

The Effect of Asymmetric Dynamic Range on Speech Intelligibility and Binaural Unmasking in Normal Hearing Individuals Listening to Vcoded Speech



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INTRODUCTION

- In normal hearing individuals listening with two ears can provide access to binaural hearing, resulting in improved speech intelligibility in noisy environments.
- Many individuals with cochlear implants (CIs) demonstrate asymmetric speech intelligibility between their ears and limited binaural benefits, specifically binaural unmasking.¹



- This may be partially due to differences in dynamic range (DR) across ears, which have been shown to affect speech intelligibility.²

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 different, because binaural similarities in signal representation are important for integration and perceptual organization.³

METHODS

Participants

- 6 young adults (20-31 years old) 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 65 dBA over headphones at a signal-to-noise ratio of 0 dB.
- DRs were selected using log scale to evenly sample along psychometric function.

"The juice of lemons makes fine punch."
 Example of target sentence with key words underlined.

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

Table 1: Listening conditions.

Conditions

- Quiet conditions investigated effect of DR on speech intelligibility.
- Masker conditions examined effect of asymmetric DR on binaural unmasking.
- Control condition examined effect of asymmetric DR on unmasking while controlling for target DR.

Task

- Participants 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 (Table 1).
- Target ear was randomly chosen for each participant.

Procedure

- Stimuli were processed with a 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 pure tone, but contained more complicated temporal fine structure, resulting in interaural decorrelation.
- Temporal envelope of the signal in one or both ears was compressed in Praat to reduce DR.⁴
- Intensity was normalized following compression so that compressed stimuli had the 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

