A FIT Solution

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Abstract

The Fusion at Inferred Threshold (FIT) test is a clinically useful procedure for assessing airconduction pure-tone thresholds in any ear that may not be tested by conventional procedures with masking. It has not been widely reported in the literature. This article describes the FIT test procedure and provides four case studies where the FIT was used successfully to determine appropriate management strategies.

Key Words: Bilateral hearing loss, Fusion at Inferred Threshold, masking dilemma, Sensorineural Acuity Level, Stenger, unilateral hearing loss

Abbreviations: FIT = Fusion at Inferred Threshold; MRI = magnetic resonance imaging; SAL = Sensorineural Acuity Level

Almost 40 years ago, the masking dilemma in bilateral conductive hearing loss was addressed in the literature (Naunton, 1960). A few years later, the Fusion at Inferred Threshold (FIT) was described by Bergman (1964) as a means to address the air-conduction results in similar cases. If masking is not available or not possible to use for some reason (i.e., the masking dilemma), the FIT can be a valuable addition to the audiologic test battery. This test has not been widely adopted by audiologists, perhaps because it was initially reported in medical journals and has not been reported in any audiology journals to date. The purpose of this article is to describe how the FIT test can be useful in a clinical setting.

The FIT test is based on the Stenger phenomenon where audible sounds of equal intensity presented to each ear simultaneously will be perceived as a single sound in the center of the head. In contrast to the classic Stenger test (Chaiklin and Ventry, 1965), where the object is to obscure the tone in the referent ear, the application of the FIT depends on the apparent movement of the tone at the referent ear or to somewhere else on the head.

In administering a test like the Stenger, signals of identical frequency, phase, and subjective magnitude are necessary to generate a midline perception with normal listeners. Median plane localization is obtained with equal stimulation of each cochlea, regardless of cochlear pathology. A review of auditory localization/lateralization research is provided by Yost and Hafter (1987). In general, early studies presented the stimuli to the subject that differed in phase or intensity to determine if the disparity resulted in a perceptible change in lateralization. Findings essentially supported the localization data. Interaural time differences were found to have an influence up to about 1300 Hz and interaural intensity differences took over as the primary lateralization cue for higher frequencies (Gelfand, 1981). Yost and Hafter (1987) suggested that the complex process of lateralization is more than the simple interaction of time and intensity cues.

Bergman (1964) examined phase relationships and frequency differences in stimuli presented to both ears to determine if these effects would alter the fusion sensation, but found no evidence that either had an effect. Bergman also explored this phenomenon to determine whether it could be used as a method to determine monaural pure-tone air-conduction thresholds. Specifically, he believed that establishing a fusion level would be a useful procedure in evaluating patients who had large differences in thresholds between the two ears, patients who experience tinnitus, patients who may be exag-
generating a hearing loss, or patients who are inconsistent (false positive responses) in responding. He presented data on fusion levels for normal ears, pathological ears, masked thresholds, and for patients with invalid subjective thresholds. FIT levels verified traditional air-conduction threshold levels for all patient groups. Bergman suggested that the procedure could be used as a substitute for masking in air-conduction audiometry.

Chaplin and Miyamoto (1983) applied the FIT test in masking dilemma cases to help determine air-conduction thresholds and to rule out the possibility of a "dead" ear. They also employed the Sensorineural Acuity Level (SAL; Jerger and Tillman, 1960) to help ascertain the sensorineural function in the cases they reported.

PROCEDURE

The FIT can be applied in the audioligic assessment of patients across various ages, etiologies, and degrees of hearing loss. It has been successfully used for masking dilemma cases to rule out the possibility of a "dead" ear and with children who will not tolerate masking but are able to do the task. It can also be used as a quick "back-up" to check masked results and confirm findings, or as a short cut for returning patients, to verify that thresholds have not changed without the need to use masking again.

The FIT test is simple, quick, and reliable and can be performed with any audiometer that has Stenger test capabilities. The only equipment requirement is that the audiometer must allow a single, pure-tone stimulus to be presented to both ears at the same time as well as have independent control of the intensity level for each ear. Once the thresholds for the referent (better) ear are established, the FIT test can be administered. The patient is simply asked to point to where the sound is heard.

