Chapter 5

Paediatric Behavioural Testing

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'Children are not little adults. They have unique needs, vulnerabilities, and developmental stages that must be respected and nurtured.'

~Jessica Milligan

Introduction

Children's attention spans are fleeting, and their engagement hinges on creating a nurturing and engaging environment. Recognising the significance of play and alleviating fears and anxieties are pivotal in facilitating a successful assessment process. It is important to use developmentally appropriate assessments, emphasising that chronological age does not necessarily correlate with developmental readiness. By selecting assessments that align with a child's cognitive and emotional development, hearing healthcare professionals (HHP) can ensure a more meaningful and accurate evaluation of auditory function. The assessments described in this chapter are presented based on the usual flow of a paediatric audiology assessment session, but it is important to remember that flexibility is key. The diagnostic test

battery does not necessarily have to follow a specific order, as long as enough physiologic and behavioural information is obtained to make an accurate diagnosis.

A fundamental principle highlighted in this book is the importance of the cross-checking approach. The significance of accurate assessment results for early detection and intervention cannot be overstated. Misdiagnosis or delayed diagnosis can have profound implications for a child's development, speech and language acquisition and overall quality of life. This chapter emphasises the need for thorough and precise assessment protocols to facilitate timely intervention and mitigate potential long-term consequences.

Establishing Rapport

Establishing rapport with a child is an essential step in the assessment process. Before initiating formal assessments, it is crucial to observe the child's general behaviour. Chapter 15 provides more information on ways to establish rapport with the child and their family. Building a trusting relationship with both the child and the caregiver from the outset lays the foundation for effective communication and collaboration throughout the evaluation process, ultimately leading to more accurate diagnoses and personalised interventions for paediatric audiology patients.

This can also be done while taking the case history which is an essential component of any paediatric test battery. A thorough case history involves gathering comprehensive information on prenatal, perinatal, and postnatal development, family hearing history and specific concerns regarding a child's hearing and communication behaviour. This critical initial step helps identify risks for hearing loss (HL) and guides evaluation methods moving forward (JCIH, 2019).

Otoscopy

Otoscopy is used to examine structures of the ear, predominantly the external auditory canal (EAC), tympanic membrane (TM) and the middle ear. It helps HHPs visualise a wide variety of conditions such as acute otitis media (AOM), a perforated TM or a cholesteatoma (Damery et

al. 2019). Delayed diagnosis of various pathologies of the ear can lead to serious conditions or complications (Heah, Soon and Yuen 2016).

While otoscopic examination is important for determining certain pathologies of the ear, there are multiple factors that can lead to its success or failure: poor lighting, a narrow ear canal, poor positioning of the otoscope, and cerumen blockage (Damery et al. 2019). To reduce the challenges involved in performing successful otoscopic examinations, in recent years video-otoscopes have been developed and introduced into clinical practice. The video-otoscope allows the HHP a more controlled and clear view of the TM and surrounding structures by inserting a small camera into the EAC (Tötterman et al. 2019).

Otoscopic examination technique

Children rarely sit still for very long, so when conducting an otoscopic examination the HHP needs to be quick and effective. It is important to first do an external inspection of the outer ear before conducting the otoscopic examination.

An external inspection includes:

1. Inspecting the pinna and surrounding area — the HHP should look for any abnormalities, such as skin tags, preauricular sinuses or atresia.
2. Checking the position of the ears (for example, low set)
3. Noting if there is any tenderness or redness on or around the pinna
4. Noting if there is any sign of otorrhoea or a foul odour

The HHP should also ensure that the otoscopic examination is conducted in a safe manner that accounts for possible movement — this is known as the brace position and helps prevent the otoscope from going too deep into the EAC (Figure 5.1). To obtain the brace position, the HHP should follow the following steps:

1. Hold the otoscope in the hand on the same side as the ear being examined (that is, to inspect the left ear, hold the otoscope in the left hand and use the right hand to manipulate the ear).

2. Hold the otoscope like a pen, between the thumb, first and second finger.
3. Rest the pinkie finger on the child's head to stabilise both the child and the otoscope.
4. Ask the caregiver to assist in stabilising the head if necessary.
5. Manoeuvre the pinna to allow for a clear visualisation of the TM — for children this means gently pulling the pinna down and back.
6. Do the same on the opposite side.



Figure 5.1: Brace position for otoscopic examination

Visualising structures

When conducting otoscopy, the HHP should look for specific identifiers to help determine the status of the EAC and TM. See Table 5.1 for important otoscopic landmarks.

Table 5.1: Otoscopic landmarks

Structure	What to look for
EAC	1. Cerumen impaction 2. Foreign objects 3. Canal oedema (swollen/inflamed EAC) 4. Otorrhoea *Goal: Clear, unobstructed view of the TM.*
TM and middle ear space	1. Colour 2. Bulging or retraction 3. Perforation 4. Presence or absence of expected landmarks *Goal: A grey-coloured, translucent TM, allowing visualisation of the malleus.*

Below, in Figure 5.2, are comparative images of normal and abnormal TMs, including wax, retracted (pulled backward) and perforated eardrums. While a prominent malleus can be an anatomical variant, it is generally associated with retraction or negative middle ear pressure (The Royal Children's Hospital, 2021).