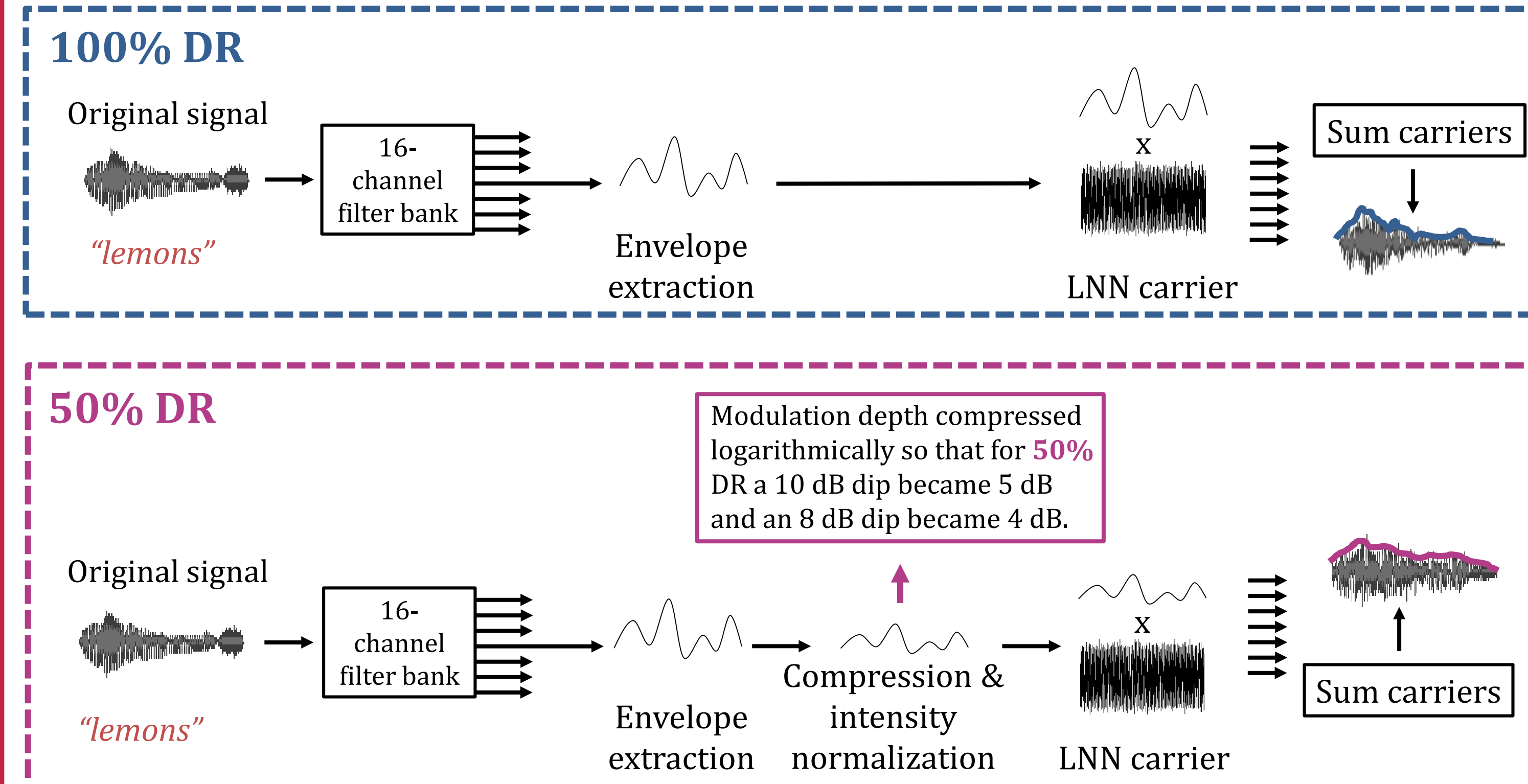


Figure 1: Schematic of vocoder processing for stimuli with no compression (top), and 50% compression (bottom).

RESULTS

Does reduced DR affect speech intelligibility in quiet?

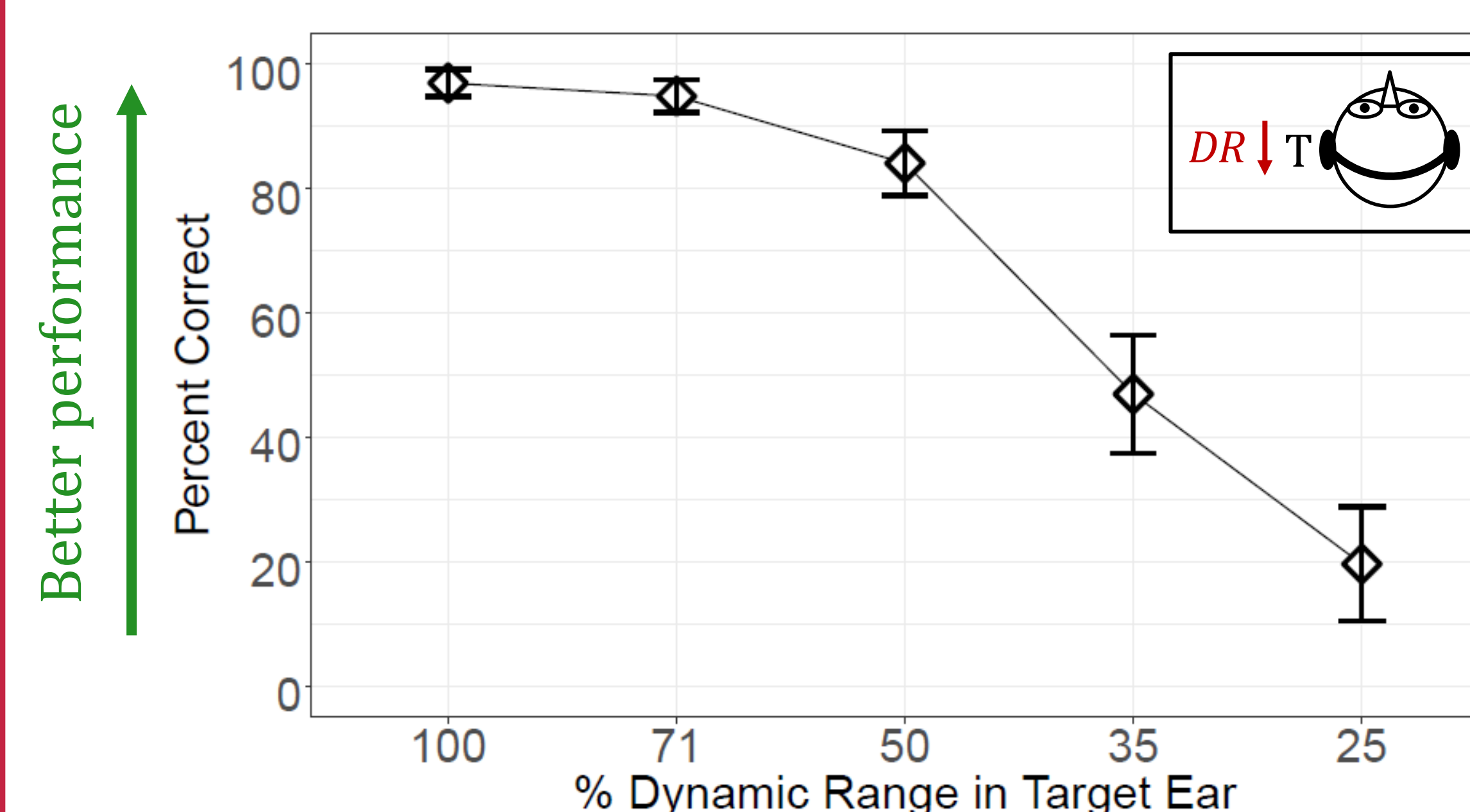


Figure 2: Mean speech intelligibility as a function of DR. Error bars are \pm one standard deviation.

