# Monoaural and Binaural Sound Source Localization in the Median Plane

Timo Oess,[1,2] Heiko Neumann,[2] Marc O. Ernst[1]
[1]Applied Cognitive Psychology, Ulm University, Germany
[2]Institute of Neural Information Processing, Ulm University, Germany

## Introduction

- The Auditory system can localize sound sources in the vertical plane based on mono or binaural signals [1].
- Spectrum of a perceived signal is compared to a previously learned map of elevation spectra.

Yet unsolved problem in vertical sound localization:
- Separately formed map of left/right ear or
- already binaural map formation

Baden-Württemberg Stiftung
WIR STIFTEN ZUKUNFT

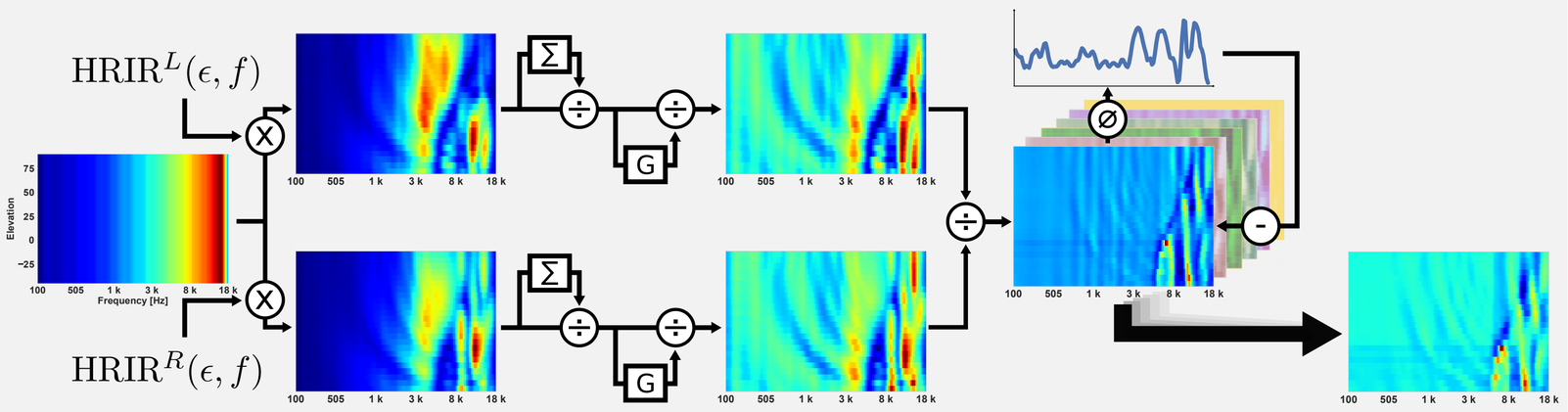
## Methods

- HRIRs of 16 subjects from CIPIC database [2]
- 20 different sound types including white noise and natural sounds
- 25 different elevations ranging from -45° to +90° in 5° steps and 0° azimuth
- Monoaural $S^{\{R,L\}}$ and binaural $S^{BIN} = S^L / S^R$ signals can be localized by looking for the elevation with maximum correlation between input and map.

1) $S_t^s(f) = HRIR^s(\epsilon, f) \cdot X_t(f) + \varepsilon$

3) $\hat{S}_t^s(f) = \frac{\bar{S}_t^s(f)}{(\bar{S}_t^s(f) * G^{Gauss}(\sigma = 1))}$

