

Relation between Interaural Envelope Delay Sensitivity and Speech Envelope Statistics in Electric Stimulation

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In normal hearing, interaural time differences (ITDs) at low frequencies are considered important for sound localization and spatial speech unmasking in the lateral dimension. It has been shown that highly salient lateralization cues can also be provided by encoding the ITDs in appropriately shaped envelopes of high-frequency sounds.

In this study, we measured the sensitivity of seven bilateral cochlear-implant (CI) listeners to envelope ITD. In particular, we were interested in the independent perceptual contribution of different features of the ongoing envelope modulation on left/right discrimination thresholds. The binaural stimulus consisted of a 1515-pulse/s pulse train modulated with a 27-Hz trapezoidal envelope, presented at an interaurally pitch-matched electrode pair. The modulation trough level corresponded to the listener-specific absolute threshold for an unmodulated, 1515-pulse/s pulse train. The slopes were linear on a linear current scale. We systematically varied the off time (the silent interval in each modulation cycle) and the slope of the trapezoid flanks. As a special case of modulation with infinitely steep slopes and maximum possible off time we also tested a 27-pulse/s pulse train. The peak levels were adjusted to obtain constant loudness and centralized auditory images across all conditions.

Increasing the off time up to 20 ms improved sensitivity. While increasing the slope did not show a systematic effect, the effect can be anticipated for shallower slopes than those tested. Our restriction on the modulation depth prevented testing such shallow slopes. The sensitivity for the unmodulated pulse train was considerably higher than that for the best-performance condition with trapezoidal modulation, which we attribute to the larger peak level.

The results were compared with the statistics of envelope parameters extracted from German and English speech recordings processed by a simulation of a typical envelope-based CI strategy. For the off-time analysis, we used a definition based on the silent interval close to the envelope peak level [Dietz et al., 2013, J. Acoust. Soc. Am. 133, 1-4]. The comparison showed that while CI-processed speech already contains some potentially perceivable envelope ITD cues, there is room for enhancing those cues by signal processing, particularly with respect to the off time.

Providing more salient envelope ITD cues might contribute to sound localization and source segregation in situations where pulse-ITD cues are ambiguous, disrupted by room reverberation, or implicitly not encoded.