Support for the frequency dominance region explanation of lateralization of larger than physiologically possible interaural time differences

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Abstract

Binaural processing allows humans to localize sound sources in the horizontal plane and communicate in noisy environments at exquisite levels. Underlying these abilities is the computation of interaural time differences (ITDs) and interaural level differences (ILDs). Improvements to binaural models (including understanding the distribution and operation of ITD-sensitive neurons across frequency and interaural delay) are critical in determining how the binaural system processes realistic and complex sounds like speech. Furthermore, this type of knowledge can ultimately help individuals who struggle with these tasks, such as those with hearing impairment.
Across-frequency binaural models have been developed based on data from highly controlled headphone experiments that measured perceived intracranial lateralization (how far to the left or right a sound is perceived inside of the head) for narrowband noises that were varied in bandwidth and included ITDs that were larger than the human physiological range (e.g., 1.5 ms). One widely accepted binaural model for explaining across-frequency ITD processing of such stimuli utilizes three components: (1) a weighting function in frequency, with the highest weight around 600-700 Hz (i.e., the "dominant region"); (2) a weighting function in ITD, with the highest weight around 0 ms (i.e., "centrality"); and (3) an across-frequency processing operation where weighting is increased by have peaks of the interaural cross-correlation function aligned across frequency (i.e., "straightness"). Previously, it has been purported that the critical model components were straightness and centrality. One shortcoming of the previous experiments, however, is that the center frequency was fixed and the bandwidth changed the highest frequency in the stimulus. An alternative explanation and the hypothesis tested here is that the critical model component is the frequency dominance region. Therefore, we redesigned this experiment to avoid the previous stimulus confound.

Young normal-hearing listeners were tested using an intracranial lateralization task. Narrowband noises with a fixed upper frequency boundary of 500, 600, 700, or 800 Hz and bandwidths of 50, 100, 200, or 400 Hz were presented to the listeners. ITDs of 0, ±0.5, ±1, ±1.5, or ±2 ms were applied. Twenty trials were collected for each condition. Control pure tone data were also collected.

The results showed that, for most conditions, intracranial lateralization did not change as bandwidth increased and it was well predicted by the highest frequency in the stimulus. Such

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a result provides support for the frequency dominance explanation, not the straightness-centrality explanation; in other words, there seems to be little need for an across-frequency processing operation to explain the results. Furthermore, since these new data appear to be best explained without across-frequency processing and no need to invoke a model with binaural delays lines that are larger than the human physiologically plausible range of ITDs, they work towards reconciling longstanding disagreements about interpreting such data in the field.