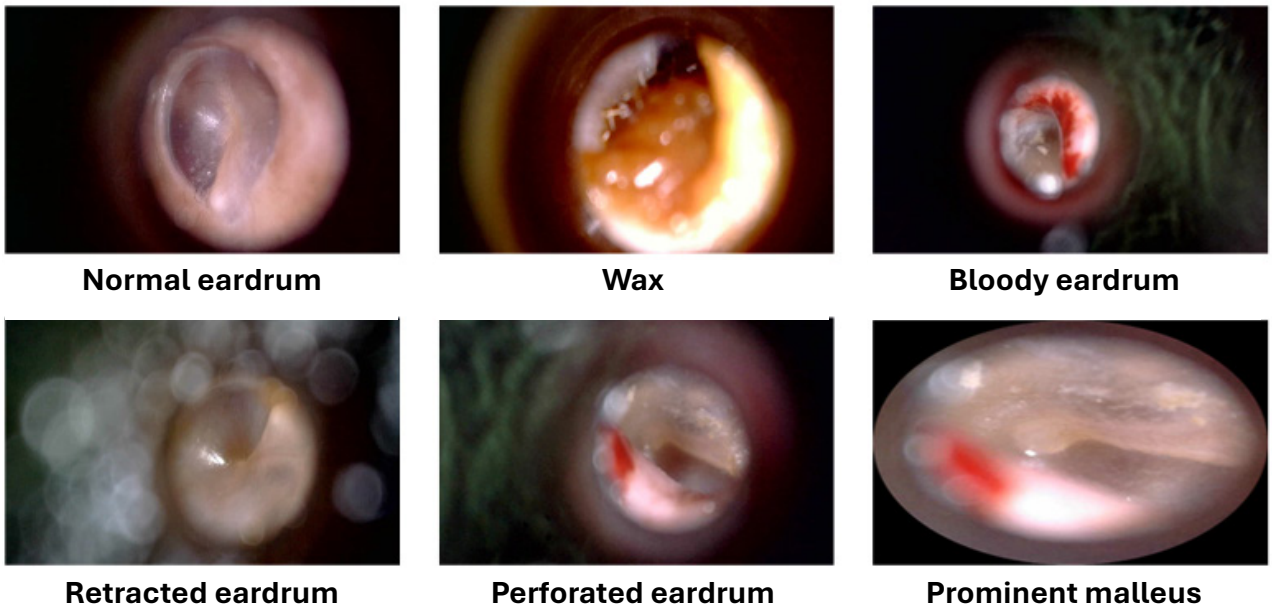


Figure 5.2 Normal and abnormal tympanic membranes

Acoustic Immittance Measures

Acoustic immittance is the umbrella term for tympanometry, acoustic reflex threshold testing and acoustic reflex decay testing (Martin and Clark 2014). These tests are designed to evaluate middle ear functioning and aid in providing a differential diagnosis for various hearing disorders, making them essential for a standard paediatric test battery (American Academy of Audiology 2012; Health Professions Council of South Africa 2012).

Immittance measures are very useful in paediatric assessment as they do not require responses from the child, and they are quick and inexpensive (Hunter and Shahnaz 2013).

These tests are critical in infants and young children as they are most at risk for middle ear problems which typically occur within the first three years of life. Immittance measures are also beneficial because young and vulnerable populations are not always able to express themselves in relation to ear symptoms, and these measures aid in validating the behavioural results obtained.

Tympanometry

Tympanometry measures the mobility of the TM and records middle ear pressure. It is important to remember that tympanometry is not a screening test for HL and cannot identify the presence of HL. It supports the identification of children who have fluid in their middle ear (commonly known as otitis media with effusion [OME]). OME can be asymptomatic in almost 50% of children, can vary in duration and may resolve without intervention (Harlor and Bower 2009).

Tympanometry takes a few seconds to complete and is performed using a soft rubber probe placed at the entrance to the EAC. The probe seals the canal while the machine sends out a soft tone, creating a change in air pressure in the ear canal. The results are automatically recorded as a graph (Tympanogram). A response from the child is not needed for this test. However, patients do need to be quiet and fairly still. Crying, chewing or talking all affect the reliability of tympanometry results. It is helpful to involve the caregiver in calming infants and young children by holding them comfortably on their lap during the tympanometry procedure.

a) Tympanometry classification

The volume, compliance and pressure values of tympanograms are classified into various types based on the shape of the peaks. The primary classifications are A, B and C. Type A indicates normal measurements for all parameters (Table 5.2), while Type B indicates no or limited compliance (<0.1ml), and Type C indicates either a significant increase (> +50 daPa) or decrease (> -200 daPa) in pressure (this is how one can categorise whether the TM is retracted or bulging). Middle ear issues are prevalent in children, making Type B and Type C results common. It is therefore important to acquire bone conduction measures during behavioural testing to identify conductive components. Children who present with abnormal tympanograms should be referred to a physician or ear-, nose- and throat (ENT) specialist to treat any middle ear dysfunction. Chapter 9 describes surgical intervention options for children with CHL or MHL secondary to middle ear dysfunction.

