



Cochlear Implantation in Children

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(Work supported by NIH-NIDCD and Psi Iota Xi National Philanthropic Sorority)



Prevalence of Hearing Loss in Children

- Congenital or early acquired: 0.5-3 per 1000 live births
- Ages 3-10: 1.1 cases per 1000 live births

About 60% are mild-moderate losses

About 40% are severe-profound losses

Does not account for children with progressive loss



Amplification for Profound Deafness

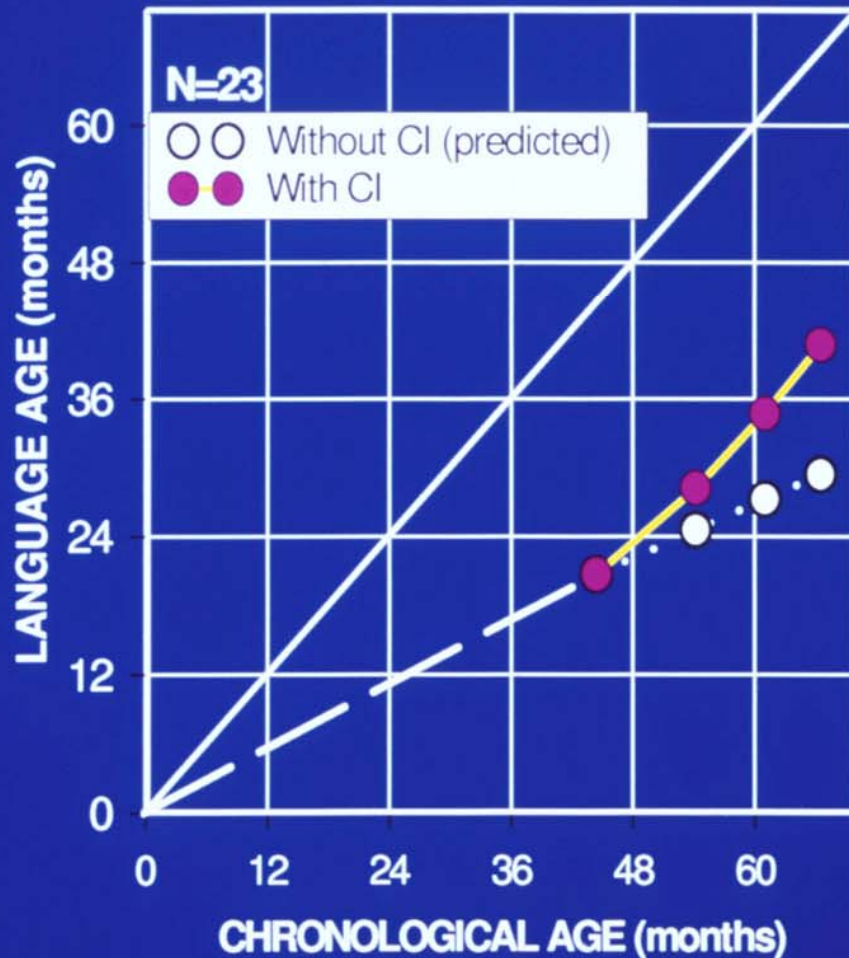
- Quieter sounds of speech = 30 dB HL
- With 60 dB of amplification, soft sounds heard by persons with 90 dB hearing loss
- If hearing loss $>$ 90 dB, hear only louder speech sounds
- Difficult to maintain comfortable audibility with variations in talker or talker distance



Impact of Prelingual, Profound Deafness

- Hearing aids yield limited auditory access to speech
- Difficulty acquiring spoken language of the surrounding community
 - May see delays and deficits in
 - Speech perception (Kirk et al., 1995; Svirsky et al., 2002)
 - Speech production (Smith, 1975)
 - Receptive and expressive language (Svirsky et al. 2000)
 - Literacy and academic performance (Geers, 2003)

