CURRENT AUDIOMETRIC TESTS FOR THE
DETECTION OF FUNCTIONAL HEARING LOSS

by

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Functional hearing loss is a phenomenon that has been recog-
nized and studied for more than a century by interested audiolo-
gists and medical personnel. However, until about 1950 there
was little systematic research devoted to the problem of tests
successful in detecting functional loss. Many of the early reports
in the literature present clinical impressions, opinions, case
histories, and descriptions of clinical techniques. However,
these articles were significant since they served as a source of
testable hypotheses for later research of clinical importance.

The need for perfecting more accurate tests for measuring
the extent of these losses was recognized by the armed services
during World War II where financial compensation made its
detection vital and necessary. Functional hearing loss is growing
in importance at the present time because of such deafness being
provoked by modern wars, work accidents, legal implications of
medical discharges from the armed services, and for compensation
of auditory trauma in industrial situations. It is also impor-
tant, to identify children who have psychogenic involvements,
so that they can receive therapy for emotional disorders.

With the increasing awareness of the growing need to detect
both psychogenic hearing losses and malingering, it follows that
the methods of detection must be known before they can be
employed. A review of research has revealed the fact that there
is no single source where such information can be obtained.
Therefore, this author felt the need to compile the techniques

now in use, the procedure for administering them, and the research done to establish the validity and reliability of these tests.

This paper will not attempt to cover the research dealing with possible causes of psychogenic deafness, or theraputic techniques employed with such cases. It will limit itself to a discussion of the tests and methods most in use today for identifying such losses.

Definitions: There are many terms used in reference to hearing loss that is of a non-organic origin. Many of these are confusing and often overlap in their connotations. An inspection of the literature reveals that the following terms have been used to refer to non-organic loss: functional hearing loss, psychogenic hearing loss, psychic deafness, auditory malingering, pseudo neural hypacusis, hysterical deafness, pseudodeafness, simulated deafness, psychogenic or functional over-lay, volitional deafness, and extra-auditory hypacusis. It was thought advisable to define the most commonly used terms as they are applied today.

Pseudohypacusis - This term is used to describe non-organic loss because it is a false hearing loss; such a loss has never been demonstrated so it can not be considered "real". The term implies that there is no organic basis, and that the patient is aware of his pretense, although he may not necessarily be fully cognizant of the basis for his pretense.[19]

Extra-auditory hypacusis - This term denotes an impairment which is beyond the known auditory pathways and mechanisms. It may

contain both organic and non-organic components, and it includes all of the disorders of hearing, apart from the organic auditory systems.[36]

Malingering - Malingering is a specific term referring to the "conscious exaggeration or fabrication of symptoms for primary or secondary gain."[11, 67] It is deliberate fabrication of symptoms in which the patient himself does not believe.

Functional or psychogenic overlay - These terms are used to refer to a non-organic component superimposed upon an organic deficiency.[67]

Hysterical deafness - The term usually refers to total deafness of the non-organic type, in which the conversion symptom is an involuntary expression of emotional conflicts at the subconscious level.

Volitional deafness - This term means the same as malingering or simulation.

Psychogenic hearing loss - If the term is broadly used, it refers to all non-organic hearing losses, more specifically, it refers to hearing loss of apparent psychological origin.

Functional hearing loss - This term is often used as a synonym for 'psychogenic' hearing loss. Recently, however, a move has been made to define this term as one being inclusive of all other terms used to describe non-organic loss. The term denotes that after investigation of the patient's loss there is no apparent organic disorder to account for the loss.[67] This term will be used throughout this paper when making references to hearing loss of non-organic origin, and will be designated as FHL.

CHAPTER II

TESTS FOR FUNCTIONAL HEARING LOSS

GENERAL BEHAVIOR IN THE CLINICAL EVALUATION: Before 1950 most
of the testing done to determine the presence of functional
hearing loss was of a subjective nature. Some patterns of
behavior were noticed by audiologists and doctors that seemed
to be present in confirmed cases of functional hearing loss.

Although many personality characteristics have been noted,
only hypochondria, anxiety, and depression have been mentioned
consistently. Subjects with functional hearing loss have been
found to come from homes of relatively high socio-economic status
in which strict child-rearing practices were employed.[35] How-
ever, their occupational level and their educational level have
been found to be relatively low.[33] Levine reported that a larger
proportion of his functional group had had psychiatric treatment
and hospitalization for a psychiatric disorder.[35] Differences
in intelligence between functional groups and nonfunctional
groups have been found repeatedly.[5, 16, 58] The Minnesota
Multiphasic Personality Inventory (MMPI), the Cornell Medical
Index Health Questionnaire (CMI), and the Rorschach test have
been used in several systematic investigations of functional
hearing loss. In general, these investigations revealed more
evidence of emotional disturbance. A comparison of the different
sections of the Cornell Medical Index indicated that persons
with FHL had more somatic complaints involving the nervous
system and more complaints of fatigability.[62] Sarver-Foner

and Dancy observed that veterans with functional hearing loss have a strong dependency need and low self-esteem.[55] The most apparent criticism of these studies seems to be that there is no operational definition of functional hearing loss. Some writers completely omit any discussion of specific criteria for functional hearing loss, do not indicate the audiological procedures used in making the diagnosis, or fail to specify the audiometric findings required for the diagnosis.

In 1965 Chaiklin and Ventry organized a large-scale multi-discipline study to test the efficiency of several methods of FHL detection. The subjects were male veterans referred for hearing evaluation for compensation purposes. Thirty six subjects had no functional component, and 64 subjects demonstrated FHL after being given a complete evaluation by specialists in audiology, otorhinolaryngology, neurology, psychiatry, and psychology. The audiometric tests included the GSR, test-retest of the pure-tone audiogram, pure tone audiogram and speech reception discrepancies, and the pure tone and speech Stenger tests. The procedures and results of this research were presented in the entire Vol. 5 of the Journal of Auditory Research. This study will be referred to in this paper as the NIH-VA study, and significant findings will be reported in the appropriate sections.

Trier and Levy, working with the NIH-VA study attempted to determine the behavioral factors involved in FHL. Each subject was evaluated by a psychiatrist and a psychologist.

The examiners did not know to which group the subjects belonged until the subject's data had been recorded. The assessment procedures consisted of interviews, personality trait ratings, psychological tests, and abstractions from the veteran's claims folder. The interviews were 90 minutes long and were conducted by both the psychiatrist and the psychologist. The pooled ratings of the psychiatrist and the psychologist were used for the data analysis.[62]

The results seemed to be in agreement with, and served to amplify the behavioral characteristics previously reported in this paper. The average education of the veterans with functional hearing loss approximated completion of the eleventh grade. The average income was approximately $2,000 lower than that of the average nonfunctional patient, but there were no significant social status differences. There were no significant differences between groups in marital instability, nomadism, or occupational instability. The intergroup difference in intelligence was significant with the IQ of the nonfunctional group showing 21% above a 90 IQ, while the functional group had 11% above a 90 IQ. Neither group had a high proportion of intellectually dull individuals. The interviews revealed a significantly higher incidence of psychiatric disorders in the functional group, more ratings of moderate to severe psychiatric impairment, and a significantly higher incidence of obsessive-compulsive behavior. Two social characteristics were observed during the psychiatric interview. First, there were hearing fluctuations in patients

with functional loss with an occasional abrupt decrease in comprehension of speech when asked about their hearing loss. Second, the functional group seemed to have more difficulty relating to the psychiatrist. There seemed to be a greater degree of health concern among the functional group, and they tended to be judged as using somatic symptoms to derive benefits from family members. The only 'hearing' symptom that was found to be significant was the complaint of tinnitus, particularly that the tinnitus was of moderate or severe intensity and that it interfered with hearing. The functional group also claimed to rely on speech reading more than the nonfunctional group.[62]

The NIH-VA study tended to agree with the other reports mentioned in this paper in relation to: (1) differences of social status, (2) differences in education and occupational level, but not in income, (3) differences in intelligence (verbal more than performance skills), (4) differences in emotional disturbance, however the emotional involvement indicated in this study was not as great as in other studies, (5) trends of hypochondria with functional hearing loss, and (6) complaints of hearing interference from tinnitus.

Some other comments have been made regarding the behavior of patients with FHL. Newby suggests that while talking with the patient, note whether he seems to be experiencing any difficulty in hearing or understanding. Check to see how closely he is watching you as you speak, since the person with a genuine hearing loss will watch speakers carefully in order

to benefit from speech reading. Talk to the patient occasion-
ally when your head is turned so that the patient cannot see
your face, or speak softly and rapidly. The patient's own
speech will give some indication of functional loss if he
claims a severe or profound loss and yet speaks with a well-
controlled voice and good articulation.[42]

One of the most frequently cited summaries of behavioral
signs of FHL is given by Johnson, et. al.. They list the fol-
lowing behavioral cues: (1) obvious psychiatric disorders,
(2) unsolicited comments or questions regarding compensation,
(3) remarks such as: "I can get along fine when I can read your
lips," "My ears ring so much I can't hear the tone," etc.,
(4) exaggerated attempts to hear, (5) exaggerated staring
attempts to impress with ability to speech read, (6) excessively
loud voice, (7) refusal to attempt speech reading, (8) obvious
nervousness.[28]

From his own experience and from published observations,
Thorne also presented a check list of behavioral cues that he
felt were common to persons with functional hearing loss. They
included: (1) normal voice inflection, (2) poor knowledge of
hearing aids, (3) comments on health, (4) learned lipreading
too quickly, (5) reluctance in behavior, and (6) extreme
passiveness or anxiousness.[60] Thorne is in disagreement with
Johnson on the matter of voice inflection. He maintains that
a 'loud or soft' voice is indicative of an organic disorder,
while Johnson expressed the opinion that a loud voice is a

sign of functionality. Behavioral characteristics are similar
to those given by other authors writing on this subject.

Chaiklin and Ventry expressed the opinion that many of the
behavioral cues presumed by some clinicians to be associated
with functional loss are also associated with organic loss,
or at least they appear in organic loss with sufficient frequency
to seriously impair their diagnostic sensitivity.[4] However,
Weiss and Windrem, on the basis of their research, concluded
that subjective evaluation of behavior should be given an impor-
tant role in the identification of functional hearing loss,
since there seem to be large disagreements between a purely
audiological classification of functional hearing loss and a
classification based on subjective evaluation of functional
hearing loss, and a classification based on subjective evaluation
of behavior.[69]

Although behavior manifestations can be an indication of
FHL, most authors and researchers seem to feel that until a more
comprehensive investigation of behavioral cues has been done,
the designation of functionality on the basis of general
behavior is a practice that should be viewed with skepticism.

THE EAR, NOSE, AND THROAT EXAMINATION: During the ear, nose,
and throat (ENT) examination, some techniques can be used to
indicate the presence of FHL. Besides the general behavior cues
available for observation, tuning fork tests, or inconsistencies
between tuning fork tests, otological findings, and medical
records have been described as ways to detect functional hearing

loss.[23, 28] Informal methods have also been described, such as questioning in a low voice during caloric testing, speaking with a cigarette between the lips, speaking softly while out of the patient's field of vision, and giving softly spoken instructions during laryngeal examination.[28] However, there have been no reports of research on the ENT clinical examination as it relates to identifying FHL, except in the NIH-VA study.

