Interaction of hearing-aid compression with spatial unmasking

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Motivation

Hearing-aid wearers complain of difficulty understanding speech in noisy environments. This difficulty is partly due to a diminished ability to use spatial location for segregating target speech from interfering speech (Noble and Gatehouse, 2006). We examine if wide-dynamic range compression in hearing aids contributes to this diminution of spatial unmasking.

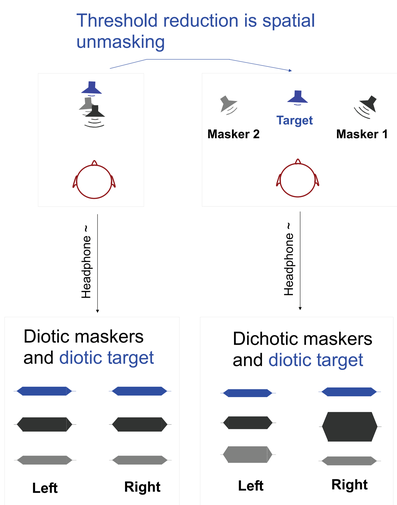
What's in this poster?

Compare spatial unmasking for stimuli undergoing compression with spatial unmasking for unprocessed stimuli.

Experiment 1: Normal-hearing (NH) listeners.

Experiment 2: Listeners with moderate hearing loss.

Headphone approximation of free-field spatial unmasking paradigm



- ITD = 0 for all stimuli
- Spatialization using constant across-frequency ILD
- Diotic masker 1 is 6 dB louder than diotic masker 2.
- Level of Σ(maskers) greater at right ear than left ear.
- Level of Σ(maskers) is 60 dB SPL at left ear.

Stimuli and compression for the experiments

Stimuli

- Targets are sentences from Coordinate Response Measure (CRM) corpus spoken by male talkers of the form "Ready *Baron* go to *Green Seven* now".
- Maskers are usually CRM sentences spoken by male talkers, except for one case where it is CRM-speech-shaped noise.

Compression

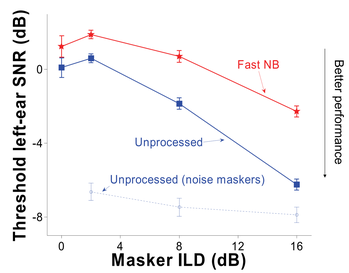
	Frequency bands	ANSI release τ (ms)	Experiment
Fast narrowband	15	~50	1, 2
Slow narrowband	15	~300	1
Fast broadband	1	~50	1, 2
Linear	256-tap FIR filter	-	2

Experiment	Compression ratios	Amplification (dB)
1 (normal-hearing)	3	0
2 (hearing-impaired)	CAMFIT prescription (< 3)	CAMFIT prescription

Compression threshold: 45 dB SPL.
FIR filter: Fit to linear CAMFIT (Moore et al, 1999) prescription for 65-dB SPL speech.

Experiment 1 Result: Compression reduces spatial unmasking in normal-hearing listeners

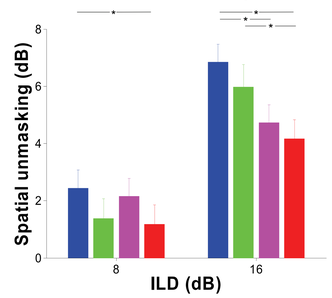
Compression reduces unmasking that is due to perceived spatial separation



- Reduction of threshold target level with increasing masker ILD separation is not due to SNR improvements at the better (left) ear.
- Threshold reduction for speech maskers but not for noise maskers is consistent with the interpretation that unmasking in this experiment is due to spatial separation reducing confusion between elements of target speech and masking speech.
- 7 subjects (ages 20-35)

All pair-wise threshold comparisons within a processing scheme for speech maskers of different ILD are statistically significant, except for comparisons between masker ILD = 0 dB and masker ILD = 2 dB.
Threshold is from 1-up 1-down tracking procedure implemented by changing target level. SNR is the ratio of target level to level of summed maskers prior to compression but after spatialization.

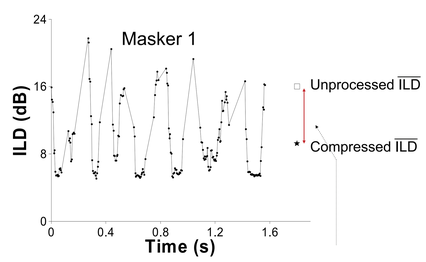
The reduction of spatial unmasking depends on compression parameters



Narrowband compression with fast dynamics (fast NB) causes the greatest reduction of spatial unmasking.