Language gap post-implant

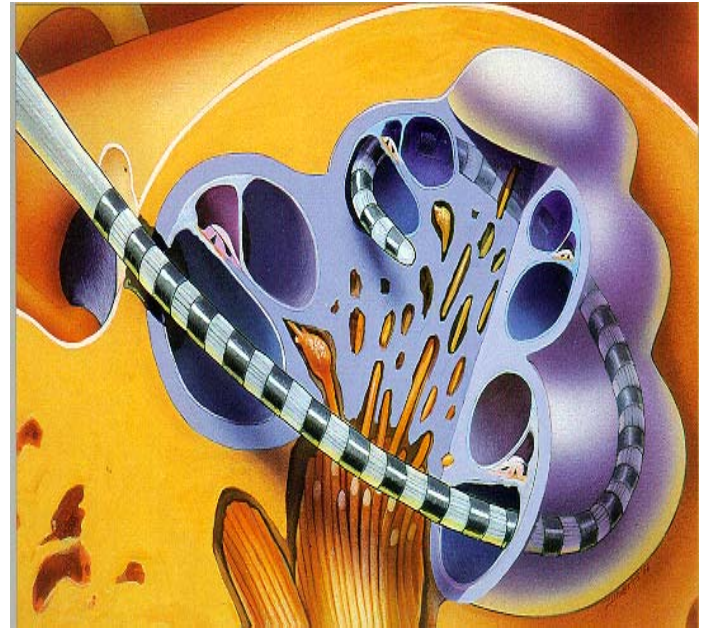


From:
Svirsky et al.,
Psychological Science (2000).

Speculation:
Earlier implantation
=>
Smaller language gap

Cochlear Implants (CIs)

- Auditory prostheses for individuals that receive minimal benefit from a hearing aid
 - Bypass damaged sensory cells in the inner ear
 - Convert sound into electrical signals that directly stimulate the auditory nerve (Wilson, 2000).





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Cochlear Implants Components

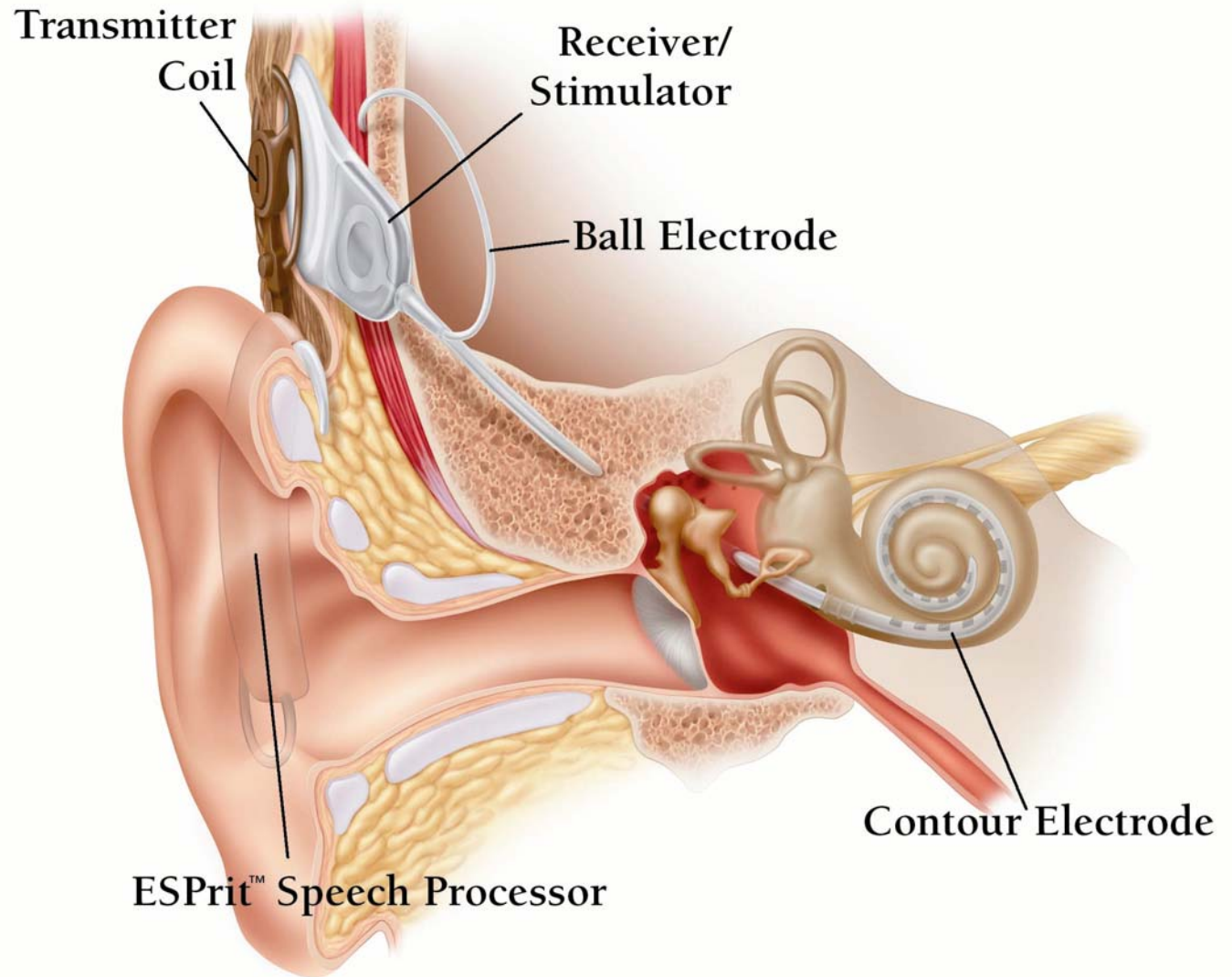
- a surgically-implanted electrode array