The ENT portion of the NIH-VA study was directed toward: (1) determining if there are significant otolaryngological differences between subjects with FHL and those with no FHL, and (2) evaluating the efficiency of various clinical (non-audiometric) tests in detecting FHL.[6] Deatsch and Ross collected data on the following variables as they relate to the ENT examination: (1) present and past history of ear disease, (2) family history of ear disease, (3) associated systemic diseases, (4) presence, severity, and type of vertigo, (5) fluctuations in hearing, and (6) incidence of prior ear, nose, or throat surgery. As a part of the ENT examination, the following tuning fork tests were administered: Weber, Rinne, Schwaback, Wells' modification of the Stenger, Lombard, and Marx test. Labyrinthine function tests were also performed on all subjects. With the help of these tests, the examiner then arrived at a diagnosis, including a judgment of whether the patient presented a functional or organic hearing loss. Four items in the history showed significant differences between the functional and nonfunctional groups. More of the functional group (56% compared to 68%)

complained of tinnitus, and it seemed to be more disturbing to
them because of its greater subjective loudness. The functional
group more frequently gave a history of exposure to noise trauma,
and had a history of organic ear disease, as well as more fre-
quent reports of minor surgical procedure, particularly tonsil-
lectomy and adenoidectomy. The otolaryngologic physical examina-
tion and neurological examination failed to differentiate the
groups except that the nonfunctional group had a significantly
greater incidence of external auditory canal abnormalities
caused by previous ear or mastoid surgery.[6]

The tuning fork test results were not very useful in
identifying subjects with FHL in the NIH-VA study. The Wells'
modification of the Stenger test identified only 3 out of 19
subjects with FHL, and there was one false positive result. The
Lombard test also proved to be unreliable in detecting subjects
with functional hearing loss. Only five positive responses,
and one false positive result were obtained from the total group
of 100 subjects, of whom 65 actually exhibited FHL. Only the
Marx tuning fork test had some degree of reliability in
identifying subjects with FHL. From a total of 70 subjects, 11
of the 45 functional group were correctly identified, while
none of the 25 subjects of the nonfunctional group were incor-
rectly identified. However, the combination of the results of
all tests in the otolaryngological examination had some diag-
nostic usefulness. At the time the ENT test was completed the
FHL of 13 patients had been resolved. Of the 32 patients with

unresolved functional hearing loss examined by the otolaryngologist, 17 (53%) were correctly identified by the combination of tests, and there were four false positive identifications. The factors in the examination that enabled the otolaryngologist to make a clinical diagnosis of functional hearing loss were the positive tuning fork tests, discrepancies between the tuning fork tests, and the ability of the patient to hear conversational voice.[6]

PURE-TONE AUDIOMETRY:

Test-retest Test - It appears that one of the easiest and most reliable indications of FHL that can be obtained is the use of the pure-tone audiogram (PTA). However, it has been only recently that any research has been done to determine the efficiency of such tests. One characteristic of the patient with functional loss is that he has difficulty in demonstrating the same degree of loss on repeated tests. Newby concludes from personal experience, that it is wise to administer more than one pure-tone test to the patient so that the results can be compared, and it is important to have an interval of a day or two between the tests. Provided no problems occur between tests, the examiner should suspect FHL if the patient is unable to duplicate his test results within plus or minus 10 dB on successive tests.[42]

Portman and Portman suggest essentially the same idea by stating that when "certain rustic and inexperienced individuals convey with very bad grace, thresholds of extreme variety during the same seance, they are immediately the subject of special

tests of simulation research." However, some subjects who are more experienced in the giving of a false audiogram will avoid this obvious method, and such a patient almost always gives a horizontal curve, both for bone and air conduction, at a level which he has previously decided upon for all frequencies. The rapid passage from one ear to the other and from high frequencies to low ones sometimes permits an examiner to obtain thresholds that differ by as much as 10 to 15 dB from the original audiogram, and suggests simulation. The Portmans agree with Newby that test-retest consistency does not necessarily eliminate the possibility of functional hearing loss.[47]

Gundrum recently compared the test-retest audiograms of 50 subjects with normal hearing who were requested to simulate bilateral partial deafness, with the audiograms of 50 patients who possessed bilateral partial organic hearing loss. In the former group only two subjects were able to simulate reasonably well the thresholds of their first test, while the second group (organic loss) showed only minor variations between the two tests.[21] It is possible that this may have occured because of a lack of motivation on the part of the simulating subjects.

The results of Ventry and Chaiklin's NIH-VA study showed that 31 (66%) of 47 FHL patients were correctly identified by the test-retest procedure. However, four 1000 Hz threshold measurements were made in each ear instead of the traditional two measurements at 1000 Hz.[65]

A simple re-run of the pure-tone audiometry as a check on functional hearing loss has several advantages: (1) no special equipment is needed other than a pure-tone audiometer, (2) the administration of the test can be standardized easily, and (3) the limits of variability have been established for both normal and hard-of-hearing subjects. Several audiologists suggest that, barring organic conditions that might cause fluctuations in threshold, test-retest thresholds should agree within $\pm$ 5 dB.

Saucer-Shaped Audiograms -- Some more recent research both confirms and denies the indication by Portman that "the subject of whom one expects simulation almost always gives a horizontal curve for both bone and air conduction." Doyle and McConnell found that seven of nine children found to have FHL showed an audiogram that was 'saucer-shaped' with a moderate rising contour rather than a flat curve. However, the saucer-shaped audiogram did not seem to be a good diagnostic tool since the same kinds of audiograms were shared with a much higher number of children with organic loss, that is, 45% of the total number of cases studied exhibited the saucer-shaped audiogram.[9]

In contrast, Doerfler found that about 80% of the patients with FHL had audiograms that were saucer-shaped, and they tended to range between 50 and 90 dB HL. He suggested that this occurred because of the patients' tendency to make an equal loudness contour or to follow the phon lines. They also tended to follow the 60 dB equal loudness contour, presumably because it

corresponds roughly to the comfort loudness listening level of the normal ear. When there is functional over-lay, or an exaggeration of an organic flat hearing loss, the obtained audiogram might be expected to lie in the region of the 90 dB equal loudness contour, depending upon the degree of organic involvement.[8]

Johnson, Work and McCoy illustrated the emergence of the saucer-shaped audiogram in patients with simulated deafness whose true hearing thresholds were normal except for a dip at 4,000 and 8,000 Hz. The explanation for the saucer-shaped audiogram seems to lie in the catching up in loudness effect of recruitment at those two frequencies. Hence it would appear that the saucer-shaped audiogram should be used with caution as a diagnostic tool, and that it should be used in conjunction with other tests for functional hearing loss.[28]

Ventry and Chaiklin designed a study to check the efficiency of the saucer audiogram in the NIH-VA research. The audiograms were evaluated by experienced audiologists, and their task was to determine whether a particular audiogram corresponded in both shape and hearing level to either one of two audiograms that had been characterized as typical of FHL. Finally, the judges were asked whether the audiogram, in their personal opinion and disregarding all statements and other material furnished them, was or was not a saucer audiogram.[63] They found that the configurations of the nonfunctional group and the functional group did not appear to differ significantly except that the

functional group presented greater total hearing loss. The
functional composite audiogram did not follow either the 60-
phon line or the 90-phon line, however they were similar to the
40-phon line (right ear) and to the 50-phon line (left ear), at
least in the low frequencies. Differences in the extent of
hearing loss were relatively large in the low and middle fre-
quencies, and became much smaller at 4000 and 8000 Hz. This
finding indicated that the amount of functional over-lay was
primarily found in the mid and low frequencies. A composite
audiogram drawn after the resolution of the functional hearing
loss demonstrated that this result might have been obtained
because loudness recruitment limited the extent of the functional
overlay in the 4000-8000 Hz region. Recruitment had little or
no effect on the magnitude of the functional overlay at the
lower frequency regions where the sensori-neural component was
small. The conclusion was made that the saucer audiogram
appears infrequently in patients with FHL, (in approximately 8%
of their functional sample) and that it has a comparably low
frequency of occurrence in patients with no FHL. It is probably
immaterial whether an audiogram looks like a 'level' saucer
or like a 'tilted' saucer, but there may be diagnostic value
in whether a particular audiogram corresponds closely to any
equal loudness contour or corresponds to the low frequency
(below 1500 Hz) portion of an equal loudness contour. Almost
any configuration of an audiogram can occur in functional

hearing loss, regardless of the extent of the underlying
sensitivity deficit.[63]

False-alarm Responses During Pure-tone Audiometry - Another
measurement that can be made during pure-tone audiometry is to
note the false-alarm responses. The error is one of commission
by the subject, in that he makes a response when there is no
signal. In the NIH-VA study this test appeared to be reliable
and valid. A stop watch was used to time 60 sec. sampling
periods. The first false-alarm sampling period occurred after
the threshold measurement at 2000 Hz; the second sampling period
was after threshold measurement at 250 Hz. False-alarm responses
were also tallied when they occurred at times other than the
sampling periods. The 40 FHL subjects gave a total of only 80
false-alarm responses, 53 of them by one subject. This is in
contrast with a total of 330, or six times as many, by the 36
nonfunctional subjects. Both groups gave more false-alarm
responses at 2000 Hz than at 250 Hz. However, the difference
between the two groups' behavior is more decisively demonstrated
by classifying subjects according to presence or absence of
false-alarm responses occurring at any time during pure-tone
audiometry.[64]

Inappropriate Lateralization - Evidence of unilateral simulated
deafness is apparent when, in the course of the pure tone air
conduction test, the audiogram of one ear is either normal, or
relatively so, with complete absence of response in the opposite

ear. In the case of severe or complete unilateral deafness, a
'shadow curve,' or cross hearing will take place at about 50 dB
above hearing level in the good ear.[18]

Chaiklin and Ventry consider the lateralization test to be
an important one in determining the presence of functional hear-
ing loss. They further suggest that the patient who presents
a shadow curve, but whose thresholds in the poorer ear are sig-
nificantly poorer than might be expected, also indicates a
functional loss. In their study, the test had limited usefulness
since complete unilateral loss was exhibited in only 2% of the
experimental group.[4]

Bone conduction audiometry affords the clinician another
opportunity to evaluate the shadow-curve phenomenon. Only 10 dB
are necessary to make the shadow appear for bone conduction. As
a general rule, failure of a response curve to appear at between
50 and 60 dB hearing level relative to the obtained threshold in
the admittedly good ear for air conduction, as well as failure
of the bone response curve of the supposedly deaf ear to appear
at a level 10 to 15 dB greater than the recorded bone curve of
the better ear, strongly suggests functional deafness.[4, 47, 18]

Kodman has developed a series of lateralization tests to
detect the unilateral functional loss. He uses the pure-tone
air conduction shadow curve (shadowgram), a lateralized speech
reception threshold (Lat-SRT), a lateralized speech discrimina-
tion score (Lat-PB) determined by the same procedures as
the pure-tone shadow curve, and a voice quality report. The

'shadowgram' should parallel the pure-tone, air conduction thresholds in the better ear. The lateralized SRT measure should agree with the mean of the three frequencies, 500, 1000, and 2000 Hz of the shadowgram pattern in genuine organic loss. The lateralized SRT is obtained and the SRT for the better ear is substracted from it. The resultant score will always be on the order of 50 dB $\pm$ 10 for organic loss. A greater difference indicates functional loss. The lateralized discrimination (PB) score is obtained by presenting 50 words by monitored live voice at a level 15 dB above the lateralized SRT. To this score is added the percentage error of the PB loss in the better ear so that the expected PB score will always be on the order of 50% $\pm$ 10 for the normal ear, or ear with organic loss. (If the PB score for the normal, contralateral ear is 98% and 2% less than perfect, the 2% is added to the obtained lateralized PB score). Here again, a greater discrepancy indicates a functional loss. The voice quality report is made after the lateralized PB score is obtained and at the same audiometric level. The patient with a deaf ear who is responding correctly will most often comment that the voice sounds faint. This is the case because he is hearing the speech at a sensation level of 15 dB. If he has feigned the loss so that the lateralized stimuli are heard binaurally, he will usually comment that the speech is clear and distinct. Kodman asserts that from his case files, monaural deafness occurs in about one out of five cases, and that the lateralization method has proven to be "extremely valuable" for

the 60 cases of monaural hearing loss used in his study. If the monaurally deaf patient is able and willing to cooperate, then he will pass the four criteria of the test series. If he is unable or unwilling to cooperate, he will fail one or more of the four measurements in the method.[32]

