Masking (1)
INTRODUCTION

- When the vision being tested, one eye is covered to be certain that the uncovered eye is the one tested and this cover is called masking

- Masking principle is also applied in hearing tests. But, covering the untested ear is not enough to eliminate its participation
As a result, noise needs to be introduced to non-tested ear to raise its threshold and eliminates its response to the signal presented to the tested ear.

Clinical masking allows accurate assessment for each ear separately by withdrawing the non-tested ear (NTE) while testing the other ear (tested ear/TE).
Why do we need to mask?

- In AC testing

  - By headphones and inserts - if the presented stimulus sufficiently loud, it escapes through the headphones, passes across the head and stimulate the other ear
In BC testing-

- The presented stimulus passes equally to both cochleae via the 3 routes; Osseotympanic stimulation, inertial stimulation and distortional or compressional stimulation.
Why do we need to mask?

- If we are going to assess the auditory function of each ear, we must be sure that the contra-lateral (opposite) ear is not participating in responding.

- So, we need to prevent the cross hearing.
CROSOVER AND CROSS HEARING

Crossover:

- The passage of sound from the TE to the NTE without stimulating it, sound transmitted physically only

- **TE**: The Ear Being Tested, Receive the tone.
- **NTE**: The Ear that not being tested, receive the noise in masking.
Cross hearing:

- When there is a significant difference between both ears’ hearing acuity level (greater than IA), the better ear (non-tested ear) may respond when the stimulus presented to the poorer ear (tested ear), the transmitted sound become audible in the contra-lateral side (NTE)
The thresholds of poorer ear is a shadow of the better ear

It’s also known as shadow hearing or transcranial hearing

So, the shadow curve will be resulted
IN SUMMARY,

- Crossover is not a synonym of cross hearing
- Cross hearing occurs only if the sound that arrived to the NTE cochlea by crossover from the TE is heard by the NTE cochlea
The difference between cross over and cross hearing?

<table>
<thead>
<tr>
<th>CROSS OVER</th>
<th>CROSS HEARING</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Transmission of the sound from TE to NTE (physically only))</td>
<td>(Transmission of the sound from TE to NTE become (Audible))</td>
</tr>
</tbody>
</table>

- So, if both ears have the same threshold, no cross hearing.
Cross Hearing / Shadow Curve?

- Cross Hearing:

  Happened when the tone presented to the (TE) transmitted across the head and heard in the (NTE) and it responds instead of the TE, so the resulted audiogram is known as (Shadow Curve).
**Shadow Curve / Shadow Audiogram**

- An audiogram reflecting cross-hearing before masking application

- Shadow curves usually seen when thresholds of the ear with greater hearing loss (e.g. severe or profound) are a reflection (mimic) of thresholds of the ear with normal or near normal hearing levels.
ILLUSTRATION EXAMPLE:

Normal       Profound HL.
1- Expected Audiogram
2- Shadow curve (resulted audiogram/unmasked audiogram)
3 - Masked Audiogram (Audiogram after applying masking)
The AC signals may reach the opposite ear by sound conduction route via:

1. Sound escaping through the headphone cushion on the test side (TE), traveling around the head and penetrating the other side (NTE) headphone cushion
2. Earphones vibration on the test side might be transmitted via the headset to the earphone on the non tested side

3. More commonly known actual crossover route for AC signals occurs principally by BC route to the cochlea of non NTE
INTER-AURAL ATTENUATION (IA):

- The amount of energy lost during the transmission of sound (by AC or BC) to the contra-lateral ear

- **Example:** when a 95 dB HL presented to the TE and 45 dB HL reaches the NTE, the amount of lost energy = 95-45= 50 dB
  - IA = 50 dB
IA is also known as **transcranial transmission loss**

It’s is preferable to have a high IA value to reduce the possibility of cross-hearing

IA values are varied for AC and BC stimuli
IA for Air Conduction

3 factors cause the variability:

1. **Subject variability**-
   - Area of head exposed,
   - skull properties
   - and test- retest variability
2. Frequency spectrum of test signal-

- IA ranges from 45 to 70 dB from 250 to 8000 Hz for supra-aural (Average about 60 dB). And 70 to 100 dB for inserts (average 80 dB).

