GLOBAL EDITION

Introduction to Audiology

TWELFTH EDITION

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ALWAYS LEARNING

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Introduction to Audiology

TABLE 6.3 Example of Effective Masking*

1 Hearing Level of 1,000 Hz Tone	*2* Hearing Level of Noise in Same Ear to Just Mask Out Tone	*3* Difference	*4* Safety Factor	*5* Correction Factor to Be Applied to Reach 30 dB Effective Masking	*6* Masking-Level Dial Reading for This Effective Masking Level	*7* Effective Masking
30	35	5	10	+15	45	30
20	25	5	10	+15	35	20
10	15	5	10	+15	25	10
0	5	5	10	+15	15	0

**Units are in decibels. Assume that the average for a dozen normal-hearing subjects shows that, at 1,000 Hz, a 30 dB HL tone is barely masked with a 45 dB HL masking noise.*

The initial masking level would be 20 dB EM. The hearing-level dial to achieve 20 dB EM would be 35 dB HL, which is the threshold of the ear to be masked (20 dB HL) plus the predetermined correction factor of 15 dB, which includes the 10 dB safety factor. Stated as a formula:

$$EM = AC_{NTE} + CF$$

Central Masking

Decades ago, Wegel and Lane (1924) showed that a small shift is seen in the threshold of a pure tone when a masking noise is introduced to the opposite ear. This threshold shift increases slightly with increased noise but averages about 5 dB. It is believed that the elevation of threshold is produced by inhibition that is sent down from the auditory centers in the brain and therefore has been called **central masking.** Central masking must be differentiated from **overmasking (OM),** in which the masking noise is actually so intense in the masked ear that it crosses the skull and produces an undesired masking of the test signal in the test ear.

Masking Methods for Air Conduction

Masking must be undertaken whenever the possibility of cross hearing in air conduction exists. A survey of clinical audiologists on contemporary clinical practices (Martin et al., 1998) showed more disagreement on masking methods, and apparently greater insecurity, than on any other clinical procedure.

The "Shotgun" Approach

It is possible, in a large number of cases, for clinicians to mask by using some fixed or arbitrary level of noise in the masked ear, without really understanding what they are doing. In uncomplicated cases, the masking procedure often appears to be satisfactory. Because of insufficient feedback about their errors, some individuals fail to profit from their mistakes and continue with erroneous philosophies such as "Just use 70 dB of noise," with no recognition of the properties of the noise or of its effectiveness. Clinicians may be unaware of when they have used too little or too much masking noise.

The Minimum-Noise Method

Through calibration, it is possible to determine the minimum amount of noise necessary to mask a pure tone at a given intensity. There is no need to burden the patient with any more noise than is necessary to get the job done. As discussed earlier, the best way to do this is to regard the noise level in terms of decibels of effective masking.

Several time-consuming, and frequently clinically impractical, formulas have been developed over the years for the determination of the minimum and maximum amounts of effective masking to be used. Martin (1974) has shown that the different formula approaches yield the same noise sound-pressure levels as does a simple, direct approach, requiring almost no calculation. This simple approach is described in the following paragraph.

When test results suggest the possibility of cross hearing, they should be examined closely. Consider the example in Figure 6.2. The criteria for masking are met for the left ear by air conduction, assuming the use of supra-aural earphones, because the threshold (60 dB HL) minus minimal IA (40 dB) is greater than the bone-conduction threshold of the right ear (10 dB HL). Because the test was presumably performed carefully, we know that the 60 dB response was a threshold. However, here is the question that arises: "The threshold of which ear?" If the right (nontest) ear can be removed from the test by masking, and the threshold of the left (test) ear remains unchanged, this means that the original response was obtained through the test ear. If, however, eliminating the right ear from the test results in a failure of response at the left ear at the previous level (plus 5 dB for central masking), the right ear provided the hearing for the original response, and further masking is required to determine the true threshold of the left ear. It should be noted in this example that, had insert receivers been used, the entire issue of masking would have been averted.

The minimum amount of noise required for the threshold test described is an effective masking level equal to the AC threshold of the nontest ear plus the predetermined correction factor, and may be referred to as **initial masking (IM).** This is just enough noise to shift the threshold of that ear 5 dB, by both air conduction and bone conduction. If the threshold of the tone presented to the test ear was originally heard by bone conduction in the nontest ear, raising the threshold of the nontest ear with masking will eliminate the possibility of this response.