Table 5.2: Guideline for basic paediatric tympanometry norms

Parameter	< 12 years of age	> 12 years of age
Ear Canal Volume (ml)	*0.3 to 0.9 ml*	*0.3 to 1.4 ml*
Compliance (ml)	*0.2 to 0.9 ml*	*0.3 to 1.4 ml*
Pressure (daPa)	*+50 to -200 daPa*	*+50 to -200 daPa*

Source: Minnesota Department of Health (2014)

b) 1 kHz vs 226 Hz Tympanometry

Studies have shown that newborn ears are very resistant to low-frequency tones, likely due to the flaccidity of their middle ear systems (Tharpe and Seewald 2016). For this reason, 226 Hz tympanometry is not recommended for newborns and young infants. Various studies have produced evidence indicating that newborn tympanometry using higher frequencies is more sensitive to changes in middle ear function or status, particularly in infants younger than four months of age (Swanepoel et al. 2007). For this reason, the JCIH (2019) suggests the use of 1 kHz tympanometry for babies that are younger than six months old.

Acoustic reflexes

Acoustics reflexes are useful in paediatric assessment as it can confirm middle ear dysfunction, cochlear HL or retro-cochlear dysfunction. Studies have found that acoustic reflexes in newborns are similar to those of adults, but only if a 1 kHz probe tone is used (Hunter and Shahnaz 2013). Evidence suggests that present acoustic reflexes at normal levels (less than or equal to 100 dB HL) are indicative of a healthy middle ear. When combined with tympanometry, acoustic reflexes are a powerful indicator of middle ear effusion, but alone it is not sufficient.

When performing acoustic reflexes in infants younger than six months, ipsilateral presentation using a 1 kHz probe tone, at 1 kHz and 2 kHz, and no louder than 100 dB SPL, is sufficient

(Katz et al. 2015). In children older than six months, a standard 226 Hz probe tone is suitable and should be paired with tympanometry for accurate measurement of middle ear status.

Reflexes are a quick, easy, cost-effective way to assess the possibility of auditory neuropathy spectrum disorder (ANSD), even in a screening clinic, when combined with OAE or behavioural testing. Patients with risk factors for ANSD, who pass OAEs but have absent or elevated reflexes are at high risk for ANSD and should receive a diagnostic ABR assessment (Berlin et al. 2005).

Visual Reinforcement Audiometry (VRA)

Central to the success of VRA testing is an understanding of children's physical and cognitive milestones. For VRA testing to be effective, children typically need to have reached a developmental stage where they possess adequate motor and trunk control to engage in the behavioural response required, namely turning their heads in response to auditory stimuli (Bonino et al. 2021). During VRA testing, children are conditioned to respond to auditory stimuli by being rewarded with visually reinforcing stimuli, such as animated toys, lights or videos. This conditioning process is based on the principles of operant conditioning, where the desired response (for example, head turned toward the sound) is reinforced through the presentation of a rewarding visual stimulus, which increases the likelihood of the desired behaviour recurring in the future (Norrix 2015). However, children must be cognitively ready to learn to associate the auditory stimulus with a head turn and subsequently with a rewarding visual stimulus. This cognitive readiness to engage in associative learning normally emerges by around six months of age in typically developing children (Tharpe and Seewald 2016). Furthermore, children's cognitive abilities, including attention span, ability to discriminate stimuli and understanding cause-and-effect relationships, play a crucial role in their ability to participate in VRA testing (Tharpe and Seewald 2016).

VRA represents a significant part of the paediatric audiological test battery and offers a reliable and effective method for assessing the hearing abilities of infants and young children. By relying on children's developmental characteristics and utilising conditioning principles, VRA enables the HHP to obtain valuable information about children's auditory function in a manner that is engaging, non-invasive and developmentally appropriate.

VRA equipment and set-up

The testing room should be big enough to accommodate the patient, their caregiver and the distractor, as well as the necessary test equipment and furniture. The testing room should be soundproofed, particularly when testing in the sound field, and should be at least six metres by four metres (British Society of Audiology, 2013).

While there are various ways a VRA room can be set up, Figure 5.3 displays the recommended standard: two testers, two rooms (with the tester operating equipment from a second observation room), allowing for optimal tester view and minimal distraction for the child. This setup is also beneficial for training purposes and for allowing other family members or HHPs to observe the assessment without becoming a distraction. The room setup should also allow the tester to hear what is happening in the test room clearly, ensuring appropriately timed stimulus presentation and communication. With the addition of a two-way headset, the tester and distractor can hear one another and communicate via a more discreet channel.

