Session: P17

The Effects of Interaural Frequency Mismatch on Spatial Release from Masking

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Introduction

- In normal hearing (NH) listeners, binaural benefits occur when frequency-matched inputs from the two ears arrive at the brainstem.
- Many profoundly deaf individuals receive bilateral cochlear implants (BiCIs) in an attempt to restore the benefits of binaural hearing, but their performance in noisy environments and ability to localize sound sources is still worse than that of NH individuals.
- Due to the differences in implantation depth, neuronal death that often accompanies hearing loss, and current methods of mapping implants, stimulation may not be delivered to the expected location of the respective cochleae. This can result in spectral information being delivered to a different place in the cochlea in the one or both ears.
- It has been previously shown that a mismatch of frequency information between the ears with narrow-band stimuli negatively affects a listeners ability to use localization cues such as interaural timing and level differences. [1,2]
- These shifts in frequency information may be the cause of many of the difficulties that BiCI users experience.
- The present study investigates the effects of these frequency shifts by simulating these conditions in NH listeners and measuring spatial release from masking (SRM).

Methods

Stimuli

- Target stimuli were 5 word sentences spoken by a female. Target words were selected from the closed-set BUG corpus.[3]
- Maskers were IEEE sentences spoken by two males. [4]

Spatial Filtering

- Speech samples were given spatial information by processing them through KEMAR HRTFs. [5]
- Target speech was set to the front (0°)
- Masker speech was set to the front (0°) in the collocated condition or to the right (+90°) in the separated condition.

Vocoding

- Sine carrier to avoid interaural decorrelation with mismatched shifts
- Occurred after spatial filtering
- 8 channels
- 150-8000 Hz (unshifted condition)

Task

- Subjects listened to each sentence and responded by choosing each word from a closed set of 8 options (see fig. 1).
- Testing for both experiments took ~10 hours over 5 visits

Jane	took	two	new	toys
Gene	gave	three	old	hats
Pat	lost	four	big	shoes
Bob	found	five	small	cards
Sue	bought	six	red	pens
Mike	sold	eight	blue	socks
Lynn	held	nine	cold	bags
Jill	saw	ten	hot	gloves

Figure 1. Experimental test screen showing the 5 x 8 AFC word options.

Training

- 2 hour block during first session
- Feedback and replay provided
- Trained on all shift conditions at SNR of +10 dB

Conditions

	Exp 1. Matched	Exp 2. Mismatched
SNR	+10, 0, -5, -10 dB	+10, +5, 0, -5 dB
Masker Location	Collocated, Separated	Collocated, Separated
Spectral Shift	0, 3, 4.5, 6 mm	-6, -4.5, -3, 0, 3, 4.5, 6 mm

Exp. 1: Matched Shift

Purpose

- Investigate the effect of an interaurally matched spectral shift on speech recognition and spatial release from masking.

Methods

- 11 normal hearing subjects
- 25 sentences * 5 words/sentence = 75 words/condition
- Spatial release from masking (SRM) is the measure of ability to use spatial cues.
  - SRM = Separated % correct – Collocated % correct

Spectral shift definition

- Both ears shifted upward in frequency by the distance along the cochlea specified in mm according to the Greenwood function (fig. 2).

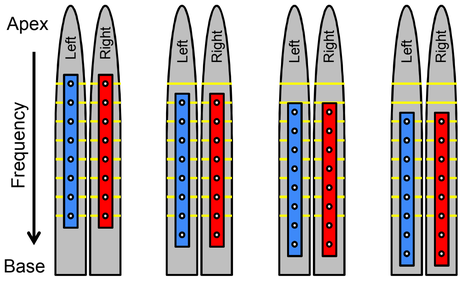

Figure 2. Diagram showing simulated electrode locations on unrolled cochleae for matched shifts. Yellow lines represent the expected locations of each channel.

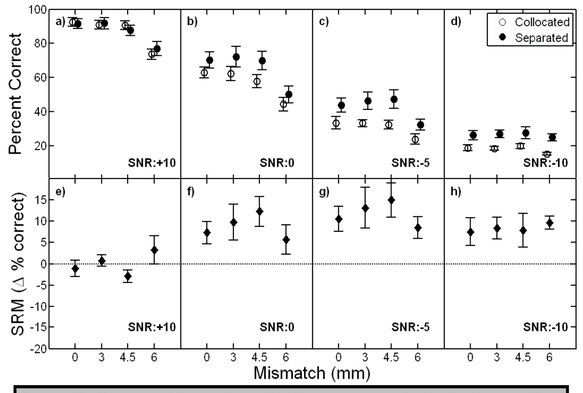

Figure 3. Results of experiment 1, bars represent standard error. For SRM (e-h), positive values indicate an ability to use spatial cues.

