Three-dimensional sound localization of nearby sources in echoic rooms

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Abstract

Sound localization is typically examined separately in the three spatial dimensions of azimuth, elevation, and distance. While multiple studies have examined localization performance for sources varying simultaneously in two of the dimensions, very few have considered sources varying simultaneously in all three dimensions. Santarelli et al. (J. Acoust. Soc. Am. 105, 1024, 1999) performed an experiment in a reverberant classroom in which subjects were asked to point to the perceived position of broadband-noise sound sources presented from a random location in the right hemifield within 1 m of the listener's head. However, while the source locations varied simultaneously in all three dimensions and the responses were recorded in 3-D, prior analysis only considered each spatial dimension separately. Here, a new analysis examines how localization response biases varied with source location simultaneously in all three dimensions.
Directional 2-D localization performance was examined simultaneously in azimuth and elevation by projecting the data onto the surface of a unit sphere with the observer at the origin and separately considering near (distance $<$ 50 cm) and far (distance $>$ 50 cm) source locations. After binning the data for the two distances into 25 directional bins, the mean stimulus and response directions were determined using the cartesian coordinates, while mean distances were determined on a logarithmic scale.

Cone-of-confusion error analysis showed relatively large error rates, with approximately 20% of responses falling into a different quadrant than the source quadrant, out of which 87% were front-back, 6% up-down, and 6% front-back & up-down confusions, approximately independent of the distance. Directional errors in responses varied in a complex way across the three dimensions. For instance, the largest errors occurred for sources behind and below the subject's head, with responses biased medially and downwards for near sources, while reversing to an upwards bias for far sources. For near sources only, there was a general upwards bias trend. For both near and far sources close to the horizontal plane and away from the medial vertical plane, a lateral bias was observed. Additional analysis will consider dispersion of responses, biases within and across subjects, and comparisons to anechoic performance. These results provide a normative characterization of 3-D localization performance for nearby sources in reverberation, showing that errors can be larger than observed previously when stimuli vary simultaneously in all three dimensions.
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