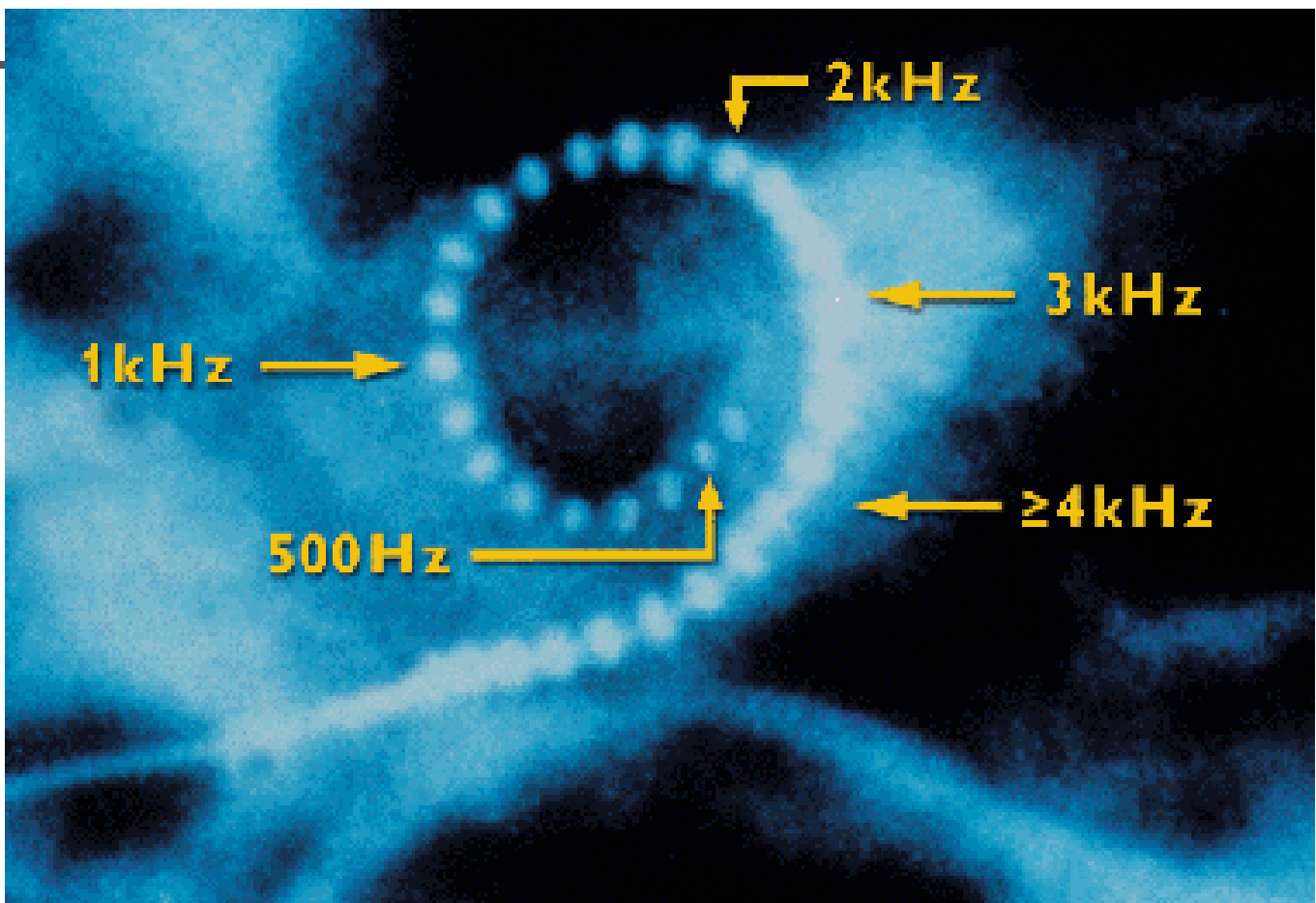
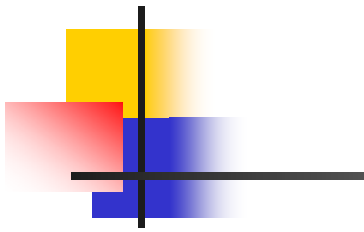