Maximum Masking

Just as a tone can lateralize from test ear to nontest ear, given sufficient intensity, so can the masking noise lateralize from masked ear to test ear, both by bone conduction. An individual's interaural attenuation cannot be less than the difference between the air-conduction level in

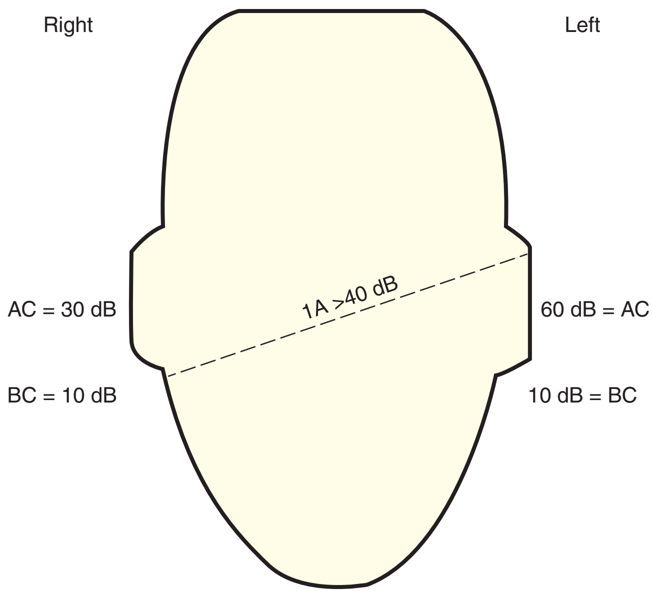


FIGURE 6.2 Illustration of the need to mask during air-conduction tests. Because the difference between the left-ear air-conduction threshold (60 dB HL) and the right-ear bone-conduction threshold (10 dB HL) exceeds the minimum possible interaural attenuation (40 dB, assuming supra-aural earphones were used), cross-hearing is a possibility. Note that the minimum interaural attenuation for this patient must be 50 dB (AC left minus BC right). Masking needed for the right ear is 30 dB EM.

the test ear and the bone-conduction level in the nontest ear at which threshold responses are obtained. For example, even though Figure 6.2 does not illustrate cross hearing per se, but rather the possibility of cross hearing, the interaural attenuation for the individual illustrated cannot be less than 50 dB for the test frequency (air-conduction threshold of the test ear minus bone-conduction threshold of the nontest ear).

Whenever the level of effective masking presented to the masked ear, minus the patient's interaural attenuation, is above the bone-conduction threshold of the test ear, a sufficient amount of noise is delivered to the cochlea of the test ear to elevate its threshold. This is overmasking (see Figure 6.3). The equation for overmasking for pure tones is:

$$EM_{NTE} \geq BC_{TE} + IA$$

Therefore, maximum masking is equal to the threshold of the test ear by bone conduction plus the interaural attenuation, minus 5 dB. When ears with large air-bone gaps are tested, minimum masking quickly becomes overmasking, sometimes making determination of masked pure-tone thresholds difficult. In such cases, audiologists must recognize the problem and rely on other tests and observations to make their diagnoses.

The Plateau Method

This text presents a modification of a popular masking method first reported more than half a century ago (Hood, 1960). By combining Hood's plateau method with the minimum-noise method, one begins with the initial masking level (the air-conduction threshold of the masked ear plus the predetermined correction factor). If the tone is no longer audible, the threshold for the tone is measured again in the presence of the contralateral masking noise. The noise level is then increased 5 dB, and the threshold is measured again. This often results in necessary increases in the tone level of 5 dB for every 5 dB increase in noise in order to keep the tone audible. The assumption is that the threshold of the tone in the test ear has not been reached (**undermasking**), and that both tone and noise are heard by the nontest ear (see Figure 6.4A). When the threshold of the tone for the test ear has been reached (see Figure 6.4B), the level of