- But 40 dB is commonly use by (BSA, 2011) and ASHA (1978) for supra aural headphones and 70 dB for inserts
3. **Transducer type:** (supra-aural headphones Vs inserts),

- The IA difference in accordance with transducers’ types is happened as a result of that the IA is inversely related to the contact area between the earphone and the head and this area is much less for the insert receivers than that for supra-aural earphones.
IA for Pure Tones Using Supra-aural and Insert Earphones

<table>
<thead>
<tr>
<th>Frequency in Hz</th>
<th>A—Supra-aural Earphones</th>
<th>B—Supra-aural Earphones</th>
<th>C—Insert Earphones</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>61</td>
<td>45</td>
<td>89+</td>
</tr>
<tr>
<td>500</td>
<td>63</td>
<td>50</td>
<td>94+</td>
</tr>
<tr>
<td>1000</td>
<td>63</td>
<td>55</td>
<td>81</td>
</tr>
<tr>
<td>2000</td>
<td>63</td>
<td>60</td>
<td>71</td>
</tr>
<tr>
<td>4000</td>
<td>68</td>
<td>65</td>
<td>77</td>
</tr>
</tbody>
</table>
IA FOR BONE CONDUCTION TESTING

- It’s significantly less than the AC IA: both cochleae enclosed in each temporal bone of the same skull

- When skull starts to vibrate, both cochleae are stimulated
ILLUSTRATION FIGURE FOR SKULL BONES

- frontal bone
- nasal bone
- parietal bone
- supraorbital process
- temporal bone
- lacrimal bone
- zygomatic bone
- nasal concha
- pterygoid process
- mandible
- mental tuberosity
- mental protuberance
- coronal suture
- forehead boss
- glabella
- supraorbital foramen
- sphenoid bone
- ethmoid bone
- maxilla
- volmer
- nasal spine
- ramus
- angle of jaw
For frontal placement, forehead,
✓ No IA noted

For mastoid placement,
✓ IA values varied across frequencies and patients, it varied roughly from 0-15 dB at 2000 & 4000 Hz among patients

IA is commonly defined to be 0 dB, so crossover is likely all the time
MASKING, TO OVERCOME THE CROSS HEARING

- The process used to overcome the cross-hearing by *temporarily* elevating the hearing threshold of NTE by a known amount of energy to enable an accurate assessment of the TE thresholds >>>>>
This achieved by presenting a masking noise to the NTE at appropriate intensity level to prevent it from detecting the test signal and participating in responding and at the same time measuring the accurate thresholds for the TE.
Clinical Masking (General Terms)

- Masking the right ear:
  - Means the noise is put into the right ear, so the tone cannot be heard in that ear (obscure its participation)
  - Masking noise goes into the NTE and the testing signal goes into the TE
Unmasked air conduction /bone conduction (unmasked air/bone);

- Refers to an AC threshold that was obtained without any masking noise application and the same as Unmasked BC.
Masked AC (Masked air / Masked TE air);

- Refers to an AC threshold of TE with masking noise in the opposite side (NTE)
Types of Masking Noise

- Type of used noise in masking depends on signal being masked

1. If the signal is a wide spectrum, like speech and clicks, the masker should be wide spectrum too
a. Broad band noise (white noise)

b. Pink noise

c. Speech-shaped noise

d. Multi talker babble

2. WBN is not a good choice to mask pure tone as it is inefficient and unnecessarily loud, therefore, critical bands noise optimally to be used. I.e. Narrow band noise (NBN)
When to mask? “Masking rules”

First rule: (BC masking rule)

- In masking, the order is reversed to the PTA testing, we start by looking for whether BC masking is needed or not.

- This should be done because determining when masking is needed for AC depends on knowing the true BC thresholds.
Generally accepted masking rule for BC, if there is an air-bone gap (ABG) within the tested ear that is more than 10 dB

ABG (TE) $>$ 10 dB
EXAMPLE

@ 1000 Hz

RE (NTE)  LE (T E)

AC = 50 dBHL  AC = 70 dBHL
BC = 45 dBHL  BC = 45 dBHL
RE unmasked AC threshold = 50 dB HL
LE unmasked AC threshold = 70 dB HL
BC threshold = 45 dB

For RE: $ABG = 50 - 45 = 5 \text{ dB} < 10 \text{ dB}$ ...
no need to mask

For LE: $ABG = 70 - 45 = 25 \text{ dB} > 10 \text{ dB}$ ...
Masking is needed

So, noise will be applied to the RE through the earphone while, tone presented to the left ear through the BV


