On the link between glottal vibration and sonority
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In the simplest view of the source-filter theory, the source (voicing) and the filter (articulation) are treated as completely orthogonal. In particular, voicing is predicted to be the same for all voiced segment types, regardless of their oral constriction. At the same time, investigations into source-filter interactions have found that the degree of oral constriction can affect the ability to initiate and sustain voicing (Stevens 2000). In the present experimental study, we more thoroughly investigate whether effects of source-filter interactions distinguish among voiced consonants and vowels of varying degrees of vocal tract constrictions, along the lines suggested by Stevens (2000). We then consider whether these differences among voiced segment types correlate to standard notions of sonority, an important principle underlying explanations for various phonological phenomena (e.g., assimilation, syllable structure phonotactics). Adequate characterization of its physical manifestation, and quantification thereof, is currently debated, but so far does not make a connection to inherent source-filter dependencies beyond ascribing some role to voicing in general (Parker 2002). Other attempts to forge a link between sonority and articulatory factors have divorced glottal state (source) from aperture/constriction (filter) (e.g., Miller 2012). The present investigation thus allows us to explore the implications of detailed characterizations of voicing for an articulatory basis of sonority.

We replicated and extended Mittal et al. (2014), a prior investigation into the effects of vocal tract constriction on glottal vibration. We recorded and took acoustic and glottal measurements from fourteen consonants representing the span of the sonority hierarchy: (1) approximants ([j, w, l, ʎ]); (2) trill and tap ([r, ɾ]); (3) nasal ([n]); (4) fricatives ([ð, ɣ, ʃ, z]); and (5) affricates and stop ([ðʒ, ɣʒ, d]). Affricates were segmented as stop closure (cl) and fricative release (rel). In a second task, we recorded and measured seven vowels: (1) front unrounded ([i, e, a]); (2) front rounded ([y, ø]); and (3) back rounded ([o, u]). Data collection was performed using a Glottal Enterprises EG2-PCX electroglottograph to record an EGG signal, and a high-quality B&K microphone to record the simultaneous audio signal, both at 22kHz. Consonants and vowels were repeated three times each in [aCa] and [wV] frames respectively. All fourteen study participants were trained phoneticians and fluent speakers of English.

Hand-aligned Praat TextGrids (Boersma and Weenink 2015) were created by identifying intervals in which at least three glottal pulses of voicing were maintained throughout the target constriction. After eliminating mispronounced and insufficiently voiced tokens, a total of 774 tokens were analyzed. Acoustic and glottal measurements were extracted automatically from the segmented speech and EGG signals using VoiceSauce (Shue et al. 2011) and EggWorks (Tehrani 2012) software. We rely on the Contact Quotient (the proportion of a complete vibratory cycle for which vocal fold contact area is greater than a specified threshold) from EGG signals and a Strength of glottal Excitation measure (the relative amplitude of impulse-like excitation derived from the instant of significant excitation of the vocal-tract system during production of speech; Murty and Yegnanarayana 2008). A lower Contact Quotient (CQ) indicates a more spread glottis (breathier voicing), and a lower Strength of Excitation (SoE) indicates less acoustic energy from voicing.

Our null hypothesis is that there should be no difference in CQ or SoE across voiced segments, with the exception of voiced fricatives; the glottis during voiced fricatives is more spread due to increased airflow requirements and a lower CQ is independently expected. Results indicate that not only do voiced fricatives have lower CQ, but a range of values of both measures is observed across different segment types. Although fricatives have a lower CQ than voiced stops, they nonetheless have a higher SoE value, indicating more voicing energy. Compared to nasals, liquids and glides, voiced stops also have lower CQ and SoE values. Vowels, on the whole, have the highest CQ and SoE values, indicating strongest voicing energy and most glottal contact. From the perspective of sonority, while CQ and SoE together accurately capture the ends of the sonority scale, they make independent distinctions within the major segmental categories, with CQ...
making distinctions among obstruents and SoE among sonorants.

We also examined the time-course of CQ and SoE during voicing in segments with full closures (trill and stop closures), which could make voicing maintenance difficult. CQ and SoE are relatively sustained across the entire trill, reflecting fairly consistent energy in voicing. Stop closures, however, have a sharp decrease in both measures, reflecting the difficulty in maintaining voicing during these closures: breathier voicing and less acoustic energy as voicing dies out. These results therefore support the observation that trills are more sonorant-like than stops despite the repeated articulatory contacts in a trill.

The results of our study thus indicate that CQ and SoE, contrary to the null hypothesis, do vary depending on the degree of oral constriction, exemplifying effects of the filter on the source. Additionally, CQ and SoE together separate segments along the phonological sonority scale, with each measure making distinctions in one part of the scale: CQ for obstruents and SoE for sonorants.

![Figure 1: Scaled CQ by Scaled SoE by segment. Size of symbol indicates standard deviation.](image)

**References**