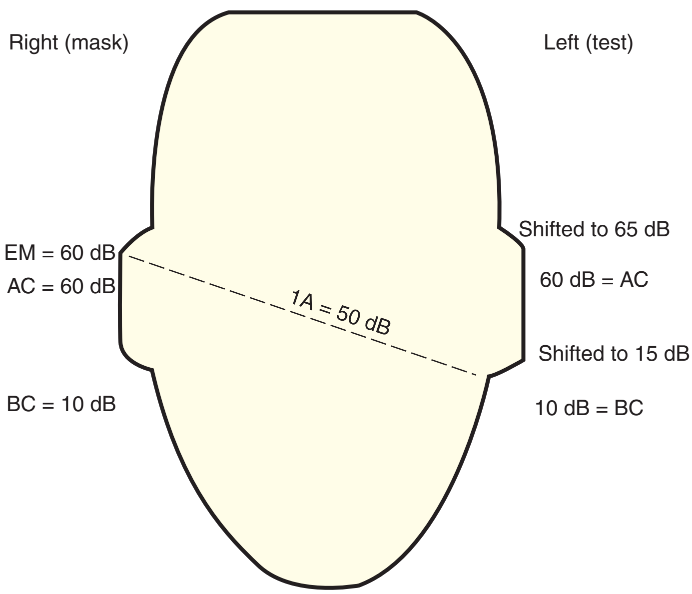
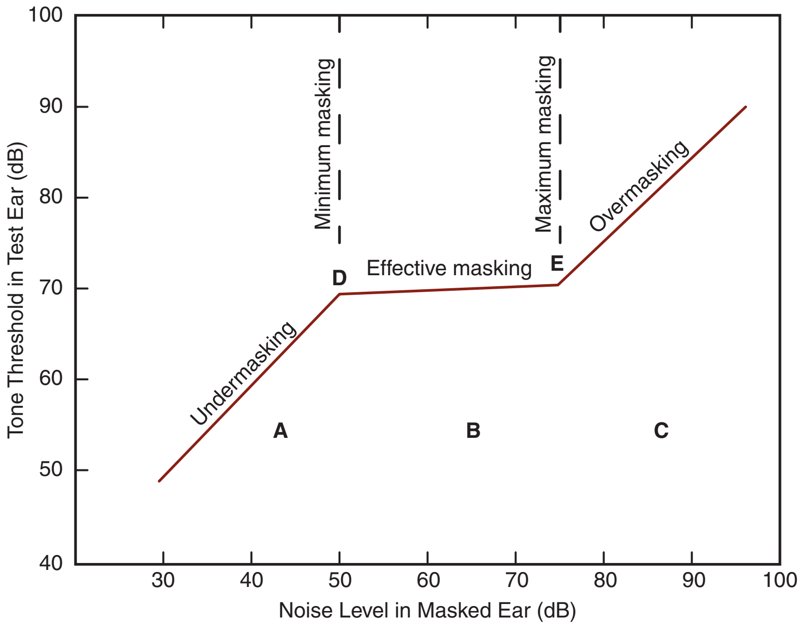


FIGURE 6.3 Example of overmasking. The effective masking level in the right ear (60 dB) is decreased by the interaural attenuation (50 dB) so that 10 dB EM is received by bone conduction in the left ear. This shifts the bone-conduction threshold to 15 dB, plus any additional shift for central masking. Adding more noise to the right ear results in increased masking at the left ear, with further threshold shifts. In this case, the minimum amount of noise required to mask out the right ear produces overmasking.

FIGURE 6.4 The plateau method for masking. (A) Undermasking: The tone (by cross hearing) continues to be heard in the masked ear despite the noise because the tone level is below the threshold of the test ear. (B) The plateau: The tone has reached the threshold of the test ear. Therefore, raising the masking level in the masked ear does not shift the threshold of the tone. (C) Overmasking: The masking level is so intense that it crosses to the test ear, resulting in continuous shifts in the threshold of the tone with increases in the masking noise. Minimum (D) and maximum (E) masking are found at either side of the plateau.



noise can be increased several times without affecting the level of tone that evokes a response. This is the **plateau.** If the noise level is raised beyond a certain point (the bone-conduction threshold of the test ear plus the interaural attenuation), overmasking takes place, and the tone and noise are mixed in the test ear. Further increases in noise result in further shifts in the threshold of the tone (see Figure 6.4C). Minimum and maximum masking are shown in Figures 6.4D and 6.4E.

Problems of overmasking plague all the masking methods, including the plateau system, whenever there are large air-bone gaps in both ears. The larger the air-bone gap, the narrower the plateau; the smaller the air-bone gap, the broader the plateau.

The width of the masking plateau is determined by three variables: (1) the air-conduction threshold of the nontest (masked) ear, (2) the bone-conduction threshold of the test ear, and (3) the patient's interaural attenuation. The higher the air-conduction threshold of the masked ear, the greater must be the initial masking level; the higher that level is, the greater are the chances that the noise will cross to the test ear. The better the bone-conduction threshold of the test ear, the greater is the likelihood that a noise reaching the cochlea of that ear from a masking receiver on or in the opposite ear will exceed its threshold, producing a threshold shift in the test ear. The smaller the interaural attenuation, the higher the level of the noise that reaches the test ear. By increasing interaural attenuation from the test ear to the nontest ear as well as from the nontest ear to the test ear, insert receivers decrease the chances of overmasking and widen the masking plateau. These concepts are summarized in Table 6.4.

