



Equipment-specific ABR test parameters for newborn diagnostic ABR testing

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Background

The BSA currently publishes, via its web site, recommended procedures and practice guidance including some guidance documents formally written for and controlled by NHSP for the post-screening diagnostic testing of newborns. The BSA recommended procedure “Auditory Brainstem Response (ABR) Testing in Babies” (2019) offers stimulus and recording parameters which are summarised on the next page. However, it is not always possible to set up some ABR systems to exactly reflect those parameters. For example, the recording window length for higher frequency stimuli is 20ms yet the Biologic Navigator Pro system does not offer this option; the nearest value is 21.33ms and this has consequences for the preferred stimulus rate. Instead of the preferred 49.1/s, the rate considered appropriate for a window of 21.33ms on this system is 45.1/s.

The purpose of this document is to offer users of ABR systems the test parameters most closely and appropriately meeting the guidance given in the BSA Auditory Brainstem Response (ABR) Testing in Babies (2019) document. Making this available has the potential to avoid errors and promotes peer review. As a practical and pragmatic guide for ABR system users, this document concludes with a short section giving hints and tips for good practice and strategies to reduce the effects of interference.

Disclaimer

ERA Training & Consultancy has made this document available in good faith in the hope it will be helpful to the profession but cannot accept responsibility for errors of interpretation or omission. It applies to only post-screening diagnostic ABR testing.

Historical Perspective

The idea to produce equipment-specific test parameters was conceived by John Stevens and Guy Lightfoot in June 2010 whilst at a conference on lake Como, Italy. Notes for the first version were written on several beer mats one evening on the veranda of the bar of the lake-side Hotel Miralago. Since that time the national guidance has undergone several revisions and new ABR systems have become available.

Review date

This document will be reviewed when needed rather to a defined schedule. Historically, this is likely to be approximately annually.

ABR users and manufacturers are encouraged to offer suggestions for revision to Guy Lightfoot – contact details below.

SUMMARY OF RECOMMENDED ABR PARAMETERS

	Click, Nbchirp~ & 2kHz / 4kHz tone pip	0.5kHz / 1kHz tone pip
Electrode location ¹	Positive : High forehead (as close to vertex as possible but avoiding fontanelle) Negative : Ipsilateral mastoid Common : Contralateral mastoid	
Stimulus type	Alternating polarity	
Stimulus timing	Click: 100µs Tone pip: 2-1-2 cycles (linear rise–plateau–fall) or 5-cycle Blackman	
Stimulus rate ²	45.1 - 49.1/s	35.1 - 39.1/s
Calibration values for OdBnHL	Refer to NHSP calibration data	
Amplifier reject levels	±3 to ±10µV ³ peak-to-peak. Start at ≤ ±5µV peak-to-peak	
Amplifier filters	Low frequency: 30Hz High frequency: 1500Hz	
Window length ⁴	20ms	25ms
Number of sweeps averaged per replication	Typically: 2000 click & NBchirp, or 3000 for TP Minimum: 1500 click & NBchirp, or 2000 for TP	
Display scales	Within range 25-100nV ≡ 1ms See equipment specific settings	
Display	Wave V up	

The frequencies used for frequency-specific testing should be 0.5, 1, 2 or 4 kHz.

Whilst most systems require a maximum number of sweeps to be defined, upon completion of which an averaging run is terminated, latest guidance has moved away from the concept of defining the number of sweeps towards the number needed to obtain a result. For a “CR” this might be as little as 1500 sweeps or for RA could be 8000 or even more. Clinicians need the decision-making skills to know when it is appropriate to terminate an averaging run. The number of sweeps defined in a test set-up therefore should be at least the maximum a clinician is likely to need, such as 8000. Readers should not interpret this to suggest that 8000 will be needed in all averaging runs.

~The term chirp relates to the specification for chirp stimuli given in IEC 60645-3 (2020). The CE-Chirp is an example of one design of chirp stimulus meeting this standard, for which ABR dBnHL-to-dBeHL corrections have been published. Other designs of chirps compliant with IEC 60645-3 (2020) may require different corrections.

¹ Alternative electrode montage: Negative – nape; Common – forehead at least 4cm from positive or negative electrodes (low forehead or to one side). Note that some manufacturers label positive and negative as active and reference respectively. Referring to common as Ground or Earth is technically incorrect; indeed it is dangerous to ground a patient. For two-channel BC see Appendix B.

² Most equipment can provide a rate within these ranges for the suggested window length (see equipment-specific parameters). The rate must not be related to 50Hz. If chirp stimuli are used the optimum rate depends on the chirp duration.

³ See Appendix D for note on using 10µV rejection setting.

⁴ These window lengths are nominal values and should be set to the closest value available on the equipment. Chirps should be used with a window length of 20ms regardless of stimulus frequency.

BSA/NHSP ABR Parameters on specific systems

Biologic (Windows software version 6.3 & 7.0)

The parameters are set in: Setup/Collection Protocols and in each protocol by selecting the relevant tab in the software headed 1/Recording, 2/Stimulus, 3/Amplifier.

Recording

Epoch time(window)
For Clicks & tone pips at 2kHz & 4kHz: 21.33ms
For Tone pips at 500Hz & 1kHz: 26.67ms
Points (No. of data points in average): 512 (only 256 possible with 26ms epoch)
Pre/post: 0
Blocking: See table below
Fsp details: tick enable but not stop criterion See table below for range; set skipped points to 0.

