# Measuring Auditory Performance Of Pediatric Cochlear Implant Users: What Can Be Learned for Children Who Use Hearing Instruments?

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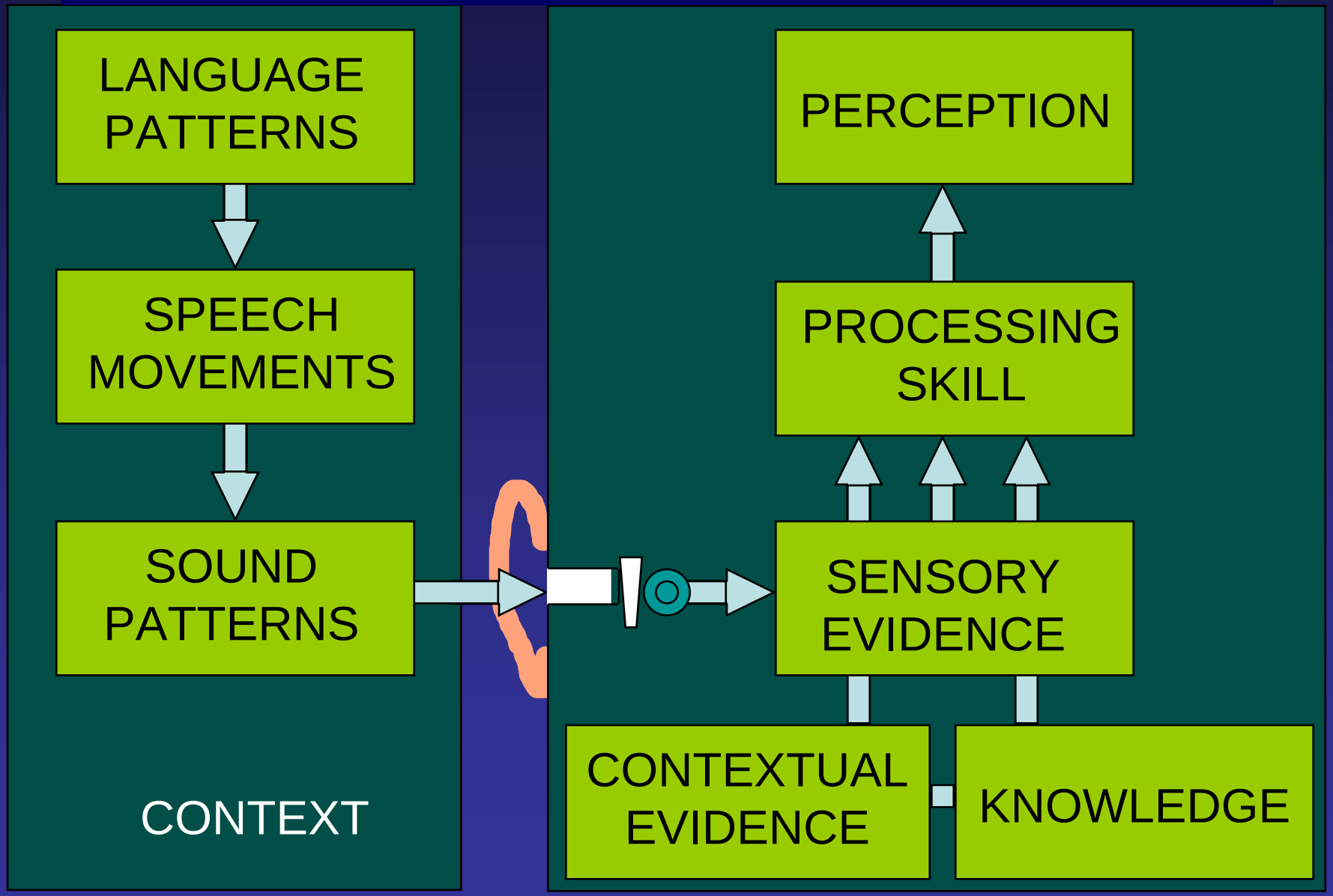
*Celebrating 30 years of pediatric cochlear implantation (1980-2010)*

# Speech Perception



# In this Presentation….

*We will be discussing:*

- Considerations in pediatric speech perception assessment
- Tracking speech perception outcomes in children with cochlear implants
- New developments in speech perception tests for infants and toddlers

# Considerations in Pediatric Speech Perception Assessment

# Speech Perception

- Also known as…
  - Speech reception
  - Speech discrimination
  - Speech identification
  - Speech recognition
- Scoring options
  - Percent correct
  - Confidence level
  - dB level
  - Reaction time

# Why Speech Perception Assessment is Important

Test results are the most direct indicator of improvement, benefit, or lack thereof from the use of an auditory sensory device, particularly when measured at typical listening levels (i.e., suprathreshold).

# Reasons Why Speech Perception Assessment May Be Useful

- Device candidacy and/or selection
- Programming of devices
- Tracking performance over time
- Establishing guidelines for (re)hab

# Speech Perception Dependence on Age

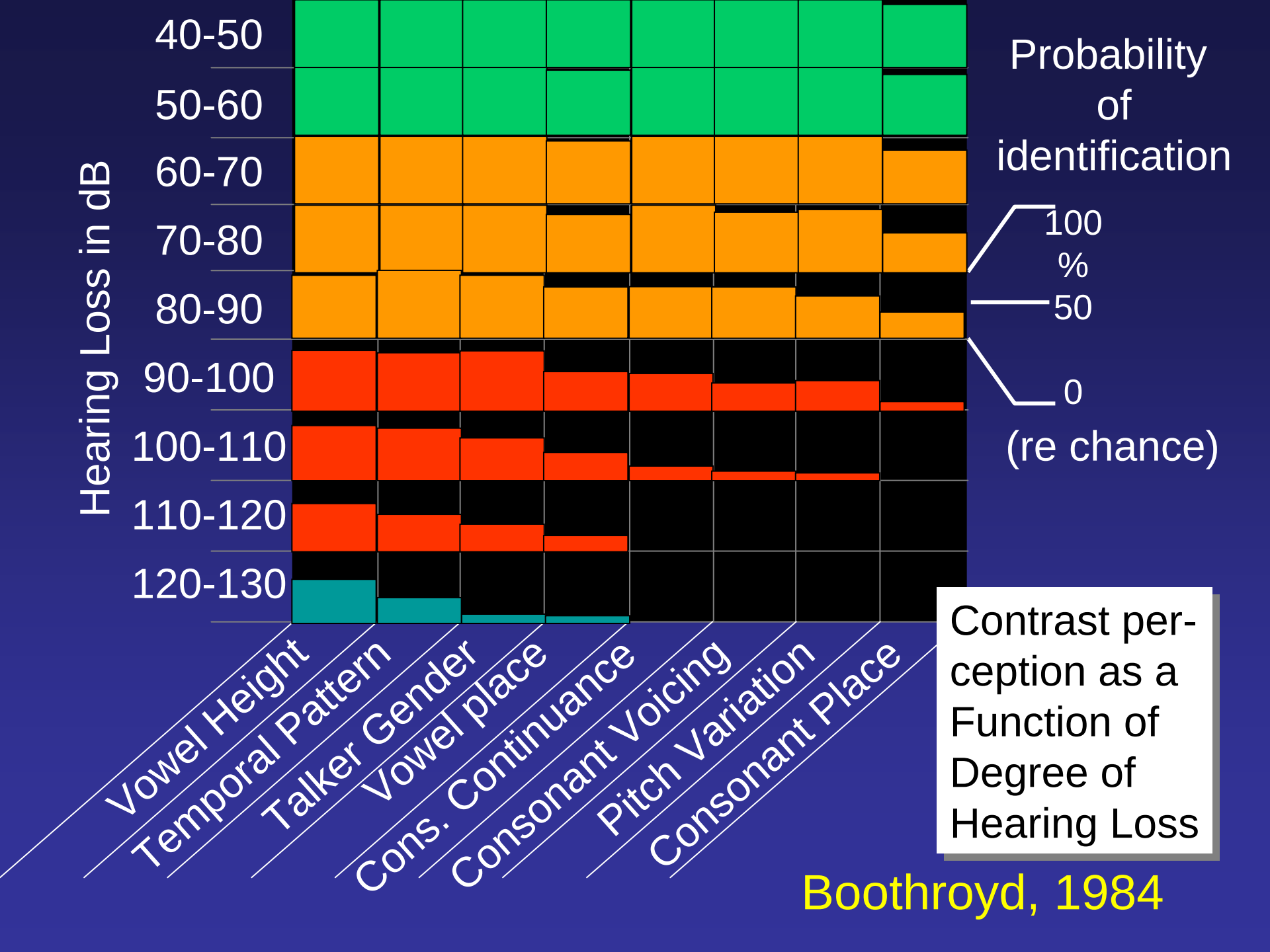
- The ability to perceive speech improves as the child matures (in some cases up to adolescence).
- Child may not have a complete set of phonemic categories or may have a limited vocabulary.
  - Articulation difficulties reflect an imperfect set of phonemic categories.
- Child may be unable to use contextual information.

# Speech Perception
## Dependence on Degree of Hearing Loss

- Performance decreases with increasing hearing loss.
- Suprasegmental features (intonation, duration, stress) are perceived with greater accuracy than segmental features (vowels, consonants).

# Dependence on Degree of Hearing Loss cont.

- Vowels are perceived with greater accuracy than consonants.
- Vowel height is perceived better than vowel place, and consonant voicing and manner better than place.


