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Clinical Implications for Pediatric Bimodal Fittings

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Moderated by:
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Clinical Implications for Pediatric Bimodal Fittings

Audiology On-Line

September 6, 2017

Lisa S. Davidson, PhD

Agenda

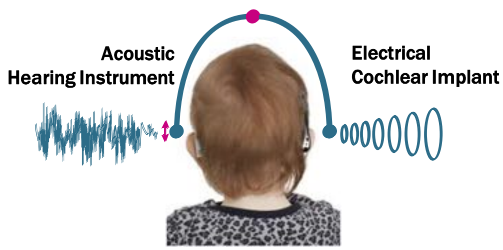
- Terminology/Patient Characteristics
- Benefits of Acoustic Hearing
- Considerations in Pediatric Bimodal Fitting
- Clinical Implications for Bimodal Fittings
- Case Study

Participant Outcomes

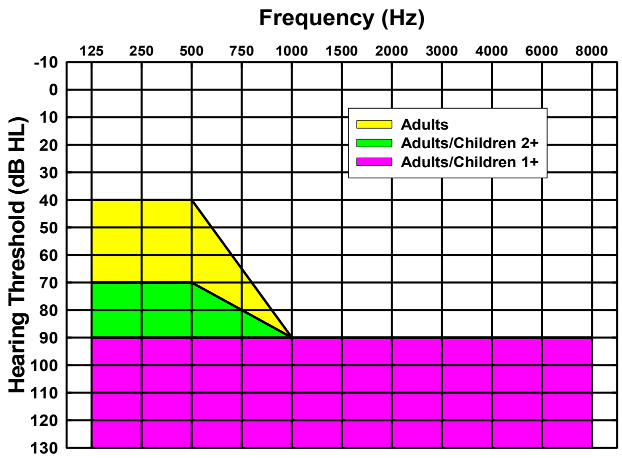
1) Participants will be able to summarize research findings related to how acoustic hearing may facilitate spoken language development for pediatric CI recipients.
2) Participants will be able to summarize fitting strategies related to fitting bimodal devices.
3) Participants will be able to describe outcome measures to assess bimodal benefit for pediatric CI recipients

Terminology/Patient Characteristics

BIMODAL DEVICES



Guidelines for CI Candidacy



SPEECH RECOGNITION CRITERIA

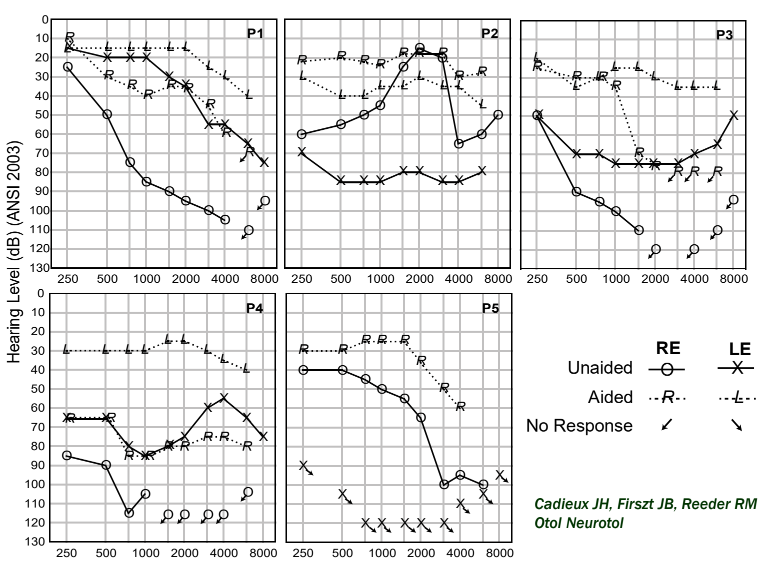
Adults:
≤ 50% Sentences aided in ear to be implanted
≤ 60% Sentences best-aided

Children:
< 2 yrs old: profound range for thresholds
> 2 yrs old: ≤ 30% LNT, or MLNT, best-aided

Pediatric CI Candidacy

- Age at implantation (12 months)
- Consideration of children with more residual hearing at both ears (≥ 2 years old)
- Consideration of children with asymmetric hearing loss (≥ 2 years old)
- Poor audibility in high frequency range