Stimulus

Transducer: headphones/insert earphones/bone oscillator
Insert delay: 0.80ms
Polarity: alternating
Stimulus rate: 45.1/s (for a 21.33ms window)
35.1/s (for a 26.67ms window)

NB check stimulus rates can be achieved and that high rate does not produce an artefact.

Intensity (initial level for 4kHz pips but refer to BSA/NHSP guidelines; aim is to start at discharge level +10dB):

Headphone: 40dBnHL

Insert earphone: 30dBnHL

Intensity step 5dB

Stimulus type:

Click; Duration 100µs.

Tone burst (tone pip)

Rise/fall time: 2 cycles

Plateau: 1cycle

N.B. Earlier software may require values in ms as follows:

	500Hz	1000Hz	2000Hz	4000Hz
Plateau	2	1	0.5	0.25
Rise time	4	2	1	0.5

Ramp: Blackman or linear (not critical)

Mask: none

(Noise calibration: 0dB of noise is actually 20 dB SPL)

Amplifier

Channel 2 enable: unchecked

Gain: 240,000 or 300,000

Artefact reject level: $\pm 5\mu V$ to $\pm 9.9\mu V$ ($\pm 3\mu V$ for CM tests)

WARNING reject level can change if the gain is changed - check reject levels are correct on display, especially after changing the gain setting.

Filters: Low 30Hz High 1500Hz. Notch filter: unchecked

Input 1: Cz Input 2: A1/A2

Electrode switching: use only if you understand how this works.

Display

Setup/Default Display parameters. Waveform Grouping: Select superimpose as default. Scale: Normally split screen, format (two charts side by side – Ear Panel Same). Specific 0.2µV (0.3 for large responses). Do not manually alter chart size /position with the mouse – likely to alter aspect ratio.

Fsp range & blocking duration:

Stimulus	Blocking (ms)	Fsp range (ms)
Click	1.5	6-14
4k Pip	1.5	6-14
2k Pip	2.5	8-16
1k Pip	5.0	11-19
500 Hz Pip	10.0	13-21

There is an option to show the waveform (response) or show a flat line over the blocking period. The default option should be “show response” and the “show flat line option should be used only if the size of the stimulus artefact causes the chart to expand unreasonably. This tends to occur only when testing by BC at high stimulus levels. The default option is set in: Setup, Default Display Parameters, Stimulus Blocking Appearance. Toolbar buttons are provided to temporally change the option when required. “Show flat line” should never be selected in CM tests.

Adding Waveforms

Select the waveforms to be added: select the first waveform by clicking on it on the control panel listing. Hold the Ctrl key down and do the same for the second waveform to be added. Repeat process if more than two traces are to be added.

This highlights the waveforms to be added in the control panel.

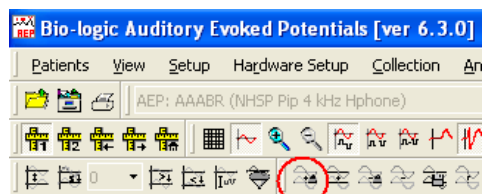
Select: Analysis (from toolbar at top of screen)

Calculations (from drop menu)

Weighted Add

The weighted added waveform appears on the waveform display.

Alternatively use the weighted add icon, thus:



Weighted add icon

Maximum stimulus levels: (Note: these are not the maximum recommended levels)

The following levels, in dBnHL, are typical for the Nav Pro when calibrated the levels advocated by NHSP. Users can use these as an approximate guide as a check for appropriate calibration. Individual systems are unlikely to have maximum stimulus levels that depart from these levels by more than 5dB. When making this check it is necessary to set the system to a stimulus step size of 1dB (not 5dB).

	Click	4k pip	2k pip	1k pip	500 pip
Supra-aural	99	107	107	114	109
Insert	100	109	109	112	109

BC	61	55	69	61	58
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Fsp >7 for the NavPro in both replicated waveforms using the BSA/NHSP recommended settings support the conclusion that the response probably exceeds the 3:1 condition component of the BSA/NHSP CR criteria. A CR decision still requires that the other interpretation criteria have been met. The principal use of Fmp and Fsp is in guiding the user when sufficient sweeps have been acquired.

Note that high Fsp values can sometimes be obtained in cases of low frequency drift (a sloping baseline) so the user must exercise judgement and require all BSA/NHSP criteria for CR to be satisfied.

Residual noise: Set to most strict (lowest value) if you do not want to auto-stop.

The BSA/NHSP 25nV “average gap” criterion is likely to correspond to an RMS noise value of $\leq 15\text{nV}$ in a single waveform or $\leq 21\text{nV}$ in both of a pair of waveforms.

Interacoustics Eclipse EP25 (software versions 4.4 and later)

If any users have not yet been updated from earlier versions, please mail the Interacoustics support team on servicehub@interacoustics.com

System Setup

Auto Test Protocols:

Type of Measurement: ABR-30

Stimulus Properties:

Stimulus Type:

Traditional Click or

Tone Bursts (same as "Tone Pips"):

Blackmann: 5 sines

(Alternative: *Manual*: Rise/fall = 2 sines and Plateau = 1 sine)

CE-Chirps may also be used if desired. These require special test settings.

Stimuli per sec (but for chirps see the table below):

20ms recording length: Click protocols: 49.1 /s;

Tone Burst protocols: 2kHz or 4kHz: 49.1 /s

24ms recording length: Tone Burst protocols: 500Hz or 1kHz: 39.1 /s

Polarity: Alternate

Stimulus Ear:

Binaural Stimulation: Off

Masking Difference: Off

Recording Properties:

Recording:

Begin: 0ms (but for CM tests use -1ms)

Display to: 20ms (24ms for 500Hz and 1kHz Tone Bursts).