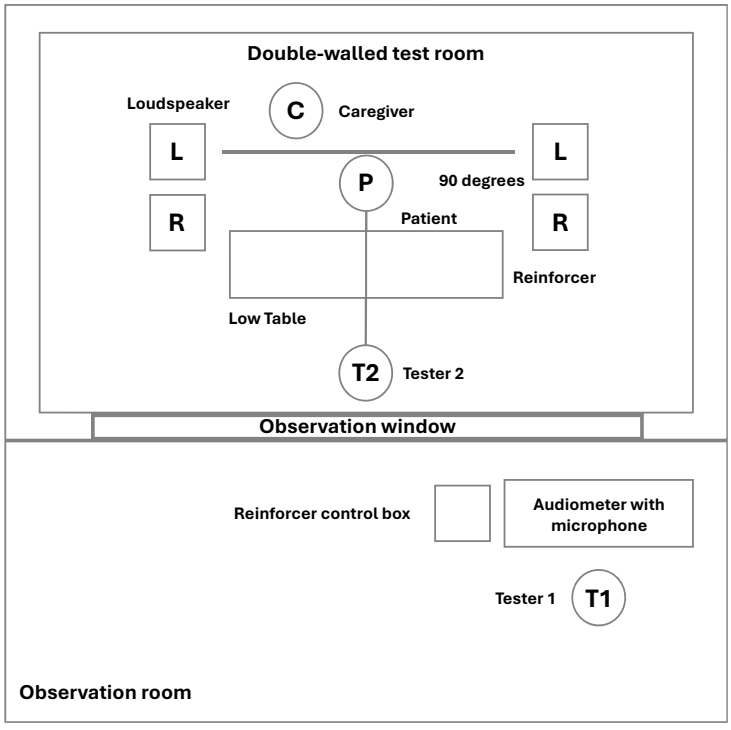


Figure 5.3: Recommended VRA room setup

Loudspeakers should be placed at 90 degrees and at least one metre from the test position at each side (BSA 2013). Ideally, the speaker should be level with the child's head as this allows for the most effective conditioning and establishment of minimum response levels. The reinforcers should be positioned at 90 degrees in order to obtain a clear head turn and should not be more than one or two metres away from the child. There should be minimal distance between the loudspeaker and the reinforcer to ensure the best conditioning when testing using sound field stimuli (that is, one above the other). Adjustable reinforcers are useful as they can be moved closer to the child to assist with better reinforcement. This is particularly useful for children with limited visual ability or reduced developmental age. However, loudspeaker calibration should not be compromised. Additionally, having reinforcers positioned on either side of the child allows them to be rewarded on the side that they prefer (especially when testing with ear-specific transducers or if there are mobility limitations).

Some children prefer videos or Graphic Interchange Format (GIF) over the traditional light-up toys. Children with Autism Spectrum Disorder (ASD) often prefer simple, black line drawings or monotone images. Alternatively, various themed slideshows can be used, such as those focusing on the 'cartoon-of-the-moment'. Observations from initial interactions are especially useful as they may provide insight on whether a child prefers video reinforcers or the 'old-school' light-up reinforcers. Having an array of themed slideshows ensures that the HHP has the correct material for a variety of age and population groups. This way the HHP will be able to switch to more interesting reinforcers if the child loses focus.

Patient seating

Seating required during testing is dependent on a child's developmental age and their level of comfort in the test environment. Regardless of the type of seating used, the child should always be placed in the centre of the test room, so that 90-degree azimuth is used as reference for a clear head turn. Ideally, for testing young children and infants, the use of a highchair is most practical (preferably one with straps to limit movement and sliding out under the table). A highchair will keep the child contained and limit distraction and movement, which is essential when trying to condition and maintain concentration (Figure 5.4). Using a highchair will also eliminate the child's reliance on their caregiver, as well as any possible bias or assistance a caregiver may provide in localising stimuli.

For slightly older children, a small table and chair that are easy to clean but aid in keeping noise levels low are beneficial for distraction and engagement. This setup is also useful in limiting the child's interaction with the various distractors. Children with cognitive or physical limitations may not be able to sit in a highchair or at a table and can in such cases be tested in either their wheelchair or buggy (for example, children with cerebral palsy). Their assistive device can replace the highchair or table in the centre of the room.

Understanding the unique preferences of children, especially those with ASD, is vital. Some may prefer being on the floor rather than in a chair. Getting down to their level can significantly impact session success, as forcing them into an uncomfortable position where they feel caged in may disrupt the testing process.



Figure 5.4: Set up with a highchair

Distractors

Distractors should be both age- and developmentally appropriate. It is equally important to ensure that distractors are regularly disinfected. Distractor toys should be attention-grabbing but also not overly distracting (a fine balance must be struck), while being silent so as not to confuse the child during testing. Light-up toys are often enjoyed the most.

Distractor toys should be kept out of sight by storing them in a locked box or cupboard in the test room. In this way, the child does not get overwhelmed. Having easy access to distractors are essential so that the HHP can quickly switch between toys as needed. The HHP should

try to limit the child's physical interaction with the distractor toys so that they do not lose focus on the task at hand (the VRA assessment).

Managing distractors effectively (in terms of toys and the environment) is essential for accurate results. Maintaining distractor competence and controlling noise levels while avoiding direct cues during stimulus presentation is critical. The HHP's distance from the child should also be considered: Continuous engagement should be maintained without the child being overwhelmed. To maintain focus during VRA sessions, minimising distractions, such as siblings that may have accompanied the caregiver to the appointment, is essential. Siblings may inadvertently provide cues or disrupt the testing environment with noise, affecting the accuracy of results.

Incorporating these techniques and considerations into VRA sessions ensures thorough and accurate assessment of paediatric auditory function, which in turn facilitates timely and appropriate intervention.