Hearing Loss in dB
40-50
50-60
60-70
70-80
80-90
90-100
100-110
110-120
120-130
Probability of identification
100 %
50
0
(re chance)
Vowel Height
Temporal Pattern
Talker Gender
Vowel place
Cons. Continuance
Consonant Voicing
Pitch Variation
Consonant Place
Contrast perception as a Function of Degree of Hearing Loss
Boothroyd, 1984

# Challenges in Pediatric Speech Perception Assessment

- Maturation
- Experience
- Perceptual skill
- Motor skill
- Motivation
- Rapport between child and examiner
- Attention / fatigue / emotional state

# Considerations in Testing

- Open-set vs. closed-set measures
- Stimuli (phonemes, syllables, words, sentences)
- Quiet vs. background competition
- Auditory-only, visual-only, auditory-visual
- Live voice vs. recorded

# Tracking Speech Perception Outcomes in Children with Cochlear Implants (CI)

# First Clinical Trials with Adults

- In the 1970s, few tests were available to determine CI candidacy or track performance.
- Patients would show floor effects on open-set tests used in the clinic.
- *New assessment tools and batteries were needed to determine candidacy and track outcomes*

# FDA Clinical Trials

- Regulations published in 1980
- Medical devices required to undergo clinical trials to determine risk vs. benefit

# Early Tests Used in Adult Clinical Trials

- Single-channel implants
  - HRRC Rhyme Test (HEI)
  - Environmental Sounds Test (HEI)
  - Monosyllable, Trochee, Spondee (MTS) Test (Erber at CID)
- Multichannel implants
  - Minimal Auditory Capabilities (MAC) Battery (UCSF)
  - Iowa Battery (University of Iowa)

# Early Test Batteries Used in Pediatric Clinical Trials

- Single-channel implants
  - Test of Auditory Comprehension (LA County)
  - Discrimination After Training Test (HEI)
  - Glendonald Auditory Screening Procedure (GASP) (Erber)
  - Speech tracking (Defilippo & Scott, NTID)
- Multichannel implants
  - Subtests from MAC Battery
  - Subtests from Iowa Battery
  - MTS
  - GASP

# NIH-Funded Pediatric CI Research

- Central Institute for the Deaf (CID)
  - *Hierarchical batteries*
- Indiana University School of Medicine (IUSM)
  - *Preschool- and school-age batteries*
- Johns Hopkins University School of Medicine (JHU)
  - *Hierarchical/preschool- & school-age batteries*

# CID Test Battery (Hierarchical) Auditory-Only

| Test | Stimulus | Presenta-tion | Response Format |
|---|---|---|---|
| Speech detection threshold | Speech | A | Closed set |
| Early Speech Perception Test (ESP) | Patterns (1-, 2-, or 3-syllable words)<br>Spondees<br>Monosyllables | A | Closed set |
| Word Identification by Picture Identification (WIPI) | Monosyllables | A | Closed set |
| Matrix Test | Phrases | A | Closed set |
| Phonetic task evaluation | Syllables | A | Closed set |
| Phonetically Balanced Kindergarten word list (PBK) | Monosyllables | A | Open set |
| Grammatical Analysis of Elicited Language-Presentence Level (GAEL-P) | Words | A | Closed set |

# CID Test Battery (Hierarchical) Auditory-Visual

| | | | |
|---|---|---|---|
| Craig Lipreading inventory | Monosyllabic words<br>Sentences | A; AV | Closed set |
| Monsen Sentences | Sentences | A; AV | Open set |
| CID Sentences | Sentences | A; AV | Open set |
| CUNY Sentences | Stories | A; AV | Open set |

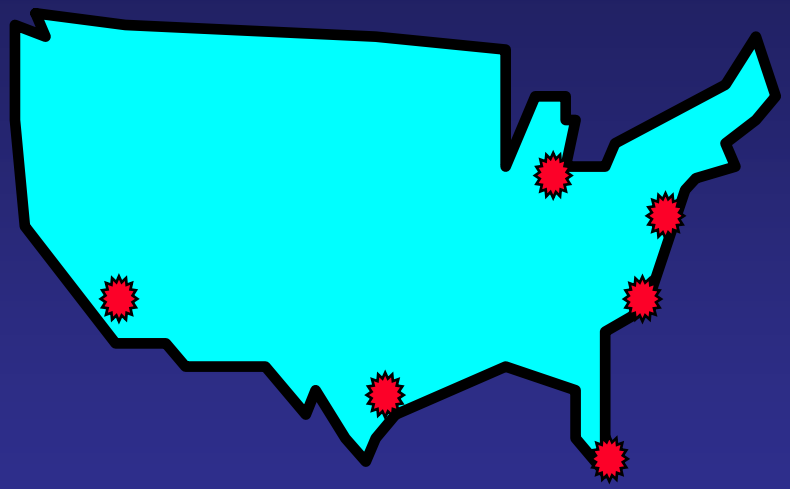
# IUSM Approach Preschool Battery

| | | | |
|---|---|---|---|
| Test | Stimulus | Presenta-tion | Response Format |
| Screening Inventory of Perceptual Skills (SCIPS) | 1-, 2-, or 3-syllable words | A | Closed set |
| Grammatical Analysis of Elicited Language-Presentence Level (GAEL-P) | 1-, 2-, or 3-syllable words | A | Closed set |
| Mr. Potato Head Task | Mr. Potato Head toys | A | Modified open set |
| Pediatric Speech Intelligibility Test (PSI) | Single words and sentences | A; V; AV | Closed set |
| Meaningful Auditory Integration Scale (MAIS) | 10 probes | Structured Interview | Parent report |

# IUSM Approach
# School-age Battery

| | | | |
|---|---|---|---|
| Test | Stimulus | Presenta-tion | Response Format |
| Minimal Pairs Test | 1-syllable words | A | Closed set |
| Multisyllabic Lexical Neighborhood Test (MLNT) | 2-, 3-syllable words | A | Open set |
| Lexical Neighborhood Test (LNT) | 1-syllable words | A | Open set |
| Phonetically Balanced Kindergarten word list (PBK) | 1-syllable words | A | Open set |
| Common Phrases | 2- to 6-word phrases | A; V; AV | Open set |

# Childhood Development after Cochlear Implantation (CDaCI) Study



Longitudinal cohort study:

- 188 CI and 97 NH children
- enrolled between 2002 and 2004
- 6 participating implant centers

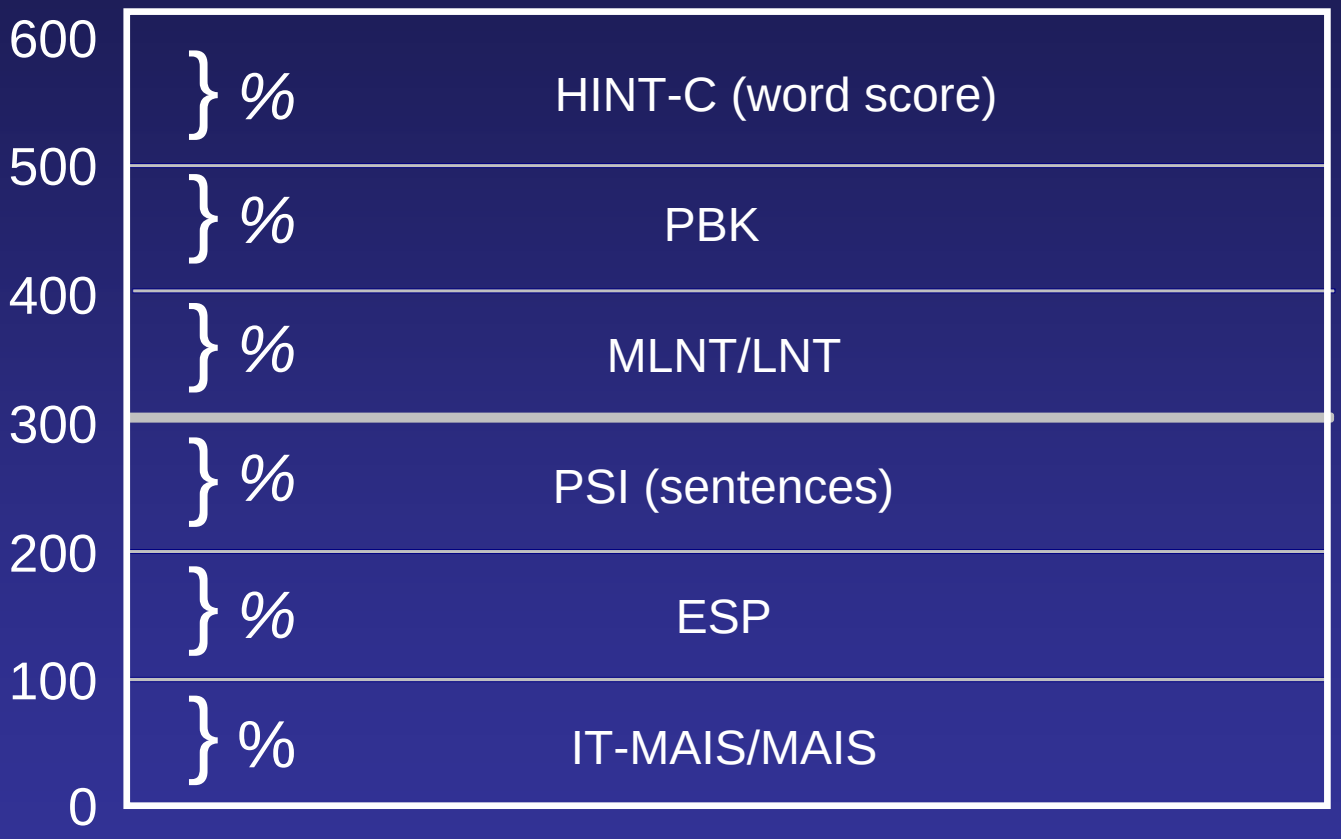
# CDaCI Speech Recognition Hierarchical Test Battery

- Combines the CID and IUSM approaches.
- Structured according to the child's age and functional hearing ability.
  - Enables child to be assessed on materials that are not too easy and not too difficult.
- Criterion level required to progress to more difficult tests.
  - Test discontinued when ceiling is achieved at two consecutive intervals.