Example Audiograms for Some Non-traditional Pediatric Bimodal Recipients

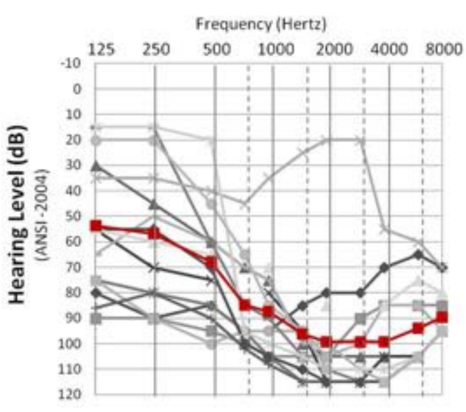


Cadieux JH, Firszt JB, Reeder RM (2013) Otol Neurotol

Increased Number of Bimodal Recipients as CI Candidacy Expands

- Numbers of bimodal recipients have increased (2002: 10% were bimodal users (Tyler et al.) 2009: ~30% (Fitzpatrick et al.)2010: >50% with aidable hearing in non-CI ear (Dorman & Gifford):
  - Greater level of residual hearing/speech recognition at non-implanted ear (Fitzpatrick et al 2009; Gifford et al., 2010; Sampaio et al., 2011; Mowry et al., 2012,)
  - Non-traditional candidates with asymmetric hearing profiles (Firszt et al., 2012; Cadieux et al., 2013)

Unaided Audiometric Threshold Profiles at HA Ear for Bimodal Recipients



Davidson et al., 2015

Benefits of Combining Acoustic and Electric Hearing

- Benefits (compared to unilateral CI use) for adults and children may include: speech perception in quiet and noise, localization, speech quality, music appreciation/recognition & ease of listening
- **A period of HA use, prior to receiving a 2^{nd} CI, may facilitate spoken language and literacy skills in pediatric CI recipients (Nittrouer & Chapman, 2009; Nittrouer et al., 2012; Nittrouer et al., 2014)**
- Benefits may vary across individuals and conditions

(See review from Ching et al. 2007; Sammeth et al. 2011; & Schafer et al., 2011)

What Are the Possible Mechanisms Underlying Bimodal Benefit?

Low Frequency Acoustic Cues (F0, F1, F2)

- Allow CI listeners to segregate speech when competing talkers present
- Improve performance by providing phonetic information (i.e. voicing and manner)
- Improve performance by providing phonetic cues for lexical boundaries and prosodic information

Ching et al., 2005; Mok et al., 2006; Brown and Bacon, 2009 & 2010; Spitzer et al., 2009; Cullington et al., 2010

What are the contributions of Acoustic and Electric Hearing?

Hearing Aid

- **Supra-Segmental Cues** (voice pitch (F0)/ voicing and manner cues)
- Music appreciation
- Perception in noise

Cochlear Implant

- **Segmental Cues** (phoneme perception/ high frequency audibility/place cues)
- Speech intelligibility

(Ching, 2011; McDermott, 2011; Sheffield & Zeng, 2012)

Speech Perception

Two main areas of speech perception:

- **Segmental** Perception: "what is said"
  - vowels and consonants; words; sentences
- **Suprasegmental** Perception: "how something is said" or "who said it"
  - prosody, intonation, stress; talker characteristics (emotion, gender, age, accent, etc.)

Both types of perception are necessary for effective spoken communication and spoken language development (Abercrombie, 1967; Pisoni, 1997)

Possible Bimodal Benefits for Spoken Language Development

How might a HA (combined with a CI) facilitate spoken language development– especially in the first year(s) of life?

- Good perception of the **Fundamental Frequency, F_0**, of voiced speech is considered important:
  - especially for <u>infants</u>, to segment speech and learn lexical boundaries (i.e., words) – possibly via the exaggerated prosody of infant-directed speech
  - to learn talkers' voices, which may interact with word-learning
  - to segregate voices when competing talkers' speech is present
  - to perceive indexical properties of talkers (e.g., gender, emotion)

  [Above may be considered suprasegmental speech perception]
  - to understand semantic "tone", for tonal languages
- **HAs** (depending on listener's level of hearing) **convey F_0 information better than CIs**

