Effects of Asymmetric Envelope Compression on Speech Intelligibility and Binaural Unmasking

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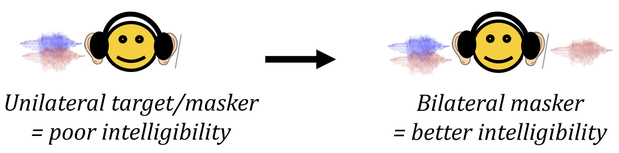
Binaural Hearing & Speech Laboratory

INTRODUCTION

- Listening with two ears gives access to binaural hearing, resulting in improved speech intelligibility in noisy environments.
- Many individuals with cochlear implants (CIs) demonstrate asymmetric speech intelligibility between the ears, and limited binaural benefits (e.g. binaural unmasking).[1]

Binaural Unmasking (BU):



Unilateral target/masker = poor intelligibility → *Bilateral masker = better intelligibility*

- This may be partially due to differences in dynamic range (DR) across ears, resulting in degraded temporal envelope representation.

PURPOSE

Explore the influence of asymmetric DR on binaural unmasking in normal hearing individuals listening to vocoded speech.

We hypothesized that binaural unmasking would be greater for conditions in which DR was similar across ears versus when it was very different, because binaural similarities in signal representation are important for perceptual organization. [2]

METHODS

Participants

- 6 young adults with normal hearing thresholds.

Stimuli

- Target (T): Harvard IEEE sentences spoken by a woman.
- Masker (M): AzBio sentences spoken by a woman.
- Stimuli were presented at 65dBA over headphones.

"The juice of lemons makes fine punch."

Example of target sentence with key words underlined.

Task

- Listeners verbally repeated target sentences. Responses were scored by an experimenter.
- Each target sentence was scored out of five key words.
- 30 trials were blocked into two runs per listening condition and order was randomized.
- Target ear was randomly chosen for each participant and held constant throughout duration of testing.

Procedure

- Stimuli processed with 16-channel vocoder whose carriers were low-noise noise (LNN). LNN carriers were 1 ERB wide and had an essentially flat temporal envelope like a sinewave, but contained more complicated temporal fine structure, resulting in interaural decorrelation when generated independently for each ear.
- All masker/noise conditions were presented at signal-to-noise ratio (SNR) of 0dB.
- Temporal envelope of signal in one or both ears was compressed in Praat to reduce DR.
- Overall intensity was equalized following compression so that compressed stimuli were same intensity as non-compressed stimuli.

Vocoder parameters:
- Low corner frequency:100 Hz
- High corner frequency: 8000 Hz
- Envelope filter cutoff: 600 Hz

