Perceptual weighting of elevation localization cues across frequency

Ahrens, Axel; Brimijoin, Owen

Publication date: 2019

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

Citation (APA):
Perceptual weighting of elevation localization cues across frequency

Axel Ahrens1,2 & Owen Brimijoin3
1Hearing Systems, Technical University of Denmark, Lyngby, Denmark
2Facebook Reality Labs, Redmond, Washington
3aahr@dtu.dk

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 the horizontal plane, no such weighting exists for vertical (elevation) localization. Many 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).

Methods

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 1 kHz wide noise bands with randomly permuted individual HRTFs from seven elevations. The reference stimulus contained the same frequency bands but all with an elevation of 0°. An example of a stimulus is shown in light grey and the reference stimulus in dark grey. Each stimulus was 300ms in duration. The procedure was repeated 445 times for each condition.

B) Above/Below decision task.

Perceptual elevation weighting

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.

A) Azimuth angle of 15° to the left.

B) Azimuth angle of 45° to the left.

Relation between perception and HRTF features

Fig. 3: 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 blue line the mean over the listeners.

A) Azimuth angle of 15° to the left.

B) Azimuth angle of 45° to the left.

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. Zoonooz 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


Lord Rayleigh (1907) On our Perception of Sound Direction. Philosophical Magazine 13, 214


Correlation analysis between the perceptual weight and the correlation coefficient of elevation and magnitude.