If a large stimulus artifact is recorded (usually only an issue at the highest stimulus levels) then this might affect one's ability to vertically position waveforms. A new "Hide stimulus artifact" option is now available – hover over the waveform, right-click and select the Hide stimulus artifact option. This places a flat line at the start of the waveform. However, this won't help eliminate any artifact at the end of the waveform which sometimes occurs when chirp stimuli are used.

Next Intensity Conditions: Off

Single Curve: Off

Wave Reproducibility: Use the same range as for Fmp (see table).

Rejection Level (default amplifier gain setting): Manual: $\pm 40\mu\text{V}$ (AC) or $\pm 80\mu\text{V}$ (BC)

It is recommended that Bayesian Averaging is used, with $\pm 10\mu\text{V}$ rejection.

Use the Advanced option (pop-out box) to select $\pm 3\text{-}10\mu\text{V}$ if Bayesian averaging is not used or if there is heartbeat activity in the incoming EEG leading to an upward or downward sloping ABR waveform.

Filter settings for input amp: High Pass: 33Hz Low Pass: 1500Hz

Preliminary display settings: High Pass: None Low Pass: 1500Hz

Stop criteria boxes both unticked

Volt/div response curve: 75nV for tone pips and 100nV for all other stimuli

Soft attenuate /soft start (v4.4.3.21): the soft start should now be selected for this version of the software. It activates from 45 dBnHL and above for AC and from 35 dBnHL for BC.

General Setup:

Tick the following:

Multiple waveform markers on same intensity and side

Show all contra curves

Show response confidence & residual noise bars

Level measure method "Peak to trough"

Waveform order

Untick the following: Show all A+B curves, Baseline, Draw intensity handle at baseline, Show EEG too low warning

Printer Setup:

Print view: do not tick the "Keep screen aspect ratio on print out" box.

Systems with v4.4 and later should be delivered to UK customers with optimal print templates already set up for each NHSP test.

Report Setup:

Select a font size of 16

Printers:

The default printer is the IA XPS Document Writer (EPxx). This file will be overwritten each time a new printout is created.

To change the default printer go to:

<Desktop><Control Panel><Hardware and Sound><Devices and Printers>

Right click the mouse over printer of choice (PDF / MS XPS / paper printer) and from menu select <Set as default>

"All Sweeps Rejected" Warning message

There is an option in General Setup "Show rejection dialogue". Untick this box to avoid the warning appearing.

"All Sweeps Rejected" warning appears when the EEG activity exceeds the artefact reject level, even when the collection is paused. Note this may happen when the stimulus or the collection artefact reject levels are exceeded.

If the tester selects "OK" then all the sweeps collected will be lost and the collection needs to be started again.

If the tester selects "Cancel" the warning will keep appearing whilst the EEG is greater than the artefact reject level.

Advice is to ignore this warning box unless the stimulus artefact levels are being continuously exceeded. This would suggest that there is a problem with the electrodes or there is other electrical interference, for example when using the bone transducer at high stimulus levels.

Adding waveforms

When using the add facility to create two waveforms from four, add waveforms 1 & 3 and 2 & 4.

The two waveforms being added must be at the same stimulus level.

The following adds two waveforms (which are retained) into a new waveform (weighted add):

With one of the two waveforms selected, position the cursor over the dB label of the other waveform and right-click, then select the "add this curve" option. A third (new) combined waveform is displayed. If more than two waveforms need to be added, select the new combined curve and repeat the process with the next waveform to be added.

Using the Merge option is also a weighted add but combines two waveforms into a single waveform (originals are not seen but are available if the Merge function is undone). This is helpful as it avoids clutter by reducing the number of displayed waveforms and the number of lines on the parameter page of the printout.

Masking Noise:

- Noise is calibrated and presented in dBSPL

Fmp values and residual noise

The advice relating to Fmp depends on the software version being used.

For version 4.4, the criterion corresponding to a high likelihood of a response being present is 7.0 or more but high values of Fmp can be recorded when there is a sloping ABR baseline, even when no response is present. The user therefore must not rely on Fmp if there is a noticeable slope. Software version 4.6.1 and later overcomes this advantage, and a lower Fmp criterion, 2.2 or more, can be used to infer response presence, providing an ABR-like waveform is evident.

Residual noise values may be used as a guide of when to stop averaging if the outcome of the test appears to be a candidate for RA status. The recommended target value for the Interacoustics Eclipse (v4.4.2.x or later) corresponds to an RMS noise value of $\leq 15\text{nV}$ in a single waveform or $\leq 21\text{nV}$ in both of a pair of waveforms.

Objective calculation of signal-to-noise ratio (SNR).

The BSA 3:1 criterion for response presence relies on the subjective visual assessment of residual noise as the average gap between a pair of optimally superimposed waveforms. However, if the user places wave V and SN10 markers (edit tab), the SNR is displayed (termed “ratio”). Defer doing this with fewer than 1000 sweeps as the position of the peaks will be susceptible to noise and will need repositioning. Since the way in which the Eclipse measures residual noise is not “average gap”, the SNR criterion is not 3:1. For a single waveform, the SNR criterion to adopt is >5.5 . If two waveforms are used, each must have an SNR of >4.0 and should be superimposed as usual, to additionally allow the BSA 3:1 criterion to be assessed. The SNR can be monitored during averaging and providing an ABR-like response is evident, the user can stop averaging. A narrated presentation (“Objective ABR measurements”) on this is available via the Presentations page at <https://www.eratraining.co.uk/resources.html>

Maximum stimulus levels: (Note: these are not the maximum recommended levels)

The following levels, in dBnHL, are typical for the Eclipse when calibrated to the levels advocated by BSA/NHSP. Users can use these as an approximate guide as a check for appropriate calibration. Individual systems are unlikely to have maximum stimulus levels that depart from these levels by more than 5dB.