Bone Conduction Audiometry - Bone conduction is not generally used as a method for detection of FHL. However, Johnson suggests two findings, based on bone-conduction audiometry, that may be related to functional hearing loss: (1) bone-conduction thresholds are significantly poorer than air-conduction thresholds, and (2) bone-conduction thresholds are equally depressed 20-40 dB for all frequencies tested.[28] These findings were not supported by the NIH-VA study, with results suggesting that: (1) there is no typical bone-conduction threshold configuration in functional hearing loss, (2) a significant percentage (84%) of subjects presenting a functional hearing loss, present air-bone gaps of at least 15 dB at one or more frequencies, and (3) a large percentage (57%) of functional subjects demonstrate lateralization during bone-conduction audiometry. It is Ventry and Chaiklin's opinion that the results of bone-conduction audiometry offer little help in the identification of functional hearing loss.[4]

Miller described a test using masked bone-conducted speech as an aid in detecting functional loss. Basically, this technique uses bone-conducted speech stimuli while white noise is presented through earphones. The earphones are positioned in

the routine manner, and the bone-conduction oscillator is placed
on the center of the subject's forehead. The procedure is as
follows: (1) determine the subject's bone-conduction SRT with
spondee words, (the signal will be attenuated by the bone-
conduction receiver by approximately 45 dB), (2) continue
presenting spondees at the subject's SRT and gradually introduce
white noise, masking binaurally and through the earphones at a
rate of 5 dB per spondee, (3) record the masking level where
the subject ceases responding to the spondees (Binaural Masking
Interference Level (BMIL), (4) remove the binaural masking and
gradually introduce white noise into the subject's poor ear at 5
dB per spondee, (the good ear's threshold should not be affected),
(5) repeat step four, applying the white noise masking to the
good ear, (6) record the Monaural Masking Interference Level
(MMIL) for the good ear, (7) compare the MMIL for the poor ear,
(this will be the total amount of masking available, usually
about 75 dB) and the MMIL of the good ear with the BMIL. A
positive interpretation, that is, the detection of a feigned
unilateral hearing loss could be one of the following: (1) the
MMIL for the poor ear is the same as the MMIL for the good ear,
indicating equal hearing sensitivity, and (2) the MMIL for the
poor ear is less than the BMIL. Since the BMIL is of necessity
an indication of the good ear sensitivity, a lower MMIL is not
actually possible, and therefore, invalid. Even though this
test has only been tested on a limited number of sujbects,
Miller concludes by saying that "this technique appears to have
some very useful qualities."[40]

SPEECH AUDIOMETRY

Speech Discrimination - Portman and Portman maintain that the
discrimination test can be very useful in detecting functional
loss. Such loss is indicated by a discrimination score that is
too high for the pure-tone audiometric pattern, such as a 70%
score with a pure-tone loss of 70 dB. Another indication is for
one or two weak changes in the intensity level to make a sudden
change in the score, such as a change from 0% to 100% intellig-
ibility. In such a case, the patient is not conforming to the dis-
crimination intelligibility curve. The patient who takes much
too long a time before repeating the words in order to look for
words of similar consonance is likely trying to impress the
audiologist with his difficulty in hearing. The Portmans suggest
that words can be alternately presented at very low intensities,
and then at very high intensities. Gradually, without the
patient realizing it, the level of sound intensity is lowered.
In this way two incompatible responses are obtained for similar
intensities. The patient should be told that the audiologist
is aware that he is feigning his loss and warn him not to continue.
An 80 dB noise can be introduced to make the patient lose his
reference level of intensity, and eventually the patient will
begin to weaken and give a more normal curve.[47]

The NIH-VA data indicate that subjects with functional
hearing loss have significantly lower speech discrimination
scores than those without functional involvement. However, a
report by Kuhm indicated a difference of opinion. He found no

significant differences between the functional group and the
nonfunctional group. On the other hand, Carhart contends that
patients with functional hearing loss characteristically make
speech discrimination errors that differentiate them from other
patients.[4]

Speech Reception Threshold - Perhaps the most frequently cited
audiometric indication of functional hearing loss is an SRT
significantly lower than the appropriate PTA.[2, 3, 7] This
relationship has been found in both children and adults. The
NIH-VA study results indicated that the most efficient measure
of functional hearing loss was the SRT-PTA measure, which cor-
rectly identified 70% of the subjects, or 33 out of the 47 sub-
jects. All of these subjects had SRTs significantly lower
(12 dB or more) than their PTAs. This was in comparison to the
test-retest measure which correctly identified 31 subjects or 66%
of the functional patients. With a combination of the two tests,
40 subjects were correctly identified, or 85%.[65]

Errors During Measurement of Spondee Threshold - Chaiklin and
Ventry, using 36 subjects with organic loss and 59 subjects with
FHL gathered data on the errors made during the measurement of
the speech reception threshold. Two kinds of errors were counted:
(1) no-response errors, and (2) responses incorrectly made. The
responses incorrectly made were divided into three general
categories: (a) errors not containing part of the stimulus,
(b) single word errors containing part of the stimulus, and

(c) multiword errors containing part of the stimulus. The results revealed that there were no significant differences between the groups in the mean number of responses incorrectly made, but the functional·group had significantly more no-response errors and total errors than the nonfunctional group. Also, more functional than nonfunctional subjects failed to give response errors. The data revealed that many subjects, mainly in the functional group, gave no responses at all in the categories that appeared to hold promise for differentiating the groups, while subjects in the opposite group usually gave responses in these categories. These results suggest that the absence of response errors itself is an indication of functional hearing loss. There were significant differences in the following: (1) errors consisting of the first half of the stimulus, (2) errors consisting of the second half of the stimulus, (3) errors that are one-syllable words not containing part of the stimulus (35% by functionals, and 89% by nonfunctionals), and (4) errors that are spondees from the stimulus list such as substituting farewell for the word baseball (35% by functionals and 89% by nonfunctionals). Of the 35 nonfunctional subjects, only 3 gave half-stimulus errors (9%) while 22 (46%) of the functional group gave half-stimulus errors. This supports the impression that half-stimulus responses are associated with functional hearing loss. The errors of the functional subjects were characterized by: (1) a disproportionate number of no-response errors, (2) response errors that are half of the stimulus word, and (3) one-syllable words not containing part of the stimulus. The errors of the non-functional subjects were

characterized by: (1) a relatively high ratio of errors by
responding when there was no stimuli, to total errors, and (2) by
response errors that are spondees from the stimulus list.
Errors that were characteristic of the functional group were
produced infrequently by the nonfunctional group. A repeat of
this study with different subjects produced percentages not
significantly different from the ones above.[64]

A spondee error index (SERI) can be calculated by adding
the number of no response errors (NRE) to the number of one-
syllable responses, either half-stimulus or other one-syllable
responses (OS), subtracting the spondee errors from the stimulus
list (SL), dividing that figure by the total errors (TE), and
then multiplying it by 100.

$$SERI = \frac{NRE + OS - SL}{TE} \times 100$$

A score of 86 or higher indicates that functional loss may be
present. If an audiologist uses the absence of false-alarm
responses at any time during pure-tone audiometry, and the
spondee error response index (SERI) of 86 or higher as criteria
for functional hearing loss, then he can expect to identify about
79% of the functional hearing loss subjects. An analysis was
made of the effect of using the SRT-PTA in conjunction with the
SERI and the false-alarm response criteria. By using a positive
result on both the SERI and false-alarm response tests, and a
positive result on the SRT-PTA criterion, 85% of the functional
subjects were correctly identified. These results suggest

that the SERI and the absence of false-alarm responses may be valuable in identifying patients missed by the widely used SRT-PTA test.[4]

Inappropriate Lateralization - Inappropriate lateralization of speech signals can be tested in the same manner as inappropriate lateralization for pure-tone audiometry, and it has the same significance in identifying FHL.[4]

PURE-TONE STENGER TEST: The Stenger test is based on the principle that when both ears are stimulated by a tone of the same frequency but of differing intensity in each ear, an individual with normal hearing or with an equal bilateral hearing loss is aware of hearing the tone only in the ear in which it is louder.[42] It should be noted that recent literature in audiology does not support this theory, but maintains that the tone is experienced, not as a separate sensation in each ear, but rather as a single sound located at a point within the head, depending on the intensity of the sound at the two ears.

The test requires an audiometer having twin channels capable of delivering an identical frequency to matched receivers. Two audiometers may also be used, however it is difficult to have the tones perfectly matched with two audiometers. A modification of a standard audiometer can be obtained to allow for dividing the output between the earphones, and for separate intensity controls. To administer the test, the patient's pure-tone audiogram is obtained. Then the tone is presented at 1000 Hz,

5 or 10 dB above the threshold in the good ear. Without disturb-
ing the level of the tone in the patient's good ear, the tone is
introduced into the poor ear, and gradually the tone is increased
in intensity until it exceeds the level of the same tone in the
good ear. When the tone becomes about 10 dB greater in the poor
ear than it is in the good ear, the patient will have the sensa-
tion of hearing it only in the poor ear. He then has two
responses that he can make: (1) he may cease to respond to
tones in both ears, or (2) he may continue to respond. If he
reports that he no longer hears the tone, the audiologist knows
that he is actually hearing the tone in his poor ear at that
sensation level, and he knows that the patient is aware that he
is hearing it in the poor ear. If the patient chooses to continue
to respond, the examiner can fade the tone completely from the
earphone for the good ear. If the patient continues to maintain
that he hears the tone in his good ear, the examiner knows that
the threshold of the poor ear is actually no greater than the
sensation level of the tone at that time in the poor ear. The
test may be rendered ineffective if the patient should have
diplacusis since the pitch he hears in one ear will not be quite
the same as the pitch in the other ear.[42, 47] Menzel cautions
that invalid results may be obtained by the "gradual increase of
the tone," and that the tone should be interrupted simultaneously
in both earphones, and then the increase or decrease in intensity
should be made.[37]

Several modifications of the Stenger test have been devised. Newby and Portman suggest an ascending method of gradually increasing the intensity of the signal in the poor ear. However, Goetzinger and Proud suggest that a descending method be used to give the test. The signal is presented in the poor ear at 40 dB HL (this intensity is used so that no cross-over will take place), and in the good ear at 5 dB HL. The attenuator controlling the signal to the poor ear is lowered in 5 dB steps until the subject makes a response. If the patient does not respond until the intensity of the tone is equal to the intensity of the tone in the admittedly good ear, there is definite evidence that the ears are approximately equal in sensitivity. If the patient responds at the initial settings of the attenuators (40 dB and 5 dB) then there is the possibility of true organic loss in the poor ear. To check this possibility the tone is removed completely from the admittedly good ear. If the patient responds on reintroduction of the signal, he is definitely hearing the tone in the poor ear since the poor ear is the only one being stimulated.[42, 47]

Ventry and Chaiklin made a comparison between the efficiency of the Stenger, the speech reception threshold-pure-tone test, and the test-retest measurement, and found that the Stenger test was the least efficient of the three. The pure-tone Stenger test was positive for 43% of the functional group. The test was given only to patients with a threshold difference of 20 dB or more between ears for the same frequency, and was

presented with the ascending method described above. The results
of this test do not agree with the results found by Goetzinger
and Proud, who have found the test "unbeatable",[18] and Menzel,
who claims that "the Stenger test is one of the most useful and
important tools for detecting auditory malingering."[37] Some
factors that could account for the low efficiency are: (1) the
size of the functional component in the better ear, (2) the size
of the interaural sensitivity difference, and (3) the size of the
functional component in the poorer ear. The size of the over-
lay in the good ear may not be of significance in predicting
results, except for its relation to interaural sensation level
differences; in other words, the results are more likely to
be positive with a large functional component.[65] Another area
that requires research is the effect of diplacusis on the
Stenger. Perhaps a more basic question is whether it is always
the Stenger effect that causes the Stenger to be positive, since
some authors report that some patients respond for a tone that
is equal to, or weaker than the signal in the assumed better
ear, suggesting that the patient either perceives a midline
localization, or no definite sensation of localization at all.
Some other variables that may influence the results of the test
may be phase difference, beats, different kinds of pathology
such as recruitment, and a poor frequency match of the oscilla-
tors.

