What factors influence variation in directional microphone benefit?

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Background

Many studies have demonstrated an average directional microphone (dir mic) benefit of 3-3.5 dB, a value that corresponds well to expectations from physical performance measures of conventional directional instruments. A rather large range of benefit values, up to 13 dB, has also been reported, suggesting that the benefit can vary from none up to 10 dB[1]. This trend is curious as it would be expected that the physical performance of the dir mic remains fairly constant when fitted to individuals.

Objective

To determine the factors that decrease or increase the benefit obtained from directional microphones in individuals, with a focus on: 1) variation in physical SNR improvement after the directional microphones have been fitted to individuals, 2) variation in the individuals' ability to utilize an SNR improvement, and 3) measurement error.

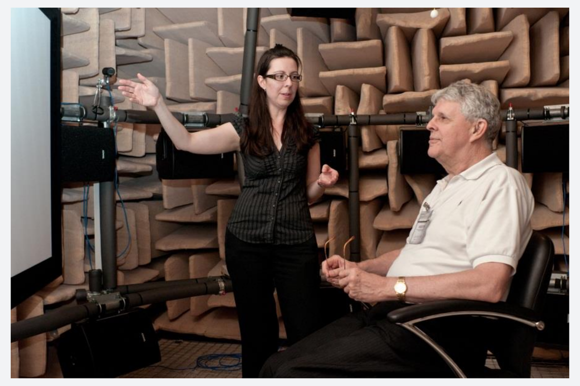
Method

- 59 participants with a mean pure tone average (PTA) of 41 dB HL, varying from 25 to 58 dB HL.
- Siemens devices (BTE) equipped with a fixed hyper-cardioid microphone.
- Devices fitted to the NAL-NL2 prescription with all adaptive features switched off.
- The directional benefit was defined as the difference between speech reception thresholds measured in noise (SRTn) with devices in omnidirectional and directional mode.
  - BKB sentences at 0° azimuth
  - Babble noise uncorrelated at ±45° and ±135°azimuth
  - Noise level fixed at 55 dB SPL

[1] Freyaldenhoven MC, Nabelek AK, Burchfield SB, Thelin JW. (2005). Acceptable noise level as a measure of directional hearing aid benefit. J Am Acad Audiol 16: 228-36.

Independent variables:

- PTA
- Auditory attention
- Speed of processing
- Working memory
- Angle of microphone port re: loudspeaker axis
- Frequency range dominated by amplified sound (f_{amp})
- In situ SNR benefit at low and high frequencies using the stimuli from the SRTn measurements (LF SNR benefit, HF SNR benefit)
- In situ 3D AI-DI benefit at low and high frequencies (LF AI-DI benefit, HF AI-DI benefit)
- Measurement errors (3 repetitions of SRTn)

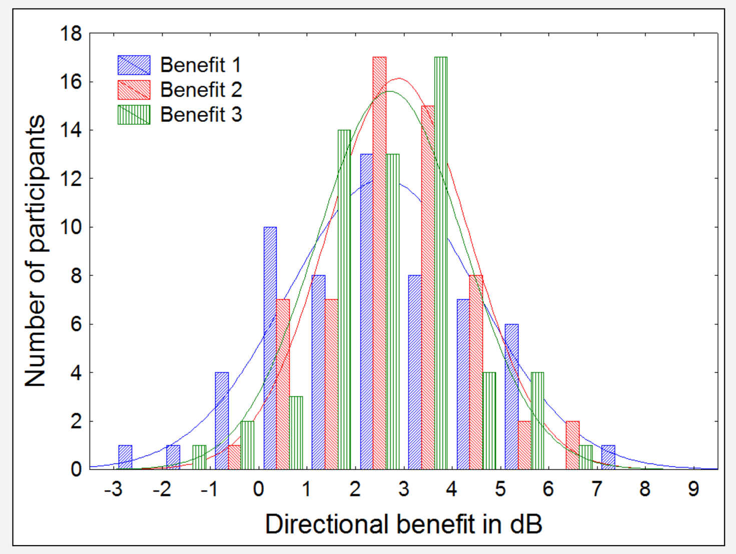


In situ measures based on the Hagerman & Olofsson (2004) approach[2].