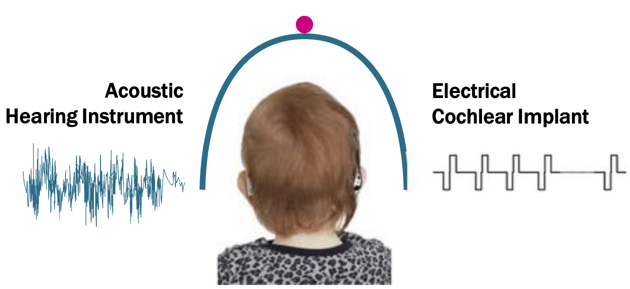
Ching et al., 2005; Mok et al., 2006; Brown and Bacon, 2009 & 2010; Spitzer et al., 2009; Cullington et al., 2010; Sheffield et al., 2015; Grant, 1987; Most & Peled, 2007; Carroll & Zeng, 2007; Perrachione et al., 2011; Sidtis & Kreiman, 2012

Considerations for Fitting Bimodal Devices

Challenges for Bimodal Device Fitting

- Mismatches in pitch, timing and loudness across CI and HA
- Mismatches in gain and compression characteristics across commercial CI and HA systems

Obstacles to bimodal fitting related to current commercial CI and HA systems (For a review see Francart & McDermott, 2013)



Optimizing Bimodal Fittings

- Studies' results support the coordinated fitting of a hearing aid (HA) and cochlear implant (CI) for bimodal use (CI + HA at non-implanted ear) that emphasizes balanced ***loudness*** across the two ears/devices (Blamey et al.,2000; Ching et al., 2001; Ching et al., 2007)
  - No widely established fitting protocols for balancing loudness/audibility across CI and HA, although some published protocols include:
    - Loudness matching task used to balance loudness of three warbletone stimuli centered at 500 Hz, 1000 Hz & 2000 Hz (presented at 65 dB SPL) across CI and HA ears for 16 pediatric bimodal recipients. Modifications to HA made to NAL-RP gain/output targets (Ching et al., 2001).
    - Loudness scaling task (7-point scale from "not heard" to "too loud") using narrowband stimuli at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz was administered in CI alone and HA alone condition to pediatric and adult bimodal recipients. Adjustments to devices made based on loudness scaling. Pediatric recipients had HA set to DSL output targets (Keilmann et al., 2009).
    - Loudness matching task using broadband, live voice or calibrated running speech across CI and HA ears for adult bimodal recipients. Changes to HA made to gain/outputs set to various fitting targets (Mok et al., 2006; Veugen et al., 2016).

Some Recommendations for Adjusting Bimodal Fit for Loudness

- Balance comfort/loudness of input levels of speech from soft to loud across devices using:
  - Live voice speech presentation
  - Calibrated running speech @ ~65 dB SPL, ~70 dB SPL, ~80 dB SPL
  - Environmental sounds at various levels
- Adjust Global Map C/M levels or volume, adjust output of hearing aid, evaluate compression characteristics of each device, evaluate frequency-specific C levels, output etc.

Some Optimization Recommendations

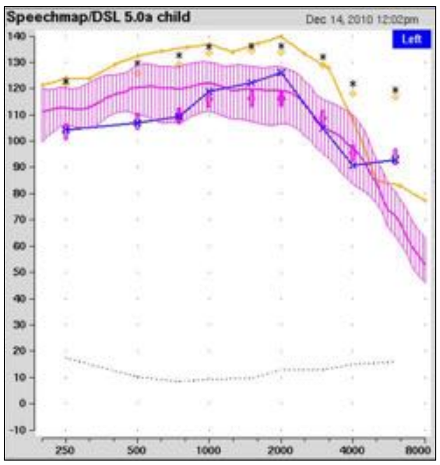
- Huart, S. A., & Sammeth, C. A. (2008). Hearing aids plus cochlear implants: Optimizing the bimodal pediatric fitting. *The Hearing Journal, 61*(11), 54,56-58.
- Bimodal Hearing Aid Fitting Guidelines: Oticon White Paper 2015 - Carisa Reyes/ Boys Town National Research Hospital