# CDaCI Speech Recognition Hierarchical Battery*

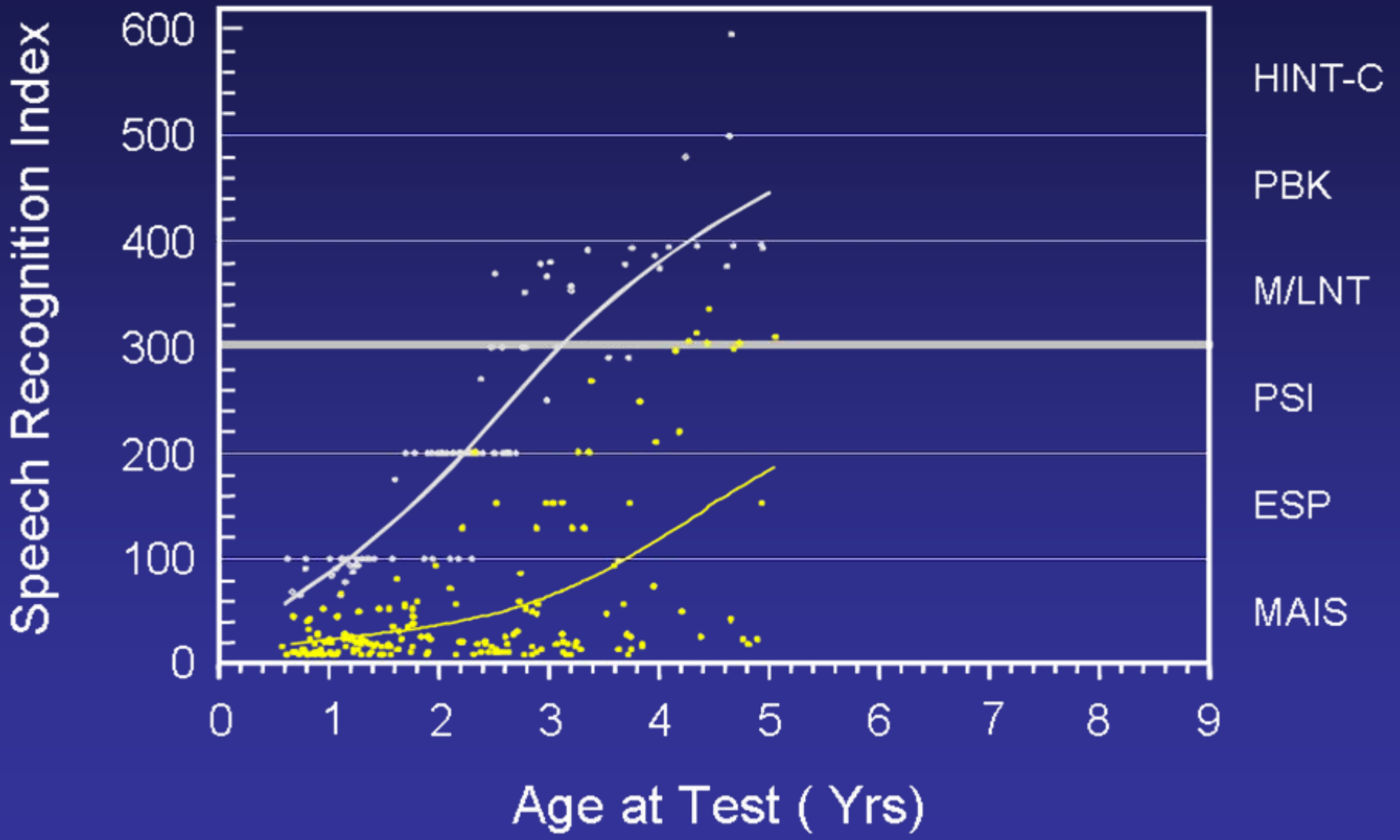

*Eisenberg et al., 2006

# Speech Recognition Index (SRI-Q)*



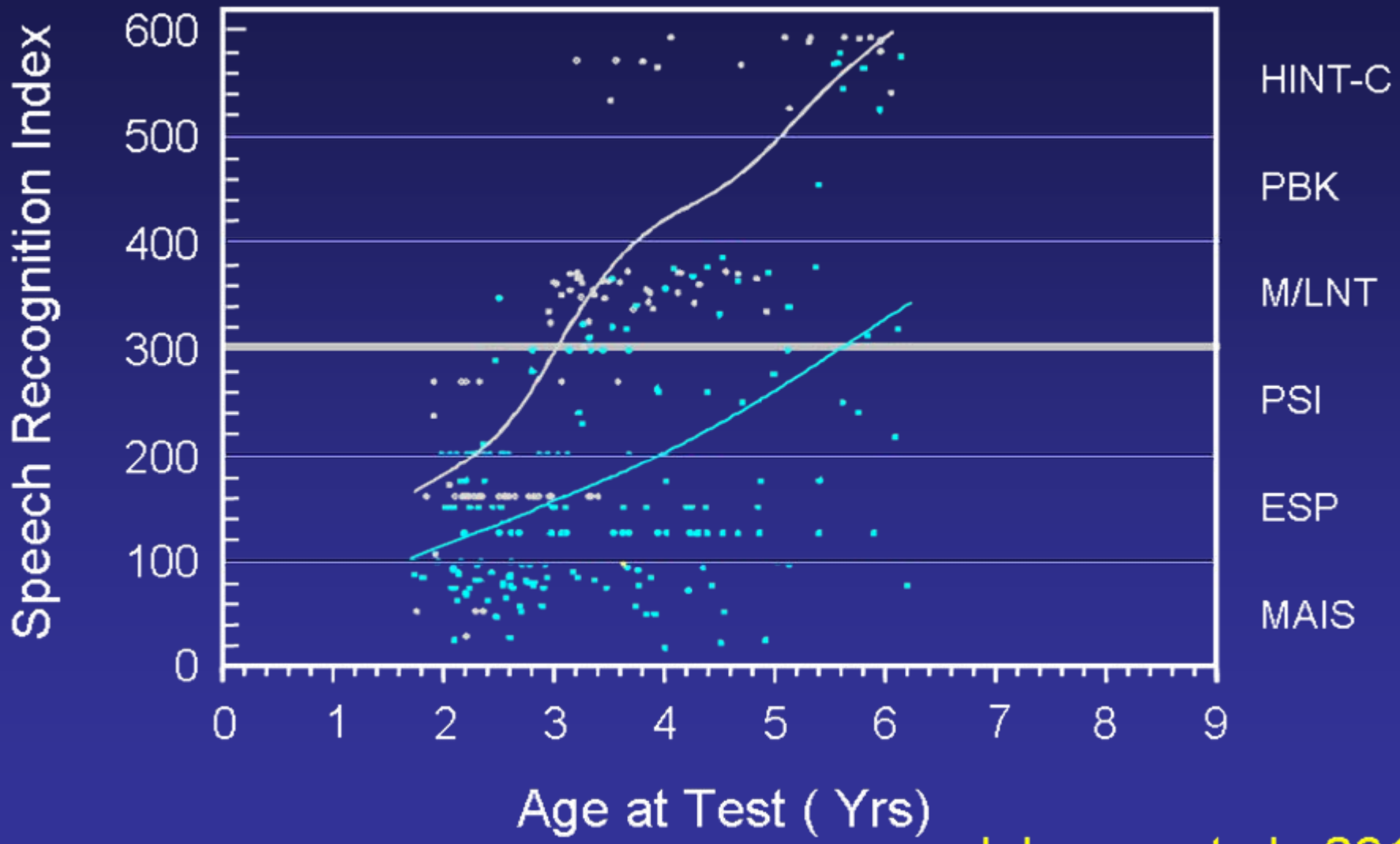

*Wang et al., 2008

# Speech Recognition: Baseline



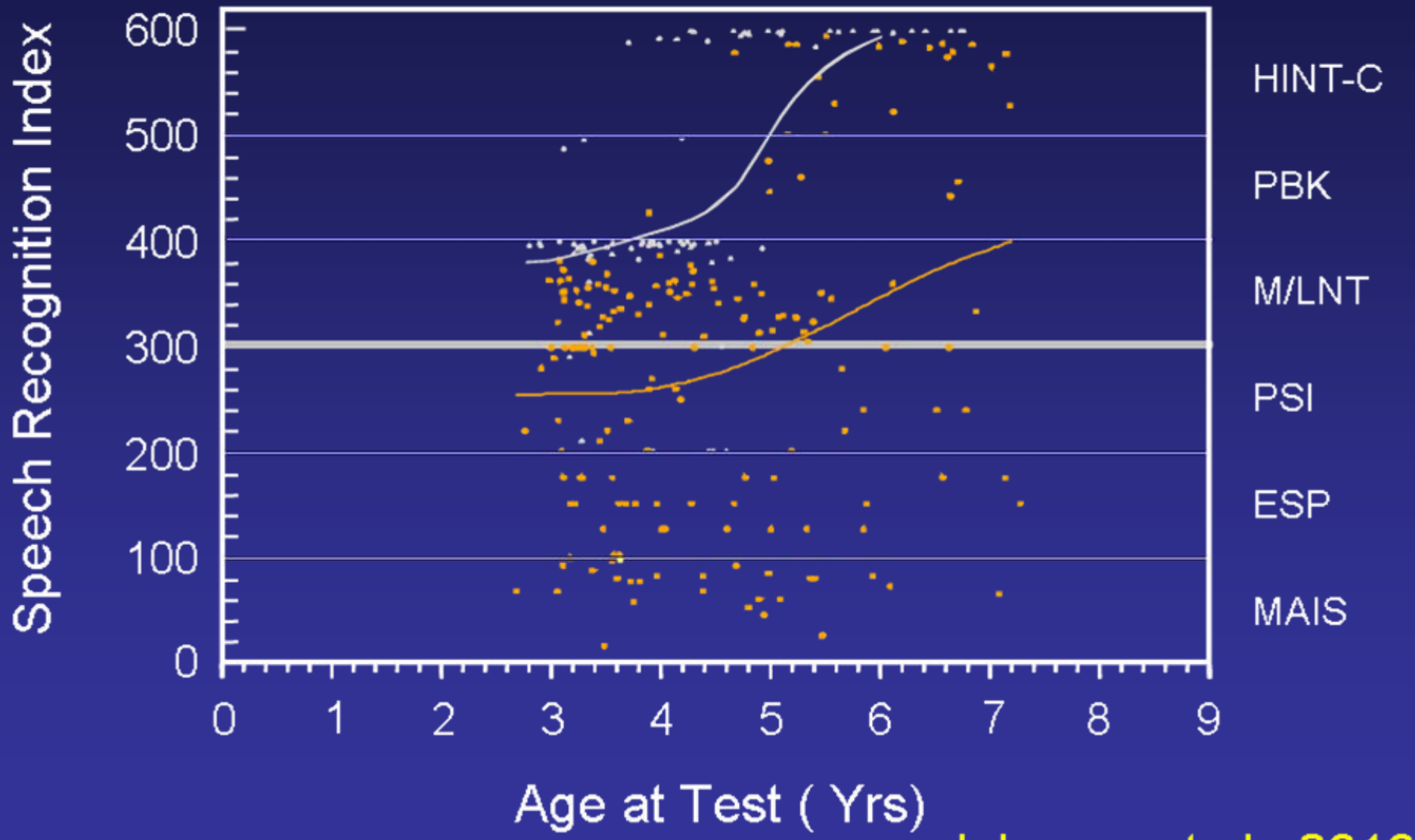

Johnson et al., 2010

# Speech Recognition: 12 Mos Post



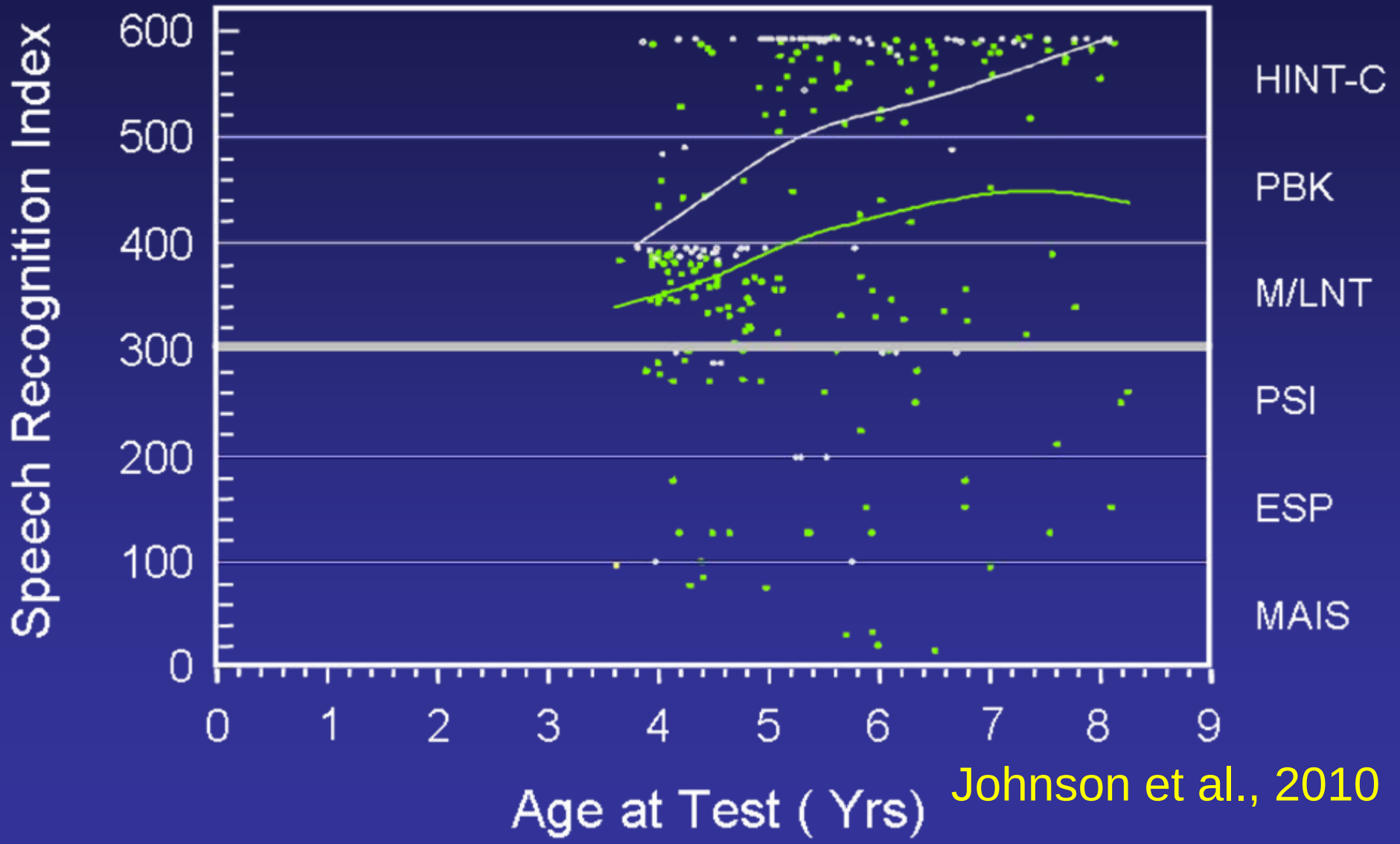

Johnson et al., 2010

# Speech Recognition: 24 Mos Post



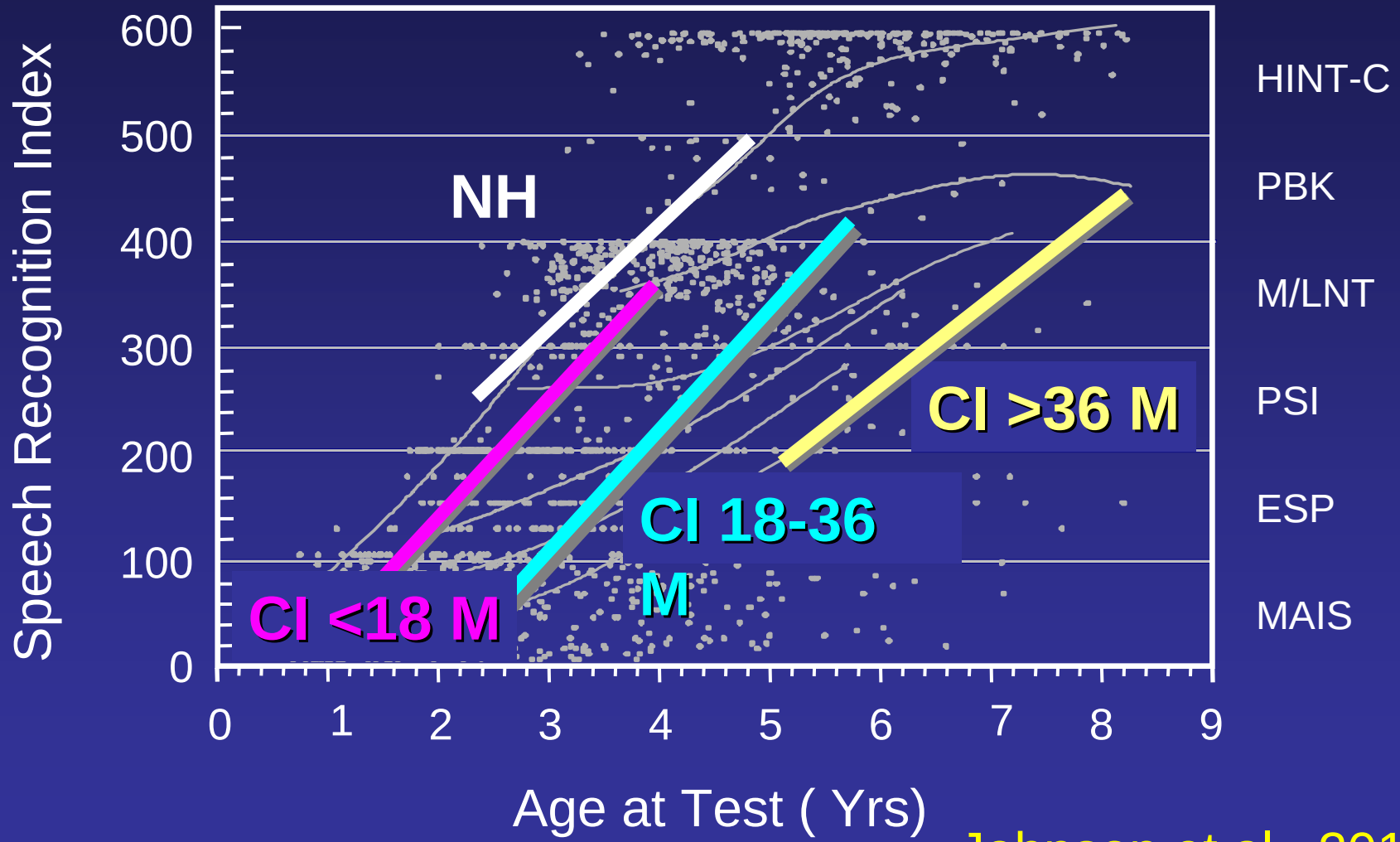

Johnson et al., 2010

# Speech Recognition: 36 Mos Post



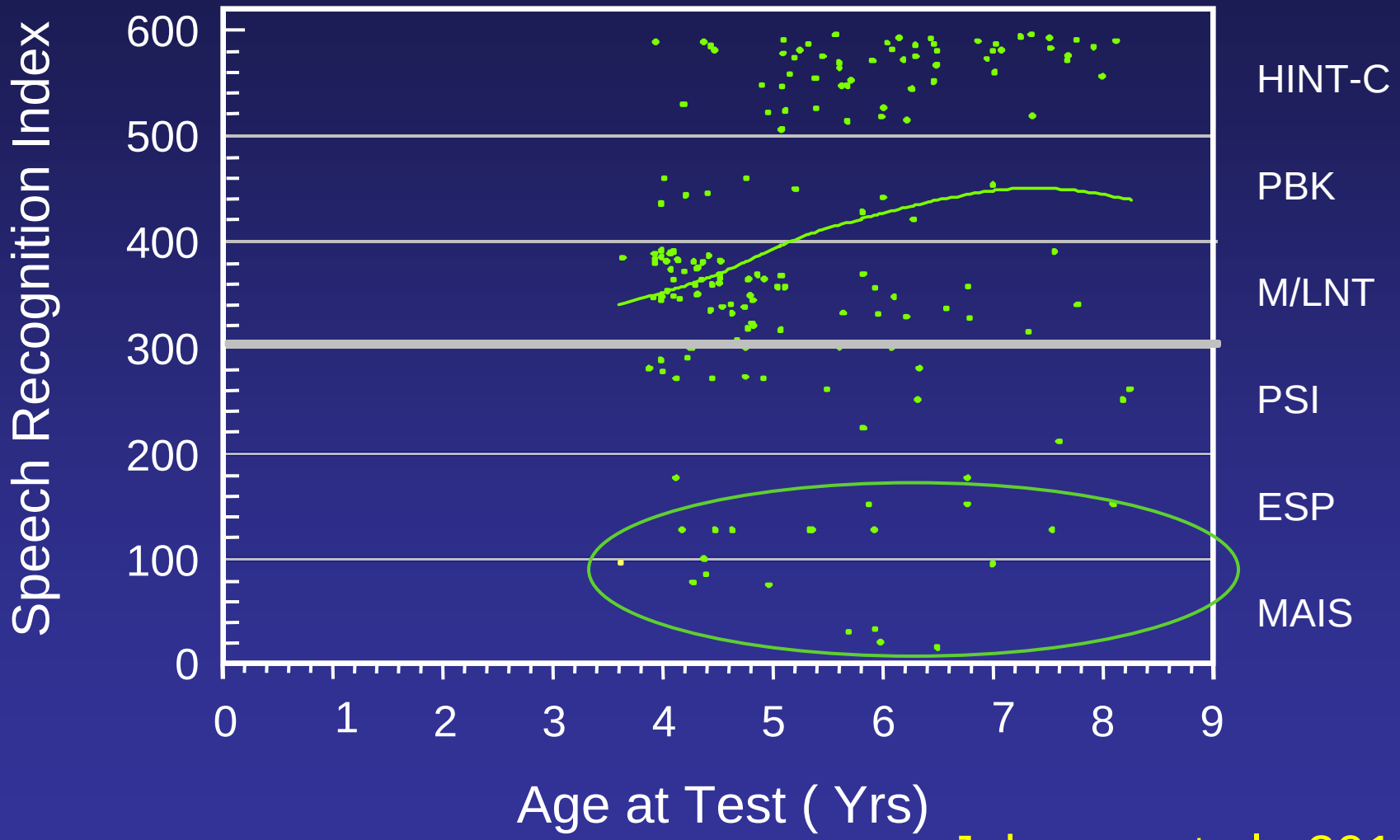

Johnson et al., 2010

# Speech Recognition By Age at Implantation




Johnson et al., 2010

# Speech Recognition: 36 Mos Post




Johnson et al., 2010