MODIFIED (SPEECH) STENGER TEST: The speech Stenger test utilizes
the principle of the pure-tone Stenger test, but uses speech

signals instead of pure-tones. The Spondees can be delivered
either by live voice or by recording. Goetzinger and Proud
claim that it is "indispensable" in the battery of tests for
functional deafness, and cite it as particularly well-suited
for the examination of children.[18] The test is applied when
there is a significant interaural difference in the SRTs between
the two ears. In the use of the Stenger test, it should be con-
sidered that some patients can be candidates for the pure-tone
Stenger test but not for the speech Stenger test since they
may have a significant interaural pure-tone threshold difference,
but little or no interaural SRT difference. The situation can
be further complicated because the patient may present a large
unilateral functional over-lay for pure-tone thresholds, with
the SRTs close to their true thresholds. Thus, he may have a
positive pure-tone Stenger result and a negative speech Stenger
result. The speech Stenger has the advantage that it avoids the
invalidating effects of diplacusis.[4] The results for the
efficiency of the speech Stenger in the NIH-VA study are similar
to the pure-tone Stenger test in that study.[65]

DOERFLER-STEWART TEST: The Doerfler-Stewart (D-S) test requires
a two room set-up, and speech audiometric equipment that allows
a masking noise to be mixed and varied with the speech signal.
This requires a two-channel speech audiometer. The test is
based on the observation that a person with either normal hearing
or an organic hearing loss will not succumb to the masking
effects of noise upon speech until the level of the noise is

about 20 dB greater than the level at which the speech is being presented. However, the functionally deaf patient's speech reception is disturbed and in many instances completely obliterated when the level of the noise is 10 to 15 dB weaker than even the admitted speech reception threshold.[18]

Briefly, the test is administered by slowly increasing the level of the masking noise until it has exceeded the level of speech presentation presented at SRT by 20 dB or more. The level at which the speech was given is then lowered by 20 or 25 dB. Gradually the noise is attenuated until the lower level of speech again emerges through the noise. Subjects with functional loss, having lost their reference level, will begin to respond again, but this time at a level 20 to 25 dB below their former admitted reception level for speech.[18]

Newby describes in some detail the test procedure for the D-S test given by Doerfler and Epstein. The Doerfler and Epstein procedure is generally accepted by audiologists, and it has been used in research to determine the efficiency of the D-S test. This description in its original is an unpublished monograph and is unavailable to this author, hence the description given by Newby will be presented in this paper. Doerfler and Epstein say that the D-S test should be administered before any standard speech audiometry is attempted because it is not desirable for the patient to have the opportunity to establish a reference level for amplified speech. Speech should be avoided when using the audiometer even for giving instructions. Once

the test is begun it should not be interrupted. The following is a step by step procedure quoted from Newby.

1. Obtain the SRT for spondees by starting with the attenuator set at zero sensation level. Present three spondees at that level, and then increase the intensity by 5 dB and present three more spondees. Continue in this fashion until the patient repeats two of the three spondees correctly. This is considered to be the patient's SRT, provided that when the intensity is increased by another 5 dB he repeats all the next three spondees correctly. If at this higher level he does not repeat all three words correctly, present six spondees at the same level. If he gets more than half of them correct, decrease the intensity by 2 dB steps until the patient is no longer able to repeat three of the six words correctly. His SRT is then defined as the point 2 dB above the level at which he failed to repeat 50 per cent of the words correctly. Record the SRT.

2. Increase the intensity of the spondee words 5 dB above the patient's SRT (SRT (1) + 5).

3. Now introduce the saw-tooth masking noise superimposed on the speech signal. Start with the noise at zero sensation level, and gradually increase its intensity by one 5 dB step for each spondee word until the noise is at a level of 20 dB below the intensity of the spondees, or 20 dB below SRT (1) + 5. Then increase the noise in 2 dB steps at the rate of one step per spondee until the patient fails to repeat three or four consecutive spondee words. Note the sensation level of the noise at this point, and record it as NIL (Noise Interference Level).

4. Still presenting spondees at the level of SRT (1) + 5, increase the intensity of the noise in 5 dB steps until it is at least 20 dB above the NIL, or at least 30 dB above SRT (1) + 5, whichever point is reached first.

5. Keeping the noise at the level reached in step 4, decrease the intensity of the spondees in 5 dB steps until they are being delivered at a level 15 dB lower than SRT (1) + 5, or, in other words, 10 dB lower than SRT (1).

6. Decrease the level of the noise in 10 dB steps until the noise is at the level of SRT (1); then decrease the noise in 5 dB steps until it is completely attenuated. If the patient should start repeating words again as the noise level is decreased, note the level of the speech at this point (SRT (1) - 10), and, keeping the noise constant, decrease the level of the spondees again. Resume the decrease of the noise in 5 dB steps. If the

patient responds to the lower level of the spondees as the noise is being attenuated, it is evident that his actual SRT is better than the SRT (1) which you have previously recorded.

7. Starting with the spondee words at the level of SRT (1) - 10, or at the level at which the patient last responded during the preceding step if any responses were obtained while the noise was being attenuated, proceed to find the patient's SRT again in the same manner as in step 1. Record this SRT in the box labeled SRT (2). (see diagram)

8. Discontinue the presentation of spondees (for the first time since the test was started). Instruct the patient to signal you when he first detects the presence of the masking noise. Start the noise at zero sensation level and gradually increase its intensity until the patient signals. Record the sensation level of the noise at this point in the box labeled NDT (Noise Detection Threshold). The test is now complete.

The results obtained can be recorded in a special form arranged as follows:
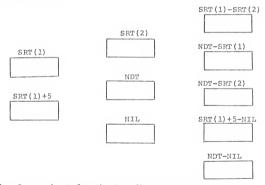

Fig. 1. Score sheet for the Doerfler Stewart test.

The D-S test is positive, that is, suggestive of functional loss, if the following results are obtained:

1. The difference between SRT (1) and SRT (2) is greater than $\pm$ 5 dB.

2. The NIL is lower in intensity than SRT (1) + 5 by more than 3 dB or greater in intensity than SRT (1) + 5 by more than 18 dB.

3. The NDT is greater in intensity than SRT (1) or SRT (2) by more than 7 dB or less in intensity than SRT (1) or SRT (2) by more than 15 dB.

4. The NDT is any greater than an intensity of 2 dB below the NIL or any lower than an intensity of 31 dB below the NIL.

Care must be taken when recording the scores for this test to preserve the algebraic sign of the difference, except in the case of SRT (1) - SRT (2). A result suggesting functional loss should be preceded by a plus sign.[42]

Menzel published data on the D-S test's efficiency indicating that the D-S test was positive in 58% of his subjects with a functional component, and he concluded that the test is "... a sensitive detector of nonorganicity." However, Menzel did not do his study to determine the efficiency of the D-S test, and he did not specify how the D-S test was performed. Also he did not give the bases on which the test was judged positive or the number of false-positive identifications that were made.[38]

The only study done to determine the efficiency of the D-S test is the NIH-VA study. Doerfler and Epstein indicated that the most sensitive measures of the D-S test were the measures involving noise detection and noise interference (NDT-NIL and SRT (1) + 5 - NIL). These two measures were given more weight than the speech reception thresholds. The NIH-VA study was done to determine the efficiency of the test, and to determine

the best combinations of the D-S test measures. Two variations
were made on the Doerfler-Epstein test given above: (1) the
subjects had had prior exposure to speech audiometry, but the
exposure had been a minimum of five weeks before the test, and
(2) measurements of the NDT were presented in short bursts of
noise in an ascending series of 5 dB steps starting at -10 dB
hearing level. (Newby recommended that the test "start with the
noise at zero sensation level and gradually increase its intensity
until the patient signals). The D-S test incorrectly identified
50% of the nonfunctional group as functional, and 58% of the
functional group as nonfunctional. The two conditions described
by Doerfler and Epstein were the least sensitive measures. Only
the two difference scores, SRT (1) - NDT and SRT (2) - NDT,
correctly differentiated the groups at a statistically significant
level. The practical value of these two difference scores was
reduced by the fact that the false-negative identifications were
83% for SRT (1) - NDT and 67% for the SRT (2) - NDT. However,
there were no false-positive identifications for either of the
two measures.[65]

A substudy was done using new norms derived from the subjects
in the first study. These norms were: -4 to 5 dB for the SRT (1) -
SRT (2) measure; 17 to 15 dB for the SRT (1) - NDT and SRT (2) -
NDT measures; -18 to 3 dB for the SRT (1) + 5 - NIL measure; and
-31 to 12 dB for the NDT - NIL measure. The percentage of non-
functional group subjects with positive difference scores
decreased from 72% to 39% with the new norms. The percentage of

functional group subjects with two or more positive difference scores increased from 38% to 65%. There was also a significant difference between the groups when one or no positive difference scores was considered positive. With these criteria, the false-positive rate was 17% and the false-negative rate was 35%. The SRT (1) - SRT (2) difference score failed to differentiate the groups.[65]

The differences between these norms do not present sufficient evidence that the new norms should be used, however it does indicate that some study should be given to them, and other norms that may be more efficient in determining functional loss.[65] The results of both of these tests indicate that considerable caution should be used in interpreting the D-S test. Doerfler and Epstein stated that "the value of the D-S test consists in cueing the audiologist to the possibility of the existence of a functional overlay, and may be used as a screening procedure. However, the test is rather complex for the average audiologist and requires elaborate audiometric equipment.

