Poster # 349

WAISMAN CENTER

Investigating the Emergence of Binaural Processing Strategies after Surgical Correction of Congenital Unilateral Conductive Hearing Loss

Brian C. Gartrell, Alan Kan, Shelly P. Godar, Samuel P. Gubbels, and Ruth Y. Litovsky
University of Wisconsin-Madison, USA
e-mail: BGartrell@uwhealth.org

Association for Research in Otolaryngology 36th Annual Midwinter Meeting

Binaural Hearing and Speech Laboratory

Baltimore, MD

February 16-20, 2013

Introduction

•Congenital Unilateral Conductive Hearing Loss (CUCHL) is a condition known to predispose individuals to social, educational, and vocational impairments relative to normal-hearing (NH) peers (1,2). CUCHL is not uncommon, estimates of the incidence of congenital aural atresia range from 1:10,000 to 1:20,000 live births (3).

•In the past, restoration of hearing caused by CUCHL was not typically performed until adulthood if the child was found to have normal hearing in the contralateral ear (4). Currently, timing of surgery ultimately depends on the cause of CUCHL. In the case of congenital aural atresia associated with microtia, surgically is typically not performed until at least age 5-8 to allow for mastoid pneumatization, rib cartilage development for microtia reconstruction, and for comparison of symmetry to the contralateral ear (5).

•Binaural processing, which refers to the integration of inputs from the two ears at central auditory centers, is known to be important for accurate localization of sound and for segregation of target speech from noise (6,7). Individuals with CUCHL lack bilateral auditory input and thus do not display evidence of binaural processing, resulting in poor performance on localization and speech-in-noise tasks (8).

•Current knowledge on patients with CUCHL indicates improvement on localization accuracy and on speech-in-noise tasks in the short term after surgical correction (9). However, no improvement in localization accuracy or on listening ability in complex acoustic environments has been documented beyond short-term follow-up (< 6 months) (9). It is therefore unknown if these individuals demonstrate evidence of auditory plasticity and improved binaural processing at long-term follow-up.

•In noisy environments, individuals who are able to utilize binaural processing strategies demonstrate improved speech intelligibility when target speech is separated in space from one or more maskers. This phenomenon is known as Spatial Release from Masking (SRM) and is one method of assessing for the existence of binaural processing strategies (10).

Purpose

1. To compare the performance of children who have undergone surgical correction of CUCHL to NH subjects on localization and speech-in-noise tasks
2. To determine whether localization accuracy improves as surgical subjects gain long-term experience utilizing their surgically-corrected ear
3. To determine whether subjects undergoing surgical correction for CUCHL demonstrate SRM over long-term follow-up

Methods

Subjects

•Study design has 10 children ages 12 – 18 who underwent surgical correction of CUCHL
•Preliminary data are shown here for three subjects:
- All listeners demonstrated a maximal conductive hearing loss (air-bone gap > 50 dB) prior to surgery, and had normal hearing in the contralateral ear
- All subjects demonstrated improvement on audiometric testing in the surgical ear (Mean postoperative four-frequency pure-tone average (PTA) = 31 dB)
- Time between surgery and testing ranged from 20 months (1.75 years) to 76 months (6.3 years)

Subject	Surgical Ear	Surgical Age (yrs)	Testing Age (yrs)	Time Since Surgery (yrs)
CHAA	Right	9	16	6.3
CHAB	Right	10	16	5.4
CHAC	Right	12	13	1.75

•Published data obtained from NH controls with normal hearing thresholds bilaterally (PTA < 20 dB) were utilized as a comparison

Localization Task

•Listener was positioned in the center of a 19-loudspeaker arc. Loudspeakers were placed 10° apart at 0° azimuth (Figure 1)
•Stimuli involved a train of four bursts of pink noise at 50 dB SPL with +/- 4 dB rove emitted from each loudspeaker. Twenty repetitions per loudspeaker location were assessed.
•Perceived sound location selected on a touch screen monitor (Figure 2)
•Root mean squared (RMS) error was calculated for each listener (MATLAB software)