Signal Processing

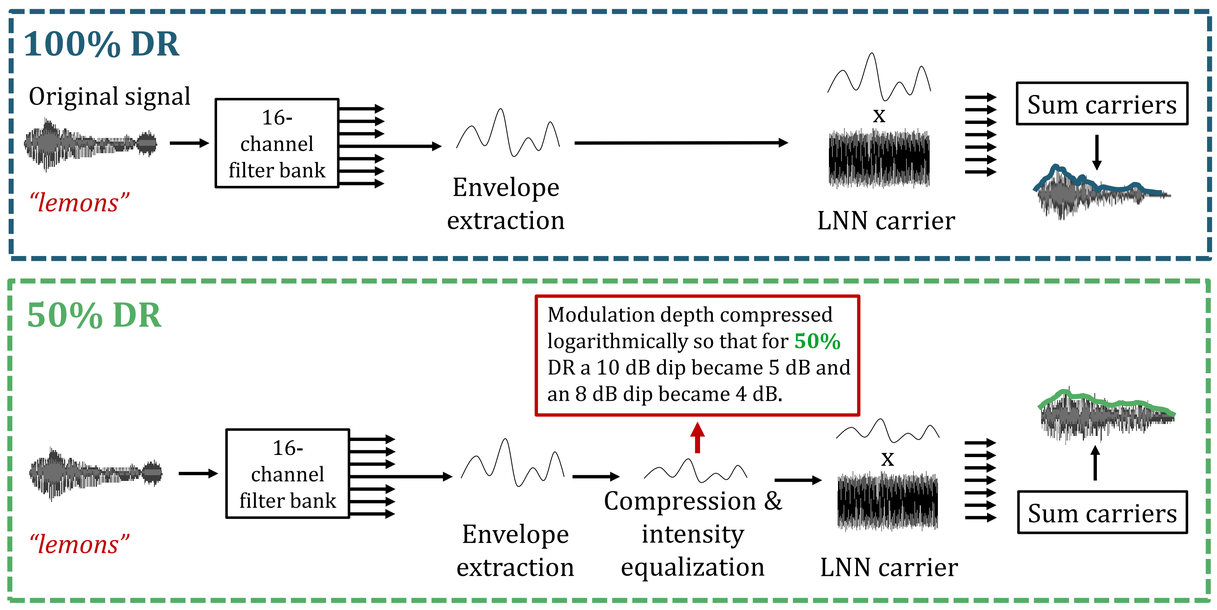


Figure 1: Schematic of vocoder processing for one spectral channel of stimuli with no compression (top), and 50% compression (bottom).

Listening conditions

		DR target ear	DR contralateral ear	
Unilateral target (Quiet)	T	100%	X	
		71%		
		50%		
		35%		
		25%		
Unilateral target/masker (Unilateral TM)	T M	100%	X	
		71%		
		50%		
		35%		
Unilateral target + bilateral masker (Bilateral)	T M M	100%	100%	Symmetric DR (Symm)
		71%	71%,	
		50%	50%,	
		35%	35%	
		71%	100%	Asymmetric DR (Asymm)
		50%		
		35%		
		100% T, 50% M	100%	Control

RESULTS

Does reduced dynamic range affect speech intelligibility in quiet?

Speech intelligibility declined with decreasing DR

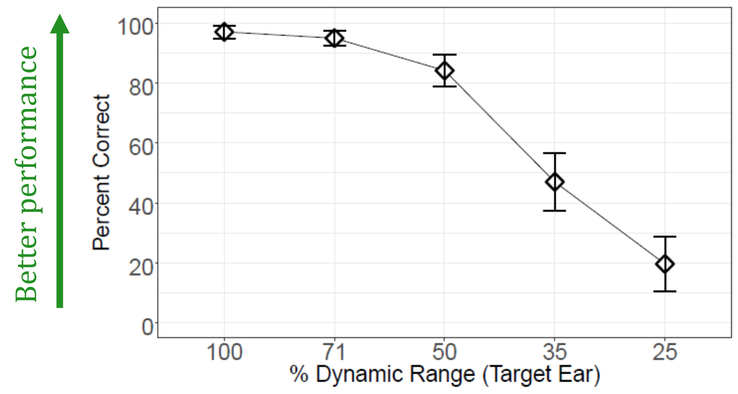


Figure 2: Quiet conditions. Mean speech intelligibility as a function of dynamic range. Error bars represent standard deviation.

Fig 2:
- Speech intelligibility was high for 100%, 71%, and 50% DR conditions, and decreased substantially for 35% and 25% DR conditions.

How do differences in DR across ears affect binaural unmasking?

Reducing DR equally in both ears elicited more unmasking than reducing DR in just target ear