# What about those children who don't progress in the hierarchy?

- Auditory-Visual Test Battery
  - Motivated by clinical need
  - Closed-set tests
  - Emphasizes multimodal processing

# CDaCI Auditory-Visual Battery

| Test* | Stimulus | Response Format |
|---|---|---|
| AV ESP low verbal | Spondees & Monosyllables | Closed set |
| AV ESP standard | Spondees & Monosyllables | Closed set |
| AV NU-CHIPS | Monosyllables | Closed set |
| AV PSI | Sentences | Closed set |

*AO optional for each test; children have opportunity to re-enter the standard protocol on individualized basis

# New Developments in Speech Perception Tests for Infants and Toddlers

# Speech Pattern Contrast Perception (SPAC)*

- Based on the original SPAC concept, but developed for young children
  - VRASPAC
  - PLAYSPAC
  - VIDSPAC
  - OLIMSPAC

*Boothroyd, 1984

# SPAC Tests

- Response task changes according to the child's age, maturity and interest level
- Performance measured as % confidence level or accuracy (i.e., % correct)
- Computerized to facilitate standardization and automatic computation of performance and data-logging

# VCV Stimulus Contrasts

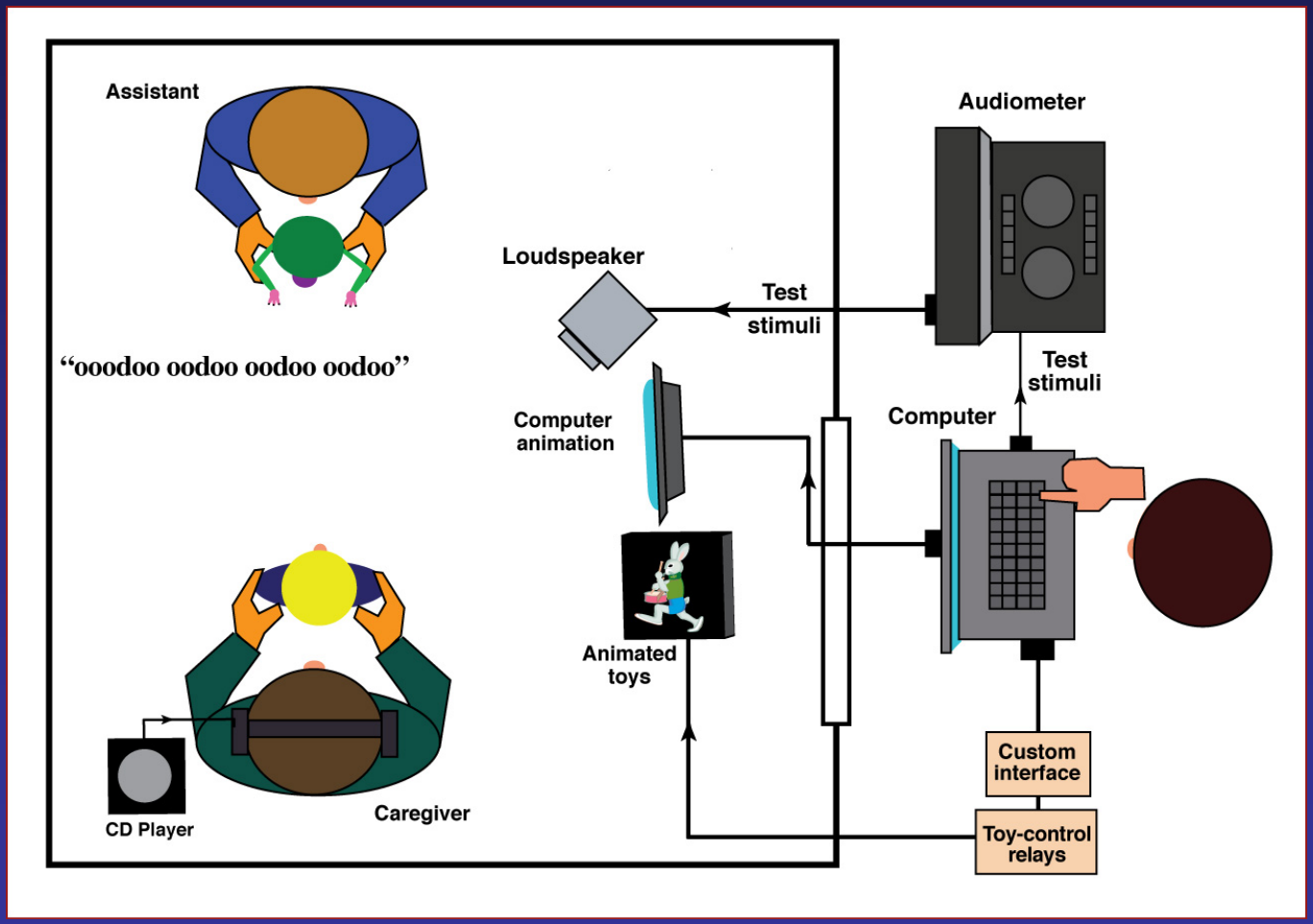
| | |
|---|---|
| Vowel Height | “oodoo” vs “aadaa” |
| Vowel Place | “oodoo” vs “eedee” |
| Consonant Voicing | “oodoo” vs “ootoo” |
| Consonant Manner | “oodoo” vs “oozoo” |
| Consonant Place (f) | “oodoo” vs “ooboo” |
| Consonant Place (r) | “oodoo” vs “oogoo” |

