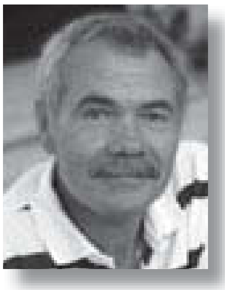
Masking the ABR



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This article is based on notes developed for the 'Harrogate' series of courses and to support staff performing post-newborn hearing screening programme (NHSP) auditory brainstem response (ABR) tests.

The subject of masking appears very simple in concept yet when applied to the ABR is actually rather complex, a situation made worse because some information (e.g. the extent of a conductive loss) is often unknown. Most Audiologists feel that they ought to be familiar with a subject as apparently basic as masking but in fact this subject is not well fact understood and as a consequence masking is often avoided or performed in a 'seat of the pants' manner. These notes are intended to provide the reader with a reasoned explanation of the relevant issues and considerations, starting with the simpler adult case and gradually adding layers of complexity associated with masking in newborns.

These notes assume that the reader is familiar with the theory and process of masking in conventional audiometry.

An Excel spreadsheet is available to perform the calculations, making the practical application of accurate ABR masking as simple as possible.

The need for masking

As in conventional pure tone audiometry, we need to ensure that the ear under test is the one responsible for evoking the patient's response. A reminder of the theory of cross hearing is therefore appropriate. Cross hearing arises when the cochlea of the contralateral ear receives the stimulus at a sensation level (level above the threshold of that ear) greater that that of the test ear and so dominates the response (behavioural or electrophysiological). In other words the response comes from the unintended ear. Two things influence the occurrence of cross hearing for a given stimulus: the relative hearing thresholds of the two ears and the extent to which the stimulus is attenuated as it passes from one ear to the other. We refer to the latter as inter-aural attenuation (IA) or transcranial transmission loss (TTL). Since it is the contralateral cochlea that picks up any cross-heard sounds it is the threshold of the contralateral cochlea (its bone conduction threshold) and the attenuation of sounds to the contralateral cochlea that are important.

IA depends to a large extent on the transducer being used – for bone conduction (BC) it is usually a small value whereas for insert earphones it can be quite high, making cross hearing and the need for masking a rarity. There is a range of values of IA for each transducer but when assessing the need for masking we must assume the worst case situation and therefore we take the minimum value of IA for that transducer. IA also varies to some extent on stimulus frequency. Table 1 provides the minimum IA for supra-aural earphones (e.g. TDH series), inserts (e.g. ER-3A) and BC derived from a number of studies. Although typical values of IA will be greater, these are the values we must assume when calculating whether masking is needed and when calculating the level of noise to use.

Table 1

Stimulus	Supra-aural earphones	Insert earphones	BC
Click	48 dB	55 dB	0 dB
4k pip	52 dB	64 dB	0 dB
2k pip	45 dB	54 dB	0 dB
1k pip	47 dB	56 dB	0 dB
500 pip	45 dB	50 dB	0 dB

There are additional issues to be considered when testing newborns but we will deal with those later – for simplicity we will consider adults for the time being. So, from table 1 if we present a 2kHz stimulus to the test ear at 60 dBnHL using TDH earphones then the non-test cochlea may receive a stimulus of up to 15 (60-45) dBnHL.

However an ABR is not recorded right down to the patient's behavioural threshold and we should express the stimulus in dBeHL since that represents the effective stimulus in terms of its ability to evoke an ABR. From NHSP guidelines[1] we know that the nHL to eHL correction at 2 kHz is 10dB so in the above example the non-test ear receives a stimulus of 5 (ie 15-10) dBeHL. If that is above the patient's non-test ear BC threshold (also in dBeHL) for that stimulus then we need to mask the non-test ear to ensure that any response we record is from the intended ear. If we don't know the non-test ear BC threshold we must assume it is zero.

So in this example masking is needed unless we know that the non-test BC threshold is greater than 5dBeHL.

Let's summarise that.

If the following expression is true then masking is needed:

(Stim dBnHL) – (nHL-eHL) – (IAs) > (BCnt)

[Equation 1]

where:

- ***Stim dBnHL*** is the stimulus level in dBnHL.
- ***nHL-eHL*** is the correction to apply at that frequency to convert electrophysiological to behavioural thresholds.
- ***IAs*** is the minimum inter-aural attenuation for the stimulus transducer and frequency.
- ***BCnt*** is the non-test BC threshold in dBeHL for that frequency, if known (default 0).

In our chosen example the values are:

60 – 10 – 45 > 0 ie ***5 > 0***

which is true, so masking is required.

What level of noise is needed?