When making this check it is necessary to set the system to a stimulus step size of 1dB (not 5dB).

	Click pip	4k pip	2k pip	1k pip	500 pip
Supra-aural	110	115	115	120	120
Insert	110	110	115	115	115
BC (B81)	70	65	75	75	75

Test protocols and their settings (AC: 40dB HL for babies <12/52; BC: max level for no masking). Applicable for software versions 4.4 and 4.5. Note that the chirp section below relates to Level-specific NB-chirps (LS).

Note that for version 4.5 the default stimulus start level has been removed.

Test Protocol Name	Default Stim dBnHL	Time base (ms)	Rate (/s)	Blocking Period(s) (ms)	Wave Repro (ms)	Fmp range (ms)
1a NHSP ABR Supra-aural Click	45	20	49.1	0-1.5	5-15	5-15
1b NHSP ABR Supra-aural 4k Pip	50	20	49.1	0-1.5	5-15	5-15
1c NHSP ABR Supra-aural 2k Pip	50	20	49.1	0-2.5	7-17	7-17
1d NHSP ABR Supra-aural 1k Pip	55	24	39.1	0-5.0	10-20	10-20
1e NHSP ABR Supra-aural 500 Pip	60	24	39.1	0-10.0	10-20	10-20
2 NHSP CM Insert Click	80	10	88.1	-1 - 0		
2a NHSP ABR Insert Click	35	20	49.1	0-1.5	5-15	5-15
2b NHSP ABR Insert 4k Pip	40	20	49.1	0-1.5	5-15	5-15
2c NHSP ABR Insert 2k Pip	45	20	49.1	0-2.5	7-17	7-17
2d NHSP ABR Insert 1k Pip	50	24	39.1	0-5.0	10-20	10-20
2e NHSP ABR Insert 500 Pip	55	24	39.1	0-10.0	10-20	10-20
3a NHSP ABR BC Click	15	20	49.1	0-1.5	5-15	5-15
3b NHSP ABR BC 4k Pip	15	20	49.1	0-1.5	5-15	5-15
3c NHSP ABR BC 2k Pip	20	20	49.1	0-2.5	7-17	7-17
3d NHSP ABR BC 1k Pip	10	24	39.1	0-5.0	10-20	10-20
3e NHSP ABR BC 500 Pip	10	24	39.1	0-10.0	10-20	10-20
Chirp protocols: the following relate to NB Chirps LS						
1f NHSP ABR Supra-aural WB Chirp	40	20	45.1	0-2/ 18-20	5-15	5-15
1g NHSP ABR Supra-aural 4k Chirp	45	20	49.1	0-2/ 18-20	5-15	5-15
1h NHSP ABR Supra-aural 2k Chirp	45	20	49.1	0-2/ 18-20	5-15	5-15
1i NHSP ABR Supra-aural 1k Chirp	50	20	45.1	0-2/ 18-20	5-15	5-15
1j NHSP ABR Supra-aural 500 Chirp	55	20	43.1	0-4/ 18-20	5-15	5-15
2f NHSP ABR Insert WB Chirp	30	20	45.1	0-2/ 18-20	5-15	5-15
2g NHSP ABR Insert 4k Chirp	35	20	49.1	0-2/ 18-20	5-15	5-15
2h NHSP ABR Insert 2k Chirp	40	20	49.1	0-2/ 18-20	5-15	5-15
2i NHSP ABR Insert 1k Chirp	45	20	45.1	0-2/ 18-20	5-15	5-15
2j NHSP ABR Insert 500 Chirp	50	20	43.1	0-4/ 18-20	5-15	5-15
3f NHSP ABR BC WB Chirp	10	20	45.1	0-2/ 18-20	5-15	5-15
3g NHSP ABR BC 4k Chirp	10	20	49.1	0-2/ 18-20	5-15	5-15
3h NHSP ABR BC 2k Chirp	15	20	49.1	0-2/ 18-20	5-15	5-15
3i NHSP ABR BC 1k Chirp	5	20	45.1	0-2/ 18-20	5-15	5-15
3j NHSP ABR BC 500 Chirp	5	20	43.1	0-4/ 18-20	5-15	5-15

Test protocols and their settings (AC: 40dBeHL for babies <12/52; BC: max level for no masking). Applicable for software version 4.6 Note that the chirp section below relates to Level-specific NB-chirps (LS).

Note that for versions 4.5 and 4.6 the default stimulus start level has been removed.