LOMBARD TEST: This test is based on the theory that we tend to monitor our own voice through the sensation of hearing. The patient is given some material to read, while a masking noise is fed into the earphones which he is wearing. If the patient's voice fluctuates, that is, if his voice increases and decreases with the level of masking noise below his admitted threshold, he is exhibiting a functional loss. The masking level where changes begin to take place in the voice can be compared with

the pure-tone audiogram to get some indication of the amount of functional component. The test can also be used as a test for a unilateral loss by putting a constant masking noise in the good ear and a variable noise in the supposedly impaired ear.[42] Goetzinger and Proud suggest that a noise of about 80 dB should be suddenly introduced into the deafened ear. A sudden increase in voice intensity will occur if the loss is simulated. Subsequently, the noise is switched back and forth between the ears. If the increased level of the voice is maintained regardless of the ear under stimulation, functional loss is indicated.[18]

Portman and Portman contend that the test "is formal proof that the patient does not hear in a negligible manner."[47] Conversely, Goetzinger and Proud suggest that the malingerer of average ability soon learns to modify his voice in the presence of unilateral noise, thus invalidating the test.[18] Newby agreed that the test is not standardized so that the actual threshold can be determined, and that the sophisticated patient can learn to control the intensity of his voice.[42] Chaiklin and Ventry maintain that the Lombard reflex is highly variable, affecting some people markedly and others only minimally.[4]

Waldron conducted an experimental evaluation of the Lombard test, using white noise to test the effects on the Lombard reflex and on reading rate. He found no significant changes in reading rate for any of the conditions studied or in the rate at which the masking noise was introduced. Statistically, significant increases in vocal intensity were found for both

monaural and binaural conditions. The binaural masking produced
significantly greater increases in vocal intensity than monaural
masking, and for this reason, binaural stimulation should be
included as part of the Lombard test. Waldron's study indicates
that the Lombard test may be helpful when gross changes in vocal
intensity occur, but that the absence of the Lombard effect
may often represent a false-negative result. It appears that the
test as presently used is relatively inefficient and should be
interpreted conservatively.[67]

Pitman suggested a modification of the Lombard test using a
combination of three tests. His procedure was devised in 1943
and utilizes instrumentation common to that time. The test
combined a stethoscope test, the Lombard test, and a double con-
versation test. Pitman used a stethoscope with a Barany noise
apparatus hooked to one tube, and a bell hooked to the other
tube. Then via a switch apparatus, the speech and noise signal
were rapidly switched from one ear to the other, supposedly
bewildering the subject. The simulator hears the noise and the
spoken voice simultaneously but cannot tell to which ear each
is directed, and he will not be able to respond correctly when
asked what he hears. The rapid shift of the noise from one ear
to the other in the Lombard test causes the patient not to be
able to synchronize his tone with the rise and fall of the noise.
In the double conversation test the Barany noise apparatus is
replaced by a second stethoscope bell and again the simultaneous
conversations will confuse the simulator and their rapid changing

from one ear to the other will prevent him from making proper
responses. Pitman maintains that the test has been found to be
very valuable since the simulator cannot protect himself against
it. "The device," he said, "seems to offer a foolproof applica-
tion of the accepted means of examining this type of case."[46]

Research on the possibility of using signals other than
white noise (recorded speech, pure tones, etc.), having patients
read at a whisper level, the effect of the Lombard reflex in
relation to different patterns of loss, and the effect of de-
creased vocal intensity as a response to the Lombard test may
provide useful data in the application of this test.[4]

DELAYED AUDITORY FEEDBACK: Considerable literature has appeared
on the phenomenon of delayed auditory feedback (DAF), since it
was observed that it caused a disruption of speech under certain
conditions. The traditional approach to the delayed feedback
test utilizes the patient's own speech signals fed through ear-
phones and delayed 0.1 to 0.2 seconds. In cases of suspected
functional loss the delayed-feedback would be set at 20 to 30 dB
below his admitted threshold. If the patient's speech deteriorates
under the influence of the delayed feedback, there would be evi-
dence that he is actually hearing his own voice through the ear-
phones at a level considerably less than that of his presumed
hearing threshold. One objective test that can be made from
DAF is the rate at which the material is read under normal con-
ditions compared to the rate under delayed-feedback conditions.

The patient is given several paragraphs of material to read, and this material is read aloud two or three times while wearing the earphones, but with no delayed feedback. The time taken to read the material is recorded for each reading with a stop watch, and the average is computed. The feedback is introduced, and the patient's reading is timed at each change in the intensity level of feedback. The effect of the feedback is usually a slowing down of the rate of reading, although occasionally a patient will markedly increase his rate apparently in an attempt to 'beat' the test. In either event the rate changes. Newby suggests that delayed feedback affects a person's reading rate when it is heard at a level of 20 to 40 dB above his threshold. A recording of the test can serve as a check for future reference.[42]

Goetzinger and Proud have some variations in their DAF procedure. After obtaining the pure-tone threshold the patient is asked to read some material consisting of at least 500 syllables of easily read expository prose. The subject is then asked to read it with 60 dB re. SRT of delayed side-tone to the better ear while presenting a masking noise level of 80 dB over the normal threshold to the poorer ear, and the reading is timed. The procedure is reversed and timed again, if there is a difference of more than 10 seconds between the readings, there is a strong indication of organic deafness. When the difference between the readings is smaller than 10 seconds, a functional element is suspected. Marked changes in speech production contribute to the diagnosis.[18]

Gibbons and Boyd present the noise and delayed-feedback in the reverse order of the procedure given above, that is, the delayed sidetone is delivered to the poorer ear first with the 80 dB of masking noise going into the better ear. The reading material is only 400 syllables of equated prose. In their test, the subject is confronted with the inconsistencies of test results in an attempt to lower the PTA threshold. In agreement with Newby, and Goetzinger and Proud, Gibbons and Boyd caution that this procedure should not be employed to quantify the extent of the auditory deficit since there is no linear relationship between time measurements and the difference in organic thresholds among subjects.[14]

Tiffany and Hanley have the subject read the material three times, the first time with the earphones, but with no delayed-feedback, the second time with delayed feedback, and the third time the same as the first. Then the three scores are compared to see the differences that took place. They found that readings one and three were similar, while there was a decrease in the second reading. Also the magnitude of the differences between readings is a positive function of the intensity of the delayed-feedback. They maintain that despite efforts by sophisticated subjects to overcome the effect of delayed speech, even at levels which were reported as not distracting, the subjects were not successful in doing so.[61]

In another study, Hanley and Tiffany observed the responses of subjects to delayed feedback levels over the lower range of

intensities from 10 to 50 dB above threshold, and sought to
determine the effectiveness of subjective analysis. Recordings
were made of 100 normal hearing subjects, 50 in a control group
and 10 in five separate groups receiving delayed side tone at
10, 20, 30, 40, and 50 dB SPL respectively. The recordings were
made of two readings; one with delayed auditory feedback and one
without it, by the five experimental groups, and two recordings
were made without delayed auditory feedback by the 50 subjects
in the control group. A panel of judges was asked to determine
which recordings were made under delayed auditory feedback.
Results indicated that delayed auditory feedback has a slight
effect on reading rate with intensity as faint as 10 dB above
threshold, 20 dB gave a highly reliable decrease in the speech
rate. However, 'near perfect consistency' was not obtained
until the delayed auditory feedback was delivered 40 to 50 dB
above threshold, that is, 10 out of 10 correctly identified by
subjective judgement, and 9 out of 10 by reading rate. Their
study indicated that subjective judgements of the overall
effects of speech break-down are not better than rate measures
alone.[22]

Ruhm and Cooper have experimented with DAF and key tapping
of dot patterns. The subjects were asked to tap the key
following the pattern of four taps, pause, two taps (.... ..).
After six patterns had been tapped without DAF the apparatus
was adjusted so that the pulses of the key tapping were delayed
and delivered back to him. Each subject was tested four times

using different sensation levels in random order, -5, 0, 5, and
10 dB.. Four delay times were also used, 100, 200, 300, and 400
msec.. The -5 dB sensation level feedback did not cause any
significant change in interpattern time. At 100 msec delay, a
significant increase in interpattern time occurred at 0 dB,
5 dB and 10 dB sensation levels. Significant increases also
occurred under the 200, 300, and 400 msec delays for 5 dB and
10 dB sensation level stimuli. The sharpest increase in inter-
pattern time between two sensation levels occurred at 200 msec
delay duration between 0 dB and 5 dB sensation level. The
highest difference score under both the 5 dB and 10 dB sensa-
tion level conditions was exhibited at 200 msec delay. Delayed
auditory feedback was effective in producing a significant num-
ber of errors only at the 200 msec delay duration for 5 dB and
10 dB. The conclusion may be drawn that it is apparent that
pure-tone delayed auditory feedback is effective in causing a
measurable disruption in rhythmic motor activity when the
auditory signals are very close to, or even at, the auditory
threshold. When either interpattern time or number error is
used as the criterion measure, the error function changes quite
sharply across sensation levels. 200 msec delay might be con-
sidered optimal for use in auditory threshold extrapolation,
since it sharply differentiates tapping performance at the 5 dB
sensation level from lower levels, and it produces a significant
increase in the number of errors.[54]

A second study done by Ruhm and Cooper compared DAF
efficiency with electrodermal audiometry (EDA) and pure-tone audio-
metry (PTA). The test was done using three groups; (1) normal
hearing subjects with an artificial loss produced by acoustic
ear plugs, (2) subjects with organic loss, and (3) subjects with
functional loss. The key tapping test as recorded in Ruhm and
Cooper's first test was given to all subjects after they had
received the EDA and PTA tests. The intensity of the feedback
was increased in 6 dB steps until a change in response was
observed. At that point the intensity was decreased to the
preceding 6 dB level, and then the feedback was introduced in
ascending steps of 2 dB until change was noted. The results
indicated that there is little difference between thresholds
obtained by means of 2 dB or 6 dB steps. The EDA thresholds
agreed well with the DAF, with the largest difference only 1.4
dB. The PTA compared well with the DAF thresholds except for the
functional group, in which case a discrepency is to be desired.
Two cautions must be observed in using key tapping DAF; (1) the
examiner must always be assured that the subjects is tapping
only with his index finger since more muscle involvement in-
creases sensitivity to 25 to 40 dB more intensity in the DAF, and
(2) some patients can not repeatedly tap the pattern (.... ..)
without feedback; in such cases the tester should require a
simpler pattern.[53]

Study should be given to the effect of recruitment on DAF,
since there is some evidence that the individual with recruit-

ment reacts to speech DAF quite differently than do normal-
hearing persons. Also there is some indication that pure-tone
DAF may be effective at much lower sensation levels than speech
DAF.[54] The majority of the research on the DAF test has been
done with normal hearing subjects, so that studies using subjects
with FHL may reveal different results. Fruitful results may also
be obtained from research on the variations exhibited among
individuals in their ability to resist the effects of DAF.[4]

PSYCHOGALVANIC SKIN RESISTANCE TEST: The major objective test
of FHL has been the Psychogalvanic reflex test (PGR). This
test is also known as psychogalvanic skin resistance audiometry
(PGSR), galvanic skin resistance (GSR), electrodermal audiometry
(EDA), and as is most commonly used today, the electrodermal
response (EDR).

There is little agreement on the specific procedure to be
used in administering the EDR test. The procedure given by
O'Neill and Oyer will be given here and some of the major
modification listed afterward.