A signal is presented to the referent (better) ear at 5 dB above threshold. A simultaneous tone is presented to the other ear at 0 dB HL. The tone in the referent ear is left unchanged and the intensity of the tone in the test ear is gradually increased (usually in 5-dB steps) until the patient reports a change in the location of the sound. The patient's only task is to indicate where the sound is perceived. A change in sound location implies a fusion of sensation from the two ears somewhere in the auditory system. The lowest level in the test ear at which this change first occurs can be used as an estimate of the hearing level for that ear. The patient's response can vary from a definitive pause in pointing to a quick change from the referent ear to the test ear.

The following four cases demonstrate the usefulness of the FIT procedure and how it can assist audiologists in the long-term management of the patient.

Case 1

RS is a 32-year-old male who presented with a history of bilateral cholesteatoma surgery and had extensive damage to the middle ear structures. This patient also had partial facial paralysis. His audiogram is illustrated in Figure 1. The air-conduction thresholds were obtained at levels indicating a moderate-to-severe hearing loss for each ear. The best bone-conduction thresholds were obtained at essentially normal levels. Because of the "masking dilemma," a "dead" ear could not be ruled out. The FIT test was administered to determine if the air-conduction thresholds were valid. For this case, the right ear was the better or "referent" ear. The "F" notation on the audiogram indicates the lowest intensity level where the patient reported a change in the location of the perceived sound. As observed in Figure 1, the FIT results for this patient are in good agreement with the unmasked left ear air-conduction thresholds, ruling out the possibility of a "dead" left ear. If this patient had no hearing in his left ear, the sound would have been perceived only in his right ear. The bone-conduction thresholds indicate that at least one ear has normal sensorineural function. As the FIT results indicated that both ears have residual hearing, a recommendation to proceed with amplification was
made. An ear level, bone-conduction aid was provided due to surgically altered ear canals and recurrent drainage.

In this case, or for similar masking dilemma cases, the SAL test (Jerger and Tillman, 1960) also could help determine if one or both ears had a conductive component. Unfortunately, few clinics have the equipment capabilities to perform this test (Chaplin and Miyamoto, 1983). Another possible way to resolve this problem would be to try amplification. If air-conduction behind-the-ear (BTE) aids are provided, and if both ears perform well with BTE aids, it can be fairly certain that both ears are primarily conductive in nature. However, if one ear does not have good word recognition skills or has an unusual quality difference, one could assume that this ear may have been compromised by additional sensorineural involvement.

Case 2

ES is a 5-year-old child with Goldenhar syndrome and mild developmental delay. She was referred to the otology department with the audiogram shown in Figure 2. No masked levels were reported for air-conduction thresholds; therefore, the left ear thresholds were suspect as they occurred at or above crossover levels. In addition, the masked bone-conduction thresholds reported for the left ear were in question since the amount of masking used was not reported.

The audiologic evaluation work-up prior to her otologic examination began with speech threshold testing with and without masking. Masked speech results are more easily obtained on young children than masked pure tones because the speech stimulus is more meaningful and salient to the child (Eisenberg, 1976). With pure tones, the task becomes more abstract and often too difficult for a young or developmentally delayed child. The audiometric test results suggested a severe to profound loss for the left ear; masked bone-conduction SRT suggested a sensorineural component.

The FIT procedure was introduced to this child as a game. Directions were slightly different than those given to an adult. She was instructed that she would hear a beep or tone in her right ear and that she needed to touch her right ear each time she heard the sound. After a brief practice session, she was told to show the examiner if the sound went somewhere else—to her left ear, the top of her head, or her shoe. This made the task fun for her and also helped the clinician ascertain if she was reliable in reporting responses. If she had pointed to her shoe, it would have suggested that she was not attending to the task or did not understand the directions.

ES never lateralized the sound to her left ear. She consistently reported that the tone was heard only in her right ear. In addition, during “control” intervals when there was no stimulus presented to either ear and the audiologist asked “Where was that one?”, she consistently reported that she did not hear anything. Results of the FIT test were in good agreement with the masked speech results, suggesting the possibility of a “dead” ear on the left side (Fig. 3).
After a bilateral myringotomy with ventilation tubes, her postoperative audiogram indicated normal hearing for the right ear and a profound hearing loss for the left ear, as seen in Figure 4.

ES was referred to the clinic’s aural rehabilitation specialist for a family interview to review the implications of a unilateral hearing loss and to discuss educational management. The recommendations included an additional year in the Head Start program prior to enrolling in kindergarten, close monitoring of ES’s auditory thresholds, close management of middle ear problems, hearing conservation measures to protect her right ear, and consideration of an FM system at school should any educational difficulties be encountered.