Test Protocol Name	Time base (ms)	Rate (/s)	Blocking Period(s) (ms)	Wave Repro (ms)	Fmp range (ms)
1a NHSP ABR Supra-aural Click	20	49.1	0-1.5	5-15	5-15
1b NHSP ABR Supra-aural 4k Pip	20	49.1	0-1.5	5-15	5-15
1c NHSP ABR Supra-aural 2k Pip	20	49.1	0-2.5	7-17	7-17
1d NHSP ABR Supra-aural 1k Pip	24	39.1	0-5.0	10-20	10-20
1e NHSP ABR Supra-aural 500 Pip	24	39.1	0-10.0	10-20	10-20
2 NHSP CM Insert Click	10	88.1	-1 -0		
2a NHSP ABR Insert Click	20	49.1	0-1.5	5-15	5-15
2b NHSP ABR Insert 4k Pip	20	49.1	0-1.5	5-15	5-15
2c NHSP ABR Insert 2k Pip	20	49.1	0-2.5	7-17	7-17
2d NHSP ABR Insert 1k Pip	24	39.1	0-5.0	10-20	10-20
2e NHSP ABR Insert 500 Pip	24	39.1	0-10.0	10-20	10-20
3a NHSP ABR BC Click	20	49.1	0-1.5	5-15	5-15
3b NHSP ABR BC 4k Pip	20	49.1	0-1.5	5-15	5-15
3c NHSP ABR BC 2k Pip	20	49.1	0-2.5	7-17	7-17
3d NHSP ABR BC 1k Pip	24	39.1	0-5.0	10-20	10-20
3e NHSP ABR BC 500 Pip	24	39.1	0-10.0	10-20	10-20
Chirp protocols: the following relate to NB Chirps LS					
1f NHSP ABR Supra-aural WB Chirp	20	45.1	0-2/ 18-20	5-15	5-15
1g NHSP ABR Supra-aural 4k Chirp	20	49.1	0-2/ 18-20	5-15	5-15
1h NHSP ABR Supra-aural 2k Chirp	20	49.1	0-2/ 18-20	5-15	5-15
1i NHSP ABR Supra-aural 1k Chirp	20	45.1	0-2/ 18-20	5-15	5-15
1j NHSP ABR Supra-aural 500 Chirp	20	43.1	0-4/ 18-20	5-15	5-15
2f NHSP ABR Insert WB Chirp	20	45.1	0-2/ 18-20	5-15	5-15
2g NHSP ABR Insert 4k Chirp	20	49.1	0-2/ 18-20	5-15	5-15
2h NHSP ABR Insert 2k Chirp	20	49.1	0-2/ 18-20	5-15	5-15
2i NHSP ABR Insert 1k Chirp	20	45.1	0-2/ 18-20	5-15	5-15
2j NHSP ABR Insert 500 Chirp	20	43.1	0-4/ 18-20	5-15	5-15
3f NHSP ABR BC WB Chirp	20	45.1	0-2/ 18-20	5-15	5-15
3g NHSP ABR BC 4k Chirp	20	49.1	0-2/ 18-20	5-15	5-15
3h NHSP ABR BC 2k Chirp	20	49.1	0-2/ 18-20	5-15	5-15
3i NHSP ABR BC 1k Chirp	20	45.1	0-2/ 18-20	5-15	5-15
3j NHSP ABR BC 500 Chirp	20	43.1	0-4/ 18-20	5-15	5-15

From software version 4.6 there is an option to show the waveform including any stimulus artefact or to hide the stimulus artefact, which then shows a flat line during the “blocking” period. The default option should be to leave the “hide stimulus artefact” box unticked. This option (box ticked) should be used only if the size of the stimulus artefact causes an issue with the display and the ability to move the waveforms on the screen. This issue tends to occur only when testing by BC at high stimulus levels. The default option is set in: System setup, Auto protocols, Rejection Level, Advanced. To select this option without changing the protocol, right click whilst the cursor is over the waveforms. Alternatively there is a tick box on the EEG pop-out box. The “hide stimulus artefact” option should never be selected in CM tests (where we do want to see the stimulus artefact in order to distinguish it from any potential CM).

GSI Audera (original version)

This relates to software version 2.6.6 or later

Stimulus Type: 100µs click / Blackman pip / CE-Chirp (software version 2.7). All of the following relates to clicks or tone pips. When using chirps, use a 20ms timebase and the rates suggested for chirps in the Eclipse section. Stimulus Polarity: Alternating

Stimulus Level: 45dB earphones or 35dB inserts (suggested starting level: 40dBeHL)

Masking offset: See # below

nHL adjustment: 3.9dB (version 2.6.5) / 0dB (version 2.6.6)*

Repetition Rate: 49.08/s (for 20ms window) / 38.98/s (25ms window)

High Pass Filter: 30Hz @ -6dB 12dB/Octave

Low Pass Filter: 1.5kHz

Waveform start at: 0.0ms

Noise (artefact) Rej Armed after 1ms (clicks), 1.3ms (4k), 2.5ms (2k), 5ms (1k), 10ms (500)

Waveform ends at: 20ms (clicks, 2kHz & 4kHz pips) / 25ms (500Hz & 1kHz pips). If total rejections occur because of the stimulus artefact, delay the start the waveform by the duration of the stimulus. For chirps delay the start by 2ms and end at 18ms.

Sweeps: Set to at least 4000 (see below) and use a number of sweeps appropriate to the prevailing test conditions.

Noise (artefact) rej level: $\pm 10\mu\text{V}$ or $\pm 5\mu\text{V}$

Sensitivity: 50µV

The Audera is one of the few systems not to include the artefact rejection setting in the printout. Since this parameter is crucial and would be scrutinised by any subsequent review please ensure the value is hand-written or added as a comment on all printouts.

Note that the Audera test protocols do not include the specification of vertical display scale; however the use of a scale of 0.2uV/division (0.5uV/div for large waveforms) is appropriate.

Under certain circumstances it is possible to record a peak having a latency of about 3ms in the absence of a genuine physiological response. This is thought to be an instrument-generated artefact related to the proximity of the amplifier cable to the front of the Audera base unit. To avoid recording this artefact ensure that the amplifier cable does not pass close to the front of the base unit.