The patient is scheduled for the EDR test at the end of
the testing series. The electrodes are placed on the index
and third fingers of the subject with the pickup electrodes
being placed on the right hand and the shock electrodes on the
left hand. The fingers are cleaned and the electrodes put in
place with electrode paste. The subject rests his arms,
palms up, on the arms of the chair and is instructed to remain
as still as possible. The examiner allows a short recording of

responses before formal testing begins, so that a response base-
line can be established, and then the recording pen is adjusted
until it exhibits minimum deflection, or is recording in a
nearly straight line.[44]

A tone of 1000 Hz is presented with no shock, at a level
well above the estimated threshold. Then the tone is presented
with minimal shock. The shock is increased in gradual increments
until the subject mentions that he feels the shock, or until the
recording unit indicates a reaction to shock. The shock level
is then increased by one increment and a series of conditioning
trials is programmed. This procedure is continued until the
subject indicates a pronounced reaction to shock and tone for at
least ten presentations. There is an interval of one-half second
between tone and shock and from 15 to 20 seconds between pairs of
stimuli. After the conditioning has been established the tone
is presented alone and the hearing threshold plotted. The
conditioning will last for about four frequencies before
extinction takes place. Further conditioning will have to be
given before the second ear can be tested. The response is
recorded on a moving strip of paper and is interpreted in terms
of the particular recording system being used.[44]

Clinicians experience their major difficulty in EDR testing
in attempting to establish conditioning patterns. Differences
are found in; (1) the level of the tone presented, (2) the
interval between the tone and the shock, and the level of shock,
(3) the length of time the shock is to be on, and (4) the

number of reinforcements that should be provided. Most
clinicians start with either a 500 or 1000 Hz tone, with tonal
presentations of one to two seconds. The shock is presented
40-50% of the conditioning time. The interval between tone and
shock is about one to five seconds. The tone must be presented
so that it is clearly audible to the subject. If the subject
can hear the tone it is usually started at 70-80 dB SPL, or
higher if the subject's threshold is very poor. However, Giolas
and Epstein indicate that conditioning should be established at
an intensity that is close to expected threshold level, because
such an approach results in greater resistance to extinction.
The examiner should establish a standard reference to determine
what constitutes a significant response to the test stimuli.[15]
O'Neill and Oyer suggest at least 5 mm. and a minimum response
slope of at least 45 degrees. Others consider the sharpness of
the recorded spike response to be of major importance. The
correct placement of electrodes is not confirmed by research,
and techniques vary with clinicians and experimenters. However
the finger tips or the palm of the hand are used most often
for adults, and the soles of the feet are used for children.[44]
Portman and Portman use the electrodes on the calf of the leg
and on the foot for both adults and children. This procedure
requires that the patient be lying down for the test.[47]

The EDR test may be affected by sudden changes in tempera-
ture, and by certain kinds of drugs, including depressants and
tranquilizers, however the amount of involvement has not been

confirmed by research.[47] Chaiklin and Ventry suggest that the strongest point for the EDR test is that it identifies the functional problem and simultaneously provides valid threshold measurements. However, more recent research has pessimistic overtones for the conditioning procedure. Some experimenters suggest that 50% of the patients can not be conditioned for the EDR,[44] while the NIH-VA study indicated that 22-24% could not be conditioned for the test. Obviously the studies done on the conditioning procedure do not seem to be conclusive. Shepherd has done a series of studies to test unconditioned stimuli verses conditioned stimuli for use in the EDR test. A subject was considered 'conditioned' if he yielded three consecutive positive responses by the time ten randomly-scheduled conditioning trials were completed. If the subject failed to meet this criterion he was automatically eliminated from the study. One group was on an instrumental-avoidance schedule so that the patient could avoid the shock by pushing the button. A second group was given the traditional conditioning test. For patients with FHL there were no significant differences in the positive responses between the two procedures. The functional hearing loss group produced less random responses with the avoidance schedule than with the traditional schedule. Shepherd felt that the procedure offered the advantage of giving reinforcement for correct responses as well as punishment for incorrect responses, hence increasing the strength of the con- ditioning. The procedure also inhibits the elicitation of a

complete emotional response and thus conserves anxiety. Since
there are fewer random responses, the procedure likely fosters
greater discrimination learning than the traditional procedure.[56]

A second study by Shepherd was designed to test the signifi-
cant differences in the consistency of responses between pure-
tone thresholds and EDR thresholds. Three tests were given:
(1) the measurement of the reference pure-tone threshold, (2)
pre-test conditioning relative to the two tests employing the
conditioned EDR, and (3) the presentation of the test signals
according to the randomized schedule. None of the groups had
statistically significant differences between the three tests.
According to the results of this study, subjects with FHL are
able to make consistent loudness judgments throughout repeated
auditory measurements using pure-tones and thus reproduce
identical feigned thresholds within the normal limits of
variability of threshold measurements.[57]

Grove designed and tested an unconditioned EDR test in an
attempt to decrease the time necessary for testing, to make the
test more comprehensive, and to increase the simplicity. Verbal
directives were used instead of the shock, on the presumption
that enough tension would accompany the falsehood to emit the
skin response. At several different points in the experimental
test, the subject was told to press a button every time he
heard a tone. Supposedly the motor response will produce more
tension than a verbal response, since it is not so often used
in falsehood. The test results of the control group and the

experimental group compared favorably, with 94.1% accuracy in the control group, and 93.1% accuracy in the experimental group (unconditioned group). Nineteen of 20 role-playing students trying to 'beat the test' were detected as malingerers. Only two subjects exhibited an EDR threshold that was in excess of 10 dB above or below their true thresholds. The unconditioned test has the advantages of; (1) not being extinguished, (2) not having patients who are unconditionable, (3) being more rapid, and (4) providing both voluntary and EDR thresholds in one brief administration. This test seems to have some merit, and a duplicate of this test or a similar test would be helpful to confirm the reliability of the unconditioned test.[20]

The major disadvantages to the EDR test are; (1) the results depend entirely on the patient's ability to present the variations of resistance, (2) skin reactivity is a variable, often unstable phenomenon and depends upon emotional factors, (3) adaptation occurs and gives diminishing returns as the test progresses, (4) there must be constant vigilance to exclude extraneous stimuli which may alter the delicate balance, (5) a certain amount of ability to comprehend and cooperate are required, and (6) some patients do not give consistent responses even at intensities well above threshold.[47, 31]

Modification of EDR test: Ruhm and Carhart used a procedure involving the establishment of a conditioned discrimination of a key spondaic word presented in sequence among other spondaic

words. This was accomplished by reinforcing only the key word using shock as the unconditioned stimulus. This test was found to be within ± 4 dB of the EDR pure-tone test. It is also possible by the use of the one conditioned word to determine whether the stimuli is heard at detection level, or at speech perception level.[4]

BEKESY TYPE V TRACING: The Bekesy test for FHL was discovered by Jerger and Herer when they noticed a consistently different Bekesy pattern in three cases known to have FHL.[27] The Type V Bekesy tracing characteristically shows the interrupted tone tracing below the continuous tone tracing. Shortly after Jerger and Herer's report, Resnick and Burke described four cases that added support to the theory that a Type V tracing was indicative of FHL.[49] A year later, Peterson presented a paper also describing four cases of FHL patients who had similar Type V audiograms.[45]

Until 1963 no research had been done to determine how efficient the tracing was in detecting functional loss, what percentage of false-negative and false-positive identifications could be expected, or what effect variations such as the frequency sweep or the rate of attenuation might have on the tracing of such a pattern.

In 1963, Stein undertook a study to provide information on the frequency of occurrence of the Type V tracing, the manner and degree to which the interrupted tracing drops below the continuous tracing, and the possible existence of additional

signs of functionality in the Bekesy audiogram. An interrupted-tone ·tracing followed by a continuous-tone tracing was obtained for 100 veterans referred to the clinic for compensation or diagnostic examinations. Determination of the presence of FHL was made on the basis of a battery of FHL tests. Of the total 30 subjects with FHL, 17 (57%) recorded Type V tracings, 3 (10%) recorded Type IV tracings, and 9 (30%) recorded unclassifiable patterns. There were no false positive results traced in the Type V pattern. There was no consistency in the extent or manner to which the tracing for the interrupted tone fell below the tracing for the continuous tone. Some of the tracings showed the interrupted tone overlapping slightly with the continuous tones and some difficulty was experienced in distinguishing between Type I and Type V patterns. A clear separation of tracings rather than a specific amount of separation seemed to be more reliable in interpreting the results. Since there were no subjects without functional loss or overlay who recorded a Type V tracing, the indication seems to be that the possibility of a false-positive result is quite small. The findings failed to disclose any identifiable characteristics of the Type V pattern on which to base an estimate of the true level of hearing.[59]

Rintelmann and Carhart investigated the levels at which interrupted and continuous stimuli were traced by 12 normal hearing subjects who were asked to trace a pattern maintaining the most comfortable loudness level. In a second tracing they

were asked to maintain the recalled loudness of a 1000 Hz refer-
ence tone. The test was done on the assumption that the subject
with functional loss was attempting to maintain a given reference
loudness in tracing the Type V pattern. Theoretically, the
continuous tone is perceived as louder than an interrupted tone
in Bekesy audiometry, hence the interrupted tone traces a
poorer threshold than the continuous tone. The tracking level
for the continuous stimulus was always better (lower) than for
the interrupted stimulus presented under similar conditions.
The subjects tended to have individualized loudness criteria
which were relatively stable, and the order of presentation of
the continuous or interrupted tone had no major effect on the
discrepancy between the levels at which the two types of stimuli
were traced.[51]

Hood, Campbell and Hutton designed a test they called a
Bekesy Ascending Descending Gap Evaluation (BADGE) test. This
procedure involved a comparison of the differences between the
following 1000 Hz discrete frequency Bekesy tracing types:
(1) continuous tone with tracing begun well below threshold,
(2) pulsed tone with tracing begun well below threshold, and
(3) pulsed tone with tracing begun well above threshold. This
study was based on the consideration that the person being
tested should never be exposed to any sound louder than that
level required to obtain a response, since the loudness of the
first auditory stimulus heard by the test subject is a governing
factor in the process by which he sets up his criteria for

positive or negative responses, and because the louder the level
of the first perceived stimulus the higher will be the level at
which the positive response criteria will be set thereafter.
They also asserted that FHL will become more apparent when the
subject is alone and when the subject himself controls the
loudness and duration of the stimulus. An evaluation of the
'gaps' between the ascending and descending tracings were made
for the pulsed descending versus the pulsed-ascending curve, the
continuous-ascending versus pulsed-ascending curve, and the pulsed-
descending versus continuous-ascending curve. Investigation of
the gaps for the organic hearing loss subjects showed that the
ascending and descending tracings quickly came together and
exhibited a considerable overlap for nearly all of the tracings.
The tracings from the functional subjects showed a gap for all
three tracings that was maintained for some time, though the
gap usually tended to decrease with time. All three kinds of
gaps seemed to be equally sensitive and differentiated between
the functional and organic groups in about 70% of the cases.[25]

Watson and Voots devised an attenuator arrangement so that
the Stenger could be done with the Bekesy audiometer. The
procedure is as follows: The patient is instructed to press the
button as soon and as long as he hears the tone. Then he is asked
which ear is his better one, and the headset is placed in position
with the reference earphone over the better ear. He is purposely
led to believe that his good ear is to be tested first, and in
this way, supposedly the threshold of the test ear can be

established without the patient's knowledge. The Stenger attenuator is set with 10 dB greater attenuation on the test ear than on the reference ear. The Bekesy audiometer is set at an intensity level below the patient's threshold, and the audiometer set into operation at a test frequency of 500 Hz. After the patient's threshold on the reference ear is stabilized, the Stenger test itself is initiated by changing the variable attenuator to a setting of zero. At this level, the intensity should be equal in both channels. If there is no change in the tracing the attenuator is increased 10 dB in the test ear. This procedure is continued, using 10 dB steps, until either a threshold shift occurs or until the attenuator is 50 dB higher than the audiometer attenuator. If that point is reached without a significant threshold shift, an additional 20 dB is introduced into the reference ear. If the patient is tracing his threshold for the reference ear, then a threshold shift would immediately occur. If such a shift did not occur, then the examiner could assume that the test tone had lateralized to the test ear, and therefore the patient could not perceive the change in intensity in the reference ear. Using this arrangement, the examiner may vary the intensity of the test tone on the supposedly poor ear while the patient is tracing his Bekesy threshold on the good ear. The signal intensity increases or decreases on both ears simultaneously as the patient operates the Bekesy response key. The authors felt that the test is clinically easier to administer and interpret than the standard Stenger, and a permanent record

of the test can be obtained. No research has been done to determine the efficiency of the test.[68]