4) $FB(t) = \frac{1}{b} \sum_{i=0}^{b} \hat{S}_t(f, \epsilon_i)$

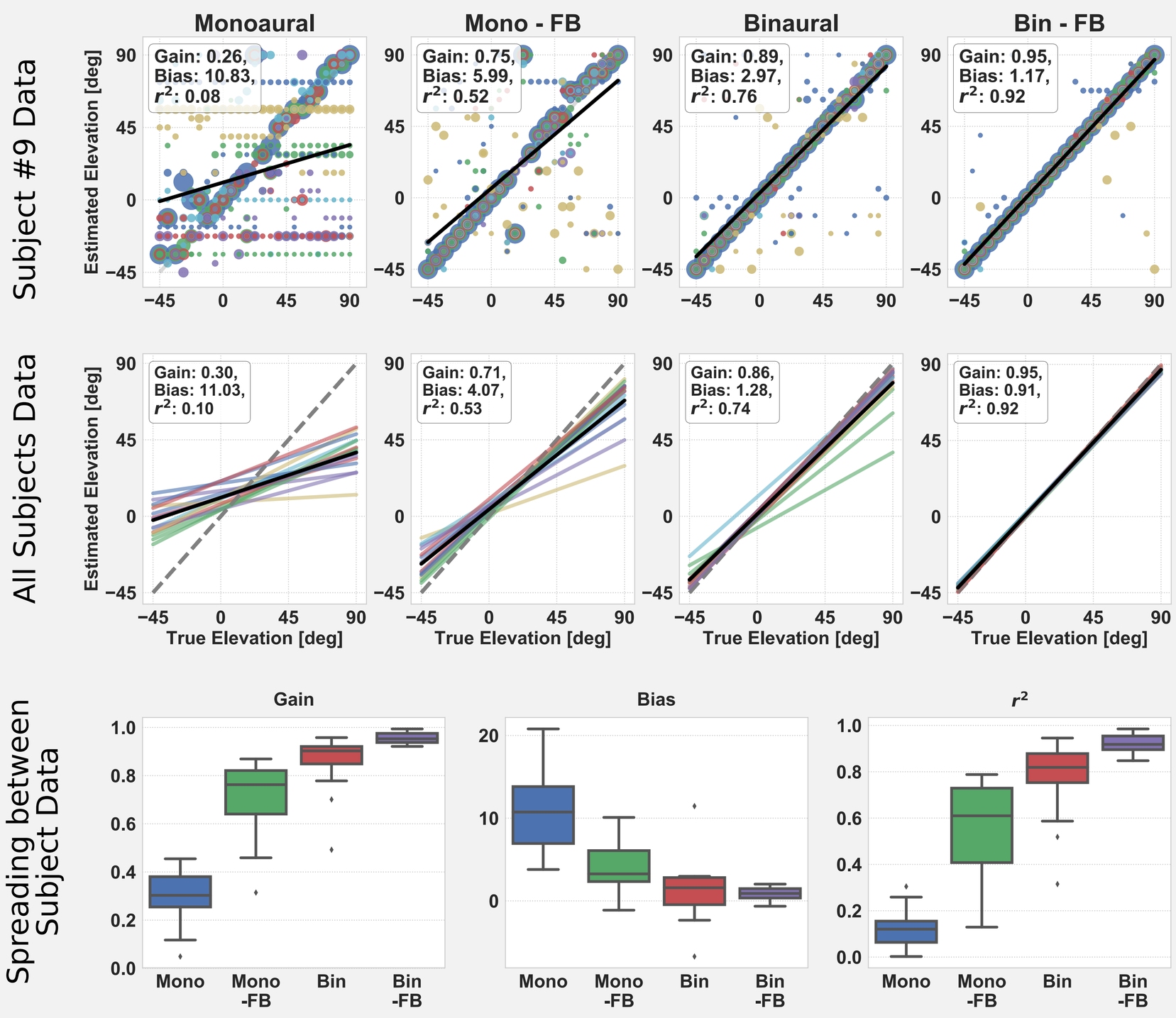



2) $\bar{S}_t^s(f) = \frac{S_t^s(f)}{\sum_{f_i} S_t^s(f_i)}$

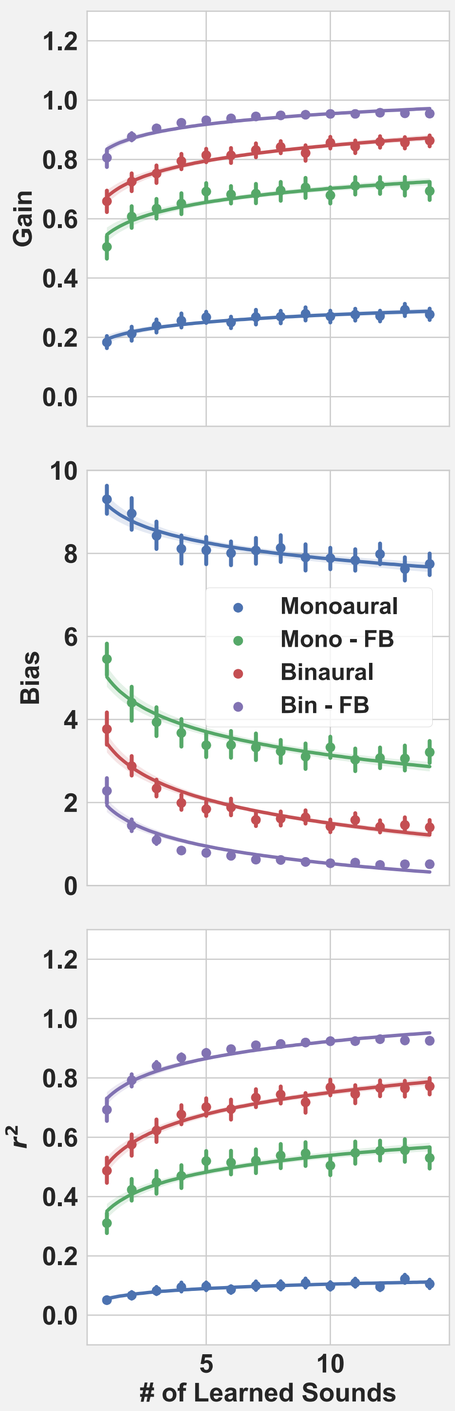
5) $L(f, \epsilon) = \frac{1}{n} \sum_{i=0}^{n} \hat{S}_{t_i}^s(f, \epsilon) - FB(t_i)$