The wave V (or wave III) – SN10 amplitude of a response can be displayed on the printout as follows:

Go into the review screen, click on options and "edit marker sets." Add an additional marker to the set to indicate the amplitude measurement (you may need to delete unwanted ones such as wave II) and then go to the Measurements tab. On the measurements tab, you can add an additional measurement and indicate the formula (peak-to-peak amplitude) or edit one of the existing ones. Tick "Measurement appears on printed reports". Then, when interpreting, mark the two points that have been entered into the marker measurements and the value will automatically be calculated and shown in the printout.

The Audera noise output is calibrated such that for noise delivered via an earphone 0dB noise is actually 10dBSPL; for noise delivered via an insert 0dB noise is actually -5dBSPL

* Select 0dB nHL adjustment and in the setup opt for the stimulus not to be compensated for repetition rate as follows:

For software version 2.6.6 and later ensure the "Constant SPL audio stimulus" option is selected (from main screen select Options, AEP Options, Miscellaneous) then in each test protocol (Test Set Definition) set the nHL adjustment to 0.0dB. This ensures correct stimulus calibration regardless of the stimulus rate being used.

Creating a weighted add on the Audera:

The Audera refers to this as **average** (its add function is an unweighted addition). On the Hierarchical Tree, locate the two waveforms to be combined mathematically. Drag the first waveform on to the second waveform and release the mouse button. This invokes the maths window. Select average.

The result of the function is displayed as a third waveform. Select OK if satisfactory. The maths window closes and the result is placed in a new chart on the main window. Unfortunately if an attempt is made to combine another waveform with the result of the previously averaged waveform the following message is seen: "One of the waveforms is the result of an existing "combine series" operation – it cannot be combined again." **This means that averaging (weighted addition) of more than two waveforms is not allowed. For this reason it is advisable to set the test protocols to at least 4000 sweeps for all protocols, for use in noisy test conditions.**

GSI Audera Pro (Software version 1.11.00)

Stimulus Type:	100µs click / 5-cycle Blackman pip. Alternating polarity. Calibration mode: HL
Masking:	Specify Tracking
Repetition Rate:	47.2/s (4kHz & 2kHz) or 37.9/s (1k & 500Hz)
Window:	25.6ms but see page settings below
Page settings:	Plot start time: 0; Plot end time: 20ms (4k & 2k) or 25.6ms (1k & 500) Scale / Other / 0.3uV Plot time Right = Left
Amplifier (both channels):	
Gain:	200K
High Pass:	30Hz
Low Pass:	1500Hz
Rejection:	±10µV (reduce if possible, ideally to 5 µV in individual babies)
Rejection region:	1.6 – 19.5ms (4k) 2.5 – 19.5ms (2k) 5.1 – 24.3ms (1k) 10.3 – 24.3ms (500)
Display:	Deselect “Automatically Adjust Size” Select “display baseline”
Sweeps:	4096 (as default; more or less may be appropriate)

The Audera Pro reports residual noise and SNR

A study by ERA Training & Consultancy (2021) commissioned by Guymark suggests that on the Audera Pro, the NHSP “average gap” noise criterion for response absence is:

- 60nV (single waveform) or
- 85nV (in each of two waveforms)

The SNR criteria for response presence in a single supra-threshold waveform are:

- 95%: SNR ≥ 1.02 (associated with 5% false positives)
- 97%: SNR ≥ 1.21 (associated with 3% false positives) **recommended**
- 99%: SNR ≥ 1.37 (associated with 1% false positives)

At threshold, responses must be replicated. The above SNR values can be reduced when replication is performed, providing the responses in both waveforms have similar characteristics. thus:

- 95%: SNR ≥ 0.72 (associated with 5% false positives)
- 97%: SNR ≥ 0.855 (associated with 3% false positives) **recommended**
- 99%: SNR ≥ 0.97 (associated with 1% false positives)

The above are in addition to the other BSA recommended criteria for response absence and presence.

GN Otometrics Chartr EP200

Channels

One channel switched on, one off.

Amplifier gain: 200k,

Artifact rejection is controlled via the Test toolbar / Artifact level.

A reject level of $\pm 5\mu\text{V}$ is achieved with Artifact Level set to 40% whereas a reject level of $\pm 10\mu\text{V}$ is achieved with Artifact Level set to 80%.

A spreadsheet which offers these and other values is available from GN support staff.

Filters: High Pass: 30Hz Low Pass: 1.5kHz

Notch: off

Artifact on

Electrode switching on

Acquisition

Sweep time 20ms (25ms for 500Hz & 1kHz tone pips)

Delay: 0

Rate: 47.1/s (37.1/s for 500Hz & 1kHz tone pips)

Stimulus

Intensity: 45 (or appropriate level to start at 40dB HL)

Transducer: as appropriate

Polarity: Alternating

Tone Frequency: as appropriate

Envelope: Blackman (preferred) or Linear

Ramp (cycles): 2

Plateau (cycles): 1

Noise calibration: The noise output is calibrated such that 0dB noise is 0 dB SPL (measured on a 6cc coupler for Supra-aural phones and 2cc HA-2 coupler for inserts).

