Cochlear Implant and Hearing Aid Research Newsletter

Introduction and History of the Laboratory

The Cochlear Implant and Hearing Aid Research Laboratory (CIHARL) began in July 2010 in the Department of Otolaryngology at Oregon Health & Science University.

The overall goal of the laboratory is to improve patient outcomes with hearing devices, whether they are cochlear implants and/or hearing aids. We take a unique view of the brain as an active rather than passive participant in the brain-device interface. It is not just the device type and program settings that determine patient outcome. Instead, the plasticity of the brain and the listening situations that the individual is exposed to also influence how the brain adapts to hearing devices. Our research focuses on how brain plasticity accommodates the limitations of hearing devices, and how experience with certain hearing device settings may lead to abnormal and thus impaired central auditory processing.

Laboratory alumni (and names you may remember) include Rindy Ito, Michelle Lang, Jennifer Fowler, David Wozny, Daniel Brickman, and Katie Loera. Current personnel include Lina Reiss (principal investigator), Jessica Eggleston (audiologist), and Emily Walker (summer student). This is the first newsletter written to provide a research update to patients and other individuals who have participated in research in this laboratory.

Welcome Research Assistant

Emily Walker is a student who will be assisting in the lab this summer. She currently attends Whitworth University, where she studies biology, chemistry, and Spanish. Emily plans to pursue a career in medicine, and looks forward to contributing to and gaining experience in research in the coming months.

Pitch Perception and Electrode Discrimination

We have measured pitch perception and how it changes over time in cochlear implant (CI) users. We found that CI users have three different patterns of pitch changes over time. Some adapt their pitch perception with the CI so that it matches what they hear in the other ear, usually aided with a hearing aid (HA). Others show no adaptation. Paradoxically, a few have pitch perception that drops in pitch for all electrodes and worsens the pitch mismatch with the other ear.

So far, we have not found any association of pitch adaptation pattern with speech perception outcomes or electrode discrimination abilities. Intriguingly, some CI users have very similar pitches across several electrodes, but have 100% electrode discrimination and vowel discrimination performance. This suggests that CI users may use other cues than pitch for electrode discrimination and vowel perception[1].

Binaural Spectral Integration

The variation in pitch adaptation patterns led us to ask whether CI users could be adapting in some other way to the pitch mismatch between the CI and acoustic hearing in the other ear. If some patients do not adapt, or even increase pitch mismatch, could the brain instead be adapting spectral integration between the two ears to reduce the *perception* of this mismatch?

Over the past two years, we began the first study to look at this question. We

[1] presented at several national meetings, including the 2011 Conference for Implantable Auditory Prostheses and the 2012 Meeting of the Association for Research in Otolaryngology, and in preparation for submission to the journal *Ear and Hearing* (Reiss, Ito, Eggleston, *et. al*).

measured how CI users fuse sounds of different pitches in each ear into a single sound. Normal-hearing listeners can tell very easily if two sounds differ much in pitch between ears, for very small pitch differences. In contrast, CI users fuse sounds that differ by as much as 3-4 octaves in pitch between ears. They are unable to tell that these sounds differ in pitch when presented simultaneously, even though they can discriminate them easily when presented sequentially. For example, a single electrode with a pitch of 240 Hz in the CI ear can be perceptually fused with acoustic tones ranging from 125 to 2000 Hz played to the other ear (about 1 octave below to 3 octaves above).

This fusion also leads to an effect we call pitch averaging, in which two sounds of different pitch that are fused across ears lead to a new binaural pitch that is an average of the two original pitches. This may reflect the personal experience of many CI users that voice pitch and musical pitch seems to change depending on whether they are wearing the CI alone or the CI together with a HA (or a second CI for bilateral CI users)[2].

Speech Perception with a Cochlear Implant and Hearing Aid: Does Frequency Overlap Cause Interference?

Due to changes in cochlear implant candidacy, people with more residual hearing are receiving cochlear implants. Therefore it is likely that people with a cochlear implant on one side may wear a hearing aid on the other side. While some report that the sound quality improves in the bimodal condition (CI on one side and a HA on the other), others report decreased performance when both devices are worn together. Benefits of bimodal devices include increased performance in noise, improved satisfaction when listening to music, and improved localization ability. Additionally, many report a more natural sound quality when the CI and HA are worn together, due to the low frequency acoustic hearing that the HA provides.