- Speech intelligibility declined with decreasing DR.
- Intelligibility was high for 100%, 71%, and 50% DR conditions, and performance decreased substantially for 35% and 25% DR conditions.

RESULTS

How do differences in DR across ears affect binaural performance?

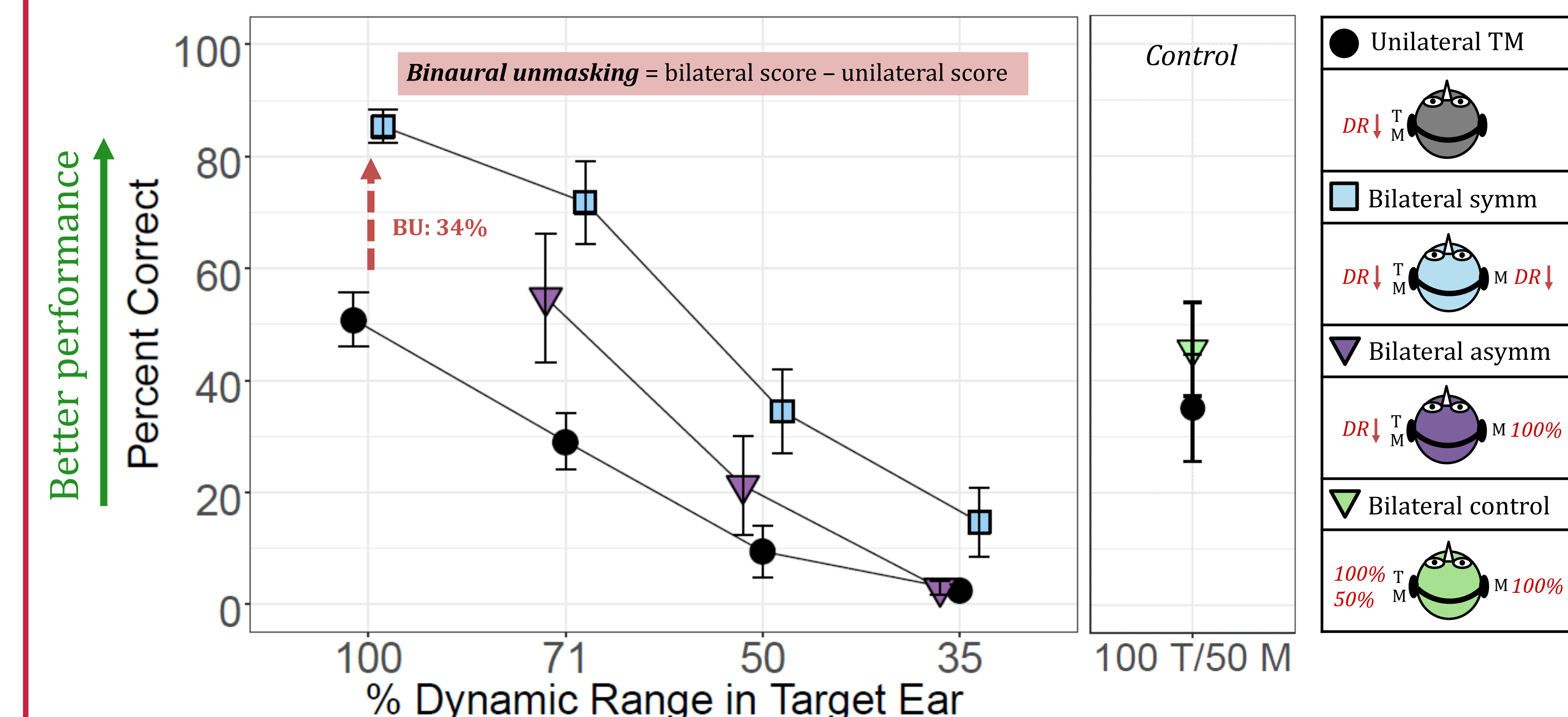


Figure 3: Mean speech intelligibility as a function of DR of the target ear. Error bars are \pm one standard deviation.

- Speech intelligibility in unilateral and both 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 masker with 100% DR harder to ignore?