TABLE 6.4 Factors That Influence the Width of the Masking Plateau

Factor	*Narrow Plateau*	*Wide Plateau*
AC threshold of masked ear	Higher	Lower
BC threshold of test ear	Lower	Higher
Interaural attenuation	Smaller	Larger

The time demands of routine audiological practice often make proper testing protocols difficult to employ. An excellent example is the need to remove air-conduction receivers; complete bone-conduction tests; and, when masking for air conduction is needed, reapply the receivers. Practicality and expediency cannot excuse a less-than-scientific approach to testing, but surely there are times when some procedures can be shortened. Table 6.5

TABLE 6.5 Examples of Seven Possible Sets of Pure-Tone Test Results That Can Indicate the Need to Mask for Air Conduction

Example	*AC Right*	*AC Left*	*BC Right*	*BC Left*
1	5	5	5	5
2	35	30	30	30
3	60 (60)	5	5 (5)	5
4	60	60	5 (5)	5 (60)
5	60	60	60	60
6	60	60 (60)	5	5 (35)
7	60 (NR)	60	5 (NR)	5 (5)

Example 1 Even without BC results, we can see that no masking is needed for AC for either ear. Many clinicians would not even perform BC in this case. The final diagnosis is obviously normal hearing in both ears.

Example 2 The air-conduction thresholds are not high enough, even using supraural earphones, to allow for cross hearing, even if the bone conduction thresholds turned out to be normal. The need for masking is not there. The final diagnosis is bilateral sensorineural hearing loss.

Example 3 Even without (before) performing BC, the need to mask the left ear is obvious because there is sufficient interaural difference to make cross hearing a possibility. After masking the left ear and retesting the air conduction for the right ear, the right BC will need to be carried out, and the need for masking the left ear becomes obvious. Final diagnosis is conductive loss in the right ear, normal hearing in the left ear, and cross hearing did not, in fact, take place.

Example 4 There is no obvious need to mask here until BC is carried out. Then AC and BC will need to be redone in both ears with masking to determine that the air-bone gap originally seen for the left ear was the result of cross hearing. The final diagnosis is sensorineural hearing loss in the left ear, conductive hearing loss in the right ear.

Example 5 The AC thresholds are the same as Example 4 and so there is no immediate need for masking. BC needs to be done to see if there is an air-bone gap in either or both ears. In this case, there is none. Final diagnosis is bilateral sensory/neural hearing loss with no masking required.

Example 6 As in Examples 3 and 4 there does not appear to be a need for masking. BC will need to be carried out before the need for masking can be determined. Final diagnosis is conductive loss in the right ear, mixed loss in the left ear. The original AC thresholds were correct.

Example 7 This is an unlikely but theoretically possible finding. Initial results show the same symmetrical pattern as in Examples 4, 5, and 6, but masking, following BC testing, reveals a totally deaf ear on the right side with a conductive loss on the left. This case would have been completely misdiagnosed had masking not been employed.

shows seven scenarios that may be encountered during routine audiometry. These examples assume the use of supra-aural earphones. Numbers in parentheses indicate the correct masked thresholds.

Only Example 3 of the seven listed in Table 6.5 clearly shows the need for masking before bone-conduction tests are completed. Examples 4 through 7 all show identical unmasked results, but when masking is used properly, the diagnoses are entirely different. In Examples 4, 6, and 7, the unmasked results would probably have been quite different had insert receivers been used, thereby increasing the interaural attenuation.

Clinical COMMENTARY

The significantly higher interaural attenuation (IA) with insert receivers makes masking considerably easier for the audiologist for two reasons. First, the need for masking is eliminated in many instances because the value for IA is placed at 70 dB in the formula that determines if masking is needed ($AC_{TE} - IA \geq BC_{NTE}$). Second, when masking is required, the chances of overmasking are greatly reduced because of the greater IA.

Masking Methods for Bone Conduction

Masking methods for bone conduction are very much the same as for air conduction, and their success depends on the training, interests, and motivation of the clinician. One problem in masking for bone conduction that does not arise for air conduction is the method of delivery of the masking noise. The matter is simple during air-conduction audiometry because both ears have earphones already positioned, and one phone can deliver the tone while the other phone delivers the masking noise. Because both ears are uncovered during bone-conduction testing, an earphone must be placed into or over the nontest ear without covering the test ear. The test ear must not be covered because this may further increase the occlusion effect created by the masking earphone. Figure 6.5 shows the proper positioning of supra-aural receivers (A) and insert receivers (B) for masking during bone conduction, with the vibrator on the mastoid and also on the forehead.

As just stated, when an earphone is placed over the nontest ear, an occlusion effect may be created in that ear. This means that the intensity of any cross-heard tones in the low frequencies is actually increased in the nontest ear. Of course, if the masked ear has a conductive hearing loss, no additional occlusion effect is evidenced, but it is not always possible to know whether there is a conductive component in the masked ear.

Because the masking earphone may make the bone-conducted tone appear louder in the masked ear, the initial effective masking level must be increased by the amount of the occlusion effect. Failure to do this results in undermasking in a significant number of cases. Therefore, the initial effective level for bone-conduction masking is the air-conduction threshold of the tone in the masked ear, plus the predetermined correction factor (CF), plus the occlusion effect (OE) for the tested frequency and can be expressed as:

$$EM = AC_{NTE} + CF + OE$$