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- Directora del programa de Audiología Pediátrica de los Hospitales de la Universidad de North Carolina
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Determinación de umbrales auditivos en bebés:
pruebas subjetivas

Hearing thresholds in infants: subjective tests

Hearing Thresholds in Infants: Behavioral Tests



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Early Identification, Diagnosis and Treatment of
Deafness in Infants

Madrid

February 21-22, 2008

Topics

- Review of Behavioral Assessment Techniques
- VRA
- Video demonstration
- Description of UNC protocol for infant hearing assessment



University of North Carolina Pediatric Audiology



- Universal newborn hearing screening since 1999
- Pediatric hearing aid and pediatric CI teams
- 700 children with hearing aids
- 600 children with cochlear implants

Joint Committee on Infant Hearing (JCIH 2000, 2007)

Purpose of audiologic test battery:

- Assess integrity of the auditory system
- Estimate hearing sensitivity
- Identify intervention options
- Describe the hearing loss
 - ear-specific estimates of type, degree, and configuration of hearing loss

Guidelines for the Audiologic Assessment of Children From Birth to 5 years of Age ASHA (2004)

“The use of any test alone for assessing children’s hearing sensitivity is discouraged
Therefore, ASHA recommends a comprehensive pediatric assessment that includes behavioral, physiologic, and developmental measures”

The 1970's



- Pediatric audiologists had limited access to physiologic tests
 - ABR, ASSR, OAE unavailable
- Assessment of hearing loss in infancy:
 - Birth-5 months: Behavioral Observation Audiometry (BOA)
 - 6 -24 months: Visual Reinforcement Audiometry (VRA)



- As physiologic tests became more widely available some criticized behavioral audiometric procedures as unreliable, less valid
- In 1976 Jerger and Hayes published study citing need for more than one test to be used in pediatric audiology “cross check principle”

In 2008: Accurate Assessment Using Behavioral Audiometric Techniques Essential

Following referral from newborn hearing screen, initial thresholds estimated using physiologic tests such as ABR and ASSR, however accurate behavioral audiometry still essential:

- Must have ability to monitor thresholds over time to determine if hearing is changing
- Children with Auditory Neuropathy/Dys-synchrony present new challenges
 - ABR/ASSR does not provide threshold information and we must rely on behavioral audiometry
- Children are being considered for CI at younger ages and physiologic testing not sufficient to determine amount of residual hearing

Behavioral (Subjective) Audiometric Test Methods

- BOA – Behavioral Observation Audiometry
- VRA- Visual Reinforcement Audiometry
- VROCA- Visual Reinforcement Operant Conditioning Audiometry
- TROCA-Tangible Reinforcement Operant Conditioning Audiometry
- CPA-Conditioned Play Audiometry

Method Used Depends on Child's Developmental Age

- Methods used vary according to the age and developmental level of the child
- If child premature, age is adjusted for prematurity and test choice depends on "adjusted age"
- If child has developmental delays, knowledge of child's developmental age is helpful
- Parents can help when documentation unavailable



Behavioral Audiometric Methods: Two General Categories

- Unconditioned Response Procedures
 - Procedures that use overt, unconditioned responses to sound to estimate auditory sensitivity
- Conditioned Response Procedures
 - Procedures that use operant conditioning procedures to estimate auditory sensitivity

Behavioral Audiometric Procedures

Unconditioned Response Procedures

Behavioral Observation
Audiometry (BOA)

Conditioned Response Procedures

Visual Reinforcement
Audiometry (VRA)

Visual Reinforcement Operant
Conditioning Audiometry
(VROCA)

Tangible Reinforcement Operant
Conditioning Audiometry (TROCA)

Conditioned Play Audiometry (CPA)