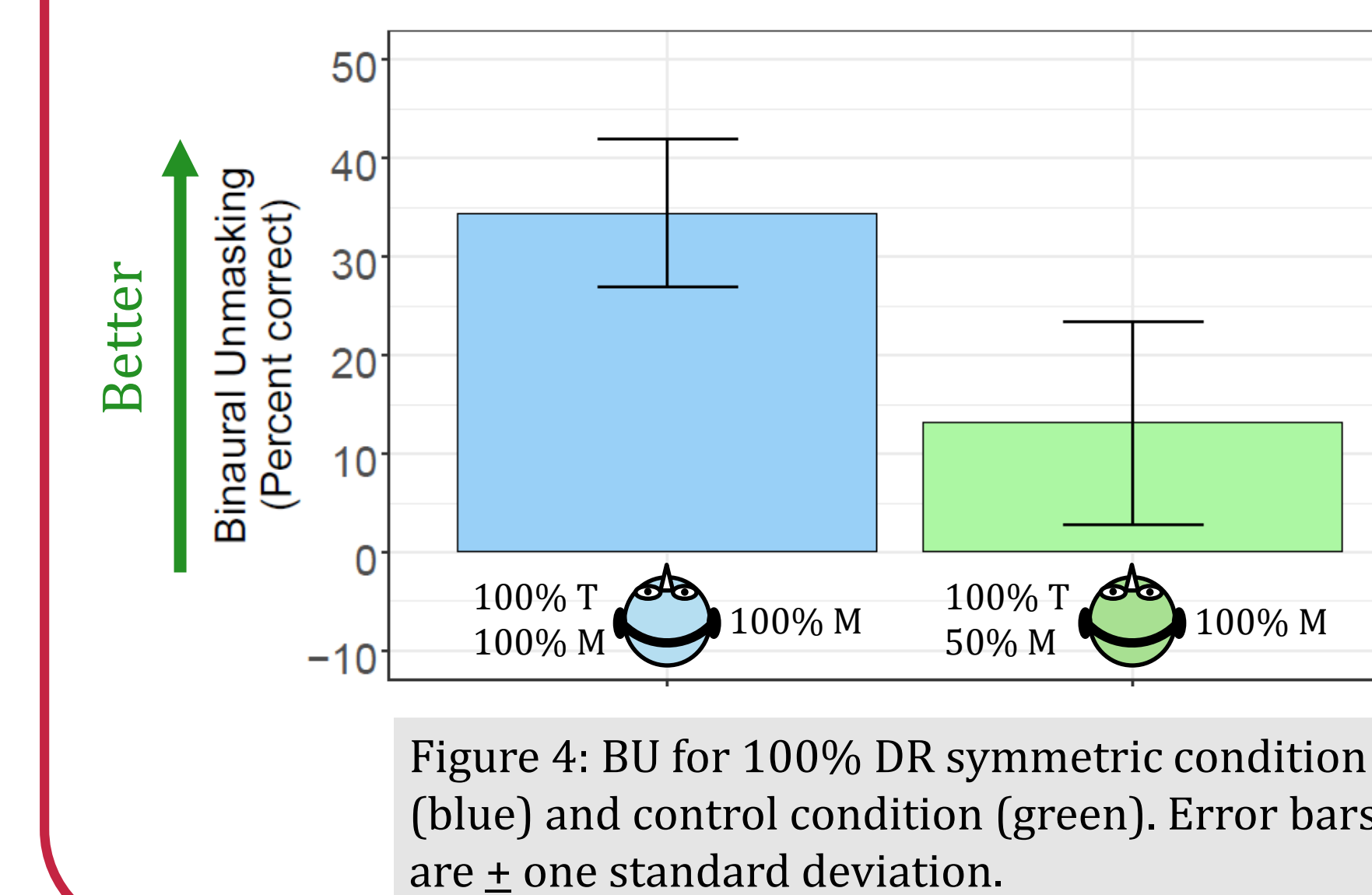


Figure 4: BU for 100% DR symmetric condition (blue) and control condition (green). Error bars are \pm one standard deviation.

- Greater unmasking in symmetric compared to asymmetric conditions could be due to the intelligibility of the contralateral masker.
- However, when target and contralateral masker DRs were held at 100%, and just DR of masker in the target ear was reduced, participants exhibited less unmasking (green versus blue).
- This suggests that disparity between symm and asymm conditions was not just due to difficulty ignoring a salient masker, but that the asymmetry in DR across ears affected participant's ability to perceptually separate target and masker.

SUMMARY

- This study explored the effect of reduced DR on speech intelligibility in quiet and the effect of asymmetric DR on binaural unmasking in normal hearing listeners.
- Intelligibility of vocoded speech decreased as DR of the signal was reduced.
- Binaural unmasking was greater when DR was compressed symmetrically versus asymmetrically. This indicates that similar representations of a signal across ears are more important for binaural processing than having one "good" ear with a larger DR.
- Asymmetries in DR across ears may be one factor contributing to the asymmetric speech intelligibility and limited binaural benefits demonstrated by individuals with bilateral CIs.

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²Loizou, P. C., Dorman, M., & Fitzke, J. (2000). The effect of reduced dynamic range on speech understanding: implications for patients with cochlear implants. *Ear and hearing*, 21(1), 25-31.
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