Spatial unmasking is threshold of each spatial separation condition (8 dB and 16 dB masker ILD) minus the average of the thresholds of the spatially co-located (0 and 2 dB) conditions pooled together.

Compression's effect on unmasking is understandable from its reduction of average ILDs



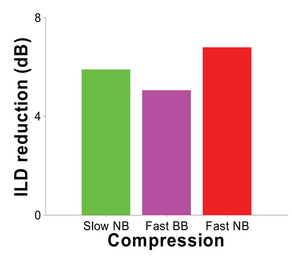
Compressor (fast NB) reduces the perceived spatial separation of target and maskers by reducing average ILD of maskers.

On computing the average ILD:

1. The effect of compression on ILD in a single time-frequency bin of a target or a masker is ild(t,f) = **Unprocessed ILD + $Gain_{Right}(t,f)$ - $Gain_{Left}(t,f)$**
2. ild(t,f) for a time-frequency bin is plotted only if its mean binaural level is greater than that of the other two stimuli.
3. Time-averaged ild(t,f), particularly for masker 1, is biased toward 0-dB because of the tendency of compressors operating independently at the ears to reduce ILDs.

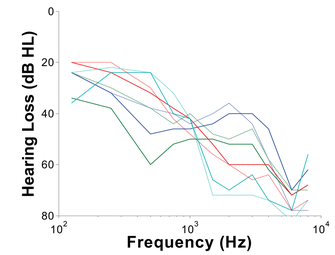
Target level = 58 dB SPL, the threshold for fast-NB compression and 16-dB ILD masker.

Dependence on compression parameters is partly explained by reduction of masker ILDs



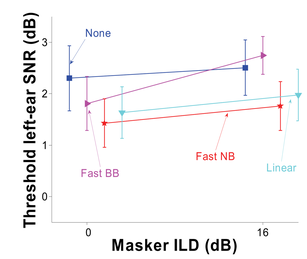
Time-average ILD of masker 1 is biased most toward the midline under fast-NB compression, consistent with it giving the least amount of spatial unmasking.

Experiment 2 Result: Hearing-impaired listeners fail to obtain spatial unmasking



Left-ear (solid) and right-ear (dashed) audiograms of 4 elderly moderately hearing-impaired experiment participants

Spatial separation fails to lower threshold for target identification under any condition



- Absence of spatial unmasking prevents observation of any interactions with compression.
- Previous studies have observed spatial unmasking by hearing-impaired listeners (Li et al, 2004; Arbogast et al, 2005). The following reasons may underlie the discrepancy with our experiment:
  - ⇒Audibility rather than target/masker confusability might be a greater determinant of performance in our experiment than in previous studies because of differences in stimuli (Arbogast et al, 2005) and differences in severity of hearing loss (Li et al, 2004).
  - ⇒Our subjects received less training than subjects with comparable severity of hearing loss in a previous study (Arbogast et al, 2005).
  - ⇒Central mechanisms for source segregation based on location might be sufficiently impaired by age and hearing loss to fail for our stimulus configuration but not for similarly impaired and aged listeners in previous studies.

Summary and Conclusions

- Compression operating independently at the ears can reduce spatial unmasking in normal-hearing listeners.
- Of all tested compressors, fast-acting narrowband compression caused the greatest reduction of spatial unmasking.
- Hearing-impaired listeners failed to exhibit spatial unmasking in our experiment, even though others have observed such unmasking.
- If the finding that compressor parameters affect spatial unmasking in normal listeners holds up with impaired listeners, then restoring normal spatial unmasking to wearers of hearing aids may require a specific compression design.

References

Arbogast et al (2005) "The effect of spatial separation on information masking of speech in normal-hearing and hearing-impaired listeners", *J. Acoust. Soc. Am.*, **117** (4), 2169-2180.

Li et al (2004) "Does the information content of an irrelevant source differentially affect spoken word recognition in younger and older adults", *J. Exp. Psychol.*, **30** (6), 1077-1091.

Moore et al (1999) "Use of a loudness model for hearing-aid fitting. III. A general method for deriving initial fittings for hearing aids with multichannel compression", *British J. Audiol.*, **33** (4), 241-258.

Noble and Gatehouse (2006) "Effects of bilateral versus unilateral hearing aid fitting on abilities measured by the Speech, Spatial, and Qualities of Hearing Scale (SSQ)", *Int. J. Audiol.* **45** (3):172-81.