Behavioral Audiometric Procedures

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graph TD; A[Behavioral Audiometric Procedures] --> B[Unconditioned Response Procedures]; A --> C[Conditioned Response Procedures]; B --> D[Behavioral Observation Audiometry (BOA)]; C --> E[Visual Reinforcement Audiometry (VRA)]; C --> F[Visual Reinforcement Operant Conditioning Audiometry (VROCA)]; C --> G[Tangible Reinforcement Operant Conditioning Audiometry (TROCA)]; C --> H[Conditioned Play Audiometry (CPA)];
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Unconditioned Response Procedures

Behavioral Observation Audiometry (BOA)

Conditioned Response Procedures

Visual Reinforcement Audiometry (VRA)

Visual Reinforcement Operant Conditioning Audiometry (VROCA)

Tangible Reinforcement Operant Conditioning Audiometry (TROCA)

Conditioned Play Audiometry (CPA)

Behavioral Observation Audiometry(BOA)

- Unconditioned response
- An observer judges if behavioral response has occurred as a result of presentation of auditory stimulus
- Only subjective method available for infants under 5 months of age

Behavioral Observation Audiometry(BOA) Infant Behaviors

- Eye widening
- Stopping/starting sucking
- Startle response
- Arousal from sleep
- Head turn

Behavioral Observation Audiometry (BOA) Limitations

- Measures babies *awareness* and does not provide true threshold information
- High inter- and inrasubject variability
 - For babies with normal hearing responses range from 20-80dB
 - Unable to differentiate between mild and moderate hearing loss
 - Dependent on state, alertness, attention, etc
- Should not be used to determine thresholds for purposes of hearing aid fitting

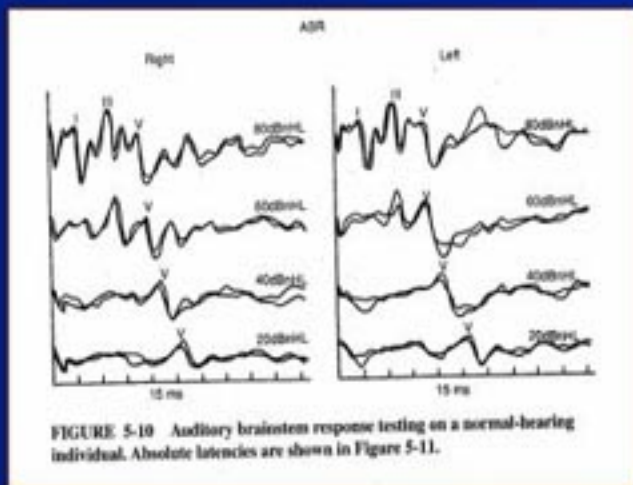
Behavioral Observation Audiometry(BOA) Summary



- May provide gross information about infants awareness of sound
- Widely used before physiologic tests were available
- Better tools available for young infants now

Birth-5 months: Tests of Choice Physiologic Measures:

- Use frequency specific threshold estimates from ABR or ASSR for use during hearing aid fitting



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Conditioning Audiometry TROCA

Conditioned Play Audiometry (CPA)

Visual Reinforcement Audiometry (VRA): 6-7 Months to 2 Years:

- Conditioned head turn response in response to sound
- Trained assistant in booth is helpful but can be done with one audiologist and audiometer in same room
- Must be sure that infant hears or “feels” stimulus before providing reinforcement
- Can sometimes be done at 5-6 months but babies with hearing loss will be more successful at 7-8 months.



Visual Reinforcement Audiometry: Room Set Up

- Audiologist outside of sound booth controlling presentation of sound and reinforcer
- Child seated on parents lap or in highchair inside sound booth
- Visual reinforcer 90 degrees to side of child
- Test assistant sits to side of child
- Variety of bright, colorful reinforcement toys will increase number of responses obtained