- an externally-worn speech processor



Nucleus 24 Contour™ System

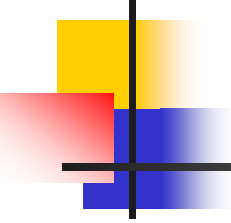






Cochlear Implants in Children

- 1990 – FDA approval for use in children with profound hearing loss age 2-17 years (Clark, 2000).
- Today –
 - Substantial technological advances in CI systems (Niparko & Wilson, 2000)
 - Concomitant broadening of pediatric candidacy criteria (Staller et al., 2002)



Current FDA Guidelines for CI Candidacy Criteria

- Now permit the implantation of children
 - with profound hearing loss as young as 12 months of age
 - with severe-to-profound hearing loss as young as 24 months of age.
- Some surgeons have elected to implant children at even younger ages
 - At least 140 children in US have received a CI prior to 12 months of age (Luxford, 2004)
 - Goal is to mitigate effects of early auditory deprivation



Additional Pediatric CI Candidacy Criteria

- Medically suitable
- Minimal benefit from conventional hearing aids
- In an environment that encourages the development of speaking and listening skills



Pre-Implant Evaluations

- Audiological
 - unaided and aided testing
- Medical
- CT or MRI scan
- Psychological (optional for adults)
- Orientation to CI program
 - includes device options



Cochlear Implant Procedures

- Outpatient surgery
 - patients typically stay one night in the hospital
- Fitting the external equipment
 - provided 4-6 weeks after surgery
 - requires multiple appointments during first few months
 - semi-annual appointments for 3 years
 - annual appointments thereafter



CI Outcomes

- Most children demonstrate
 - some speech understanding through listening alone
 - increased rate of language acquisition
 - Improved speech intelligibility
- Wide variability in individual outcomes
- Children in programs that strongly emphasize the development of speaking and listening skills make the greatest gains



DeVault Otologic Research Laboratory

- NIH-funded studies
 - ongoing for >15 years
- Goals:
 - assess benefits of CI use in prelingually deafened children
 - identify factors contributing to success



DeVault Otologic Research Laboratory

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Indiana University DeVault Otologic Research Laboratory

- NIH-funded studies
 - ongoing for nearly 20 years
- Goals:
 - assess benefits of CI use in prelingually deafened children
 - identify factors contributing to success



Effects of Age at Implantation on Long-term Cochlear Implant Outcomes



Introduction

- Earlier implantation generally seen as beneficial
 - Limits auditory deprivation and resultant neural degeneration (Kral et al., 2001)
 - Minimizes language delays by reducing gap between language age and chronological age (Svirsky et al., 2000)
- However, there are conflicting results concerning effects of age at implantation



Rationale for Present Study

- Very young children
 - May lack skills needed to participate in formal testing
 - Cognitive
 - Developmental
 - Language/vocabulary
- Age at CI effects may be obscured during early periods of CI use
- Alternatively, effects may decrease with increasing chronological age



Rationale (continued)