Transducers

Often, sound field testing is selected as the first choice when conducting VRA. However, over the years, sound field testing as the first option has been challenged. Ear-specific information is desired, and as such, earphones are required for testing. Testing under earphones will also prevent HHPs from missing a child with a unilateral HL.

Insert earphones can be purchased in various sizes, making it possible to obtain ear-specific responses during testing. If the HHP can insert an OAE probe or tympanometry probe in the child's ear, they should be trying to test behaviourally using insert earphones. In certain cases (that is, microtia or extreme sensitivity to having ears touched) this is not possible, and then the HHP should consider supra-aural headphones. Additionally, bone conduction testing can also be completed using VRA. To ensure comfort during testing, the clinician can switch out the conventional hardband and rather make use of a bone conduction device softband, tightly securing the bone conductor in position (Figure 5.5).



Figure 5.5: Example of bone conduction testing using softband

VRA Test Technique

VRA serves as a pivotal procedure in assessing the hearing abilities of children who are typically aged between six and twenty-four months, and for those with additional disabilities or challenges that may impede more conventional testing methods like play- or standard audiometry. The VRA technique proves particularly beneficial for children who are unable to grasp blocks, toys or a push-button due to physical limitations, or those facing cognitive and attention challenges, such as those with ASD.

a) Frequency selection

When initiating VRA testing, it is essential to select frequencies strategically. One should begin by testing low (500 Hz) and high (4 kHz) frequencies in each ear before filling in the rest of the frequencies. The Ling sounds or LMH 10 are ten specific sounds that cover low, mid and high frequencies of human speech. Some children only respond to speech type stimuli, as such the LMH 10 sounds can be used to check detection at various frequencies (Madell and Hewitt 2021). Some practical resources have been included as appendices at the end of this chapter to show useful ways to capture VRA responses as well as Ling responses.

Starting with speech babble, speech detection, calling the child's name or utilising the Ling sound audiogram (Madell and Hewitt 2021) should be considered to assess various frequency ranges:

- aah /ɑ/ (as in 'car')
- ee: /i/ (as in 'see')
- ooh: /ʊ/ (as in 'book')
- sh: /ʃ/ (as in 'shoe')
- s: /s/ (as in 'see')
- m: /m/ (as in 'man')
- n: /n/ (as in 'no')
- h: /h/ (as in 'hop')
- z: /z/ (as in 'buzz')
- j: /dʒ// (as in 'jump')

b) Response recognition

During VRA testing, discerning a response can be subtle. While an eyeblink or a smile may indicate a reaction to the auditory stimulus, it requires careful observation and judgement. The HHP must be careful not to mistake involuntary responses or unrelated behaviours for a genuine response to the stimulus. Careful recording of repeated, observed responses is essential for accurate assessment results.

c) Team collaboration and caregiver involvement

Successful VRA sessions often involve teamwork, including occupational therapists for regulation support and caregivers for active involvement. Instructing caregivers to participate in the assessment not only aids in maintaining the child's attention but also serves as a valuable counselling tool if the child presents with severe-to-profound HL, with no response being elicited in sound field testing.

d) Stimulus Variation

To sustain the child's interest and prevent false responses, varying the presentation of tones between ears without a predictable pattern is crucial. Balancing the need for thorough conditioning with the child's limited attention span is essential to avoid losing the child's engagement during the session.

e) Avoiding non-verbal cues

Non-verbal cues, such as eye-widening or prompting, must be avoided, as children are highly perceptive and may respond falsely based on these cues. Caregivers should also be

instructed to refrain from providing cues through body language or head movements if the child is sitting on their lap.

f) Bone conduction conditioning

In cases where severe-profound HL is suspected, bone conduction stimulation may be necessary for conditioning. Visual and animated techniques are particularly effective in engaging children with severe-to-profound HL.

g) Microtia considerations

When testing children with microtia, conducting both air conduction and bone conduction tests on the affected ear is crucial for comprehensive evaluation and subsequent selection of assistive technology.

VRA Procedures

VRA is a systematic method that is usually employed to evaluate the hearing abilities of typically developing children (aged six to 24 months) who can sit unsupported and possess good head and neck control. This section outlines the step-by-step procedures involved in conducting VRA, along with strategies to ensure accurate and reliable results. Table 5.3 details VRA normative responses per age group.

a) Brief case history

Prior to commencing the VRA assessment, conduct a brief case history with the caregivers, and observe the child before any formal assessments begin. It is crucial not to miss the opportunity to test the child, and any incomplete information can be gathered after the testing session.

b) Explanation to caregivers

The test procedure should be explained to the caregivers to ensure their co-operation and understanding. They should be informed of the following:

- If the child is seated on a chair, the caregiver should be seated slightly to the left, facing the child.
- Caregivers should be instructed not to talk to the child or provide any cues and to keep the room as quiet as possible.
- The test assistant will sit in front of the child, using a developmentally appropriate toy to maintain the child's focus on the midline. They should not sit too close to the child.

c) Testing procedure

The VRA testing procedure involves the following steps:

- The HHP should always attempt to obtain ear-specific responses under insert earphones or headphones, where possible.
- Initially, appropriately loud enough (typically 65-70 dB HL) warble tones or speech babble should be presented, along with a lighted toy or screen to condition the child.
- After the child turns their head, their attention should be redirected to the midline.
- If the child does not turn their head, the conditioning stimulus intensity should be increased, with conditioning stimulus consistently playing together with the visual stimulus (lighted toy or screen). This should continue until the HHP is confident that the child is appropriately conditioned.
- Once the child is appropriately conditioned, minimum response levels should be obtained using either a descending or ascending approach, depending on the child's response.
- Testing frequencies should start with 500 Hz, then 4 kHz, 1 kHz, and 2 kHz, and if possible, 250 Hz.