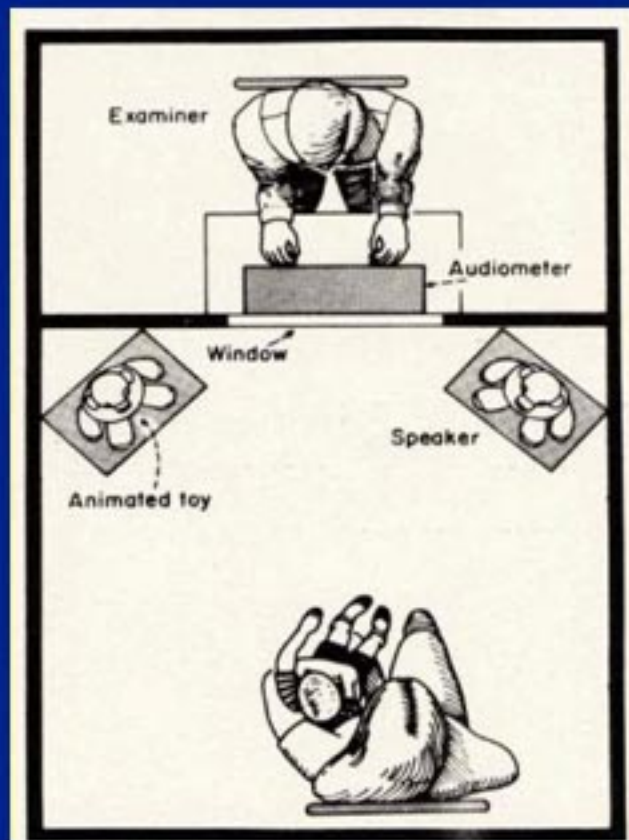


Visual Reinforcement Audiometry Procedure

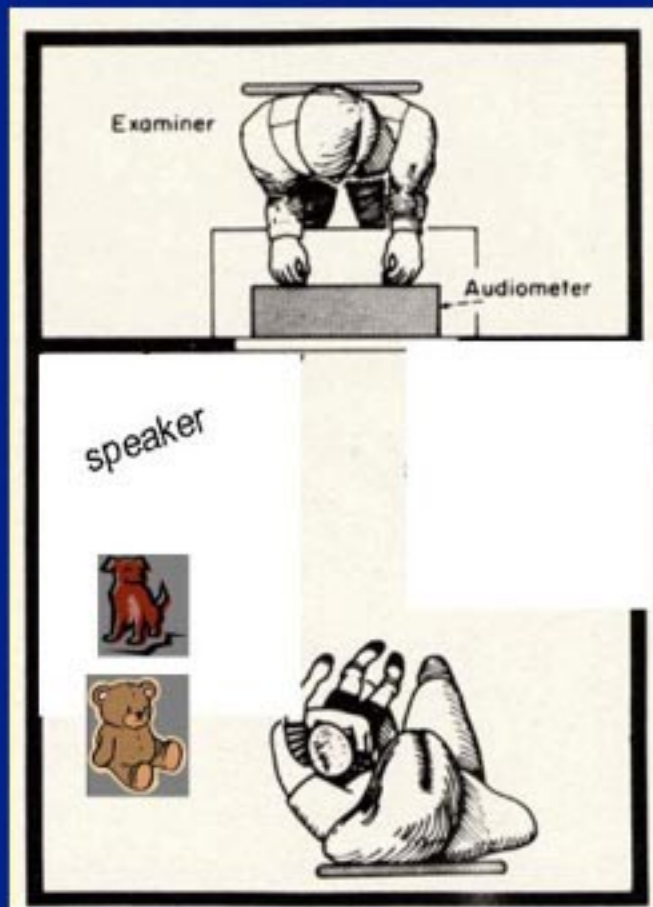
- Sound presented, when child responds, rewarded by presentation of attractive toy with or without animation
 - Short video clips can also be used
- Important audiologist has knowledge that child has heard sound before reinforcement is provided.
 - If ABR done prior to VRA testing information will be available to know what level likely to be above child's threshold



One Example of Sound Room Configuration



A Better Method



Role of Test Assistant

- Keeps child visually centered and mildly distracted
 - Uses soft, quiet toys for centering
 - Only allow child to handle toys as last resort
 - Important for assistant not to be “too interesting”
- For older infants, sometimes helpful to provide a few small edible snacks; e.g. cereal
- For very young infant may be helpful for assistant to sit on same side as reinforcer to help shape infants head turn response
- Assistant wears headphones to hear when sound is being presented and to communicate with examiner (wireless infrared system is helpful)
- Checks and reinserts earphones when needed

Visual Reinforcement Audiometry (VRA)

- Can be completed in sound field, with insert earphones or by bone-conduction
- Babies own earmolds can be attached to earphone transducer
- Helpful if reinforcement is given on the same side as stimulated ear.