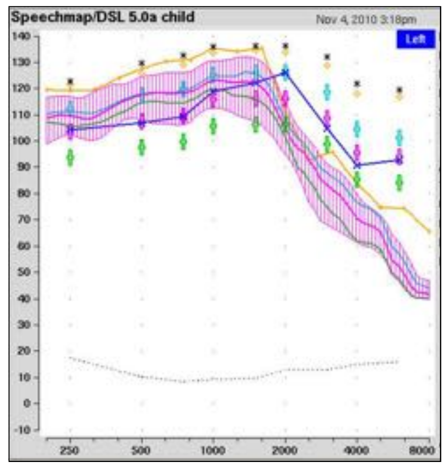
Optimizing Bimodal Fittings

- What is the best frequency response for the HA? Results vary across studies, individuals and outcome measures!
  - Do we deliver low frequencies to the HA and high frequencies to the CI? Or do we provide BOTH devices with the widest frequency range? *(Vermiere et al., 2008; Simpson et al., 2009; Zhang et al, 2010)*
  - Should we restrict HA gain to regions that have more residual hearing or to low frequency regions? *(Mok et al., 2006, 2010; Potts et al., 2009; Neuman & Svirsky, 2013, Davidson et al., 2015; Messersmith et al, 2015)*
  - Should we consider Frequency transposition/compression for HA? Or could this processing interfere with CI processing? *(Gifford et al., 2007; McDermott & Henshall, 2010; Park et al., 2012; Perreau et al., 2013)*

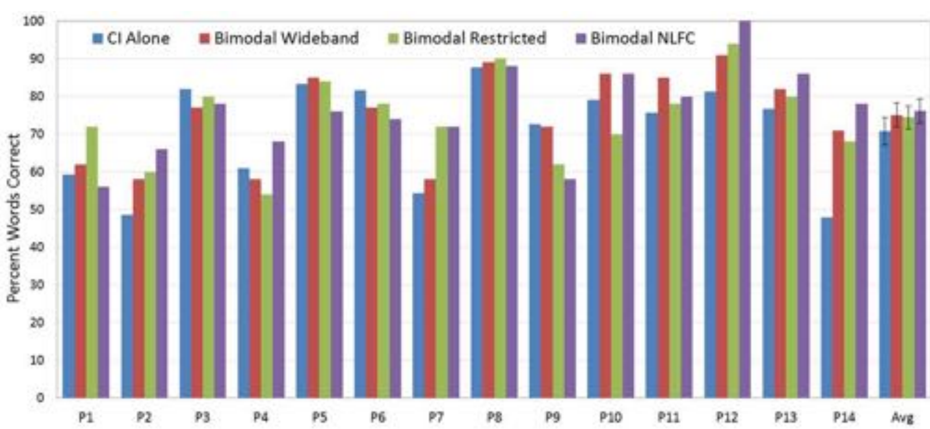
Bimodal Fitting Options

Wideband Fitting **Restricted Fitting**





Individual Differences across HA fittings for Bimodal Performance (compare to CI-only scores)



Individual Word Recognition Scores (in quiet) for three CI+HA conditions compared to CI-alone scores (Davidson et al., 2015)

What should we do clinically?

- Consider a variety of HA responses (i.e., restricted and NLFC) in addition to the traditional wideband frequency response for HA settings used in bimodal fittings
- Optimize HA for individual differences and preferences
- Consider a variety of outcome measures
- Consider measuring dead regions to determine "aidable" hearing (Zhang et al., 2014) – may be questionable for pediatric population
- Consider bilateral CI's when most outcome measures fail to produce a bimodal benefit, despite the clinicians best attempt at optimizing the bimodal fitting

Bimodal Devices on Children: A Survey of Clinician Fitting Practices in North America

Knowledge Implementation in Pediatric Audiology Group (KIPA)

Lisa Davidson[1], Steve Aiken[2], Eileen Rall[3], Leisha Eiten[4], Sheila Moodie[5], George Lindley[6], Meredith Magathan Haluschak[7], Dave Gordey[8], Kamilla Angelo[8]

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[6]Salus University, Elkins Park, PA and East Penn Hearing Center, Emmaus, PA, USA
[7]Institute for Reconstructive Sciences in Medicine (iRSM), Edmonton, AB, Canada
[8]Oticon A/S, Smørum, DK

DISCLOSURES

- THIS PROJECT HAS RECEIVED SUPPORT FROM OTICON A/S
- DAVE GORDEY AND KAMILLA ANGELO ARE EMPLOYEES OF OTICON A/S

KIPA BIMODAL SURVEY (2016)

- A web-based survey was sent out to approximately 300 clinicians, and 85 responded.
- The survey was posted on the ACI blog; and distributed to pediatric clinics and hospitals identified from cochlear implant manufacturer websites and hearing aid manufacturers in the United States and Canada.
- Survey questions requested information about clinical practices when fitting cochlear implants, hearing aids and bimodal devices in children.

COCHLEAR IMPLANTS: VERIFICATION

- Unlike hearing aids, cochlear implants lack standardized verification procedures
- Other than speech discrimination testing, the use of verification/outcome testing is highly variable and measures were not age-dependent.