**Special Considerations: If testing aided free field thresholds using hearing aids and VRA, warble tones should be used instead of narrow band noise (NBN).*

Table 5.3: VRA normative responses

Age	Minimum response level	Comments
4-7 months	≤ 40dBHL	A localising response (eye or head turn) is sometimes acceptable, but a clear 90-degree head turn should be required as an acceptable and reliable response. Note that, before recording a minimum response level, a response must have been observed twice at a particular level for a specific frequency. If a false-positive is obtained (turning head when no sound was presented), re-check that frequency and intensity.
7 – 16 months	≤ 30dBHL	
16+ months	≤ 25dBHL	

Source: Northern and Downs (2002)

Conditioned Play Audiometry (CPA)

CPA is a dynamic method used to assess the hearing abilities of children through play-based activities. This section outlines the structured procedures involved in conducting CPA, including both conditioning and testing phases, along with techniques for efficient and accurate assessment. Table 5.4 details normative values for CPA per age group.

Conditioning Phase

a) Toy selection and setup

The child should be provided with an engaging toy, such as a stacking toy or blocks in a

container. All components of the toy should be visible and accessible. When placing the earphones it is important not to draw attention to the procedure by telling the child 'It is not going to hurt'. Instead, positive information should be shared, like 'Wow, now you look like an aeroplane pilot! Let's play the game.'

b) Conditioning response

A block should be positioned in the child's hand and they should be instructed to listen carefully. The test should begin in the conditioning phase by presenting a pulsed pure tone at either 500 Hz or 1 kHz at a loud intensity, approximately 50-60 dB HL. The intensity level should be adjusted as needed, especially for children with suspected severe-profound HL, to approximately 80-100 dB HL.

c) Associative learning

A sufficiently loud, conditioning sound should be presented together with exaggerated movement, such as placing the block in the container, to establish an associative response. This procedure should be repeated with assistance for the first two presentations and assistance should gradually be withheld for subsequent presentations to assess the child's ability to respond unaided.

d) Threshold establishment

Once the child is conditioned, the intensity level should be decreased to establish the threshold using the Hughson and Westlake (1944) method, that is,10 dB HL down, 5 dB HL up. The child should be encouraged by using positive verbal or gesturing reinforcement with engagement maintained throughout the conditioning phase.

Testing phase (Threshold determination)

a) Frequency testing

Testing should begin with the right ear or the better ear, if known, and followed with these frequencies:

- 500 Hz Right & Left
- 4 kHz Right & Left
- 1 kHz Right & Left
- 2 kHz Right & Left

It is better to obtain one low and one high frequency in each ear than to have a complete set of frequencies in only one ear and no information on the other ear.

b) Bone conduction testing

Bone conduction testing should be performed as part of the threshold determination process, with masking applied if necessary for older children. Breaks should be provided as needed to ensure the child's comfort and co-operation. The bone conductor can be secured by a softband, if the child does not tolerate the hard, steel headband.

c) Masking procedures

Masking is necessary in air conduction testing when there is a difference in the air conduction thresholds of ≥ 40 dB HL at any frequency compared to the air conduction threshold in the contralateral ear. If using insert earphones are being used, masking is necessary when the air conduction difference between the two ears is ≥ 60 dB HL. For bone conduction testing, masking is required when there is an air-bone gap of ≥ 10 – 15 dB HL (Katz et al. 2015). Explaining the concept of masking may be confusing for the child. Instead of attempting to explain using long, complicated sentences, continuous masking sound be used without drawing attention to it. A pure tone at a level easily detectable above the masking sound should be presented and the child should be assisted in placing the testing object (toy block) in the container as practised in the conditioning phase.

d) Suprathreshold retesting

If the child exhibits inattention or false responses during testing, they should be reconditioned and retested at the suprathreshold level before proceeding with threshold determination. The HHP may switch between ears or different stimuli can be used if the child becomes bored. The type of stimulus used at different frequencies should be recorded.

e) Guarding against patterns

Stimuli should be presented randomly to prevent the child from anticipating the next tone. The HHP can occasionally wait a few seconds before presenting a tone, to maintain the child's attention.

