

Title: Sensitivity to the amount of aspiration noise for the perception of breathiness

A study by Shrivastav and Sapienza (2006) on the perception of breathiness reported difference limens of 10 to 20 dB in the amount of aspiration noise added to a glottal source. In this study, the amount of aspiration noise co-varied with other glottal waveform variables (e.g., open quotient, spectral tilt). The present study measured breathiness discrimination as a function of the amount of aspiration noise; the effects of other glottal waveform parameters were controlled. To facilitate comparisons with future studies on acoustic correlates of breathiness, a sensitivity measure based on detection theory (d') was obtained using a two-alternative forced choice (2AFC) task.

The stimuli were synthetic, six-formant /æ/ and seven-formant /i/ vowels modeled after utterances from the Hillenbrand vowel database (Hillenbrand, Getty, Clark and Wheeler, 1995). The vowels were produced within 'h-V-d' words by three male speakers, for a total of six vowels (two vowels by three speakers). Duration estimates, and formants and fundamental frequency estimates at eight time points during the vowel duration were used to synthesize the experimental stimuli using the cascade branch of a Klatt synthesizer (Praat software; Boersma and Weenink, 2015). Glottal waveform settings for all stimuli included an open quotient of 0.4, and voicing amplitude set to the estimated intensity contour of each recording, ranging between 82 dB to 87 dB and averaging 85 dB. All other glottal parameters were set to default values, except for the level of the aspiration noise (AH), which was set to either 50 dB (standard stimuli), 52 dB, or 54 dB.

Listeners completed five blocks of trials for each vowel. Within each trial, listeners heard a sequence of two intervals. One of the two intervals contained a standard stimulus (that is, one of the six vowels synthesized with a 50 dB AH level); in the other interval, the same vowel (comparison stimulus) had an AH value of either 52 or 54 dB. Listeners were asked to select the interval corresponding to the stimulus that sounded "breathier". Stimuli were presented at a comfortable listening level through headphones. Listeners included both expert and naive listeners.

Sensitivity, measured as d' values, consistently increased as a function of AH level, relative to the 50 dB standard; in other words, sensitivity was higher for the 54 dB than for the 52 dB stimuli. Sensitivity to AH level changes did not differ between the two vowels. If a d' value of 1 (moderate sensitivity) is taken as the empirical threshold for discriminating a change in AH level, just noticeable differences (JNDs) for breathiness were equal to about 2 dB for five out of six vowels. These JNDs are much smaller than those reported by previous

studies and suggest that listeners have high sensitivity to changes in the amount of noise present in the glottal waveform. The possible reasons for these differences and the acoustic cues associated with breathiness discrimination will be discussed.

Boersma, P., and Weenink, D. (2015). Praat: doing phonetics by computer [Computer program]. Version 5.4.19, retrieved 22 September 2015 from <http://www.praat.org/>.

Hillenbrand, J., Getty, L. A., Clark, M. J., and Wheeler, K. (1995). Acoustic characteristics of American English vowels. *The Journal of the Acoustical Society of America*, 97(5), 3099-3111.

Shrivastav, R., and Sapienza, C. M. (2006). Some difference limens for the perception of breathiness. *The Journal of the Acoustical Society of America*, 120(1), 416-423.