CONT. MASKING RULES

2nd rule: (AC masking rule)

- AC masking is needed at any frequency whenever real BC threshold of NTE is more acute than AC threshold of TE by equal to or greater than IA (40 dB for supra-aural earphones or 70 dB for insert earphones)

\[ AC \ (TE) - BC \ (NTE) \geq IA \ (40 \ or \ 70 \ dB) \]
AC (TE) – BC (NTE) is known as air-opposite bone-gap (AOBG) or air-contra-lateral bone-gap (ACBG)
EXAMPLE

@ 1000 Hz, IA = 40

RE

NTE

TE

AC = 10 dB HL  AC = 60 dB HL

BC = 10 dB HL  BC = 10 dB HL
RE unmasked AC threshold = 10 dB HL
LE unmasked AC threshold = 60 dB HL
BC threshold for both ears = 10 dB

- **For RE**: AOBG = 10 - 10 = 0 dB < 40 dB
  ... no need to mask

- **For LE**: AOBG = 60 – 10 = 50 dB > 40 dB
  ... Masking is needed

- So, noise will be applied to the RE while, tone presented to the LE, using earphone
Cont. Masking rules

Third rule: (AC rule )

- Masking needed at any frequency whenever the difference between the Right and left ear AC thresholds is equal or greater than IA (40 dB or 70 dB)

\[ AC \ (TE) - AC \ (NTE) \geq IA \ (40 \ or \ 70 \ dB) \]
EXAMPLE

@ 1000 Hz, IA = 40 dB

RE
NTE

LE
TE

AC = 10 dB HL       AC = 60 dB HL
RE unmasked AC threshold = 10 dB HL
LE unmasked AC threshold = 60 dB HL

- **For RE**: no need to mask

- **For LE**: $AC\ (LE) - AC\ (RE) = 60 - 10 = 50\ dB > 40\ dB \ldots$ Masking is needed

- **So**, noise will be applied to the RE while, tone presented to the left ear
Effective Masking Level (EML)

Masking noise should be calibrated in term of Effective Masking Level (EML)

- **EML** is the level of noise that is equal to the hearing level of a pure tone at the same frequency.
If the masking level is already calibrated in the audiometer in terms of EML, no need to measure the patient’s thresholds for masking noise prior to the hearing test with masking.

When the masking level is not calibrated to EML then, patient’s thresholds for masking noise is required before start the hearing test.
Threshold for masking noise is the lowest intensity level at which the noise can be detected.
PROCEDURE TO FIND EML

1. Put tone in Ch (1) of the audiometer and noise in Ch (2), same ear should be selected

2. Set the noise at comfortable noise (e.g. 40 dB HL) and make it constantly present (interrupt button)

3. Find out the threshold for pure tone in the presence of noise (just audible level), use the same PTA method ↑10 ↓5 dB.
4. Once the audible threshold has been found start decreasing its level again in 5 dB steps until it becomes just inaudible.

5. This is the level where the tone masked by the noise.

6. Repeat the same steps for other frequencies.
EXAMPLE OF EML

At 1000 Hz

Ch (1) RE
Pulsed Tone
Presented every time

e.g. 40 dB HL and changed

Ch (2) RE
Noise (NBN)
Constant

40 dB HL
Another method to find EML

- Both tone and noise are presented to the same ear, the tone is stable while the noise increased in steps until the patient indicates when the tone become inaudible

- NB: Most audiometers are calibrated for EML nowadays
SUMMARY FOR EML/ MEMC

Effective masking level (EML)/ Minimum Effective Masking Correction (MEMC):

- The difference in decibels between the level of a given tone and the level of given noise that just masks the tone (makes the tone inaudible).
How did the clinician set this (EML/MEMC)?

- By performing simple biological calibration study using normal hearing subjects

Procedure: present Tone + Noise to the same ear and for different normal hearing subjects and see the average of noise that made the tone not audible.
It has been assumed that the average, (mean), of noise for illustration purposes as 5 dB.

E.g.

\[
\begin{align*}
\text{RE (AC = 40 dBHL) } & \quad \text{Noise = 45 dB} \\
\text{EML/MEMC = 5 dB}
\end{align*}
\]