- Empirical data are needed to
 - Further refine our understanding of critical periods for implantation in young children
 - Examine longer-term effects of age at implantation, considering
 - Development of communication skills
 - Potential impact on academic readiness



Participant Selection Criteria

- Prelingually deafened (< 3 yrs)
 - Fit with CI by age 5 years
 - CI use > 5 years
 - Users of current CI technology
-
- Participants were stratified by age at CI

Participant Characteristics (N=40)

Age at CI	<2 yrs (n=17)	2 yrs (n=17)	3 yrs (n=9)	4 yrs (n=5)
Age at Onset	0.6 mos	3.6 mos	4.7 mos	0.0 mos
Age at CI*	19.7 mos	28.4 mos	40.0 mos	55.0 mos
Unaided PTA	113 dB HL	112 dB HL	110 dB HL	104 dB HL



Procedures

- Test battery was administered preimplant and at regular postimplant intervals
- Tests varied as a function of age at time of testing
- Data were collapsed within postimplant annual intervals



Open-Set Spoken Word Recognition Tests

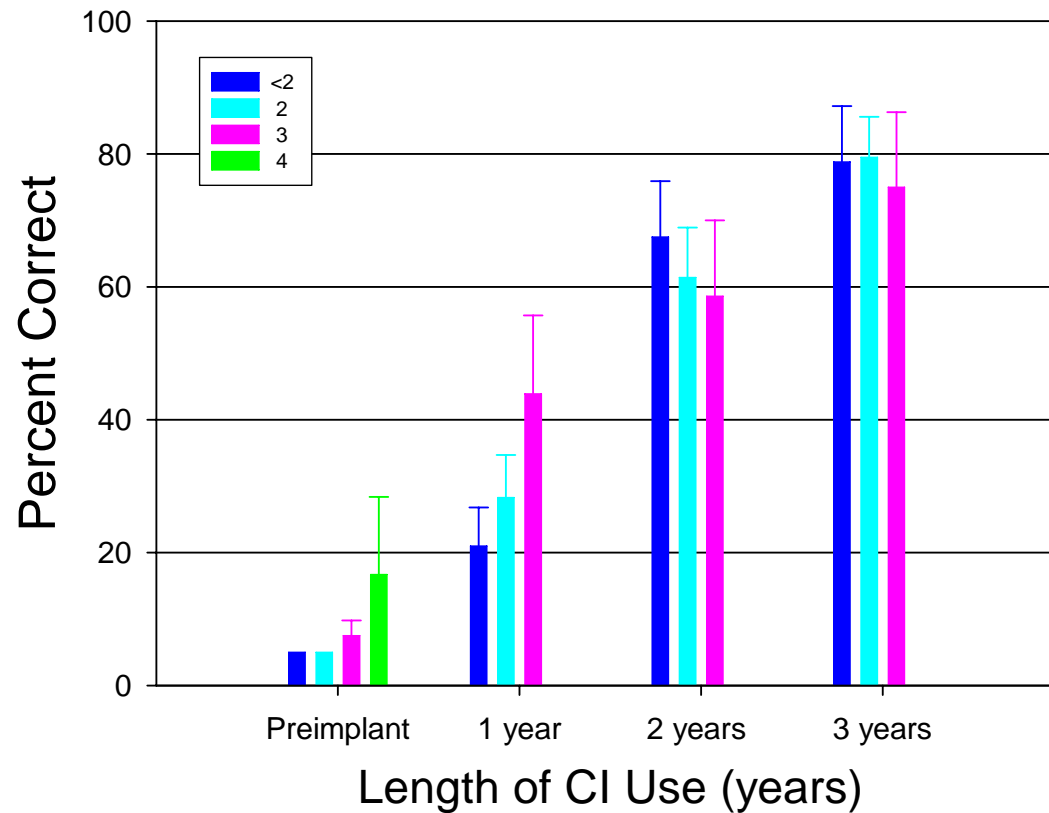
- Test is administered via live voice in auditory only presentation format
 - No manual signs / no lip reading cues
- Child responds by repeating and/or signing the word
 - No response alternatives provided
- Responses scored as percent correct



Mr. Potato Head Task

- Suitable for young children
- Consists of Mr. Potato Head toy with many body parts and accessories
- Child manipulates toy in response to verbal instructions
 - “Give him some green shoes.”
- Scored as the percent of words or sentences correct

