BILATERAL LOUDNESS BALANCING AND DISTORTED SPATIAL MAPS IN RECIPIENTS OF BILATERAL COCHLEAR IMPLANTS

Matthew B. Fitzgerald1, Alan Kan2, and Matthew J. Goupell3

1 Department of Otolaryngology, New York University School of Medicine, New York, NY, USA; 2 Binaural Hearing and Speech Laboratory, University of Wisconsin, Madison, WI, USA; 3 Department of Hearing and Speech Sciences, University of Maryland, College Park, MD, USA

Introduction

- One key benefit of bilateral cochlear implant (CI) use is an increased ability to localize sound.
- Sound localization is assumed to be best when listeners are provided with consistent localization information across frequency. For example, simultaneous stimulation of a loudness-balanced electrode pair should produce an auditory image that is centered in the head, and this image should change location with changes from an interaural level difference (ILD).
- It is unclear if consistent localization information is provided with traditional CI mapping procedures, which are based on obtaining the 'most-comfortable' loudness levels in each ear (Goupell et al., JASA, 2013).
- To address this issue, we measured the number, location, and compactness of auditory image(s) for single electrode pairs, and observed how those images shifted with different ILDs.

Participants and Equipment

- 17 post-lingually deafened bilateral CI users (Cochlear N24, Freedom, or N5 users)
- Direct stimulation with Nucleus Implant Communicator

Bilateral Loudness-Balancing Mapping Method

C Levels: For electrodes in the apex, middle, and base (typically 4, 12, and 20), the C levels (most-comfortable levels) were obtained in each ear using clinically-based procedures.

- Stimulus Duration = 500 ms
- Stimulation Rate = same as clinical map (900-1200 pps)

Unilateral loudness-balanced (ULB)-C Levels: The C levels were balanced for loudness within an ear by stimulating all three electrodes consecutively with a 500-ms interstimulus interval (ISI). The experimenter adjusted the C levels to ensure that the perceived loudness was the same across electrodes.

Bilateral loudness-balanced (BLB)-C Levels: The ULBC levels for each electrode pair were loudness balanced across the ears by stimulating each ear consecutively with a 500-ms ISI. The experimenter adjusted the C levels to ensure that the perceived loudness was the same across ears.

Results:

- Most changes from C level to BLBC level were ≤ 3 current units (CUs).
- Larger changes suggest that methods for obtaining C level may not always be bilaterally balanced for loudness.

Fusion Experiment

- To determine number, location, and compactness of perceived bilateral stimulation for BLBC levels

Method:
- An electrode pair was stimulated simultaneously at the BLBC or with an ILD (+5, ±10 CU)
- The auditory image(s) was/were categorized using an interface with 10 options (see Fig. 2).

Results:

- Responses in rows 1-3 indicate participants mostly perceived a single, fused auditory image with bilateral stimulation of a single electrode pair (Fig. 4).
- Participants were consistent in lateralization abilities for best sound localization and listeners = 2.2 CU.
- Any offset ≥ 5 CU (2 standard deviations, assuming normal distribution) is significant with 95% confidence (see Fig. 8).

Laterization Experiment

- To determine extent of perceived offset with ILDs
- To assess the variability of this method by repeating measurements on three separate days/mappings

Method:
- Listeners were stimulated at BLBC, and then reported the location of the perceived image (see Fig. 5).

Results:

- Participants could have different laterization offsets (i.e. 0-CU ILD ≠ 0 Lateralization) at different places for BLBC levels (Figs. 6 and 7).
- Participants were consistent in laterization experiment over multiple days.

Conclusions

- Careful bilateral loudness balancing generally produces minimal changes to maps, but some substantial changes can occur (Fig. 1).
- Post-lingually deafened bilateral CI users mostly perceived a single, fused auditory image with bilateral stimulation of a single electrode pair (Fig. 4).
- Bilateral stimulation at equal loudness in each ear does not always elicit a centered auditory image (Figs. 4, 6, 7, and 8).
- This suggests that some bilateral CI users are provided inconsistent localization information across frequency (e.g., each electrode pair does not provide a centered auditory image) when using the bilateral loudness-balancing method. It is likely that the same issue would arise with typical clinical mapping procedures.
- When mapping bilateral CIs, it may be necessary to use both loudness-based and location-based methods to ensure optimal localization ability.

Acknowledgments

This work was funded by NIH/NIDCD R00 DC05093 (MBF), R00 DC10206 (MJG), P30 DC004664 (CEBH), R01 DC003083 (RYL), and P30 HD03352 (Waisman Center core grant). Cochlear Ltd. graciously provided equipment and software necessary to conduct this research.