Visual Reinforcement Audiometry (VRA)

- Best if infant is able to sit up and has good head control
- Normal hearing infants condition more easily than infants with hearing loss
 - Children with HL lack auditory experience
- Children with severe to profound HL may need to condition using a vibratory signal from bone conduction transducer



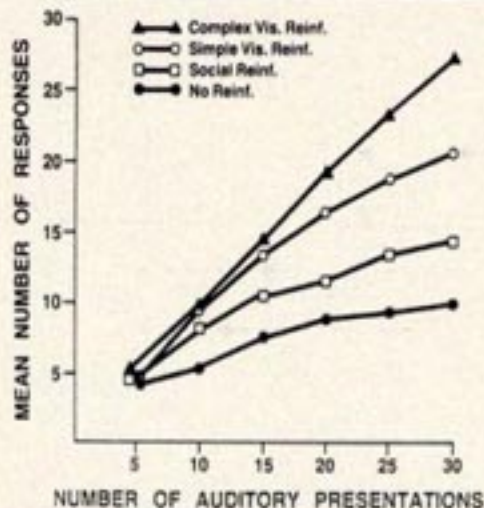
VRA Six Month Old



Visual Reinforcement Audiometry (VRA)

- Number of responses obtained is dependent on type of reinforcement used e.g. social, simple, complex (Moore et al., 1977)

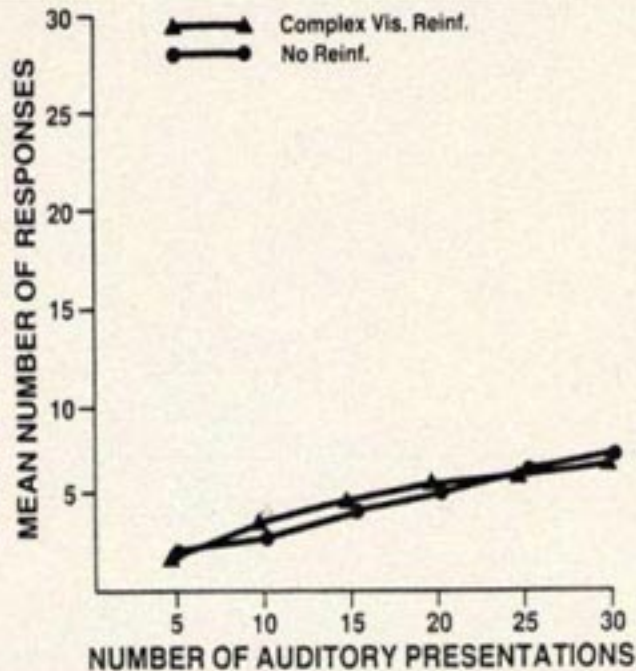
Cumulative mean head-turn responses in blocks of stimulus trials as a function of reinforcement condition - infants 12 to 18 months of age (N = 48) (From J.M. Moore, G. Thompson, and M. Thompson, 1975.)



