The Bionic Ear: Challenges of Educating Deaf Teenagers in the 21st Century

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Acknowledgements

- National Institutes of Health
- Dana Foundation
- National Science Foundation
Today, I wish to:

- Focus on the big picture:
  - Long term outcomes in teenagers using implants
- Describe:
  - Bionic ear technology
- Report:
  - Communication performance
  - Challenges associated with current population
- Muse of Future Challenges
Our Current Challenges

Hearing loss effects over 30 million Americans

90% of deaf babies are born to normal hearing parents

Average reading level of deaf students graduating from high school is third grade
Historical Attitudes

- deaf and dumb
- deaf and mute
Historical Attitudes

- Deaf
• “Girl in Green”
• By John Brewster
“Chesapeake Bay Retriever with Goose”
By Louis Frisino
“Helen Keller’s Breakthrough”
By Frederick LaMonto
“The Mechanics”
By Douglas Tilden
Is deafness a medical problem?
Deafened

Middle Ear

Inner Ear

Central Nervous System

Niparko, Kirk, Mellon, Robbins, Tucci, and Wilson, 2000
Is deafness a communication problem?
“Oh you men who think or say that I am malevolent, stubborn or misanthropic, how greatly you wrong me. You do not know the secret cause which makes me feel that way to you.....
“...for six years now I have been hopelessly afflicted, made worse by senseless physicians, from year to year, deceived with hopes of improvement, finally compelled to face the prospect of a lasting malady (whose cure will take years or, perhaps, be impossible)...”
“...My misfortune is doubly painful to me because I am bound to be misunderstood; for me there can be no relaxation with my fellow men, no refined conversations, no mutual exchange of ideas. I must live alone, like one who has been banished...”
“...I am compelled to withdraw myself, to live life alone. If at times I tried to forget all this, oh how harshly, I was flung back by the experience of my bad hearing. Yet it was impossible for me to say to people, “Speak louder, shout for I am deaf...”
Beethoven, “The Hiligenstadt Testament”, a letter to my Brothers Carl and Johann Beethoven, 6 October 1802.
deafness and technology
Volta: Subject of first cochlear implant study

- Inventor of battery
- 50 V application
- “..a boom within the head” followed by a sound similar to that of thick, boiling soup.
International Development of Bionic Technology in Literature and Theatre

Volta
International Development of Cochlear Implants

Volta

Michelson Merzenich
Simmons
House
Eddington
Simmons White
House
CLARION
(San Francisco)
3M-SC
ALL-HEAR
(LA)
INERAID
(Salt Lake City)
CHORIMAC
(Paris)
LAURA
(Antwerp)
MED-EL
(Vienna)
NUCLEUS
(Melbourne)

Professor Graeme Clark, First Nucleus Cochlear Implant
Professor Blair Simmons, UCSF Cochlear Implant, 1964
Students wearing Cochlear Implants
What does communication sound like through a cochlear implant?
Speech Waveform

22 Channel Bandpass Filter Bank

Instantaneous Spectrum - Select 6-10 largest outputs of Filter Bank

Electrode Array

Base

Electrode Position

Apex

Time

Analysis Period

Stimulate Electrodes (non-simultaneously)
Communication Outcomes
Study Design

Children tested first in elementary school when they were 8 and 9 years old (N=181)

*Ear and Hearing* Supplement, 2003

Children tested again in high school when they were 15 – 17 years old (N=112)

*Ear and Hearing* Supplement, Jan/Feb 2011
Elementary: Sample Selection

1. Between 8 and 9 years of age
2. Onset of deafness by age 3
3. 4-6 years of implant use
4. Implanted before 5 years of age
5. No additional disabilities
6. Monolingual English home environment
7. No open set speech perception
180 Participating Families

From 33 U.S. States & 5 Canadian Provinces
112 Participating Families

From 33 U.S. States & 5 Canadian Provinces

1997-2000
180 Subjects
5 more (11)
1 to 5 (22)
0 (18)
Word Perception: LNT List

Subject (n=86)

LNT - open-set word perception
age 16-7 average at 16-17
age 8-9 average 8-9
Listening in quiet and noise, ages 16-17
Intelligence
WISC Verbal & Non-Verbal Quotients

- Verbal IQ: average (90), 64% in the normal range
- Performance IQ: average (103), 87% in the normal range