## Results

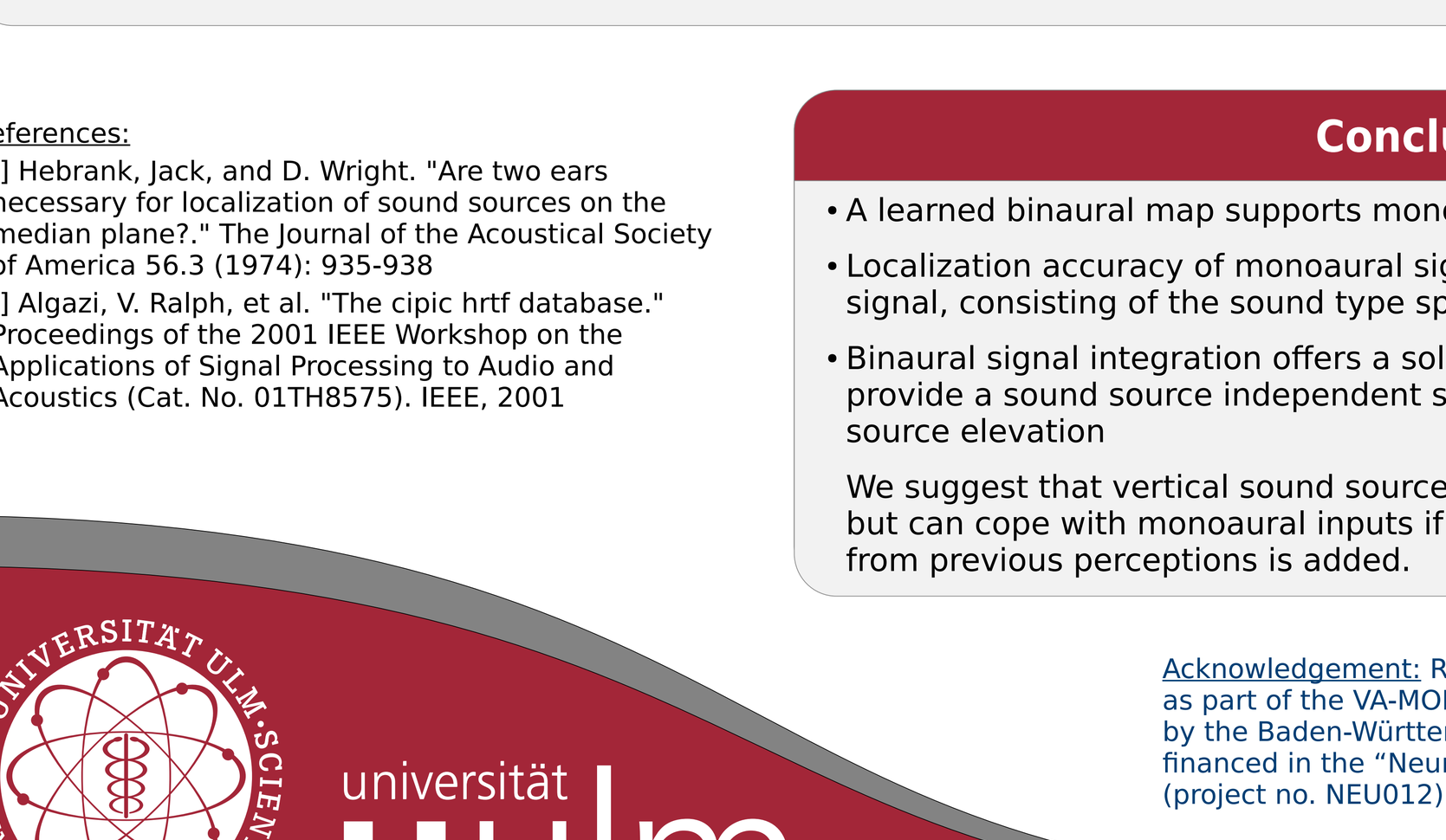
### Localization Quality




### Learned Map Quality




### Spreading between Subject Data




References:
[1] Hebrank, Jack, and D. Wright. "Are two ears necessary for localization of sound sources on the median plane?." The Journal of the Acoustical Society of America 56.3 (1974): 935-938
[2] Algazi, V. Ralph, et al. "The cipic hrtf database." Proceedings of the 2001 IEEE Workshop on the Applications of Signal Processing to Audio and Acoustics (Cat. No. 01TH8575). IEEE, 2001

## Conclusion

- A learned binaural map supports monoaural sound source localization
- Localization accuracy of monoaural signals is enhanced by a feedback signal, consisting of the sound type specific spectral mean over elevations
- Binaural signal integration offers a solution to filter out source spectra to provide a sound source independent signal that varies only with sound source elevation

We suggest that vertical sound source localization is fundamentally binaural but can cope with monoaural inputs if sound type information generated from previous perceptions is added.

Acknowledgement: Research conducted as part of the VA-MORPH project funded by the Baden-Württemberg foundation financed in the “Neurorobotik” program (project no. NEU012)

universität ulm