4 Month Olds

Complex VRA vs No Reinforcement

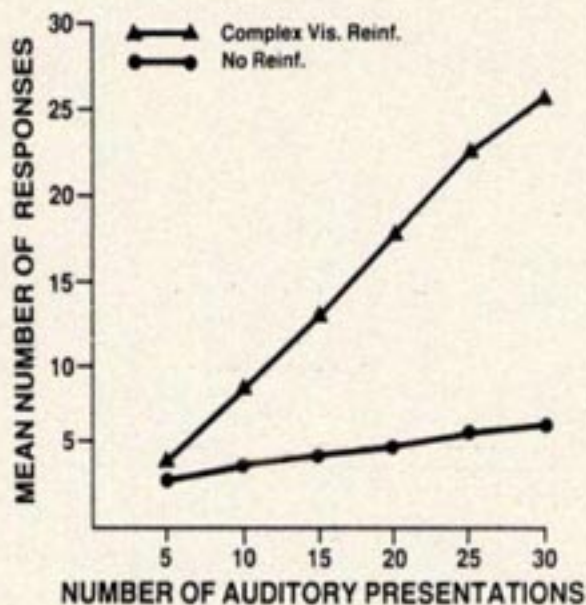
Cumulative mean head-turn responses in blocks of stimulus trials as a function of reinforcement condition - Infants 4 months of age (N = 20) (From J. M. Moore, W. R. Wilson, and G. Thompson, 1977.)



5-6 Month Olds

Complex VRA vs No Reinforcement

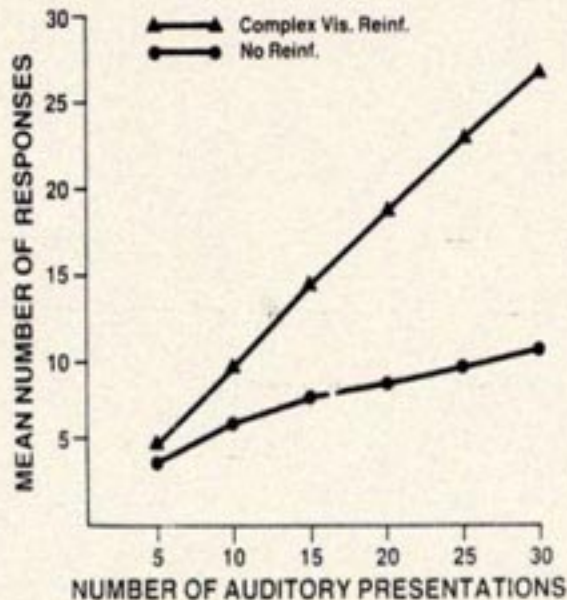
Cumulative mean head-turn responses in blocks of stimulus trials as a function of reinforcement condition - infants 5 to 6 months of age (N = 20) (From J. M. Moore, W. R. Wilson, and G. Thompson, 1977.)



11 Month Olds

Complex VRA vs No Reinforcement

Cumulative mean head-turn responses in blocks of stimulus trials as a function of reinforcement condition - infants seven to 11 months of age (N = 20) (From J. M. Moore, W. R. Wilson, and G. Thompson, 1977.)



Widen et al., 2000

- Average number of trials for 10 month-olds is 45 lasting 15-20 minutes
 - Important not to waste time above threshold

Suggested VRA Clinical Test Protocol Gravel and Hood 1999

- Present 500 Hz NBN at 30dBHL
 - If child responds, present again
 - If no response, present a third time
- Two head turn responses required
- If no response to 2 presentations at 30dBHL, increase to 50dB and repeat
- Once conditioned response established, continue test (down 20dB, up 10dB)
- Test sequence: 500Hz, 2000Hz, 4000Hz, 1000Hz

Suggested VRA Clinical Test Protocol Gravel and Hood 1999

- If no conditioned response at 70dBHL, 500Hz, establish conditioned response with “classic conditioning” using bone conduction
 - 55dB at 500Hz or 45dB at 250Hz

Gravel & Hood-1999

BEGIN:
500Hz NBN at 30dBHL

Response ? YES
Reinforce
Repeat Presentation

Response ? NO
Repeat
Response ? NO
Increase HL

Begin Threshold
Search:
Down 20dB:Up 10dB
3 response reversals

500Hz NBN
at 50dBHL x2

Response?YES
Begin Search:
Down 20; Up 10
3 response reversals

NR

Test order:
2000Hz, 4000Hz,
1000Hz

500Hz NBN
at 70dBHLx2

Response ? YES
Begin Search:
Down: 20; Up 10

NR

STOP:
Change to BC

When Infant Fails to Respond in Sound Field Training Phase

Bone Conducted Signal
250 or 500Hz NBN
(mastoid closest to reinforcer)