Mr. Potato Head Task





Lexical Neighborhood Test (Kirk, Pisoni & Osberger, 1995)

- Theoretically motivated by NAM model of spoken word recognition (Luce, 1986)
- 2 levels of lexical difficulty based on
 - Word frequency
 - Lexical density (i.e., number of similar sounding words)
- Tokens represent early-acquired vocabulary



Lexical Neighborhood Test

- 2 lists of 50 monosyllabic words
 - 25 “easy” words / 25 “hard” words per list

EASY

juice

need

watch

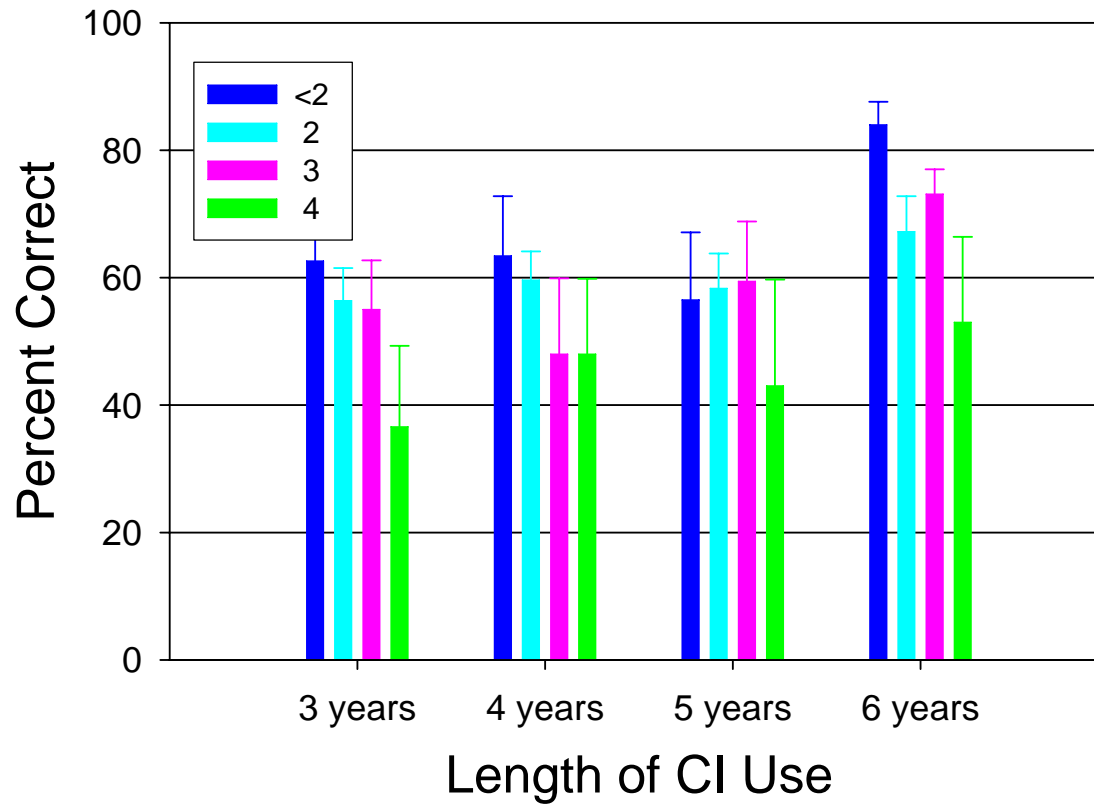