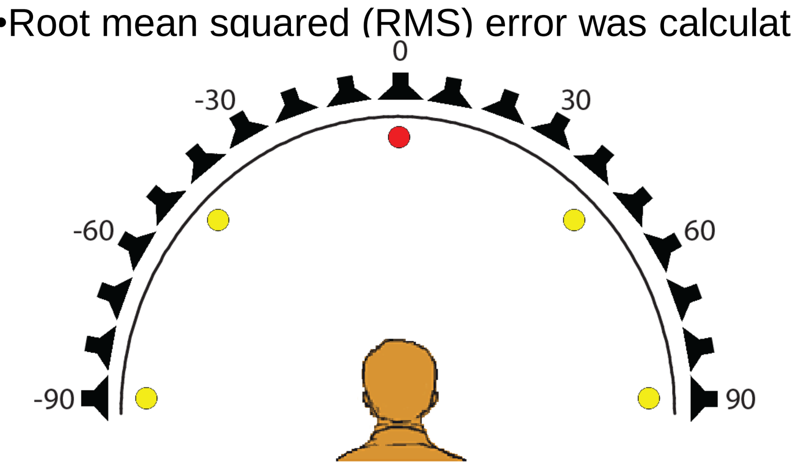

Figure 1. Localization loudspeaker array setup

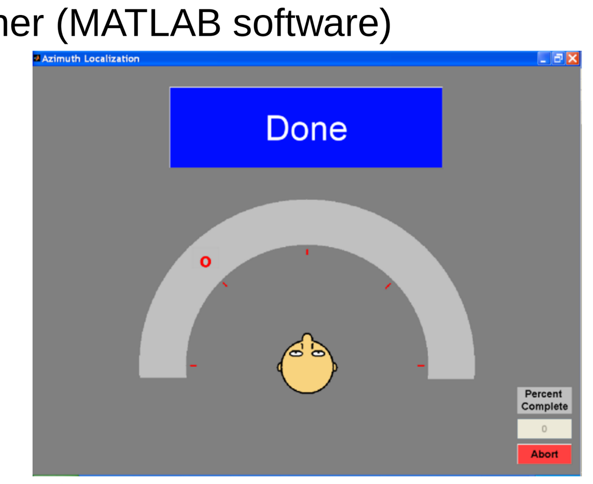

Figure 2. Touch screen used in localization task

Speech-in-Noise Task

•Target male talker (CNC words) positioned at 0° azimuth. Two female maskers (IEEE sentences) were presented at 50 dB SPL in four possible configurations (0°, +90°, -90°, or +/-90° (Figure 3)
•Testing conducted at signal-to-noise ratios (SNR) ranging from 0 to -30 dB SPL (MATLAB software)
•Listeners selected the heard word from a closed list of words on a touch screen
•SRM was computed in the bilateral, symmetric masking condition and in each unilateral masker position

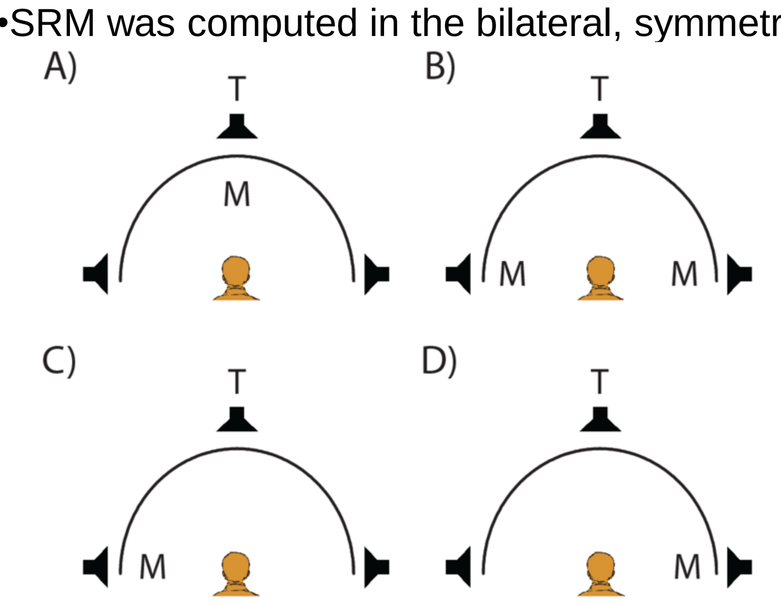

Figure 3. Speech-in-Noise Task. Each subject was tested in the binaural listening condition in four spatial configurations: A) Masker (M) at 0°; B) M at +/-90°; C) M at -90°; D) M at +90°. Target speech (T) was always presented from 0° azimuth.