SUMMARIZING SURVEY RESULTS

- Compared to hearing aids, the verification and outcome measures used for cochlear implants are highly variable. Only half of the participants report that they fit both hearing aids and cochlear implants, which makes coordinated hearing care for children using bimodal devices challenging.
- Due to the lack of evidence-based fitting protocols for bimodal devices, the majority of clinicians use their own, internally-developed fitting protocol/guideline, or do not use a systematic protocol/guideline at all.

Recommendations for Hearing Aid Use for Bimodal Fittings

- Consistent hearing aid use should be implemented prior to CI/s
- Hearing aid use after unilateral CI surgery and prior to initial activation is strongly encouraged
- Continued hearing aid use AFTER initial activation is strongly encouraged

Outcomes and Evaluation

What are the clinical issues related to evaluating bimodal benefit?

- How do we best evaluate the effects of bimodal devices using clinically available tests and procedures?
- How do evaluate very young children?
- <u>When do we consider bilateral implants</u> and is there a degree of hearing associated with this decision?

Validating Bimodal Fit

- Aided thresholds for FM tones or Ling Sounds to compare audibility across devices
- Aided speech testing (binaural & monaural)
  - Speech Perception in quiet (50 and 60 dB SPL)
  - Speech Perception in noise
  - Note that HA-only testing may not be possible; a less difficult test may be needed (good to have baseline)
  - Most important to determine whether bimodal perception is not degraded compared to CI alone

Speech Perception Outcomes

- Improvements in device technology necessitate an ever expanding speech perception test battery
- Speech perception outcomes must be interpreted in the context of linguistic, cognitive and developmental level of the child
- Speech perception outcomes should reflect real world listening environments and be replicated in a clinical setting
- A variety of outcome measures should be used to assess benefit (i.e., localization, talker discrimination, perception in quiet and noise, subjective reports)

Pediatric Speech Perception Recommendations

- Uhler, K., Warner-Czyz, A., Gifford, R., & Working Group, P. (2017). Pediatric Minimum Speech Test Battery. *J Am Acad Audiol, 28*(3), 232-247

Outcome Measures for Evaluation

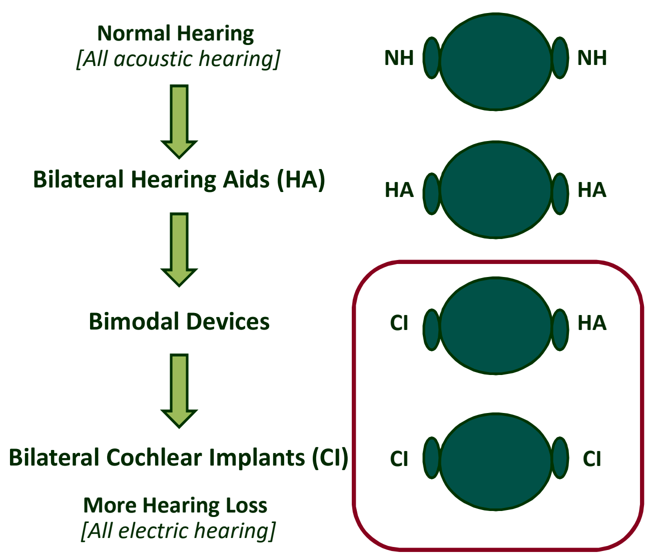
Clinical Measures

- Word and Sentence Recognition in quiet and noise (*segmental perception*)
- Subjective reports (questionnaires and patient report)
- Very young children may be limited to detection tasks (i.e., Ling Sounds, aided responses) and parent/educator reports and observation

Research Measures

- Music perception
- Localization
- Suprasegmental Speech Perception (emotion identification, stress discrimination and talker discrimination)

Clinical Standard of Care is to Fit BOTH ears



When should we move from bimodal to bilateral devices?

- Speech perception results show no/minimal bimodal benefit; however
  - Bimodal benefit may be affected by test sensitivity and may vary across test measures
  - As CI-alone performance improves bimodal benefit may appear diminished
  - Speech perception results and subjective reports may differ
- Child resists wearing hearing aid and/or reports distortion with hearing aid
  - Discussion of clarity vs. quality should be considered for some children
  - Motivation is key issue for successful transition for older children

Bimodal vs. Bilateral CIs

Ching et al. (2007). Binaural-Bimodal Fitting or Bilateral Implantation for Managing Severe to Profound Deafness: A Review. *Trends in Amplification, 11, 161-192.*

Schafer et al. (2011). A Meta-analytic comparison of binaural cochlear implants and bimodal stimulation, *Journal of American Academy of Audiology*, Vol 18, 760-775.