Price, Shepherd and Goldstein observed that the Type V tracing occurred more frequently at 500 Hz, and they also found that Type V occurs more often in the ear tested first.[48] Juers also observed that the Type V tracing gap occurred in the low and middle frequencies.[29]

No specific definition of the Type V tracing had been developed before 1965. There was no criterion set for the amount of separation that occurred between the continuous and interrupted tracings, the frequencies at which continuous above interrupted tracings occurred, the order in which the tests should be presented, or the quantitative or qualitative predictive value expected from such a definition. Reference had been made, and some controls initiated on these variables in the studies mentioned in this paper, however significant conclusions had not been drawn regarding the efficiency of specific criterion. Stein suggested that the tracings should be 'clearly separated'.[59] The range of frequencies in which separation occurs has been reported to extend from 200 Hz to 8000 Hz.[49, 45, 51] The order in which the Bekesy should be given in the battery of audiometric tests was briefly discussed by two researchers,[49, 45] and the test was presented first for one case in each study. In two studies the procedure was in second place,[59, 51] it was placed third in one study,[45] and fourth in another.[49]

Hopkinson designed a study predicated on the assumption that a patient cannot always determine appropriately what to

respond to or when to respond. In other words, she maintained
that the naive listener may trace a Type V pattern because they
did not understand the directions, or needed practice before
the instructions could be properly carried out. She defined the
criterion for the Type V audiogram separation as a 5 dB separa-
tion at the midpoints of the continuous above interrupted
tracings. The criterion for frequency range was a continuous
tracing above interrupted at 250, 500 Hz or higher, but not
lower than 250 Hz. The average separation at two of the three
frequencies, 500, 750, or 1000 Hz must be equal to at least
five dB. Fifty two organic, conductive loss patients were used
in the study, and 25 of them traced a Type V pattern before
surgery was done. On a retest after surgery, 14 subjects traced
Type V patterns, and eight subjects traced a Type V on both
tests. Since 48% of the patients had a Type V tracing, the
study would indicate that the continuous above interrupted
tracing occurs often among untrained listeners, and discrepancies
may occur because the requirements have not been adequately
defined.[26] These results are in contrast to Stein's observation
that no organic subject traced a Type V audiogram.[59]

In a current study, Rintelmann and Harford attempted to
establish a definition of the Type V tracing by analyzing the
audiograms of 33 subjects, having met the functional hearing
loss category by a battery of accepted tests for FHL. These
audiograms were analyzed for; (1) the magnitude of the difference
between the continuous and interrupted tracings in decibels,

and (2) the width of this difference as a function of the frequency range. Based on an inspection of the Bekesy audiograms, the separation distance was defined as a 10 dB separation of the interrupted and continuous tracings with no overlap at any point. The continuous tracing must show a lower sound pressure level than the interrupted trace for at least two octaves. The size of the maximum break in dB ranged from 15 to 102 dB, and it was concluded that at some point within the frequency range where there was a separation there must be a gap of at least 15 dB. A second part of the study was done to determine the incidence of the Type V tracing among individuals other than those with functional hearing loss. No Type V patterns were found among the normal listeners, one case (2%) from 50 conductive subjects, and four (3%) from 150 sensorineural subjects. The results from this test indicate that the Type V tracing identified functional hearing loss 75% of the time, and in the event that a Type V tracing is made the clinician can assume that the subject has not performed the task according to instructions regardless of the motives, and an accurate threshold has not been obtained.[51]

RAINVILLE TEST: The Rainville test is a technique whereby comparisons are made between the level of noise required to mask an air-conducted pure tone when the masking noise is presented via air conduction through earphones mixed with the test tone, and via a bone-conduction oscillator. An air-conduction threshold is obtained for a specific frequency. After this threshold is obtained, the pure tone is presented at this threshold level

while a masking noise is introduced into the same earphone mixed
with the pure tone. The intensity of the masking noise is
raised until it masks the pure tone, and that masking level is
written down. The noise is removed from the earphone and
presented through a bone-conduction oscillator that has been
placed on the mastoid behind the ear just tested. The tone is
still presented through the earphone. The masking in the bone
oscillator is increased until the tone is no longer heard. This
level of masking is written down. The absolute bone-conduction
threshold is determined by taking the difference between the
bone-conducted noise level and the level of the masking noise
presented through the earphone and comparing it with the level
obtained for normal subjects. The difference between the scores
is the amount of the bone-conduction hearing loss.[44]

Menzel and Davidson administered the Rainville to 150
veterans examined for compensation purposes and the results
showed that the presence of a nonorganic component consistently
resulted in significantly elevated Rainville thresholds. Also
the shift was greater for those subjects having some organic
hearing impairment than for purely nonorganic loss.[39]

SENSORINEURAL ACUITY LEVEL TEST: The Sensorineural Acuity
Level (SAL) is a modification of the Rainville test. Test
measurements are made of the air-conduction thresholds, and
then the measurements are repeated with white noise being
presented through an oscillator positioned in the center of

the forehead. The noise is presented at a fixed level (power equal to two volts across the oscillator). The SAL is computed by subtracting the shift that occurred under comparable testing conditions with normal ears.[44] Rintelmann and Harford reported that all of the FHL subjects "demonstrated an air-SAL gap compared to interweaving air-bone thresholds," and they interpreted this as evidence that the SAL produces a pure-tone Doerfler Stewart effect among patients with FHL. All of their subjects traced a Type V Bekesy pattern, and all subjects demonstrated a higher SRT than PTA. No other details were available in the published abstract of the study.[50]

Recently Rintelmann and Harford attempted to demonstrate that the SAL test is useful for the detection of functional hearing loss. A test battery was given to the subjects to determine the presence of functional loss, including pure-tone, speech, Bekesy, EDR, and SAL. All of the ten children exhibiting functional hearing loss responded to the SAL by showing a shift in hearing level from the initial test, that is, all cases had an air-SAL gap. The SAL responses elicited from four subjects were within 10 dB of the best estimate of the subject's threshold, however in no instance was the SAL the best estimate of threshold. These findings indicate that on the SAL test the individual with functional hearing loss does not perform like an individual with a pure sensori-neural hearing loss, since he does not have the 'built-in attenuation' provided by the cochlear lesion. Instead, he shows a threshold shift in

the presence of noise which is more like that of a normal ear.
If a patient shows an appreciable hearing loss by air conduction
measured in quiet and a large shift in threshold in the presence
of white noise delivered through the forehead, the air-SAL gap
is contra-indicative of a sensori-neural hearing loss. If
other audiometric tests indicate that the loss may be sensori-
neural, then the SAL should be indicative of functional loss
rather than conductive loss. The clinician also has some evi-
dence that the patient's pure-tone thresholds are at least as
good as the results indicated by SAL. In some cases the SAL also
causes the Doerfler-Stewart effect which disrupts the figurative
tone reference against which the patient gauges the sounds.[51]

LIPREADING TEST: Falconer has designed a monosyllabic, homo-
phenous word, lipreading test for the detection of functional
hearing loss. The test contains words which are nearly impossible
to perceive by lipreading alone. These words are presented both
by sound and vision, and if the patient can repeat the words he
is receiving auditory stimuli since the words can not be per-
ceived by visual stimuli alone. This test is usable only for
the patient who claims to 'get along so well because I read
lips'. An investigation of the procedure revealed that the
attenuation level should be presented in 6 dB steps until no
response is made. The first list of words is presented at
12 dB above the estimated threshold of the patient so that he
receives a high score. The following lists are presented in

decreasing 6 dB steps until the actual threshold is approached.
The SRT can be predicted at the last level at which five words
are responded to correctly. The word lists designed for this
test are available in the published report.[10]

THE VARIABLE INTENSITY PULSE COUNT METHOD: Ross has made use
of the pulse-tone to detect functional hearing loss in children.
Tonal pulses are presented both below and above the child's
admitted threshold rather than at one constant intensity level.
The child is told that he is going to receive a test of counting
ability, thus focusing the child's attention on counting rather
than hearing. A variable number of tone pulses are presented
above his admitted threshold until accurate responses are re-
peatedly obtained. When the responses are reliable, the intensity
of one of the tone pulses is reduced to 10-15 dB below his
admitted threshold, and then returned to the previous level.
If the count is still correct the child has perceived the less
intense tone pulse. The test is continued until thresholds for
the different frequencies have been established. The four
cases reported for VIPCM thresholds agreed very well with the
SRT thresholds. No further research has been done on this test
to determine the ages for which the test can be successfully
used, or variations that could make the test more useful. The
test is easy to administer, it can be done with conventional
equipment, and it is rapid enough to be used as a screening
procedure in public schools when functional loss is suspected.[52]

RAPID RANDOM LOUDNESS JUDGMENTS (RRLJ): Nagel designed a test
that was an outgrowth of the Alternate Binaural Loudness Balance
test. The RRLJ test, however, is designed to confuse the non-
cooperative patient. The patient's voluntary SRT and PTA are
established in each ear, then he is asked to report which of two
alternately presented tones is the louder. Then in rapid
succession the tones are presented, skipping variously one or
many octaves after each paired presentation, varying the ear of
initial presentation, and varying the sensation levels, but
giving equal time to each ear for each pair of tones. Each
presentation is preceded with the statement, 'This is number
one,' This is number two,' then, 'Which is louder?' It is dif-
ficult for the person with FHL to remember feigned threshold
levels with no regular progression of tone presentation. Evi-
dence of FHL is indicated by obvious confusion on the part of the
patient, or by a response to tones below his admitted threshold.[41]

MIDDLE EAR REFLEX MEASUREMENTS: Lamb and Peterson have deter-
mined the presence of FHL by the measurement of stapedius muscle
reflex activity. The basic procedure requires that a probe be
inserted into the ear in which the reflex activity is to be
observed and adjusted until an air tight seal is achieved. A
low-frequency probe tone is presented and adjustments are made
in phase and amplitude to obtain a balance between the input
tone and that reflected from the tympanic membrane. The test
signals are then introduced into the contralateral ear. As

the signals elicit a reflex, and bilateral stapedius muscle
contractions occur, the activity changes the mechanical
characteristics of the middle ear, altering the impedance that
the tympanic membrane offers to the probe tone. The resulting
changes in amplitude and phase of the reflected sound are
indicative of alterations in middle ear impedance and may be
measured. These measurements are compared with measurements for
normal hearing persons. Whenever the reflex threshold is better
than the auditory thresholds, some degree of functional loss is
present. Caution must be used in interpreting this test since
persons with sensory-neural hearing loss with recruitment also
yield reduced ranges between auditory and reflex thresholds,
however, the smallest difference between auditory and reflex
thresholds is about 10 dB. This test does not give exact infor-
mation about auditory thresholds and must be used as a qualita-
tive procedure.[34]

CONDITIONED EYELID RESPONSE: Little research has been done to
determine the usefulness of the conditioned eyelid blink response
for functional hearing loss. However, it has been used as an
objective measurement of hearing sensitivity. Galambos et. al.
attempted to establish the reliability and accuracy of the eye
blink in determining hearing thresholds. They used a click to
elicit an eyeblink response, and this was recorded by a rather
complex instrument, similar to the electroencephalograph.
Clicks were delivered in a more or less random manner from one

to five seconds apart. Approximately 100 signals were given for each intensity, and the trace examined on the recorder. All subjects responded to the stimulus with a response that was easily observable on an oscilloscope. The intensity of the click had to remain about 60 dB above hearing level before it elicited the eye blink, and it had to remain from 90 to 100 dB above threshold to elicit a response 50% of the time. These measurements do not permit a reliable index of the absolute threshold, however, in cases of FHL, if clicks of 50 dB or above produce a relatively large percentage of eyeblinks, the threshold should be nearly normal.[13]

