

OQ (%)	♂(LJ & RS)			♀ (JG & HV)		
phone	*1*	*2*	*3*	*1*	*2*	*3*
/v/	52 ± 6	62 ± 7	55 ± 7	53 ± 9	61 ± 7	53 ± 8
/z/	51 ± 7	59 ± 9	53 ± 8	50 ± 9	59 ± 7	56 ± 9
/Z/	53 ± 10	65 ± 9	57 ± 9	53 ± 9	63 ± 8	55 ± 8

Discussion: There was a small increase in the OQ values during the fricative, relative to that of the adjacent vowels. We can hypothesise that a more physically efficient voice is related with a decrease of the OQ value during the production of vowels (Howard, 1995). Changes observed in the EGG waveform during fricative production, thought to result from the rise in the supraglottal pressure due to a supraglottal constriction (Rothenberg & Mahshie, 1988), may be useful in a definition of weak voicing (Pinho, Jesus, & Barney, 2009).

Some differences in the OQ values were also observed for different places of articulation: alveolar (/z/) fricatives showed OQ values slightly lower (59±9) than labio-dentals (/v/) and postalveolars (/Z/) (61-65±9). Further work is needed to relate these results to vocal fold mechanics.

In **future work** we plan to extract the OQ from the inverse-filtered glottal flow (a signal we simultaneously acquired during data collection) in order to extend our study of OQ to UVFP patients where EGG cannot be reliably collected.

References

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