Subject (n=86)
Clinical Evaluation of Language Fundamentals – Language Content Index

59% > normal range

Subject (n=86)
Reading
Note: 88 is the mean at the younger age, 83 is the mean at age 16-17
PIAT Reading Grade Score and Age

PIAT Reading Grade Equivalent and Age

Primary
Secondary

Chronologic Age

Grade Equivalent Score

Primary
Secondary
PIAT Reading Grade Score and Age

![Graph showing PIAT Reading Grade Score and Age with Primary and Secondary data points.]
Speech Production
Speech Intelligibility of Children at Ages 8 and 16 years in Quiet

Individual Participants
Speech Intelligibility at 16 years in Quiet and Multi-Speaker Babble

Percent Correct (%)

Individual Participants

Quiet
Speech Intelligibility at 16 years in Quiet and Multi-Speaker Babble
<table>
<thead>
<tr>
<th>Child &amp; Family Characteristics for Elementary School</th>
</tr>
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<tr>
<td><strong>Speech Production</strong></td>
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<tr>
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<td>Performance IQ</td>
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<td>Family Size</td>
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| Explained Variance | 22% | 23% | 17% | 13% |

*p<.05, **p<.01; ***p<.001
Deafness Characteristics for Elementary School

Duration of Deafness

Sign Enhancement

Explained Variance

Speech Production

Speech Perception

Language

Reading

35%

22%

14%

7%

*p<.05; **p<.01; ***p<.001
## Processing Speed for Elementary School

<table>
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<tr>
<th>Verbal Rehearsal Speed</th>
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| Explained Variance     | 13%               | 16%               | 31%      | 23%     |

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**Processing Speed for Elementary School**

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Does communication status during elementary school predict communication status in high school?
### Child & Family Characteristics for High School

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**Explained Variance**

- Speech Production: 13%
- Speech Perception: 15%
- Language: 19%
- Reading: 17%

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<table>
<thead>
<tr>
<th>Duration of Deafness</th>
<th>Speech Production</th>
<th>Speech Perception</th>
<th>Language</th>
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<tr>
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<tr>
<td>Explained Variance</td>
<td><strong>36%</strong></td>
<td><strong>15%</strong></td>
<td><strong>6%</strong></td>
<td><strong>4%</strong></td>
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<td>7%</td>
<td>11%</td>
<td>20%</td>
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### Elementary School Predicting High School

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<td>Elementary School Performance</td>
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<td>Explained Variance</td>
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<tr>
<td>Total Explained Variance</td>
<td>65%</td>
<td>71%</td>
<td>70%</td>
<td>69%</td>
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How are they doing in High School?

• 95% mainstreamed
• 72% use the telephone
• Majority comfortable with Deaf and hearing friends
• Most expected to go to college
Students from Early Oral Communication Settings

- 93% -- intelligible speech
- 38% -- report using sign language
- 10% -- use sign interpreter for some classes
- 95% -- use speech without sign in everyday communication
- 13% -- report minimal proficiency in sign language
Communication for Early Sign Users

- 50% -- communicate using only speech
- 67% -- have intelligible speech
- 64% -- use sign interpreter in some classes
- 11% -- discontinue sign by high school
Executive Functioning

Adults execute planning in elementary school

Teenagers must learn to:

- Plan
- Prioritize
- Stick with a task to completion
- Organize
- Multitask
Executive Functioning

- Working Memory and Recall
- Activation, Arousal and Effort
- Emotional Control
- Language Internalization
- Problem Solving
Promoting Executive Functioning

- Initiate
- Inhibit
- Shift
- Plan
- Organize
- Self-Monitor
- Emotional Control
Rehabilitation Works

• Group mean scores for language, reading and social adjustment were within one standard deviation of typical age mates with normal hearing.
Rehabilitation Works

- Performance of children in early elementary grades (age 8-9) was highly predictive of their relative standing in high school.
Rehabilitation Works

- Variability in performance was accounted for by factors underlying information processing measures associated with verbal rehearsal speed and executive functioning.
Rehabilitation Works: Early Counts

- Children in early elementary grades who relied on spoken language (as indicated by receiving no benefit from manual signs) demonstrate higher verbal rehearsal skills and higher levels of speech perception, speech intelligibility, language and literacy in high school.