Interpretation of results

a) Threshold acceptance

Responses at 10 dB HL should be accepted instead of spending excessive time attempting to obtain 0 dB HL or 5 dB HL thresholds. It should be indicated on the audiogram that these are minimum response levels.

b) Monitoring responses

If the child's responses suddenly change or deviate from expected levels, the previous thresholds should be repeated to check for reliability. The following factors should be considered: concentration, testing materials or the need for a short break.

c) Abnormal responses

If tympanometry indicates normal middle ear function but the threshold for one or more test frequencies exceeds 15 dB HL for air or bone conduction, a follow-up assessment should be scheduled. Children's attention levels can fluctuate, and more reliable responses may be obtained after rest or at a different time of day (that is, after a nap, or earlier in the morning).

Table 5.4: Norms for CPA

Normative response	Age	Condition
≤ 15 dB HL	*> 24 months*	*Transducer (AC or BC)*
≤25 dB HL	*>16 months*	*Free field*

Source: Northern and Downs (2002)

By following these structured procedures and techniques, HHPs can conduct CPA effectively, ensuring comprehensive assessment of paediatric hearing abilities and appropriate follow-up appointments, as needed.

Standard Audiometry

Standard audiometry is a behavioural hearing test that assesses the hearing sensitivity of the individual through conventional test methods. It typically makes use of pure-tone stimuli with responses via hand raises or the push of a response button. This section highlights the test procedure involved, including speech audiometry.

Preparation phase

a) Instructions

Clear instructions should be provided to the child so that they understand what is expected of them during testing. Children should be informed that they will hear a beep and that as soon as they hear it, they should push the button. They should be informed that the beeps may be loud and soft, and that it is important to push the button when they hear them.

b) Conditioning

The child should be allowed to hold the response button in their dominant hand, and they

should be instructed to listen carefully. The test should begin in the conditioning phase by presenting a pulsed pure tone at either 500 Hz or 1 kHz at a loud intensity, approximately 50-60 dB HL. Make sure that that they hear the sound and are aware of what they should be listening for. The intensity level should be adjusted as needed, especially for children with suspected severe-profound HL, to approximately 80-100 dB HL.

c) Threshold establishment

Once the child is conditioned, the intensity level should be decreased to establish the threshold using the Hughston Westlake (1944) method. The child should be encouraged by using positive verbal or gesturing reinforcement and maintaining engagement throughout. If inconsistent results are obtained, the child should be reinstructed and testing resumed at a louder intensity. Determining thresholds, bone conduction testing, masking indications and interpretation of results for Standard Audiometry is the same as for CPA (see section above).

Speech Audiometry

Speech audiometry is an umbrella term used to describe a series of audiometric tests in which speech is the primary stimulus. These tests can be done both in quiet and in noise. When combined with pure-tone audiometry, they can assist in determining the type and degree of HL (Eggermont 2017). Additionally, pure-tone audiometry is limited in its predictability of an individual's ability to recognise speech. Speech audiometry is an essential tool in a paediatric hearing assessment. Speech testing can help identify the reliability of a child's responses by cross-checking their speech and pure tone audiometry results.

Speech detection testing

During speech detection testing (SDT), the HHP should determine whether the child can hear speech. It is the most basic of speech tests as no level of understanding is required. This is often the mode of speech testing used when conducting VRA testing. It is presented via loudspeaker or earphones.

The speech stimuli should be presented at various intensity levels and an observation of whether the child reacts to the stimulus noted. Frequency-specific sounds (that is, the Ling sounds) should be presented at the level at which the child detects at least 50% of the

speech, which is considered their speech detection level. Starting at 10 dB HL is recommended, increasing intensity in 5 dB HL increments until a response is obtained.

Speech recognition testing

Speech recognition testing (SRT) builds on the foundation of SDT, with the expectation that the child not only detects the speech but is also able to recognise the word/s presented to them. These words are known as spondee words, of which various standardised lists exist. SRT is used to confirm the reliability of the pure tone audiogram. SRT should always be attempted under earphones.

a) Materials

No more than five spondee toys or trochee toys (trochee words have two syllables: the first is stressed and the second is unstressed, which is similar to spondee words) should be used. These are most appropriate for the two-to-three-year-old age group. Spondee pictures boards are most suitable for ages four and older and can include six-to-eight pictures.

b) Procedure

It is essential to make sure that the child is familiar with the words being used. For SRT, testing should commence at 25 dB HL above the child's pure tone average. Their recognition level is the lowest intensity if they are able to identify 50% of the words correctly.

Word identification testing

This form of speech testing is when the child is presented with a list of phonetically balanced words at a single frequency, which they must repeat out loud. They are scored on whether they repeat the words correctly or incorrectly, and the result is expressed as a percentage. Word identification scores can typically be obtained from around four years old(or two to three year old if the child has good language skills).

a) Stimuli

Recorded material or live voice are available. There has been a movement away from live voice testing due to variations in tester tone and pronunciation of words. Most of the newer

audiometers have built-in recorded speech tests available making this more accessible than previous years. The first list should be presented at 50 dB HL or 30 dB HL above the SRT.

b) Material

The most common clinically used word identification tests are the phonetically balanced kindergarten 50-word list (PBK-50), the Word Intelligibility by Picture Identification (WIPI) test and The Northwestern University Children's Perception of Speech (NU-CHIPS) test. These are available in various countries and cover a range of vocabulary ages. Typically, one list (25 words) is presented at each level.

c) Responses

Non-verbal responses or pointing is accepted for closed-set testing, with the HHP providing positive reinforcement. If a child's vocabulary is adequate, then a verbal response is required.

d) Results

To calculate results, the number of correct responses (out of 25) should be multiplied by four to obtain the percentage word score (out of 100%). If the score is between sixteen and 88%, it is recommended to increase the word list to 50 words as this will improve the reliability of the results. The total percentage score at each level is then plotted on the speech audiogram. Once plotted, it is critical to check for retro-cochlear pathology by using the rollover index formula. A rollover index of more than 0.45 is indicative of a retro-cochlear pathology and further referral is indicated (Katz et al. 2015). The child's actual responses should be recorded to allow for phonemic analysis, if indicated.