HARD

pie

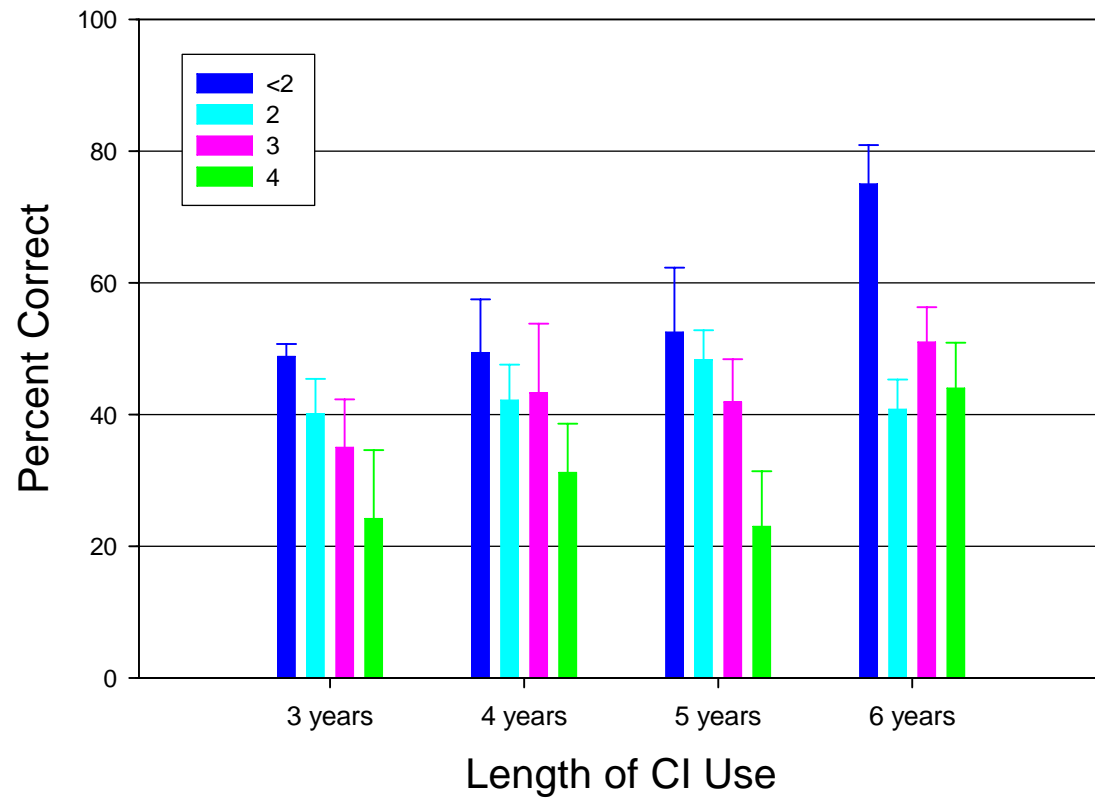
cut

tea

LNT – Easy Words



LNT - Hard Words





Language Tests

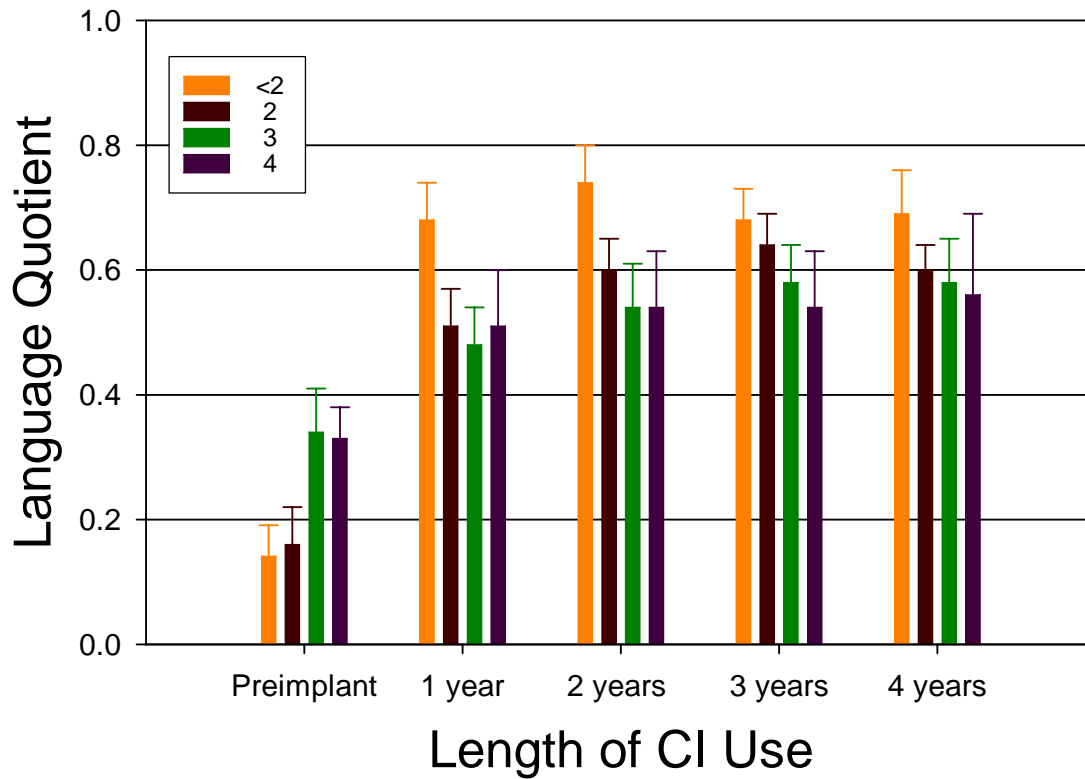
- Administered in child's preferred modality
 - Oral – auditory and visual speech cues
 - Total Communication – auditory and visual speech cues and manual signs
- Raw score is converted to language age using normative data
- Language Quotient is then derived
 - $LQ = \text{Age Equivalent} / \text{Chronological Age}$