Having decided that there is a risk of cross hearing then we need to calculate the sound pressure level (SPL) of noise required to effectively mask the non-test ear. In its simplest form this is dependent on three things: the stimulus level, the minimum IA and a quantity that tells us the level of noise needed to effectively mask the stimulus in the ear receiving that stimulus – the relative masking level (RML), thus:

dBnSPL = (Stim dBnHL) – (IAs) + (RML)

[Equation 2]

Lightfoot, Cairns & Stevens (2010) reported upper and lower values for RML in adults as:

Table 2

Stimulus	RML upper	RML lower
Click	33 dB	18 dB
4k pip	28 dB	13 dB
2k pip	33 dB	13 dB
1k pip	28 dB	13 dB
500 pip	33 dB	18 dB

where noise is calibrated in dB SPL and the stimulus is calibrated in dBnHL (ISO 389-6).

Like IA, there is a range in RML but if we are to be confident that masking of any cross-heard stimulus is achieved in *all* patients it is the upper RML values we must use when calculating the level of noise to use.

Using the previous example equation 2 gives:

60 – 45 + 33 = 48 (dB SPL)

Most systems work in 5dB steps so in practice you'd select 50dB. When applying this calculation in clinical practice you might be forgiven for assuming that the noise output is calibrated in dB SPL. Surprisingly there is no international (ISO) standard for wide-band (white or unfiltered) noise and ABR equipment manufacturers vary in the way in which they set up the noise in their systems. A manufacturer-specific correction therefore needs to be made to account for this unless the system has been adjusted to give noise in dB SPL.

At this point we need to introduce a new but unwelcome complication: an air-bone gap in the non-test ear (ABGnt). If the ear into which we are introducing the noise has a conductive loss (or a conductive element in a mixed loss) then this will attenuate the level of noise reaching the non-test cochlea, reducing its effect. We must increase the noise level by an amount equal to the ABGnt in order to ensure adequacy of masking. A practical problem is that in most cases in which we perform threshold ABR testing ABGnt is unknown so an educated guess is the best we can do, based on all available clinical information. The theory is straightforward however and equation 2 becomes:

dBnSPL =

(Stim dBnHL) – (IAs) + (RML) + (ABGnt)

[Equation 3]

The risk of cross masking

As in conventional pure tone audiometry, there are some audiometric configurations that create a 'masking dilemma' in which the level of noise used for masking the non-test ear is sufficiently high to also mask the test ear cochlea, thus obscuring the test ear ABR and thus exaggerating the extent of the hearing loss. The classic example is a patient with a considerable bilateral conductive hearing loss.

Let's again use the previous example, this time adding a 40dB air bone gap in the non-test ear.

Using equation 3:

dBnSPL = 60 – 45 + 33 + 40 = 88 dB SPL.

In practice we'd use a noise level of 90 dB SPL.

We need to be able to calculate whether this level of noise is going to effectively mask not only the non-test cochlea (as intended) but also the test cochlea, causing cross masking.

To assess the risk of cross masking we need to calculate the level of noise reaching the *test* ear cochlea and then determine whether this level is capable of masking the test ear ABR. The level of noise reaching the test ear cochlea is simply the level of the noise (88 dB SPL) minus the minimum IA for the noise transducer (45dB): 43 dB SPL in this case. It that enough to cause cross masking? Table 2 gives the RML levels but this time the worst case scenario is the *minimum* RML value: 13dB. However there is evidence to suggest that noise levels up to 20dB below the RLM can delay or reduce the amplitude of the ABR (Burkard & Hecox, 1983) so we ought to take that into account too. The following expression must result in a value that is less than the stimulus reaching the test ear cochlea if cross-masking is to be discounted:

(dBnSPL) – (IAn) – (RMLmin) +20

[Equation 4]

where:

- ***IAn*** is the IA of the noise delivery transducer.
- ***RMLmin*** is the minimum relative masking level for that stimulus.

Using our example we have:

88 – 45 – 13 + 20 = 50

Since this is less than the stimulus level of 60dBnHL there is no risk of cross masking.

However if the conductive loss is bilateral and *both* ears have a 40dB ABG the stimulus reaching the test ear cochlea is not 60dBnHL but is only 20dBnHL: much less than the result of equation 4, and in this situation cross masking is highly likely.

Cross masking is likely not only in air conduction tests in a patient with a bilateral conductive loss but also in bone conduction tests, where IA is far less than for earphones. Even very modest values of ABGnt can result in the cross masking of BC tests. Why not create your own example and apply it to the equations?

Masking the ABR in newborns – more considerations and uncertainties

Unfortunately, masking in newborns brings several additional considerations and we have only incomplete data with which we can account for them.

