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Publication date: 2019

Document Version
Publisher's PDF, also known as Version of record

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Citation (APA):
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Introduction

Much research has been conducted on the integration of information of binaural lateralization cues over frequency. Macpherson and Middlebrooks (2002) showed that listeners weight interaural time differences (ITDs) more strongly at low than at high frequencies, while interaural level differences (ILDs) are weighted more strongly at high frequencies. These findings were coherent with the proposed duplex theory of Lord Rayleigh (1907). Other studies have confirmed that binaural information is integrated over frequencies in the binaural system to lateralize sounds (Buell and Hafter, 1991; Woods and Colburn, 1992) using a spectral weighting function (Ahrens et al., 2015). While these studies investigated the weighting of information over frequency in horizontal plane, no such weighting exists for vertical (elevation) localization. In this study, we aimed to investigate if certain frequency areas are perceptually weighted higher than others. Furthermore, predictors of perceptual weights in the head-related transfer functions (HRTFs) were investigated.

Methods

- 11-2ACP (above/below decision task)
- 7 individual elevation HRTFs (±60°–20°–60°)
- Azimuth angles (θ) at 15° and 45° (left)
- Wide and narrow frequency range (0.95-15.5kHz, 3.2-12.4 kHz)
- Stimuli presented via equalized open headphones (Sony PFR-V1)
- 11 normal-hearing participants

Results are a perceptual extension to directional/boosted bands (Blauert, 1997) and a proposal for weighting function for computational models (e.g. Zonooz et al., 2019).

Perceptual elevation weighting

- The frequency band of 6.4 kHz is perceptually weighted largest with respect to elevation, however the intra-subject variation is large
- The magnitude variation predictability over the elevations of the individual HRTFs correlates with the perceptual weights
- A narrow frequency range seems to lead to less reliable perceptual weighting results

Discussion & Conclusions

- The frequency band of 6.4 kHz is perceptually weighted largest with respect to elevation, however the intra-subject variation is large
- The magnitude variation predictability over the elevations of the individual HRTFs correlates with the perceptual weights
- A narrow frequency range seems to lead to less reliable perceptual weighting results
- Results are a perceptual extension to directional/boosted bands (Blauert, 1997)
- Step towards a weighting function for computational models (e.g. Zonooz et al., 2019)

Acknowledgments

We would like to thank the complete Audio Team from the Facebook Reality Labs, particularly Ravish Mehra, Philip Robinson and Henrik Hasager. Thank you to Isaac Engel for the headphone equalization software.

References


Relation between perception and HRTF features

- Azimuth angle of 15° to the left.
- Azimuth angle of 45° to the left.

Fig. 1: A) The listeners were instructed to rate if a test stimulus was perceived above/below a reference stimulus. The test stimulus contained seven individual HRTFs from seven elevations. The reference stimulus contained the same frequency bands but all with an elevation of θ=0°.

Fig. 2: Perceptual weights calculated from a multinomial regression analysis for the wide frequency range condition. The grey lines represent the individual results from the 11 listeners and the blue line the mean over the listeners.

Fig. 3: A) Perceptual weights calculated from a multinomial regression analysis for the narrow frequency range condition. The grey lines represent the individual results from the 11 listeners and the green line the mean over the listeners.

Fig. 4: A) Magnitude at the ipsilateral ear for a azimuth source direction of 45° with respect to the source elevation in two single frequency bands. Each symbol represents a listener. B) Correlation analysis between the perceptual weight and the correlation coefficient of elevation and magnitude.