Issues to consider

- Is there an optimal period for receiving bilateral CIs?
- Can bimodal device use prevent binaural auditory deprivation (caused by unilateral CI use)?
- What degree of residual hearing at the HA ear is beneficial?

(Chadha et al., 2011; Gordon et al., 2011)

Bimodal to Bilateral Case Study

Case Study

Passed NBHS (Newborn Hearing Screening)

Diagnosed with severe - profound hearing loss at age 3, fit with hearing aids at that time and enrolled at CID

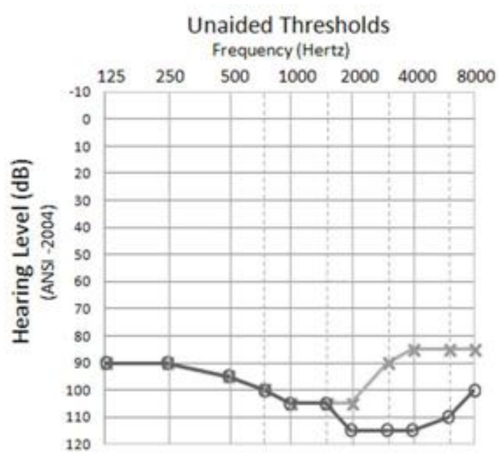
Age at Bimodal Testing: 7

Right CI - 1st - April 2008 (age 4)

Left CI - 2nd - August 2011 (age 8)

Graduated CID and entered mainstream Summer 2013

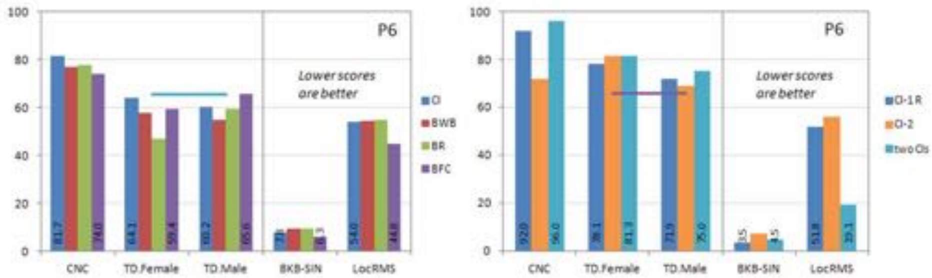
Unaided Thresholds



Left Ear-HA
Right Ear-CI

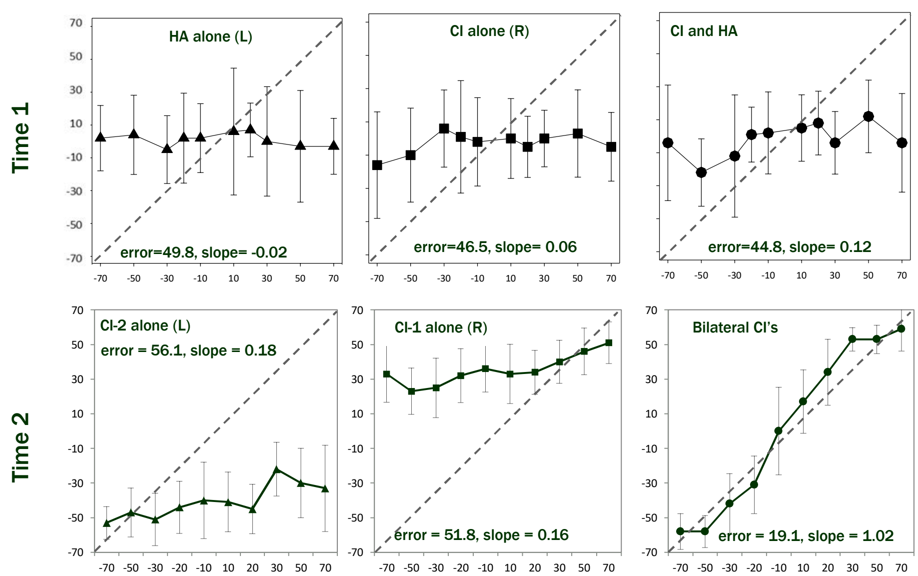
Bimodal and Bilateral Scores

Scores with bimodal devices from 2011 | Scores with 2 CIs from 2013



In summary, performance with 2CIs is no worse than bimodal and for some outcomes measures may be better. However cannot rule out effects of maturation.