Further research on a conditioned eyelid response was done by Galloway and Butler. The eyeblink was conditioned with a bright light. A conditioning trial consisted of presenting a pure tone of 450 msec duration followed immediately by a flash of light. Fifty eyelid conditioning trials were given daily for three consecutive days. A response was considered conditioned when the eyelid movement had a latency of 20 msec shorter than the shortest unconditioned latency of response. Most of the thresholds obtained by this conditioning technique were higher than those measured by other audiometric tests. This may be due to the fact that actual threshold intensities are not responded to unless the subject is attending to the task of listening. Perhaps the greatest advantage of this test is the precision with which the conditioned eyelid response can be defined. It has a conditioning advantage over the EDR test in

that the unconditioned stimulus is in no way noxious to the subject. The main disadvantages include the rather elaborate equipment necessary to measure the eyeblink response, the length of time necessary for conditioning, and the fact that some patients can not be conditioned. As an FHL test, the conditioning may be affected by attitudinal factors. This test can be 'beat', for example, by the patient simply refusing to open his eyes, or by his deliberately closing his eyes from time to time.[13]

MASKING TEST: Hood has proposed a masking test for unilateral functional hearing loss. This test is based on a principle similar to the Stenger procedure. Insert receivers for the narrow band masking noise are used to eliminate the difficulty of cross stimulation, thus enabling the use of masking noise intensities up to 80 dB above the contralateral threshold. The patient's threshold is determined first for pure tone at 1000 Hz delivered by a loudspeaker, and then with a narrow band noise centered at 1000 Hz. Because of the insert blocking the external ear canal, the intensity of the tone from the loudspeaker will be about 40 dB higher than without the insert. The masking noise intensity is then increased in steps of 20 dB and at each step the masked threshold of the pure tone is found. Assuming there is a one-to-one relationship between the levels of the masking noise and the masked pure tone threshold, the pure tone threshold should also rise by 20 dB. This parallel increase is

described by Hood as a shadowing effect, and it will "follow a
course which is predictable within very narrow limits." In the
subject with FHL, the masking noise will not create a one-to-one
increase in the threshold of the pure-tone. This test has the
advantages of having very clear-cut responses, using conventional
audiometric equipment, and indicating the presence of organic loss
with functional over-lay.[24] No formal research has been done on
this test; the above procedure was used only in random application
to a few clients. There is no indication of the kind of environ-
ment in which the tests were done, or the kind of equipment used.

SHIFTING (SWINGING) VOICE TEST: This test is designed to detect
unilateral functional hearing loss, but it may also be used in
cases of bilateral hearing loss. A two channel audiometer is
necessary for this test to enable the examiner to switch test
material from one ear to the other. Questions are asked the
subject, with one part of the question being delivered to the
good ear and the other part of the question to the bad ear. If
the subject can answer the question, there is indication that
the signal was heard in the bad ear. The level of the channel
for the poorer ear can be increased until such a response is
gained, and this will then give an approximation of the actual
loss for the poorer ear.[44, 47] Newby suggests that the examiner
should be talking informally to the patient, asking questions
and giving instructions while shifting the audiometer. Occasion-
ally a spondee can be inserted which the patient is asked to

repeat, and to indicate in which ear he heard the word. The test
is started with the intensity level slightly above the admitted
threshold in the better ear and slightly below the threshold
in the poorer ear. Pressure is kept on the patient to make
immediate response to the spondee words or to the questions
so that he does not consider in which ear the signal is heard or
at what intensity level. The intensity of the signal is inde-
pendently varied in each ear, with the object of confusing the
patient so that he 'gives himself away.'[42] Goetzinger and Proud
suggest that the examiner can tell the patient a story with the
signal being switched from one ear to the other. The patient is
then questioned on the content of the passage.[18] There has been
no research demonstrating the effectiveness of this test, and it
has the disadvantage of putting pressure on the patient and
depends on the patient's confusion. It does not give a threshold
measurement, but it is an indication of functional loss.

ELECTROENCEPHALOGRAPH AUDIOMETRY (EEG): EEG audiometry is a
relatively new innovation. Very little has been done in the
way of research on its use as an FHL test. Patterns associated
with auditory stimulation do not seem to provide consistent
threshold measures, and, in many instances, are difficult to
detect even when the auditory signal is relatively intense.[13]
It appears that auditory stimulation does produce some rather
characteristic electrical activity, however it has not been
proven that these changes give direct evidence that hearing
exists when these changes take place. The EEG test requires

interpretation by a specialist skilled in auditory changes in
the brain waves, as well as elaborate equipment. A study by
Norkus, reported by O'Neill and Oyer, was directed toward the
factor of frequency as a measure with the EEG. It was deter-
mined that the pattern of EEG for sleeping subjects changes in
response to pure tones, and there is evidence that a decrease
in frequency occurs after a delay of less than one-half second
after tonal onset. Norkus also determined that tonal intensity
is a factor that is of importance, for as the tonal intensity
is increased the frequency shift becomes greater.[43] Since EEG
audiometry is an objective test, the technique holds promise of
being effective in the evaluation of functional hearing loss.

TUNING FORK TESTS:

Weber test - The test for FHL is a modification of the Weber
fork test, and it is one of the oldest reported tests. The
patient is directed to plug the affected ear with his finger and
the sounding tuning fork is applied to the median line of the
skull. The subject who is malingering will (is supposed to)
say that he hears the sound in the unplugged ear since it seems
illogical that the sound should be louder in the poor ear. How-
ever, in cases of normal hearing, and in cases in which conduc-
tive loss has not been found, the tone will be perceived as
louder in the poor ear. The examiner must have prior information
as to whether there is a loss of hearing and which is the
poorer ear.[44]

Rinne test - This test can be used to indicate FHL if the patient has indicated a greater air conduction loss than bone conduction loss. A 'dead' fork is placed on the mastoid behind the poorer ear, while a live fork is moved toward the ear canal. If the intensity of the fork does not exceed the previously determined air-conduction threshold and the subject indicates that he hears the sound, then he is malingering. The major indications of functional hearing loss are inconsistencies between the Weber and Rinne tuning fork tests.[44]

Erhard test - The patient plugs his bad ear and a pocket watch is brought toward his normal ear and the subject is asked to count the ticks. The good ear is then plugged and the watch brought toward the bad ear. If the patient says that he does not hear the watch tick, then he is feigning a loss since he should be able to hear it (via the good ear) when it is two feet away from the bad ear.[44]

Marx test - The Marx test is done by placing a Barany buzzer in the good ear and informing the patient that his good ear is being tested. Then he is asked if he can hear the sound, if he answers the question he is malingering since he has masking noise in the better ear, and therefore must have heard the question in the supposedly deaf ear.[44]

The tuning fork tests have the disadvantages of not being standardized, not giving any indication of true threshold measurements, and of varying from examiner to examiner. As

previously reported under the section on the Eye, Ear, Nose and Throat examination, the tuning fork tests are not reliable indicators of functional hearing loss, but they seem to have some diagnostic value when there are discrepencies between the tuning fork tests.

CHAPTER III

SUMMARY AND CONCLUSIONS

Summary: Material has been presented concerning the importance
of reliable and valid tests for the detection of functional
hearing loss in both a military and civilian population. Since
functional hearing loss is becoming more common, and its detec-
tion necessary, this paper has attempted to summarize the
available commonly used tests for functional hearing loss. It is
designed not only to report test procedures, but to summarize
current literature and research in their attempts to establish
reliability and validity of these tests.

The tests are presented, beginning with observation of
behavior in the general clinical evaluation. Other subjective
tests include the ear, nose and throat examination, pure-tone
audiometry, and speech audiometry, Stenger test, Doerfler-Stewart
test, Lombard Test, delayed auditory feedback test, Bekesy Type V
audiogram, Rainville test, sensori-neural acuity level test,
lipreading test, variable intensity pulse count test, rapid
random loudness judgments, middle ear reflex measurements,
masking tests, shifting voice test, and tuning fork tests. The
objective tests include the psychogalvanic skin resistance test,
conditioned eyelid response, delayed auditory feedback, and
electroencephalographic audiometry.

The likelihood of a correct diagnosis increases significantly
when a number of tests are employed. Research has shown that
some tests are more reliable and valid than others, while

some tests have not yet been researched to establish validity and reliability. Areas for further research are indicated.

Conclusions: It was found that no single test was completely satisfactory in detecting functional hearing loss. Even using those tests that are the most reliable, it is difficult to assess the amount of true loss. Some tests are useful only in the detection of unilateral functional loss, others are useful only in the detection of bilateral functional hearing loss, while some tests can be used for either kind of loss. A categorization of these tests is given in the appendix.

An analysis of the subjective tests for functional hearing loss reveals that pure-tone and speech functional hearing loss tests are probably the most effective in detecting patients with functional hearing loss. The pure-tone test-retest procedure identifies about 66% of the functional hearing loss subjects, and in combination with the speech reception threshold, it identifies about 85% of the functional hearing loss subjects. Using the four tests; speech reception threshold, pure-tone audiometry, absence of false alarms, and the spondee error response index, approximately 85% of the functional hearing loss subjects are identified. The delayed auditory test is another reliable single test that is nearly 100% effective, provided the intensity levels are 40-50 dB hearing level, and both reading rate and speech deterioration are used in the evaluation. The Bekesy type V audiogram also has been known to identify as many as 75% of the patients with functional

hearing loss. The research has demonstrated that other subjective tests do not identify more than 40-60% of the functional hearing loss subjects.

The objective tests are not highly reliable either, and they have the disadvantages of requiring expensive and elaborate equipment as well as being difficult to administer and comprehend. They are also quite time consuming. The electrodermal response test is probably the most reliable, since it detects 93-94% of the functional hearing loss subjects, and determines the true threshold, simultaneously.

If an examiner makes use of several tests that may be available to him, he will usually be able to diagnose functional hearing loss, if it is present. Perhaps the most pressing need in regard to tests for functional hearing loss is a test that can be given with standard audiometric equipment, or with comparatively inexpensive modifications of standard equipment. It should not only determine the presence of functional hearing loss, but the true threshold as well. Testing for functional hearing loss is now a tedious task for both the examiner and the patient, and apparently will continue to be so until newer methods are devised.

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Appendix

The following is a categorization of the tests for functional hearing loss into bilateral, unilateral, or combination bilateral-unilateral tests. This is not a rigid classification, but the tests are listed as they are often used.

Unilateral Tests:

1. Inappropriate lateralization
2. Bone-conduction audiometry
3. Stenger test
4. Masking test
5. Shifting voice test
6. Tuning fork tests
7. Middle ear reflex measurement

Bilateral Tests:

1. Doerfler-Stewart
2. Lipreading test
3. Behavioral characteristics

Combination Bilateral-Unilateral Tests:

1. Errors during measurement of spondee threshold
2. Delayed auditory feedback
3. Variable intensity pulse count method
4. Rapid random loudness judgments
5. Sensori-neural acuity level tests
6. Rainville test
7. Eyelid response
8. Electrodermal audiometry
9. Ear, nose and throat examination
10. Pure-tone audiometry
11. Saucer-shaped audiogram
12. False-alarm response during pure-tone audiometry
13. Speech discrimination
14. Speech reception-pure-tone discrepancy
15. Lombard test
16. Bekesy type V tracing
17. Electroencephalograph audiometry

CURRENT AUDIOMETRIC TESTS FOR THE
DETECTION OF FUNCTIONAL HEARING LOSS

by

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B. A., Union College, 1965

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