# VRASPAC

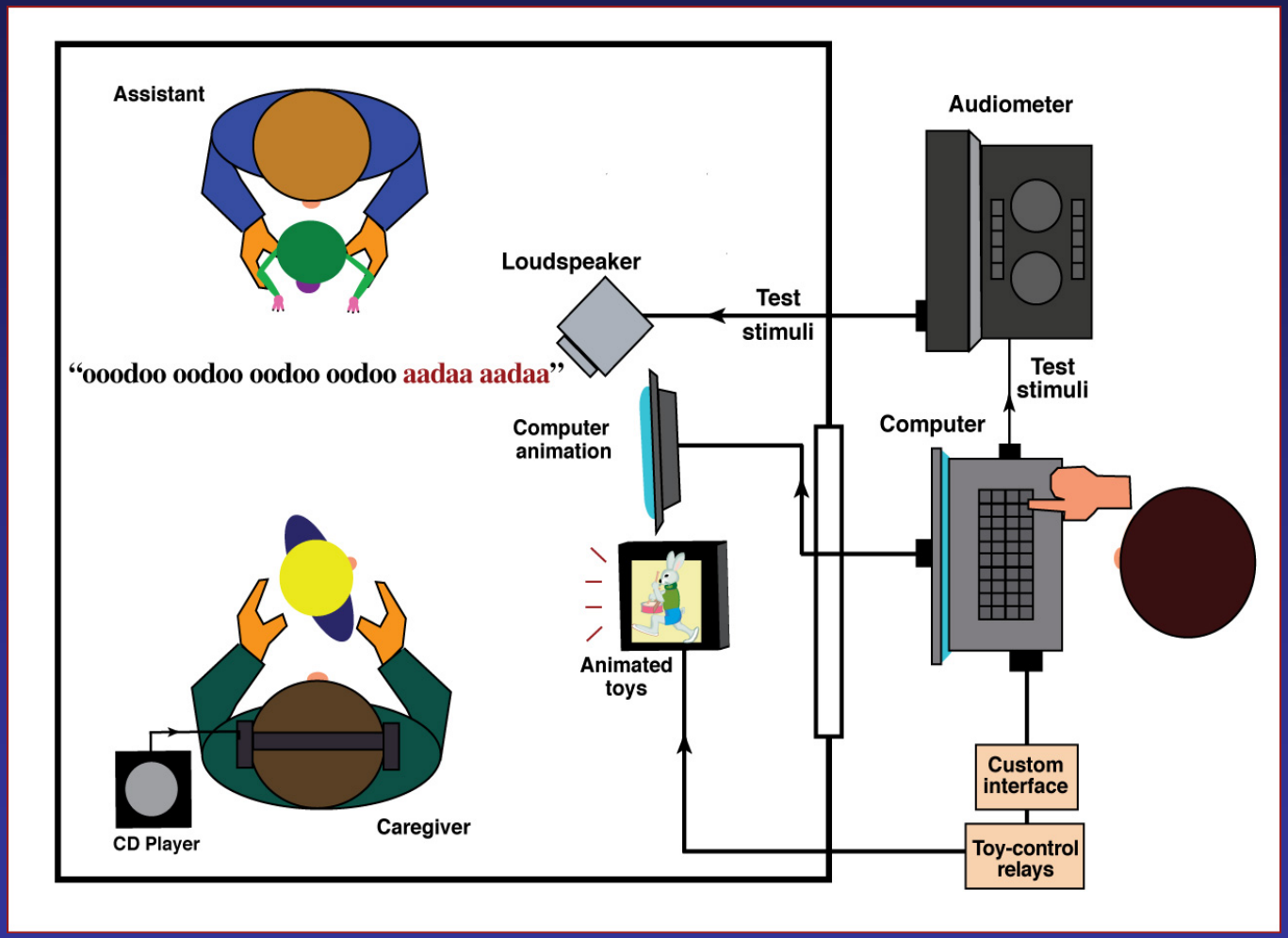
Visual Reinforcement Assessment of the perception of

Speech PAttern Contrasts

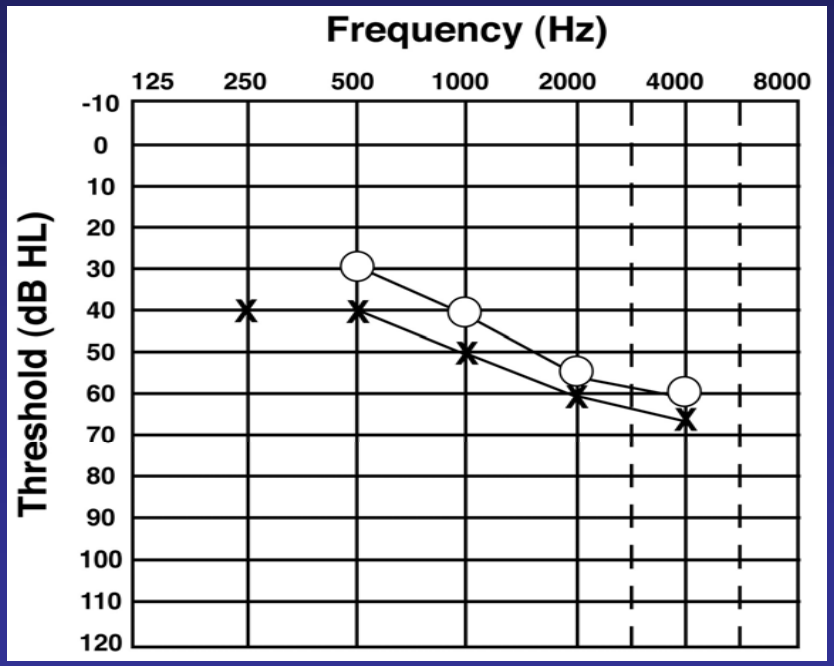
# VRASPAC Test Set-up



# VRASPAC Test Set-up

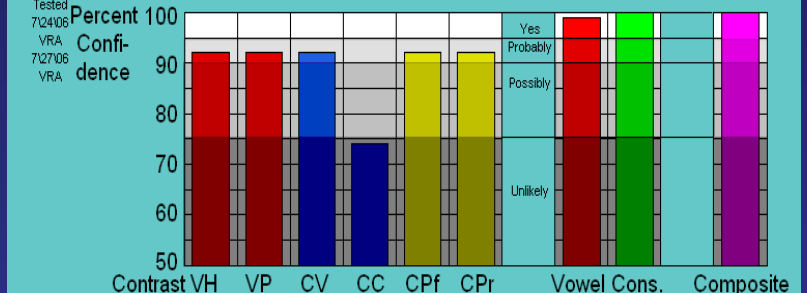


# VRASPAC Performance Profile
# 9 m/o Child with Hearing Aids



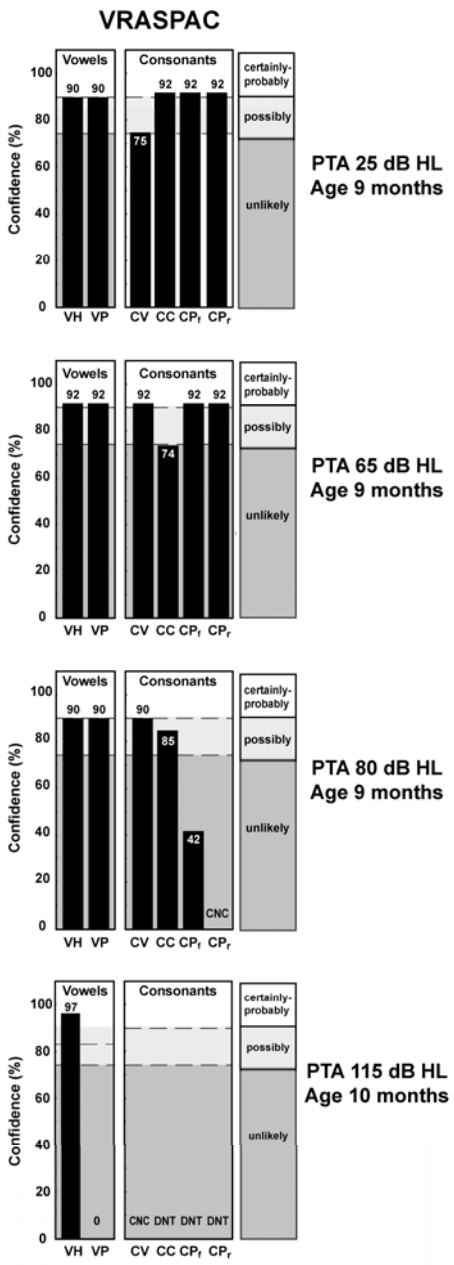

Plot ◉ Confidence (that responses are not random)
○ Performance (hit rate plus true-miss rate re chance)

Tested 7'24'06 VRA 7'27'06 VRA




| Contrast | VH | VP | CV | CC | CPf | CPr | | Vowel | | Cons. | | Composite | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Runs | 1 | 1 | 1 | 1 | 1 | 1 | | 2 | 4 | | | 6 | |
| Trials | 2 | 2 | 2 | 5 | 2 | 3 | | 4 | 12 | | | 16 | |
| Hits | 2 | 2 | 2 | 2 | 2 | 3 | | 4 | 9 | | | 13 | |
| False pos. | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | | | 0 | |
| Utterances | 29 | 42 | 49 | 70 | 49 | 49 | | 71 | 217 | | | 288 | |
| Response Windows | 7 | 7 | 7 | 10 | 7 | 7 | | 14 | 31 | | | 45 | |
| Confidence | 92 | 92 | 92 | 74 | 92 | 92 | % | 99 | 100 | % | 100 | % | |
| Performance | 100 | 100 | 100 | 40 | 100 | 100 | % | 100 | 75 | % | 81 | % | |

**VH** = Vowel Height (oo/aa) **VP** = Vowel Place (oo/ee)
**CV** = Consonant Voicing (too/doo) **CC** = Cons. Continuance (too/soo)
**CPf** = Cons. Place frontal (too/poo) **CPr** = Cons. Place rear (too/koo) **NT** = Not Tested (in this profile)