Firstly, the three main cranial plates of the newborn skull are not fused and when we test by bone conduction the transducer imparts vibration to the plate upon which it rests. Because this plate is lighter than the entire fused adult cranium the transducer imparts greater vibration than intended, giving a ‘lift’ to the stimulus level. We do have some data on which to account for this (Webb, 1993) but this is for only clicks – we do not have tone pip data and there is tentative evidence that at 500Hz the effect may be quite large. We do not know how these values change with age.

Secondly, there is a similar lift in the stimulus level when inserts are used, caused by the far smaller occluded volume of the newborn canal compared to that of adults from whom the calibration reference levels were derived. A provisional correction value of 10dB is advised by NHSP for clicks & 4 kHz pips (5dB at lower frequencies) for corrected ages up to 3 months but more accurate data are needed.

Thirdly, incomplete cranial fusion awards us with a very welcome advantage in the form of an increase in IA, reducing the requirement for masking and reducing the risk of cross masking. A provisional and unfortunately crude 20dB is assumed for all stimuli up to the age of 3 months after which it falls to zero. In reality the value is likely to be frequency specific and decline progressively with age in the first year or two. Again, more accurate data are needed.

The earlier equations should to be modified to account for these considerations – the stimulus level and IA value must include corrections appropriate to the stimulus and corrected age of the baby. We will add these factors to the earlier equations thus:

- ***(stim correction)*** is the age-related correction associated with the use of bone conduction or insert transducers in babies and
- ***(IAa)*** is the age-related additional inter-aural attenuation associated with incomplete cranial plate fusion.

A further example may clarify: bone conduction click testing in a 4 week corrected age baby. The stimulus level is 45dBnHL and the non-test ear is apparently normal.

The need for masking is assessed by a modified equation 1:

(Stim dBnHL) + (stim correction) – (nHL-eHL) – (IAs) – (IAa) > (BCnt) [Equation 5] which in this example gives ***45 + 6 – 5 – 0 – 20 > 0*** ie ***26 > 0*** which is true, so masking is needed.

The level of noise needed for this stimulus is given by a modified equation 3:

dBnSPL = (Stim dBnHL) + (stim correction) – (IAs) – (IAa) + (RML) + (ABGnt)

[Equation 6]

which in this example gives ***dBnSPL = 45 + 6 – 0 – 20 + 33 + 0 = 64*** (dB SPL)

In order to deliver this level of noise to the non-test ear any noise calibration offset applicable to the ABR system needs to be accounted for (for example in the Biologic Nav Pro we deduct 20dB since a request for 0 dB SPL of noise with this system results in a noise level of 20 dB SPL). Also, if an insert is used to deliver the noise a correction must be made for the calibration error inherent in inserts when used with babies – a crude correction can be made by lowering the noise level by 10dB.

Is cross masking an issue in this case? We need to apply equation 4, including the 20dB value for ***(IAa)***:

(dBnSPL) – (IAn) – (IAa) – (RMLmin) +20

[Equation 7]

If supra-aural earphones are used to deliver the noise ***(IAn)*** for clicks is 48dB so we have:

64 – 48 – 20– 18 + 20 = -2

Since this is much less than the corrected stimulus level of 51dB there is no risk of cross masking.

Final remarks

The above formulae assume worst case values for IA and RML; thus the calculated level of noise is rather more than that needed for the 'average' patient. Likewise the risk of cross masking is slightly bleaker than for the average patient. If presenting noise at the calculated level is problematic (for example causes the baby to stir) it would be acceptable to reduce the level by 5 dB but reductions of 10 dB or more could result in ineffective masking in some cases.

When we are in a busy clinic it is not practicable to make the necessary calculations for the need to mask, the noise level required and the risk of cross masking. This was the impetus for developing a noise calculator spreadsheet[2]. Note however that we still lack important data for newborn corrections and we await studies giving these. In the mean time we should apply the suggested noise levels with caution.

References

Burkard R, Hecox K. (1983). The effect of broadband noise on the human brainstem auditory evoked response. I Rate and intensity effects. J Acoust Soc Am.;74(4):1204-13.

Lightfoot G, Cairns A, Stevens J. (2010). Noise levels required to mask stimuli used in auditory brainstem response testing. Int J Audiol. In press.

Webb HD. (1993). Auditory screening in high risk neonates: An evaluation of the bone conduction ABR. M Med Sci thesis University of Sheffield, UK.

Footnotes

1 Guidelines for the early audiological assessment and management of babies referred from the newborn hearing screening programme. 2007.

2 This spreadsheet will be made available via the NHSP web site: http://hearing.screening.nhs.uk/