Results

- Significant benefit of target-masker separation. Subjects were able to use spatial information. (fig. 3: a-d, p=.002)
- Speech recognition more difficult with increasing mismatch. (fig. 3: a-d, p<.001)
- Amount of shift did not have an effect on SRM. (fig. 3: e-h, p=.623)
- More SRM with difficult SNRs (fig. 3: e-h, p<.001)

Exp. 2: Mismatched Shift

Purpose

- Investigate the effect of an interaurally mismatched spectral shift on speech recognition and spatial release from masking.

Methods

- Same 11 subjects from experiment 1
- 25 sentences * 5 words/sentence= 75 words/condition

Spectral shift definition

- One ear contained unshifted spectral information.
- Negative shift: left ear was shifted upward by the specified distance along the cochlea, according to the Greenwood function.
- Positive shift: right ear shifted upward in frequency by the specified distance along the cochlea (fig. 4).
- Both positive and negative shifts create a mismatch of frequency information between the ears.

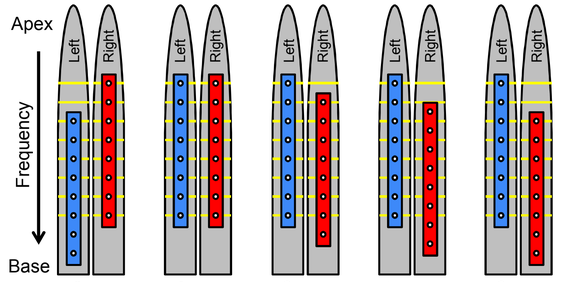

Figure 4. Diagram showing simulated electrode locations and on unrolled cochleae for mismatched shifts. Yellow lines represent the expected locations of each channel.

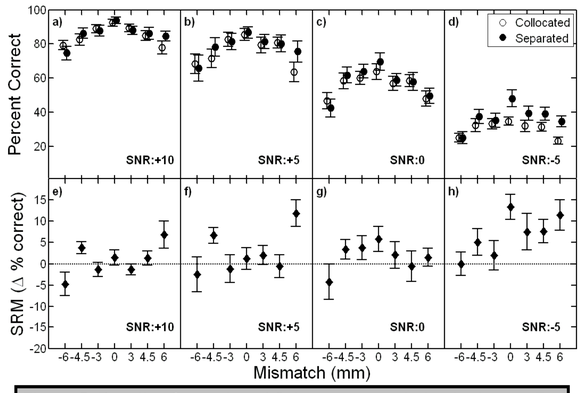

Figure 5. Results of experiment 2, bars represent standard error. For SRM (e-h), positive values indicate an ability to use spatial cues.

Results

- No significant benefit of target-masker separation. Subjects were unable to use spatial information. (fig. 5: a-d, p=.102)
- Speech recognition more difficult with increasing mismatch (fig. 5: a-d, p<.001)
- SRM larger when shift is on the same side as the masker, (right ear shifted upwards, fig. 5: e-h, p<.001)
- More SRM with difficult SNRs (fig. 5: e-h, p<.001)

Matched vs. Mismatched Shifts

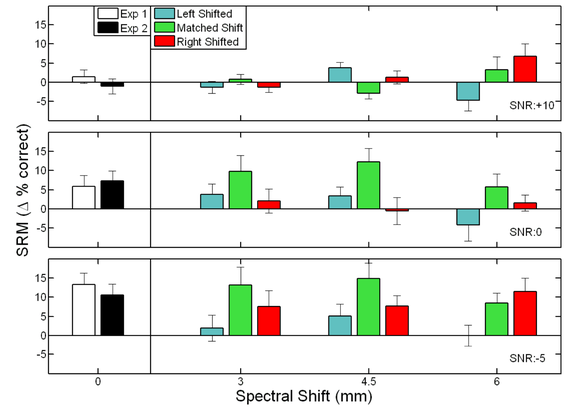

Figure 6. Comparison between experiment 1 and 2. For mismatched shift conditions (exp. 2), negative shifts are represented by the blue bars, and positive shifts are represented by the red bars. The matched shift condition (exp. 1) is represented by the green bars. Error bars represent standard error.

Results

- No difference at 0 mm between exp 1& 2. (p=.848)
- Benefit of right vs. left ear shift, especially at more extreme shifts.
- More SRM at difficult SNRs.

Summary and Conclusions

- Both matched and mismatched shift conditions negatively affected listeners' ability to understand speech.
- Listeners' ability to make use of spatial cues was hindered in the mismatched shift condition, but not in the matched shift condition.
- In the mismatched shift condition, listeners received some benefit when the shifted ear was towards the side of the masker, this provided an ear that was receiving reliable frequency information and had a better SNR.
- Matched spectral information is essential for providing listeners with useful spatial cues.
- Spectral information should be delivered to the appropriate location in order to help listeners best understand speech.

References

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