Masker Position	Spatial Release From Masking Calculation
Bilateral	Binaural (A) – Binaural (B)
Left Ear	Binaural (A) – Binaural (C)
Right Ear	Binaural (A) – Binaural (D)

Figure 4. Spatial release from masking calculations. In each configuration (Figure 3, A-D), the SNR at which 50% of target words were identified correctly (SNR(50)) was calculated for each subject in the binaural listening condition. The SNR(50) obtained when no spatial separation between target and masker was present (A) was compared to listening conditions with the target and maskers separated in space (B-D).

Results: Localization and Speech-in-Noise

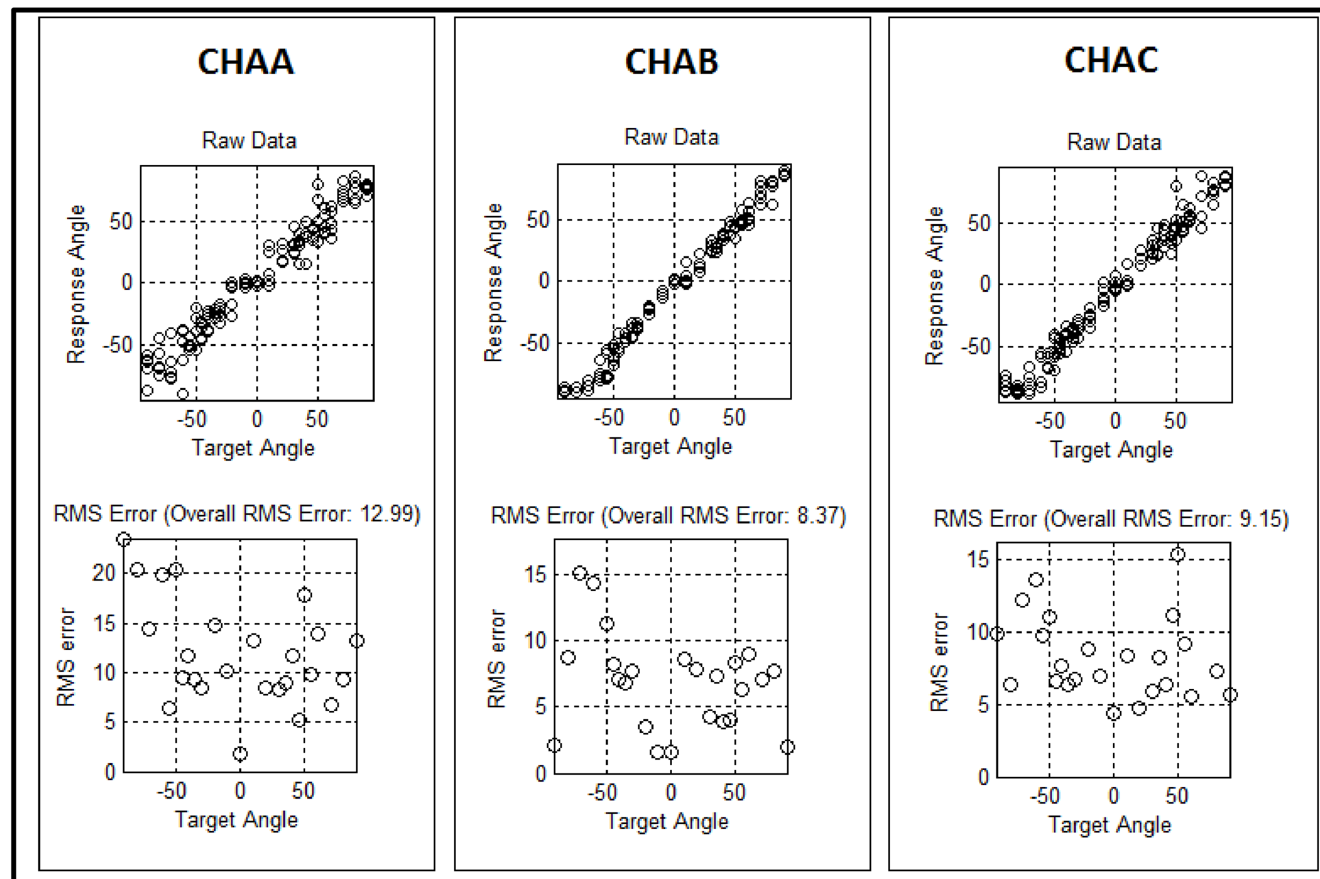

Figure 4. Localization accuracy for CUCHL subjects. Subjects were able to accurately localize the target sound within the correct hemi-field (top figures). Overall RMS error values ranged from 8.37-12.99° (bottom figures).

Reference: Average RMS Error for normal-hearing children (NH C) and normal-hearing young adults (NH YA) (Litovsky and Godar 2010)