Vivosonic Integrity V500

The following relates to software version 8.8.1 or later (previous versions are updatable to this, contact manufacturer):

Stimulus settings:

Stimulus rate: 48.7/s (4kHz & 2kHz) or 38.3/s (1kHz & 500Hz)

Maximum number of stim: over 20,000 (terminate each run manually when CR or RA are evident)

Windowing: Blackman; ramp number of cycles 2.5-0-2.5

Test settings:

High Pass filter: 30Hz; 6dB/octave

Low Pass filter: 1500Hz; 12dB/octave

Artifact rejection: unticked (use SOAP/Kalman)

Display zoom: 19.3ms (4kHz & 2kHz) or 25ms (1Hz & 500Hz)

Polarity: alternating

Test screen:

Y-Axis: 0.1 μ V (there is a system screen setting to make this a default value)

Algorithm: SOAP/Kalman Weighted Averaging

Notch filter: off

Residual noise:

The BSA/NHSP 25nV "average gap" criterion for response absence for the Integrity is ≤ 20 nV in a single waveform or ≤ 28 nV in both of a pair of waveforms.

Noise calibration: Make sure settings are in dB SPL (select in system screen), then use masking noise calculator.

Neuro-Audio (Windows software version 1.0.104.2)

Previous software versions are not recommended

The parameters are set in the test template menu by selecting the correct tab

Parameters

Stimulus rate:	49/s (for click and tone pips of 2 and 4kHz) 39/s (for tone pips of 500 and 1kHz)
Analysis time window:	
For Clicks & tone pips at 2kHz & 4kHz:	20ms
For Tone pips at 500Hz & 1kHz:	25ms
Rejection level	$\pm 10 \mu\text{V}$ (or $\pm 5\text{-}10 \mu\text{V}$ without Bayesian averaging)
Reject disabled period after stimulus:	0
Pre stimulus time:	0
Blocking:	See table below
Optimize Recording:	Weighted averaging – Bayesian

Hardware

Signal input range:	500 μV
Low Frequency (HPF)	30Hz
High Frequency (LPF)	1500Hz
Notch Filter	Off
High Harmonic Filter	Off
Sampling rate:	40000Hz
Intensity (initial level for 4kHz pips but refer to BSA/NHSP guidelines; aim is to start at discharge level +10dB):	
Headphone:	40dBnHL
Insert earphone:	30dBnHL
Change Step (dB)	5dB
Polarity:	Alternating
Stimulator - Stimulus:	Headphone / Insert / Bone conductor
Stimulator – Masking:	Headphone / Insert / Bone conductor
Masking:	0dB = 0dB SPL, use stimulus relative then use offset value from calculator
Masking noise only during stimulation	Check
Stimulus waveform:	Either tone burst or click
Envelope:	Blackman Window
Stimulus type:	Click; Duration 100 μs . Tone burst (tone pip) Rise/fall time: 2 cycles Plateau: 1 cycle

Channels

Channel 1	Ticked, Cz – M selected
Channel 2 recording is available if wanted	

A study by ERA Training & Consultancy (2021) commissioned by Natus UK suggests that on the Neuro-Audio, the NHSP “average gap” noise criterion for response absence is:

- 17nV (single waveform) or
- 24nV (in each of two waveforms)

The Fsp criterion corresponding to 97% specificity is 2.5.

Fsp range & blocking duration (clicks & tone pips):

Stimulus	Blocking (ms)	Fsp range (ms)
Click	1.5	5-15
4k Pip	1.5	5-15
2k Pip	2.5	7-17
1k Pip	5.0	10-20
500 Hz Pip	10.0	10-20

Maximum stimulus levels: (Note: these are not the maximum recommended levels)

The following levels, in dBnHL, are typical for the Neurosoft when calibrated the levels advocated by BSA/NHSP. Users can use these as an approximate guide as a check for appropriate calibration. Individual systems are unlikely to have maximum stimulus levels that depart from these levels by more than 5dB. When making this check it is necessary to set the system to a stimulus step size of 1dB (not 5dB).

	Click	4k pip	2k pip	1k pip	500 pip
Supra-aural	105	115	116	120	124
Insert	108	109	109	112	109
BC	61	62	75	66	62

ABR Practical advice and interference reduction (all systems)

This is a collection of technical hints & tips for clinical ABR testing – almost certainly incomplete!
Thanks to Gary Norman for his suggestions upon which this section is based.

GOOD HOUSEKEEPING

Request a quiet room preferably away from roads, rooms containing power supplies / fuse boards. Always log the room number/location on the ABR form unless the tests are always conducted in the same room. Make a note of any adverse conditions observed in the session.

*All fluorescent / energy saving lighting should be switched off. Use incandescent tungsten lighting.

*Do not use light dimming switches (a notorious source of interference).

*Turn off all mobile phones in the room (check with parent / carer).

*TVs in the vicinity should be turned off (not just on standby).

*Remove battery-powered wrist watches and place far away from the equipment & patient (especially important for the person holding the earphone or BC).

If a bed is used, move it away from any wall with mains sockets / trunking.

Position child with head towards centre of the room, not the wall, especially if there is a power trunking at the head of the bed.

Position equipment at end of bed (patient's head end), but as far from the patient as possible.

For babies in child seats or being held by mother position at least 1m from equipment and mains cables.

Do not position equipment near sockets or screened mains trunking.

*Unplug any power adaptors of non-essential equipment.

*Unplug any non-essential networked computers in the room remembering to remove the network cable from the data socket located on the wall or trunking.

For babies be prepared to suggest alternative positions, e.g. for the baby to be placed in a cot or pram, rather than being held by a parent.

* These items apply only if non-patient interference is present.

EQUIPMENT SET UP

Use a medical grade power isolation transformer; all interconnected equipment (even switched off) should be connected to this.