Case 3

ATJ is a 6-year-old male referred to the clinic after failing a kindergarten hearing screening. He was also referred for a speech assessment due to poor voice quality. Results of his audiological evaluation can be seen in Figure 5. Hearing for the right ear was within normal limits. The left ear thresholds suggested a sloping mild to severe sensorineural hearing loss with poor word recognition. Masked air-conduction thresholds were obtained using conventional audiometric techniques. The FIT procedure was performed to confirm the masked air-conduction thresholds, as his word recognition score for this ear was poorer than anticipated in relation to the hearing loss. The FIT levels were in excellent agreement with masked air-conduction thresholds. In this case, the FIT was a quick, easy method to confirm the conventional audiometric results.

The comprehensive otologic work-up did not reveal any indications of retrocochlear pathology and the etiology of the hearing loss in the left ear was not determined. This patient’s vocal hoarseness problems were attributed to vocal nodules. A program was initiated for school therapy and vocal hygiene at home.

ATJ’s hearing remained stable over the next few months. He was provided with a loaner hearing aid to determine if he would benefit from amplification, despite his reduced word recognition score. When he wore the hearing aid, his attention to task was reported as significantly better by his parents and teacher and his vocal intensity was also reported as more appropriate. After 6 months of trial amplification, the family purchased a hearing aid for this child. Some slight improvement in word recognition was documented, but the primary benefits of amplification were the behavior changes reported and improved detection thresholds in the aided condition.

Case 4

CW is a 43-year-old female who had a previous vestibular nerve section on the left side. She had resolution of her symptoms for a year postoperatively but returned with a continuing complaint of unsteadiness. Her hearing had been stable over the years and her audiogram, shown in Figure 6, indicated essentially normal hearing. Her otologic examination was normal but further work-up was recommended, including a repeat MRI scan and a neurologic consultation to rule out any degenerative disease processes. She was a cooperative and pleasant
patient but had difficulty distinguishing the test signal from her tinnitus, resulting in many false positive responses during conventional testing. The FIT test was administered to confirm the left ear air-conduction thresholds. This procedure helped her discriminate the tones from her tinnitus and virtually eliminated her false positive responses. She consistently pointed to her right ear until the left ear threshold was reached. At that point, she would stop pointing to her right ear and report that she was not sure where she heard the sound. Thus, there was an alteration in the location of the sound or a fusion at the inferred threshold. The FIT procedure confirmed her air-conduction thresholds for that ear and made the task less frustrating for the patient and the clinician.

LIMITATIONS

The FIT procedure does have limitations. For some patients, lateralizing a sound can be a very difficult task. In addition, children under 4 years of age are not good candidates for this procedure because they cannot consistently point to the ear where a sound is introduced. Some elderly patients often have difficulty with this task as well. Re-instructing the patient, including identifying the referent ear where most of the sounds will be heard, often eliminates confusion. A sample set of instructions is presented below:

You will hear a beep in your right [referent] ear. Point to your right ear each time you hear the sound. If the sound moves away from that ear, I want you to point to where you hear it. Remember, most of the time it will be in your right ear.

Bergman (1964) suggested that repeated presentations of only the better ear signal also may help a patient. He suggested presenting the sound to the better ear only for two or three presentations and then introducing it into the test ear. This may make the binaural fusion contrast stronger and thus make the task easier for the patient. The rest of the procedure remains unchanged, with the referent tone staying at the same intensity (about 5 dB above threshold) and the intensity of the signal in the test ear increasing in intensity until a change in the location of a sound is reported.

Some adults are not consistent, even when these strategies are used. The FIT procedure is not a good measure to use for this population. A possible area of future research is to explore if this inability to localize a sound might be a “soft” sign of a central auditory processing difficulty (Jerger and Harford, 1960).

SUMMARY

The FIT test is a valid procedure for estimating air-conduction pure-tone thresholds that has largely been unknown to audiologists. Although Bergman (1964) suggested that the FIT could replace traditional masking, this article suggests that it can be an excellent addition to the test battery for selected cases to confirm test results; the ease of administration makes it a very practical clinical tool.

There are many advantages of the FIT test. It is a quick, reliable, easy to administer test and can be a valuable measure for determining air-conduction thresholds in difficult test cases. It has also been used successfully for many children with developmental delays who will not tolerate masking. It has also been applied successfully with patients who have normal hearing, conductive hearing loss, and sensorineural hearing loss (Bergman, 1964).

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REFERENCES