NH C (ages 4.4-5.8): 10.2° +/- 10.72°
NH YA (ages 19-26): 3.6° +/- 1.63°

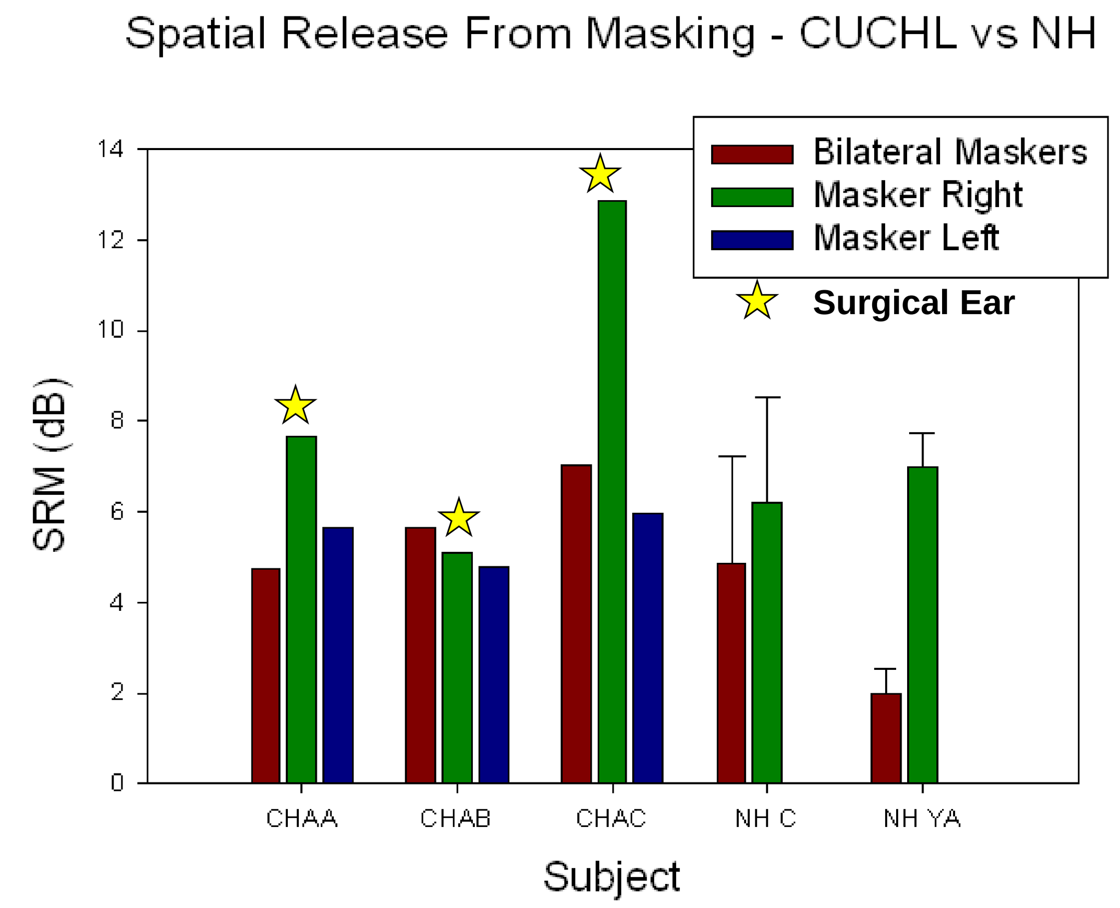

Figure 5. Spatial Release From Masking (SRM) values for CUCHL and normal-hearing (NH) subjects. SRM was measured using bilateral maskers (dark red bar), masker positioned to the right (green bar), and masker positioned to the left (blue bar). In NH subjects, masker right values are assumed identical to masker left results. Three CUCHL subjects (CHAA, CHAB, and CHAC) are compared to normal published values for NH children (NH C) ages 7-9 (Misurelli and Litovsky 2012) and for NH younger adults (NH YA) ages 18-22 (Jones and Litovsky 2011).

Conclusions

•Subjects undergoing surgical repair of CUCHL demonstrate SRM within the range of values of NH controls at long-term follow-up
•Localization accuracy was slightly worse in CUCHL subjects than in NH young adults, but comparable to performance of NH children.
•Individuals undergoing repair of CUCHL demonstrated SRM at long-term follow-up. The presence of SRM may be a result of auditory plasticity, suggesting that binaural processing strategies may mature with continued auditory stimulation in a surgically corrected ear over the long term.

References

1. Bess FH, Tharpe AM. Unilateral Hearing Impairment in Children. Pediatrics, Aug 1984, 74(2):206-216.
2. Wie OB, Pripp AH, Tvete O. Unilateral Deafness in Adults: Effects on Communication and Social Interaction. *Annals of Otology, Rhinology, and Laryngology* 2010; 119(11):772-781.
3. De la Cruz A, Teufert KB. Reconstruction of the Auditory Canal and Tympanum. In: Flint: Cummings Otolaryngology: Head & Neck Surgery, 5th ed. 2010 Mosby Press.
4. Service GJ, Roberson JB Jr. Current Concepts in Repair of Aural Atresia. *Curr Opin Otolaryngol Head Neck Surg* 2010 Dec;18(6):536-538.