Equipment needs to be set up in a methodical fashion. In particular, ensure the transducers being used tally with the type (insert –v- phone –v- BC) assumed in the ABR software.

Stage A calibration check should be performed on site immediately prior to use.

Carryout a further listening check if no responses are seen or unusual waveforms are recorded.

Odd-looking responses can be recorded if the electrode leads are incorrectly connected (response may be inverted) and a flat-line is likely if we inadvertently record across the mastoids. Some equipment has automatic electrode switching options. If selected, check that the appropriate electrode set-up has been used.

If interference occurs try running any laptop on battery, disconnected from its power supply with the power supply unplugged (check battery charge is adequate to complete the test).

* Do not have a printer plugged in or switched on during testing.

* Do not have a tympanometer plugged in or switched on during testing.

Do not cross over any leads/cabling, especially electrode / transducer / power supply leads.

Run electrode cable from one direction to the patient and earphone cable from the other direction to the patient –DO NOT LET THEM CROSS.

* Use blankets/pillows to support cables across any point they may touch bed or pram frames. The bed / pram framing may act as an aerial.

An in-line RF filter between electrode box and electrodes sometimes eliminates RF interference.

Run electrode leads close together. If artefact is a problem plait longer electrode leads or use short electrode leads, gathered or twisted together.

DURING TESTING/ASSESSMENT

A larger ABR response is obtained with the positive electrode as high as the fontanelle allows and the negative electrode just behind the ear and level with or slightly lower than the meatus (allowing BC placement above).

It is a common mistake to place the active electrode too low and the mastoid electrode too high.

Change electrode leads to new set or different type if any interference persists.

Ensure the equipment is switched from impedance mode to collection mode, when applicable.

Keep electrodes plus their leads away from bone conductor and its leads. Use practical positioning that will not diminish response (particularly important for recording CM). When testing by BC the vibrator should be above the level of the mastoid electrode. If there is no response, when expected, it is worth checking the vibrator placement.

Increase artefact rejection from default value to 7.0 or 10.0uV as required but recognise that many more sweeps will be needed to average out the noise that this allows in to the recording. Doubling the noise requires a four-fold number of sweeps to preserve the noise content of the average.

Record changes made on the waveforms and reasons why.

Exercise care to avoid occlusion of the ear canal associated with pressure (especially transverse) when using supra-aural phones. Likewise debris can occlude a canal when an insert is placed. Bone vibrator pressure and placement should be consistent if variation in stimulus level during testing is to be avoided.

IDENTIFYING & ELIMINATING ELECTRICAL INTERFERENCE

Know your enemy! Try to deduce the source of the interference from its appearance in the incoming "EEG" display (or acquire a 1-sweep average; unfortunately many ABR systems do not allow this) with filters wide open (e.g. 1Hz to 3kHz) and amplifier gain / artefact rejection adjusted so as to accept large signals.

Measure / estimate the period of any waveform and calculate its frequency ($f=1/t$)

Myogenic activity from the patient will fluctuate.

Endeavour to link the frequency of interference to its likely origin. Mains will have a period of 20ms.

If interference is clearly 50Hz (mains) and all efforts have failed (including obtaining approximately equal & low electrode impedances) to reduce it to a workable level then the use of a mains notch filter may allow testing to continue. However be aware that notch filters can distort the ABR waveform for 500Hz stimuli and their use for low frequency stimuli is not recommended. Their use should be noted in the clinical report.

Check the room for patches of electrical interference using an analogue (non-DAB), battery-powered radio on "AM" e.g. medium wave. Try to avoid testing at these places. This technique sometimes allows the source of the interference to be identified. A 'dummy' patient box comprising a resistor network to simulate typical electrode contacts is also useful to track down sources of interference and is preferable to shorting the electrode contacts together.

TESTS IN THEATRE

Operating theatres are usually acoustically noisy. Insert earphones help attenuate ambient noise and are safer in post-myringotomy cases where blood could make an electrical connection between the patient and the transducer but the transducer should be held (with a drip stand) at a higher level than the tip to avoid blood entering the transducer under gravity.

Theatres are also notoriously electrically noisy – the use of diathermy in adjacent theatres can be problematic but they tend to be used intermittently.

Autoclaves and microwave ovens also radiate interference, as do hospital pager systems, mobile phones (actually turn them off), lifts, escalators, air conditioning systems etc.

Pulse oximeters are sometimes a source of electrical interference. Try turning it off to see if this eliminates the interference (if so, then negotiate with the anaesthetist to do without if possible).

If an oximeter is used, position as far away from patient and equipment as possible (at patient's feet end). Run Oximeter on battery if this eliminates interference and is available.

If plugged into mains power, use sockets away from those used for ABR equipment.
Log Oximeter serial number and type if problems occur and try to avoid in the future.
Try to negotiate carrying out the testing at theatre quiet times.

HEALTH & SAFETY

Request assistance to transport heavy equipment.
Secure leads and wires before transit to prevent trailing or falling from trolley.
Refer to BSA or NHSP advice on sterilisation of equipment, electrode leads, transducers etc.
Always use single-use electrodes and take necessary precautions to avoid cross-infection via electrode prep paste or electrode gel container.

Interim Safety Advice to Audiologists on Performing Hearing Tests and Fitting Hearing Aids to Patients with a Programmable Ventriculo-peritoneal Shunt (PVP Shunt). All patients, parents or carers must be asked if the patient has a shunt. Read the BSA 2021 PVP shunt position statement available on the Resources page of the BSA web site.