Case Study: Localization



Conclusions

- Bilateral device use should be standard for Pediatric CI recipients (Bimodal or Bilateral CIs)
- Bimodal Fittings should optimized for individual performance and preference
- A variety of outcome measures should be considered when evaluating benefits

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- Oticon

Projects reported reviewed by institutional IRB, protocols number 201106097 and 201010735

Thank You

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References

Blamey, P. J., Dooley, G. J., James, C. J., & Parisi, E. S. (2000). Monaural and binaural loudness measures in cochlear implant users with contralateral residual hearing. *Ear Hear, 21*(1), 6-17.

Cadieux, J. H., Firszt, J. B., & Reeder, R. M. (2013). Cochlear implantation in nontraditional candidates: preliminary results in adolescents with asymmetric hearing loss. *Otol Neurotol, 34*(3), 408-415.

Chadha NK, Papsin BC, Jiwani S, Gordon KA. (2011) Speech detection in noise and spatial unmasking in children with simultaneous versus sequential bilateral cochlear implants. Otol Neurotol 32(7):1057–1064.

Chang, J. E., Bai, J. Y., & Zeng, F. G. (2006). Unintelligible low-frequency sound enhances simulated cochlear-implant speech recognition in noise. *53*(12 Pt 2), 2598-2601.

Ching, T., Psarros, C., Hill, M., Dillon, H., & Incerti, P. (2001). Should children who use cochlear implants wear hearing aids in the opposite ear? *Ear Hear, 22*(5), 365-380.

Ching, van Wanrooy, E., & Dillon, H. (2007). Binaural-bimodal fitting or bilateral implantation for managing severe to profound deafness: a review. *Trends Amplif, 11*(3), 161-192.

Ching, T. Y. C. (2011). Acoustic Cues for Consonant Perception with Combined Acoustic and Electric Hearing in Children. *Semin Hear, 32*(01), 032-041.

Dorman, M. F., Cook, S., Spahr, A., Zhang, T., Loiselle, L., Schramm, D., et al. (2015). Factors constraining the benefit to speech understanding of combining information from low-frequency hearing and a cochlear implant. *Hearing Research, 322*(0), 107-111.

Firszt, J. B., Holden, L. K., Reeder, R. M., Cowdrey, L., & King, S. (2012). Cochlear implantation in adults with asymmetric hearing loss. *Ear Hear, 33*(4), 521-533.

Francart, T., & McDermott, H. J. (2013). Psychophysics, fitting, and signal processing for combined hearing aid and cochlear implant stimulation. *Ear Hear, 34*(6), 685-700.

Gifford, R. H., Dorman, M. F., Shallop, J. K., et al. (2010). Evidence for the expansion of adult cochlear implant candidacy. *Ear Hear*, *31*, 186–194.

Gifford, R.H., Dorman, M.F., Spahr, A.J., and McKarns, S.A (2007). "Effect of digital frequency compression (DFC) on speech recognition in candidates for combined electric and acoustic stimulation (EAS)," Journal of Speech Language and Hearing Research 50, 1194-1202.

Gordon KA, Papsin BC. (2009) Benefit of short inter-implant delays in children receiving bilateral cochlear implants. Otol Neurotol 30:319Y31.

Gordon, K. A., Jiwani, S., & Papsin, B. C. (2011). What is the optimal timing for bilateral cochlear implantation in children?. *Cochlear Implants Int, 12*(2).

Illg, A., Bojanowicz, M., Lesinski-Schiedat, A., Lenarz, T., & Buchner, A. (2014). Evaluation of the bimodal benefit in a large cohort of cochlear implant subjects using a contralateral hearing aid. *Otol Neurotol, 35*(9), e240-244.

Kong, Y.Y., Stickney, G.S., and Zeng, F.G (2005). "Speech and melody recognition in binaurallycombined acoustic and electric hearing," J Acoust Soc Am 117, 1351-1361.

McDermott, H., & Henshall, K. (2010). The use of frequency compression by cochlear implant recipients with postoperative acoustic hearing. *J Am Acad Audiol, 21*(6), 380-389.

McDermott, H. (2011). Benefits of Combined Acoustic and Electric Hearing for Music and Pitch Perception. *Semin Hear, 32*(01), 103-114.