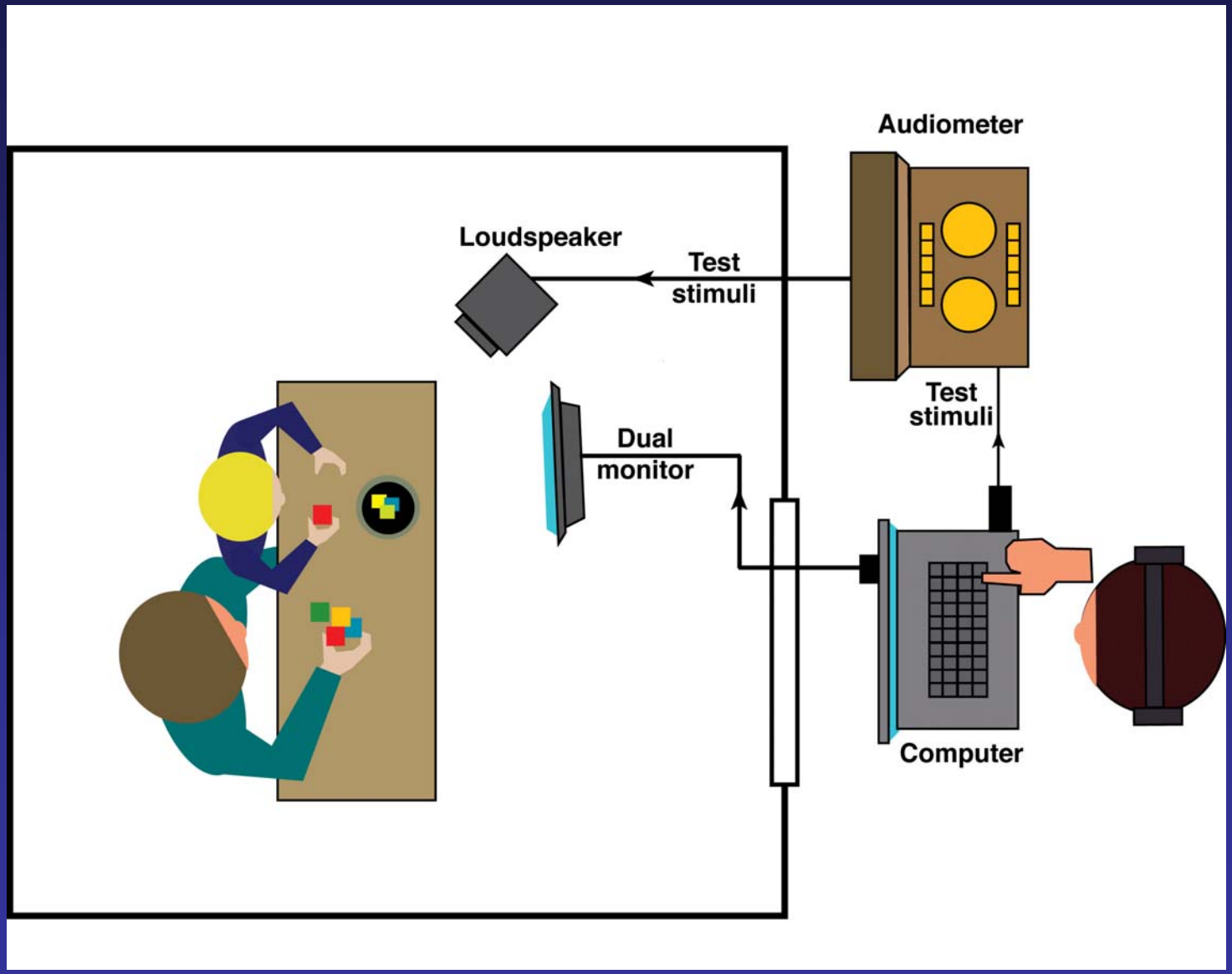



Eisenberg, Johnson, Ambrose, & Martinez, submitted (Werner book)