Results

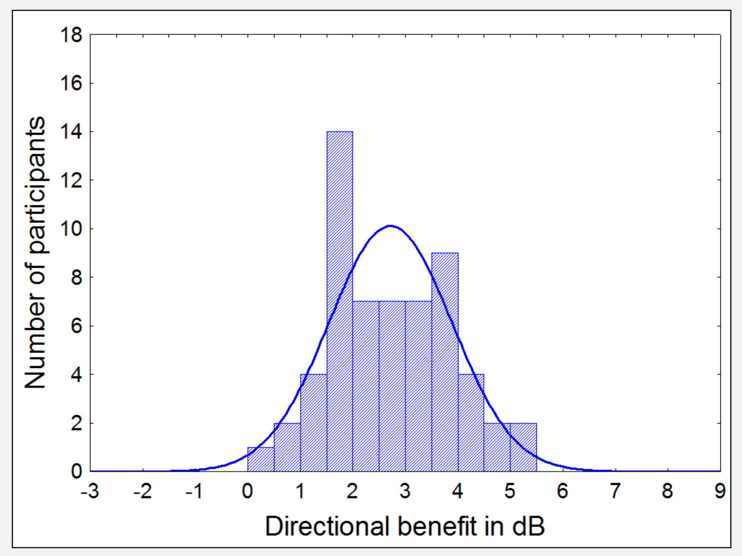
Single SRTn measurements:

- Mean benefit ~ 2.7 dB
- Range up to 10 dB
- Mean intra-subject variation, $\overline{\sigma}_S^2$ = 2.1 dB²



Average SRTn measurements:

- Mean benefit = 2.7 dB
- Range = 5 dB
- Inter-subject variation, σ_B^2 = 1.35 dB²



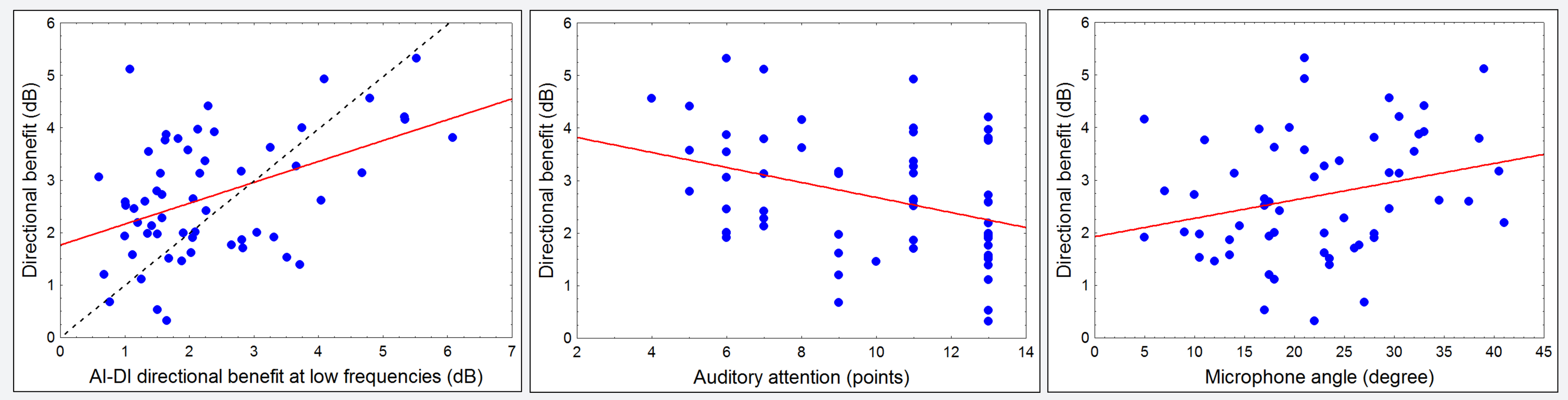
Measurement error explains 100* $\overline{\sigma}_S^2/(3^* \sigma_B^2)$ = 52% of the variation in measured directional benefit.

[2] Hagerman B, Olofsson Å. (2004). A method to measure the effect of noise reduction algorithms using simultaneous speech an noise. Acta Acoustica 90: 358-61.

Excluding the LF SNR benefit and f_{amp} (highly correlated with the LF AI-DI benefit and PTA, respectively), a forward stepwise multiple regression analysis produced a significant model ($F_{5,53}$ = 7.58; p = 0.00002) that explained a further 36% of variation in measured directional benefit.

Independent variable	B	SE of B	β	R²	p-level
LF AI-DI benefit	0.49	0.14	0.56	0.60	0.001
Auditory attention	-0.13	0.04	-0.33	0.08	0.004
Microphone angle	0.03	0.01	0.25	0.11	0.03
PTA	-0.03	0.02	-0.22	0.60	0.17
HF AI-DI benefit	0.18	0.17	0.12	0.19	0.31

In particular, greater benefit was obtained from the dir mic the more effective the dir mic was across the low frequencies, the poorer the person's auditory attention was (this parameter is assumed to be in the model due to its relation to a physical performance measure not captured in this study), and the more the microphone was pointing upwards (front-to-side ratio may be greater in this position and ceiling less reflective – to be verified).



Conclusion

Variation in measured directional benefit is largely explained by measurement errors and a combination of factors primarily describing the physical performance of the dir mic after being fitted to the individual. Findings specifically emphasize the importance of optimizing the effectiveness of a dir mic across the low frequencies.