5. Murakami CS, Quatella VC, Sie KCY, Shvidler J. Microtia Reconstruction. In: Flint: Cummings Otolaryngology: Head & Neck Surgery, 5th ed. 2010 Mosby Press.
6. Litovsky RY, Parkinson A, Arcaroli J. Spatial Hearing and Speech Intelligibility in Bilateral Cochlear Implant Users. *Ear Hear* 2009;30:419-431.
7. Hawley ML, Litovsky RY, Colburn HS. Speech Intelligibility and Localization in an Multi-source Environment. *J Acoust Soc Am* 1999 Jun; 105(6):3436-3448.
8. Middlebrooks JC, Green DM. Sound Localization by Human Listeners. *Annu Rev Psychol* 1991;42:135-159.
9. Wilmington D, Gray L, Jahrsdoerfer R. Binaural Processing after Corrected Congenital Unilateral Conductive Hearing Loss. Hearing Research, 1994, 74:99-114.
10. Litovsky RY, Godar SP, Difference in Precedence Effect Between Children and Adults Signifies Development of Sound Localization Abilities in Complex Listening Tasks. *J Acoust Soc Am* 2010 Oct; 128(4): 1979-1991
11. Misurelli SM, Litovsky RY. Spatial Release from Masking in Children with Normal Hearing and with Bilateral Cochlear Implants: Effect of Interferer Asymmetry. J Acoust Soc Am. 2012 Jul;132(1):380-291.
12. Jones GL, Litovsky RY. A Cocktail Party Model of Spatial Release from Masking by both Noise and Speech Interferers. *J Acoust Soc Am* 2010 Jan;127(1):400-414

Acknowledgements

•We would like to thank all of our listeners

•The authors would like to thank Heath Jones for preparing the diagrams depicting the localization and speech-in-noise setups

•Work funded by NIH-NIDCD (R01DC8083 and R01DC8365) and NIH-NICHD P30HD03352

•SG receives support from the Clinical and Translational Science Award (CTSA) program (KL2 scholar), by the National Center for Advancing Translational Sciences (NCATS), grant 9U54TR000021