# PLAYSPAC

PLAY assessment of
Speech PAttern Contrasts

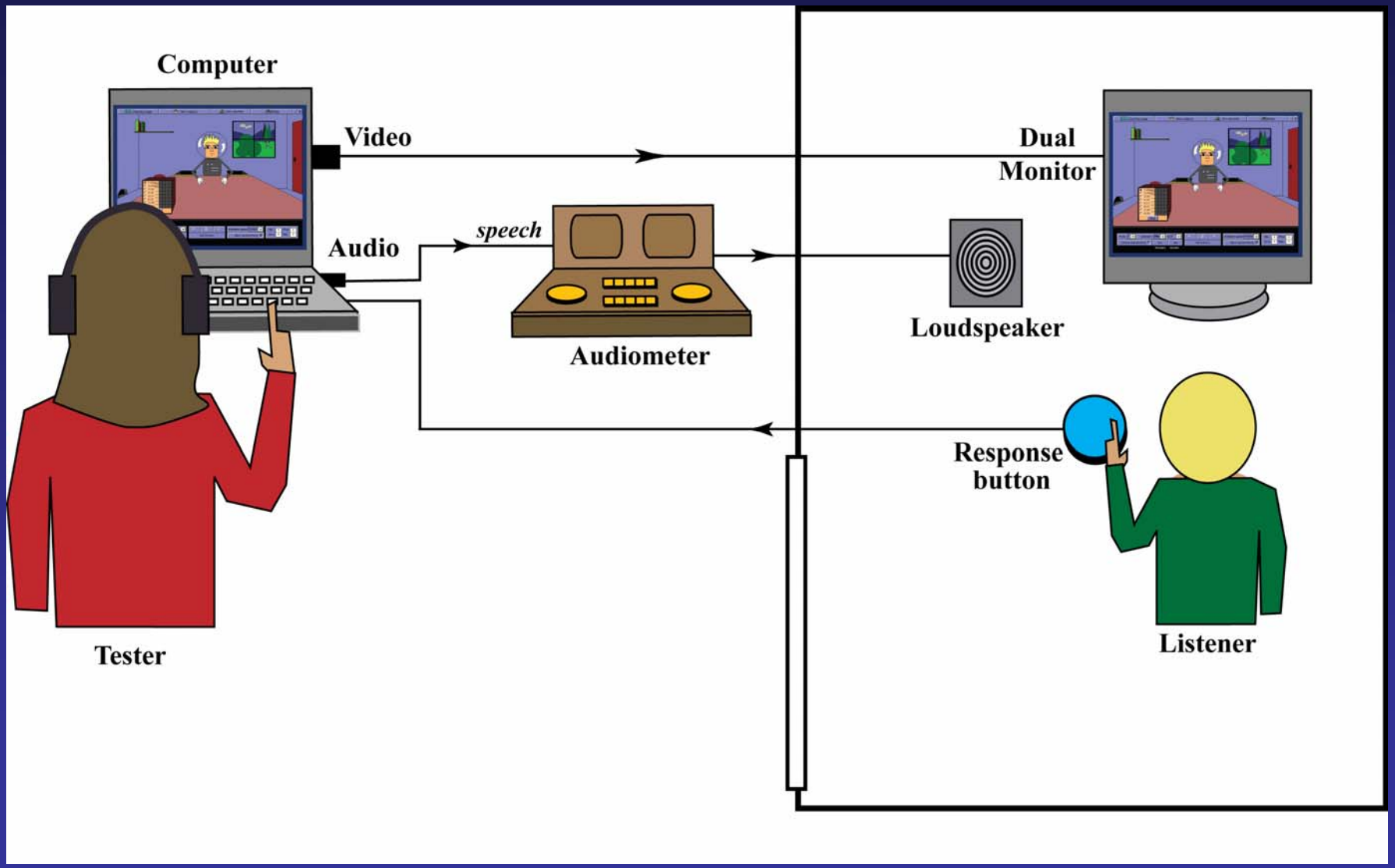
# PLAYSPAC Test Set-up



# VIDSPAC

VIDeo game approach to assessing the perception of SPeech PAttern Contrasts

# VIDSPAC Test Set-up

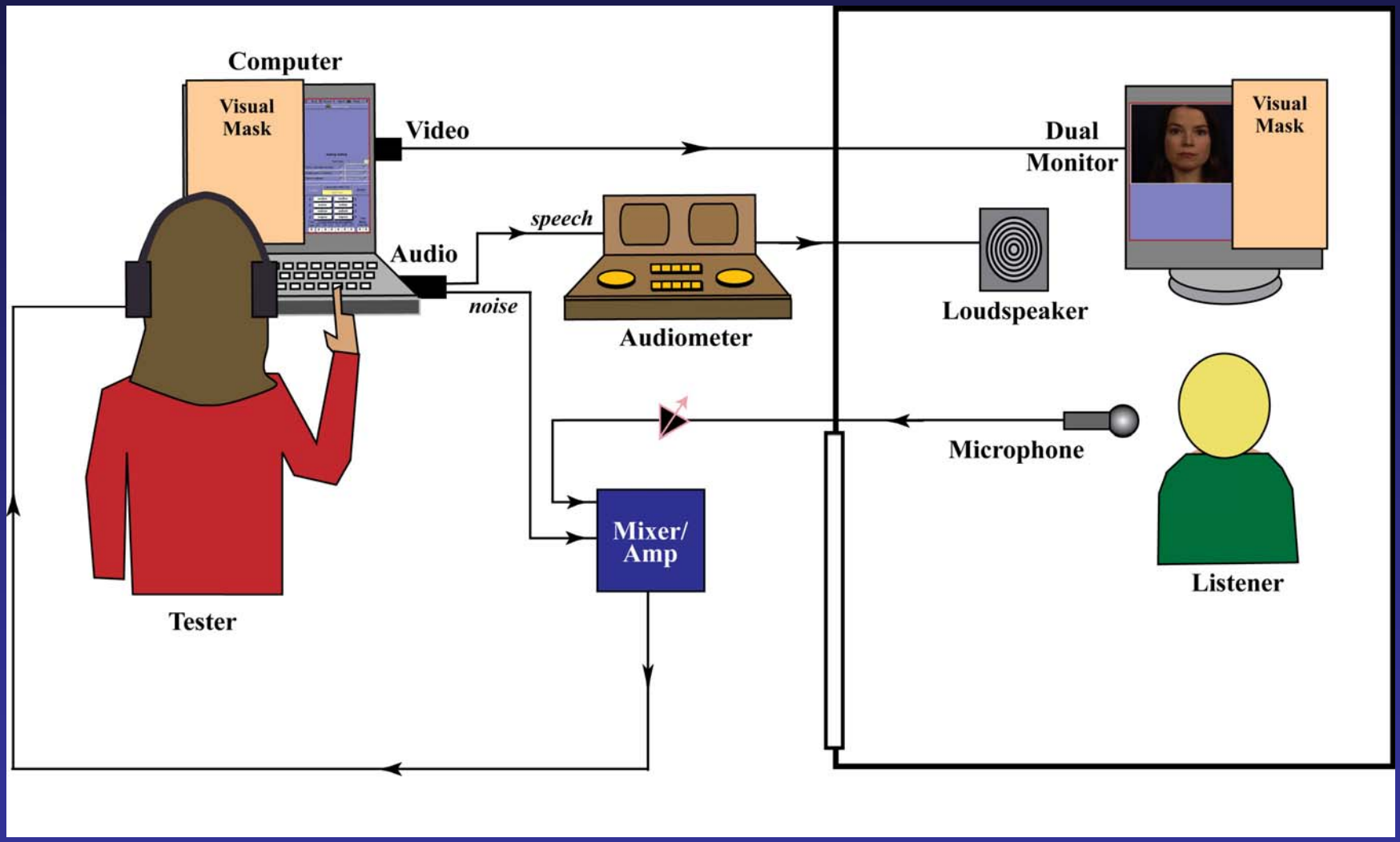


# OLIMSPAC

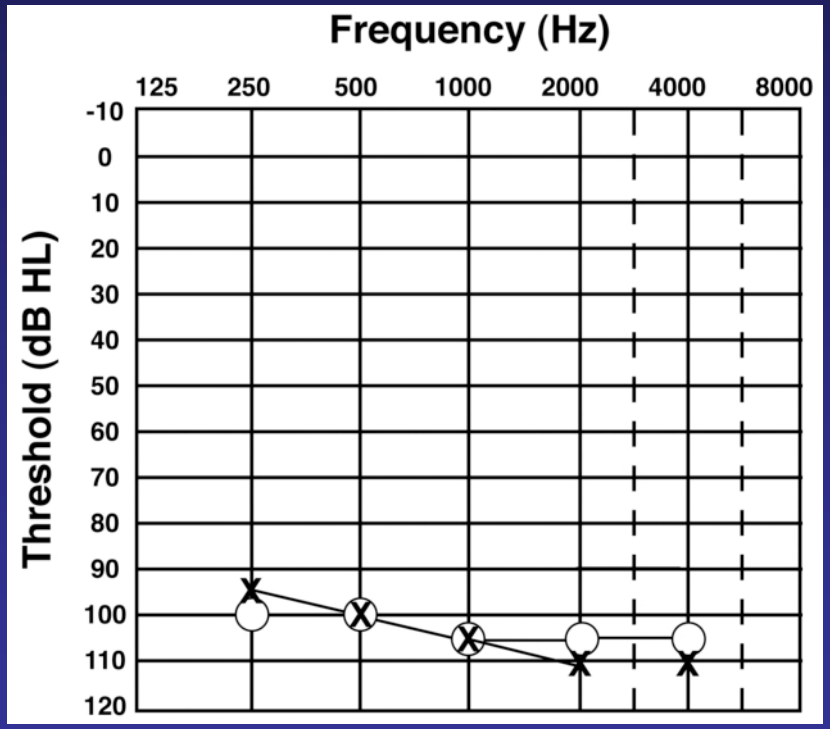
On-line implementation of the IMitative Test of Speech PAttern Contrast Perception

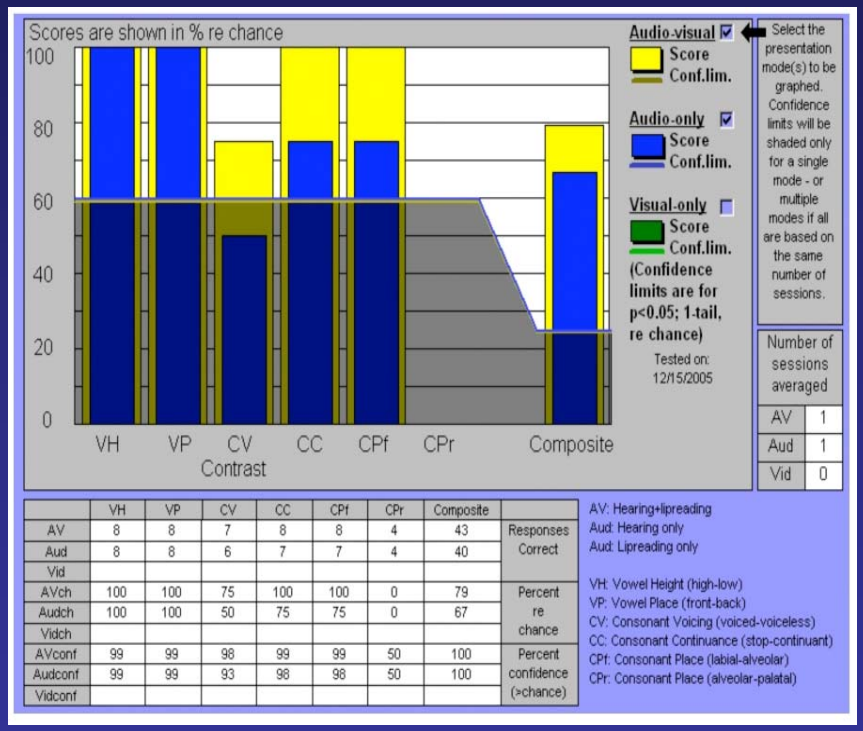
- Measures the child's ability to imitate utterances that convey phonologically significant information
- Multimodal
  - Audio visual
  - Auditory only

# OLIMSPAC Test Set-up

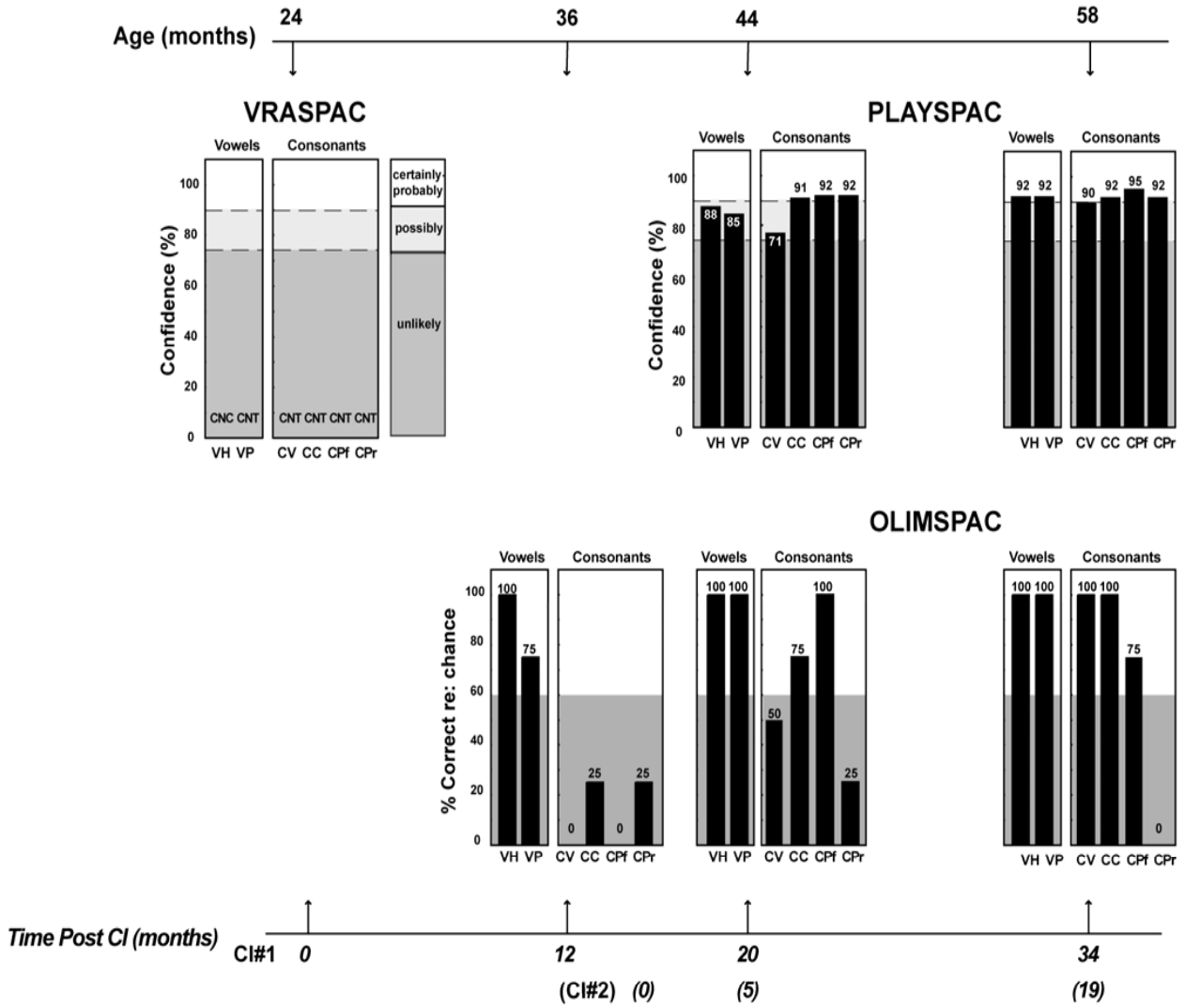


# OLIMSPAC Patient Profile
# 4.5-year-old CI user




| | VH | VP | CV | CC | CPf | CPr | Composite | |
|---|---|---|---|---|---|---|---|---|
| AV | 8 | 8 | 7 | 8 | 8 | 4 | 43 | Responses Correct |
| Aud | 8 | 8 | 6 | 7 | 7 | 4 | 40 | |
| Vid | | | | | | | | |
| AVch | 100 | 100 | 75 | 100 | 100 | 0 | 79 | Percent re chance |
| Audch | 100 | 100 | 50 | 75 | 75 | 0 | 67 | |
| Vidch | | | | | | | | |
| AVconf | 99 | 99 | 98 | 99 | 99 | 50 | 100 | Percent confidence (>chance) |
| Audconf | 99 | 99 | 93 | 98 | 98 | 50 | 100 | |
| Vidconf | | | | | | | | |




Eisenberg, Johnson, Ambrose, & Martinez, submitted (Werner book)

# Ages of Administration

- VRASPAC: 9 to 18 months
- PLAYSPAC: 36 months and older
- OLIMSPAC: 36 months and older
- VIDSPAC: 60 months and older

- *VORSPAC (New test): 18 to 36 months?*

# Clinical Implications

- Cochlear implant research and clinical programs continue to track auditory performance using a variety of speech perception tests. *Hearing aid programs should be encouraged to follow this model.*
- If you are a clinician, there are many tests to select from that account for age and degree of hearing loss.
- If you are a hearing aid manufacturer conducting clinical trials, consider implementing a hierarchical approach.

# Pediatric Hearing Loss and Auditory Perception Laboratory

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