Begin conditioning
Pair stimulus with the reinforcer

Complete bone-conducted threshold search:
Previous up-down rules

Switch to air-conduction testing
NBN at 500Hz using ascending technique

Test ear closest to reinforcer first

8-12 Month old Infants and VRA - Widen et al 2000

Identification of Neonatal Hearing Impairment: Hearing Status at 8-12 months chronological age using VRA (n=2995)

- 96 % infants successfully conditioned
 - Of (4%) babies CNT:
 - Developmental delays
 - Visual impairments
 - Could not condition
 - Did not return

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Conditioning Audiometry TROCA

Conditioned Play Audiometry (CPA)

24 months-5+ Years: Conditioned Play Audiometry (CPA)



Play audiometry
using insert
earphones



Play audiometry
using supra-aural
earphones

24 months-5+ Years: Conditioned “Play” Audiometry

- Important to have variety of simple but fun toys.
- Change game as needed to maintain attention
- If assistant not available, portable audiometer in same room as child may be better choice.



Play Audiometry



“The Terrible Twos”

- Some two year olds not quite patient enough for play audiometry
- Sometimes helpful to use combination of procedures to maintain attention



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Visual Reinforcement Operant Conditioning Audiometry (VROCA)

- Combination of play audiometry and VRA
- Child responds as during play audiometry but is only reinforced by use of animated VRA toy once response is completed
- Works well to keep attention of children who are not quite ready for play audiometry

VROCA 28 month old



Tangible Reinforcement Operant Conditioning Audiometry (TROCA)

- First described by Lloyd et al in 1968
- When child gives correct response edible treat dispensed from TROCA unit
- If child responds incorrectly no treat dispensed
- Accompanied by social reinforcement
- Useful for young children who are required to give many responses e.g. during CI programming

Summary of Behavioral Test Measures by Age:

- 6 Months – 24 Months
 - Visual Reinforcement Audiometry (VRA)
- 24-30 months:
 - VROCA, TROCA
- 24 Months – 5 years
 - Conditioned play audiometry (CPA)
- Important to remember that ages are based on infant's *developmental* age

University of North Carolina at Chapel Hill
Program Results
1999-2007



Review of first 70 infants seen following referral from newborn screen with mild to profound hearing loss:

- Median age at ABR 2.6 months
- Median age at HAF 3.9 months.
- *Median age audiogram obtained for each ear using behavioral audiometry 8.5 months.*

University of North Carolina Infant Assessment Protocol

- Birth -5 months:
 - Estimate hearing thresholds using ABR
 - Proceed with hearing aid fitting using estimated thresholds based on ABR
- 6-7 months of age: Schedule first behavioral hearing test
 - Test initially in sound field using VRA:
 - Obtain air conduction audiogram (250-4000Hz)
 - Obtain bone conduction audiogram (500-4000Hz)
 - Begin obtaining individual ear measures using insert earphones attached to child's own custom earmolds

University of North Carolina Infant Assessment Protocol

- By 8-9 months of age:
 - Goal is to have complete audiogram (250-4000Hz) air conduction and bone conduction
- From 8-9 months through 24 Months:
 - Continue with VRA until child is able to perform either VROCA or traditional play audiometry
- 24-30 months and older:
 - Play audiometry

Summary

- Physiological tests such as ABR remain the best method for estimating thresholds for purposes of hearing aid fitting for infants under six months of age.
- Behavioral audiometry is essential in management of infants with hearing loss and can provide reliable thresholds for infants who are developmental age of 6 months and older
- For best results use established protocols such as those described by Judy Gravel and Judith Widen
- Accuracy of hearing aid fitting is only as good as our ability to determine the infant's auditory capacity

Gracias!