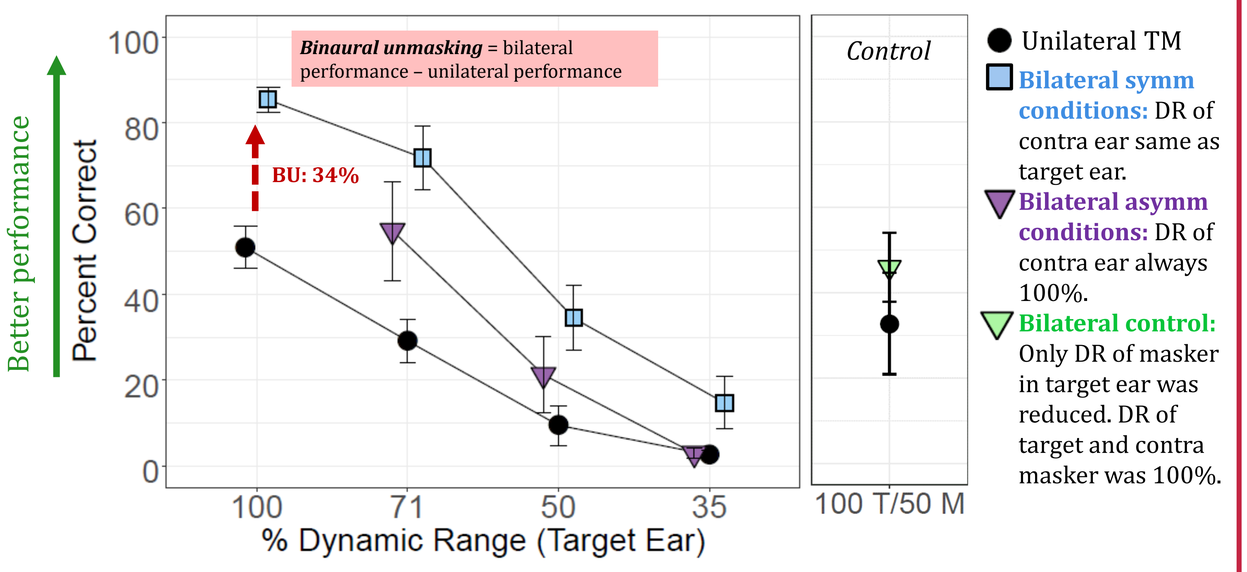


Figure 3: Masker conditions. Mean speech intelligibility as a function of DR of the target ear. Error bars represent standard deviation.

Fig 3:
- Speech intelligibility in unilateral and both symmetric and asymmetric bilateral conditions declined as DR decreased.
- Performance increased from unilateral to bilateral conditions (binaural unmasking) at every DR except 35%.
- For bilateral conditions, performance was better when DR of both ears was symmetrically reduced (blue), compared to when it was asymmetrically reduced (purple).

Is a more salient masker simply harder to ignore?

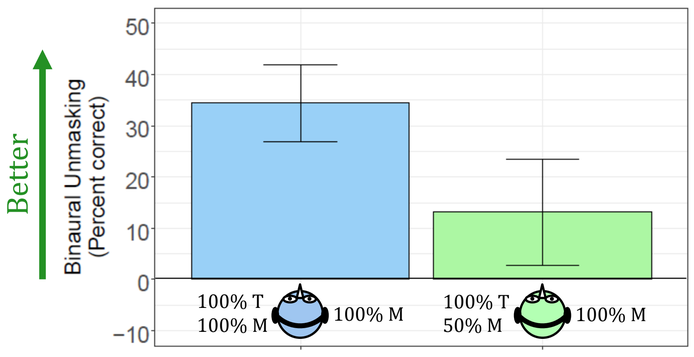


Figure 4: BU for 100% DR symmetric condition (blue) and control condition (green). Error bars represent standard deviation.

Fig 4:
- When everything was held constant and just DR of masker in the target ear was reduced, participants exhibited less unmasking.
  - Suggests disparity between symmetric and asymmetric conditions was due to the actual difference in DR across ears and not just masker fidelity.

SUMMARY

- Intelligibility of vocoded speech decreased as dynamic range of the signal was reduced.
- Binaural unmasking was greater when dynamic range was compressed symmetrically versus asymmetrically. This indicates that similarity in temporal envelopes across ears is more important for binaural processing than one "good" ear with a larger dynamic range.
- Asymmetries in dynamic range across ears may be one factor contributing to the limited binaural benefits demonstrated by individuals with bilateral cochlear implants.

[1] Goupell, M. J., Stakhovskaya, O. A., & Bernstein, J. G. (2018). Contralateral Interference Caused by Binaurally Presented Competing Speech in Adult Bilateral Cochlear-Implant Users. Ear and hearing, 39(1), 110-123.
[2] Bregman, A. S. (1994). Auditory scene analysis: The perceptual organization of sound. MIT press.

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