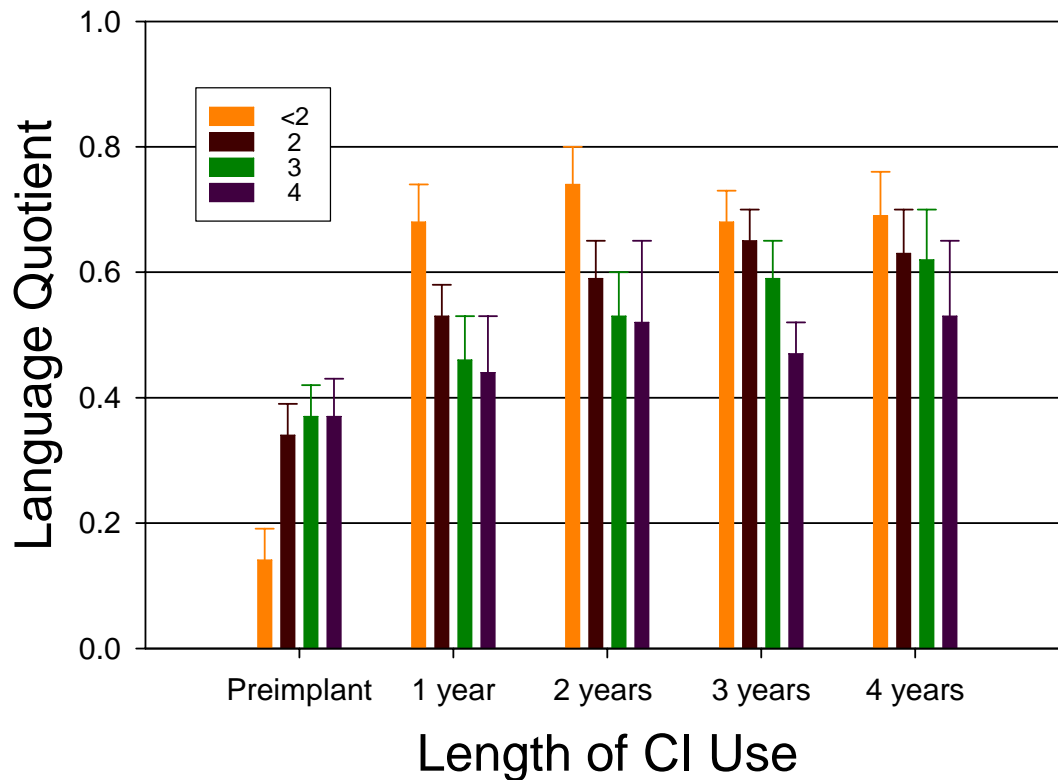
Reynell Developmental Language Scales

- Receptive and expressive skills evaluated independently
- Used extensively with deaf children
- Broad age range, 1-7 year olds
- Reflects real-world communication

Reynell – Receptive Language



Reynell – Expressive Language





Summary and Conclusions

- Speech perception and language skills develop over a long time course
- Nature of the early experience impacts long-term outcomes
 - Early access to auditory information is crucial for the development of spoken word recognition and spoken language processing
 - Additional studies with larger numbers of participants are needed