Currently, bimodal CI patients are given the same one-size-fits-all program for their speech processor as the early patients who did not use HAs. However, each patient has a differing amount of residual hearing in the HA ear. The question asked in this study was whether programming should be adjusted for bimodal CI users based on the amount of hearing in the opposite ear. In other words, can too much frequency overlap between the CI and HA lead to interference in bimodal CI users?

In this study, a lab CI sound processor was programmed with four experimental programs in which the low frequencies were cut-off at various increasing frequency ranges. For example, with the Cochlear Freedom processor, the frequency range was allocated as follows: P1; 188-7938 Hz (the default program), P2; 438-7938 Hz, P3; 688-7938 Hz, and P4; 938-7938 Hz. These four programs thus corresponded to successively decreasing overlap with the low-frequency information provided through the HA. Speech perception tests were administered in quiet and in noise with each CI program in the CI+HA and the CI only conditions.

Unilateral CI users (CI only) performed best with the lowest cutoff frequency and the widest frequency range, as expected without a HA to offset any loss of low-frequency information. Bimodal users (CI+HA) showed a mix of optimal conditions. About half of the subjects achieved peak performance in condition 1 at the lowest cutoff frequency. The other half performed best in conditions 2, 3 or 4, indicating an interference effect that was reduced with less overlap, and this effect depended on the amount of residual hearing. This suggests that less low-frequency overlap between the CI and HA

[2] presented at the 2013 Association for Research in Otolaryngology meeting, and submitted for publication in *JARO* (Reiss, Ito, Eggleston, and Wozny).

is better for some bimodal CI users, and that bimodal CI fittings may need to be customized based on the amount of residual hearing in the HA ear[3].

Speech Perception with a Cochlear Implant and Hearing Aid: Is Loudness Balancing Important?

Standard CI and HA fittings are currently performed independently and may result in substantial interaural loudness mismatches due to differences in intensity and frequency content. It is unknown how loudness mismatches affect bimodal benefit.

We explored this question using computer simulations of bimodal CI+HA stimulation in normal-hearing listeners. Word recognition thresholds in background noise were measured for 3 conditions: HA at 7 dB softer than the CI, CI and HA loudness matched, and HA at 7 dB louder than the CI.

Subjects needed on average a 1-dB higher signal-to-noise ratio (performed worse) in the condition with the HA softer than the CI compared to the other two conditions, especially when the limited spectral resolution of the CI was replicated. This 1 dB decrement translates to 8-10% change in speech recognition scores, and indicates the need for careful loudness balancing of the CI and HA to obtain maximum benefit[4].

Future Studies

New studies are underway to model how abnormal binaural spectral integration affects speech perception when two devices are combined across ears. This effect may explain why some individuals experience interference with two hearing devices compared to one worn alone (such as a CI with a HA, or two CIs compared to one CI worn alone). Abnormal integration could also limit binaural benefit from the second device, because interference can cancel any binaural benefits. Future work will also extend these studies to the bilateral HA user population (see recruiting section below) and to pediatric CI and HA users.

Better understanding of the factors leading to abnormal binaural spectral integration will help in eventually designing new device processing strategies or training programs that redirect the brain toward more “normal” integration. The goal of these strategies will be to reduce interference and increase binaural benefit, especially for speech perception in background noise.

Recruiting for New Study

We are recruiting subjects who have moderate to severe sensorineural hearing loss, and are currently wearing bilateral hearing aids (and have been wearing them for at least one year). This study will look at how input is combined between two ears, and how this may affect variability in speech and music perception in hearing aid users. Subjects will be asked to listen to words and sounds and respond verbally or by pushing a button on a touch screen. Subjects are compensated for their time. Please contact our lab at (503) 494-5868 or reiss@ohsu.edu for more information on participating in the study.

THANK YOU to all of you who have participated in this research!!!

Please do not hesitate to contact us if you have any questions about the research or if you would like to request copies of publications.

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[3] presented at the upcoming 2013 Conference for Implantable Auditory Prostheses (Fowler, Eggleston, and Reiss).

[4] presented at the 2011 Conference for Implantable Auditory Prostheses and in preparation for submission to Ear and Hearing (Brickman, Reiss, and Leek).