Mok, M., Grayden, D., Dowell, R., Lawrence, D (2006). “Speech perception for adults who use hearing aids in conjunction with cochlear implants in opposite ears”. J Speech Lang Hear Res, 49, 338–351.

Mok M., Galvin K.L, Dowell R.C., McKay, C.M (2010). “Speech Perception Benefit for Children with a Cochlear Implant and a Hearing Aid in Opposite Ears and Children with Bilateral Cochlear Implants”. Audiol Neurotol 2010;15:44–56

Mowry, S. E., Woodson, E., Gantz, B. J. (2012). New frontiers in cochlear implantation: Acoustic plus electric hearing, hearing preservation, and more. *Otolaryngol Clin North Am*, 45, 187–203.

Nittrouer, S. and C. Chapman, *The effects of bilateral electric and bimodal electric–acoustic stimulation on language development.* Trends Amplif, 2009. **13**(3): p. 190-205.

Nittrouer, S., Caldwell, A., Lowenstein, J.H., Tarr E. and Holloman, C. (2012). Emergent Literacy in Kindergartners with Cochlear Implants. *Ear Hear, 33(6):* 683-697.

Nittrouer, S., Caldwell-Tarr, A., Sansom, E., Twersky, J., & Lowenstein, J. H. (2014). Nonword repetition in children with cochlear implants: a potential clinical marker of poor language acquisition. *Am J Speech Lang Pathol, 23*(4), 679-695.

Nittrouer, S., Tarr, E., Bolster, V., Caldwell-Tarr, A., Moberly, A. C., & Lowenstein, J. H. (2014). Low-frequency signals support perceptual organization of implant-simulated speech for adults and children. *Int J Audiol, 53*(4), 270-284.

Neuman, A. C., & Svirsky, M. A. (2013). Effect of hearing aid bandwidth on speech recognition performance of listeners using a cochlear implant and contralateral hearing aid (bimodal hearing). *Ear Hear, 34*(5), 553-561.

Park, L. R., Teagle, H. F., Buss, E., Roush, P. A., & Buchman, C. A. (2012). Effects of frequency compression hearing aids for unilaterally implanted children with acoustically amplified residual hearing in the nonimplanted ear. *Ear Hear, 33*(4), e1-e12.

Perreau, A. E., Bentler, R. A., & Tyler, R. S. (2013). The contribution of a frequency-compression hearing aid to contralateral cochlear implant performance. *J Am Acad Audiol, 24*(2), 105-120.

Potts, L. G., Skinner, M. W., Litovsky, R. A., Strube, M. J., & Kuk, F. (2009). Recognition and localization of speech by adult cochlear implant recipients wearing a digital hearing aid in the nonimplanted ear (bimodal hearing). *J Am Acad Audiol, 20*(6), 353-373.

Sammeth, C. A., Bundy, S. M., & Miller, D. A. (2011). Bimodal Hearing or Bilateral Cochlear Implants: A Review of the Research Literature. *Semin Hear, 32*(01), 003-031.

Sampaio, A. L., Araújo, M. F., Oliveira, C. A. (2011). New criteria of indication and selection of patients to cochlear implant. Int J Otolaryngol, 2011, http://dx.doi.org/10.1155/2011/573968

Schafer, E. C., Amlani, A. M., Paiva, D., Nozari, L., & Verret, S. (2011). A meta-analysis to compare speech recognition in noise with bilateral cochlear implants and bimodal stimulation.. *Int J Audiol, 50*(12), 871-880.

Sheffield, B. M. and Zeng, F. G. (2011). The relative phonetic contributions of a cochlear implant and residual acoustic hearing to bimodal speech perception. *J. Acoust. Soc. of Am., 131*(1), 518-530.

Zhang, T., Spahr, A. J., & Dorman, M. F. (2010). Frequency Overlap Between Electric and Acoustic Stimulation and Speech-Perception Benefit in Patients with Combined Electric and Acoustic Stimulation. *Ear and Hearing, 31*(2), 195-201.

Zhang, T., Dorman, M.F. and Spahr, A.J. (2010) Information From the Voice Fundamental Frequency (F0) Region Accounts for the Majority of the Benefit When Acoustic Stimulation Is Added to Electric Stimulation. *Ear and Hearing, 31*; 63-69.

Zhang, T., Dorman, M., Gifford, R., Moore, B., 2014. Cochlear dead regions constrain the benefit of combining acoustic stimulation with electric stimulation. *Ear Hear* 35 (4), 410e417.