It is important, as far as possible, to obtain word identification scores for a child who has been referred with the following concerns: Poor school performance, limited attention, auditory memory challenges or a language delay, as these identifiers are commonly associated with auditory processing difficulties.

Conclusion

The need for assessing hearing in young children has been understood for almost a century. During this time, test procedures have evolved, with evidence showing that using developmentally appropriate test techniques allows for an efficient and precise manner of obtaining audiological outcomes. The information that HHPs are able to obtain through behavioural testing is the quantifiable functional hearing of a child. It is essential that all test protocols and recordings are carried out in consistent and repeatable ways to ensure that the authenticity of results is maintained.

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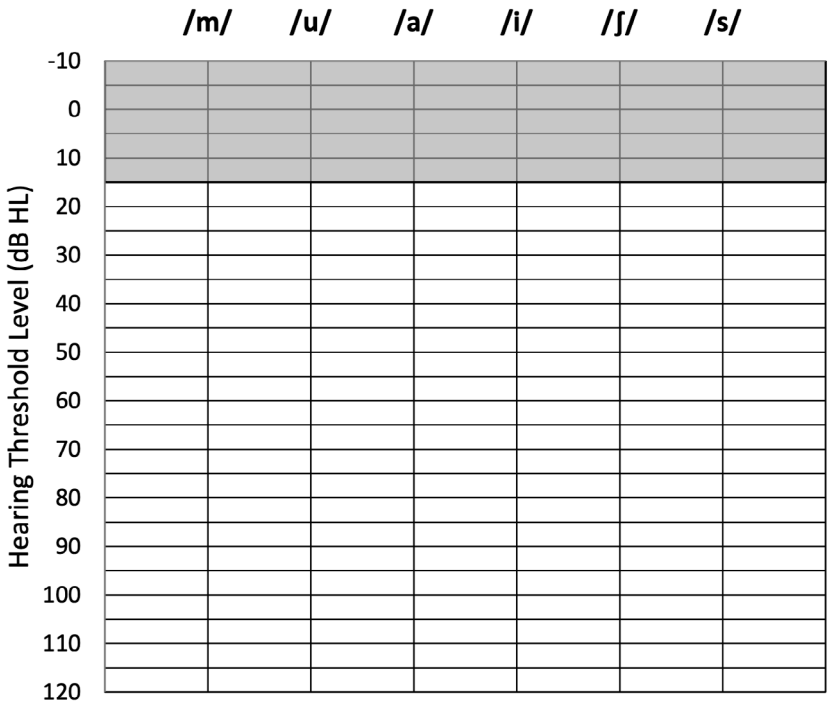
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Appendices

Appendix 1. Sample Ling audiogram



Appendix 2. Sample VRA recording audiogram

Patient Hospital Sticker

Referred by: _____ Contact No.: _____ Test Date: _____ Stats No.: _____
Audiologist 1: _____ Test No.: _____
Audiologist 2: _____ Reliability: POOR FAIR GOOD

TRANSDUCER	
Insert Earphones	
Supra-aural headphones	
Speaker / Soundfield	

STIMULUS	
Warble/FM Tone	
Narrowband	
Live speech	

ICD CODES	
RIGHT	
LEFT	

PAEDIATRIC AUDIOGRAM

VISUAL RESPONSE AUDIOMETRY (VRA)				
	RIGHT		LEFT	
	dBHL	Response	dBHL	Response
250Hz				
500Hz				
1000Hz				
2000Hz				
4000Hz				
6000Hz				
SDT				

AGE-APPROPRIATE SOUNDFIELD NORMS FOR NORMAL HEARING		
MONTHS	dBHL	X
0-4	≤ 60	
4-7	≤ 40	
7-16	≤ 30	
>16	≤ 25	

ABBREVIATIONS	
LOC	Localised Response
N	Neutral Response
CON	Conditioning Response
NR	No Response
MR	Minimum Response

TYPMANOGRAM		
PROBE TONE: □226Hz/□1kHz	RIGHT	LEFT
TYPE		
PRESSURE		
COMPLIANCE		
ECV		

IPSI-LATERAL ACOUSTIC REFLEXES				
	500Hz	1kHz	2kHz	4kHz
RIGHT				
LEFT				

SCREENING OAEs		
	RIGHT	LEFT
PASS		
REFER		
NOISE		
CNT		

AABR SCREENER		
	RIGHT	LEFT
PASS		
REFER		
NOISE		
CNT		

NOTES:

HISTORY:

SUMMARY & PLAN: