

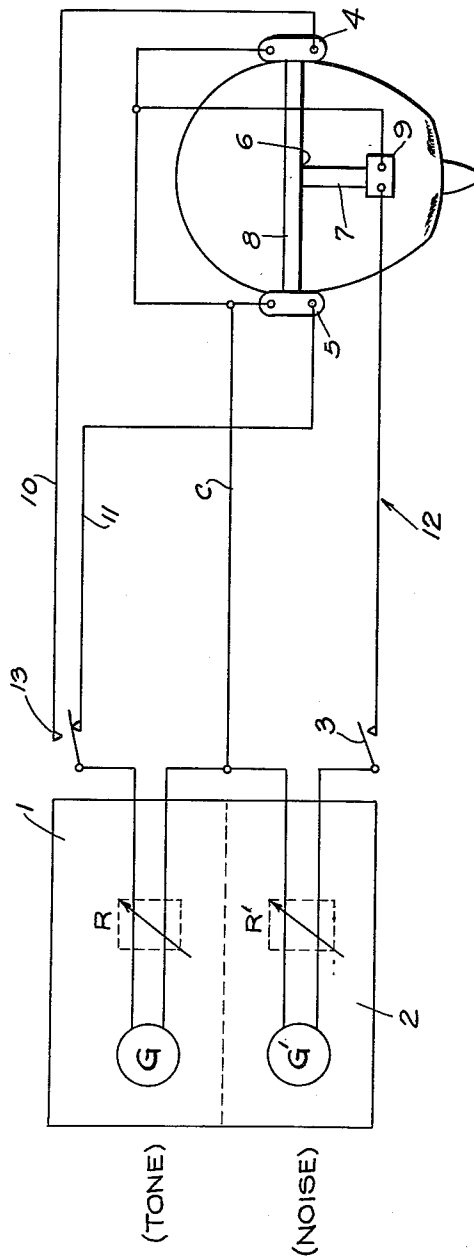
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METHOD FOR TESTING HEARING ACUITY

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1

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METHOD FOR TESTING HEARING ACUITY
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This invention relates to methods for testing human hearing acuity, and particularly for securing relatively precision results for the use of, for example, doctors and surgeons for diagnostic or prescriptive purposes, or both.

The primary objects of this invention are to provide a new and improved method for effecting relatively precise and dependable hearing tests of the foregoing character by direct, expeditious, or time-saving, operations.

Heretofore, methods have been employed for testing the hearing acuity of human ears, and the results of these tests have been recorded and have been used in diagnosing the patient's hearing condition and in prescribing both medical and surgical treatments, or corrections, as may seem desirable, including the prescription of compensatorily designed or adjusted hearing aid apparatus for those patients neither desiring nor requiring other treatment. Members of the medical profession, of course, may, and often do, correlate the noted test results with such other exploratory techniques and observations as may be at their command, including X-ray techniques and direct visual inspection of the ear parts and associated organic structure. From a consideration of the test results in combination with information obtained from the noted techniques, an experienced medical practitioner is placed in a position to exercise his best judgment in deciding what corrective procedure or procedures he should prescribe or recommend.

Nevertheless, the known methods of direct testing of the hearing acuity of patients are open to the drawbacks that they tend to be both time-consuming and relatively unreliable. For example, one known method is to apply an air-conducted tone signal of predetermined frequency, as a test signal, to either selected ear of a patient, and of such intensity that the patient is able to hear the tone signal (at least to some extent) under normal or quiet conditions, and then to supply a bone-conduction masking noise signal to the ears of the patient and to progressively increase the masking-signal intensity until the patient indicates by any prearranged signal that the testing tone is no longer heard, in that it has then become completely masked. A masking noise is sometimes called "white" noise in that it is preferably composed of a deliberate jumble of sounds covering substantially the entire frequency range normally assignable to the human ear and at a rather uniform sound level throughout that range. This method is open to the drawback that much time is consumed in obtaining reliable results, in that many different intensities of test signal have to be used to enable a full diagnosis to be made, and each such intensity requires masking by a separate value of masking noise.

In one known form of the above known methods, the noted bone-conduction masking noise for either selected ear is applied to the bone structure adjacent to that ear by a bone-conduction type of electrically actuated sound generator, or transducer, and is commonly accomplished through the mastoid bone of the skull by way of its skin and flesh covering at a maximum-sensitivity location determined between the tester and the patient. A drawback peculiar to this form of the method is that the point of maximum effective bone conduction to the hearing structure of the patient may vary greatly from patient to patient, thereby correspondingly lessening the value of comparisons of the results for any patient with a normal

2

"standard." A related drawback is that, since the masking noise is applied through the mastoid bones separately for each of the two ears of the patient, strict reliance on a direct ear-to-ear comparison of the results obtained is not justified. There is no reasonable assurance that the bone structure around one ear receives substantially the same intensity of masking noise as that received by the bone structure around the other ear. Proponents of this method commonly depend on a comparison between (1) a quiet threshold wherein the air-conducted tone signal is applied by ear phones, (2) an air-conduction noise threshold wherein the noise signal is applied through the same earphones, and (3) a bone-conduction threshold with the noise signal applied to the mastoid bone as above noted.

According to the invention, the foregoing and other drawbacks of known methods of testing the hearing acuity of a patient are overcome by two method features, comprising (1) applying an air-conducted tone-signal of a selected frequency to the two ears separately, preferably beginning (for either ear) at an initial low intensity which is increased gradually until the patient first signals that he can just hear it, and comprising (2) making a similar threshold-ascertaining step for the air-conducted signal while a fixed-intensity bone-conducted masking signal is applied to the skull by any desired or suitable technique. Preferably the bone-conducted masking signal is applied to the skull of the patient to reach both ears about equally, preferably at a location along a plane equi-distant from both ears, particularly at about the middle of the forehead.

The foregoing simplified method is based on a study showing that the basic causes of a more or less deafened patient's hearing difficulties may best be diagnosed when the physician is informed quantitatively of the patient's ordinary air-conducted acuity and is informed quantitatively of his hearing acuity at the cochlea, wherein the auditory nerve ends. The foregoing simplified method, among other things, permits the sensori-neural loss (loss between the auditory canal and the auditory nerve) to be estimated with some accuracy and permits the condition of the endings of the auditory nerve in the cochlea to be estimated with a related accuracy.

The foregoing simplified method comprehends the use of charts prepared from tests according to the recited steps thereof showing the shift patterns (between quiet air-conduction threshold and bone-conducted white-noise threshold for air-conducted tones) for a large number of persons of normal hearing and a large number of persons with the several known abnormalities of hearing.

Further according to the invention, a headset structure is provided which may be supported by the head of the patient to support, in the proper location, tone-signal air conduction transducers for the respective ears and a noise-signal bone-conduction transducer for the selected location along the median line of the patient's skull, thereby facilitating the testing operation and contributing to obtaining uniform and reliable test results within a relatively short time interval.

The above mentioned and other objects and features of this invention and the manner of obtaining them will be best understood by reference to the following description of the invention, taken in conjunction with the accompanying drawing, which schematically illustrates apparatus according to the structural aspect of the invention as well as apparatus useful in carrying out the method aspect of the invention.

In the drawing, 1 and 2 may comprise separate sections of a container for respective signal sources, which may be housed in separate containers if desired. Each section contains an electrical source or generator G, G'

3

of available construction and a calibrated regulator R, R' through which the sound-intensity equivalent of its output, as applied to the ear canal or to the bone-structure of the patient by the associated transducers or transducer, is visible to the test operator, as by the reading of a voltmeter calibrated for sound or energy intensity or by a known dial-and-pointer calibrated-scale arrangement.

Generator G of section 1 is a tone-signal generator. Its regulator R preferably further includes means for regulating the frequency in successive steps (four, for example) over a wide or selected portion of the ear-response frequency range. Section 1 may thus comprise a commercially available standard clinical audiometer.

Generator G' of section 2 comprises the previously noted white-noise, or masking, generator. Such a generator may sometimes be termed a thermal noise generator since such generators commonly use, in amplified form, the "thermal noise" characteristic of a vacuum tube. Regulator R' of section 2 is expected to be seldom used to raise and lower the output with respect to a given noise level, since ideally a single "standard" intensity of masking noise should be used for all tests for ready comparison purposes. However, that regulator may be used to reduce the noted standard masking-noise level to a predetermined related lower level for some sensitive patients, or to raise it to a predetermined related higher level for some very nearly deaf or insensitive patients without departing from the invention.

Items 4 to 9 comprise the previously indicated headset structure. It includes a head band 8, to which transducers 4 and 5 are attached (comprising earphones actuable from the signal or tone generator G of section 1), and an extension 7 which supports bone-conduction transducer 9, which is electrically excited by the noise generator of section 2, and which is preferably located at about the middle of the forehead of the patient when the structure 4 to 9 is in testing position. The transducer 9 may be of any usual or desired inertia or bone-conduction type, being the contact type which usually employs a massive internal member which tends to remain stationary while the outer casing itself tends to partake of a major portion of the electrically supplied vibratory energy. The head band 8 and the extension arm 7 are joined at 6, and may be constructed in any usual or desired manner, but are preferably of such construction that the acoustical interaction between transducers 4, 5, and 9 by way of the interconnecting members 7 and 8 is maintained at a minimum or negligible level. Items 4 and 5 may be sponge-rubber padded telephone receivers of any desired type, preferably of the type which has a nearly flat response curve over the frequency range important in good hearing, such as from 300 to 3000 cycles per second. The transducer 9 also preferably has a similar flat-response characteristic within the important part of the hearing range of frequencies.

The electrical circuitry over which the transducers 4, 5, and 9 are energized as desired includes common conductor C, and includes individual conductors 10 and 11 for transducers 4 and 5 and individual conductor 12 for transducer 9. Switch 3 controls the connection over conductor 12 to transducer 9, while switch 13 applies energizing current selectively to earphones 5 and 4 according to whether it is in its illustrated position or is in its alternate position. Conductors C and 10 to 12 may conveniently comprise separate conductors in the same flexible cord extending from structure 1, 2 to the transducers, and switches 3 and 13 may be mounted as a portion of structure in sections 1 and 2, or may be included as cord-attached apparatus, as preferred.

Testing procedure according to the invention may be as follows:

(1) First, with both generators G, G' not operating or effectively disconnected from the headset apparatus, the headset which holds transducers 4, 5, and 9, is so placed on the patient's head that both ears are covered

4

by the transducers 4 and 5 while the transducer 9 is positioned on the patient's forehead at about 1 to 1½ inches above the eyebrows.

(2) Second, the apparatus in section 1 is turned on or adjusted at R of section 1 to supply a predetermined test frequency within the hearing range of a sub-audible intensity, and the tone signal therefrom (which reaches transducers 4 or 5 as chosen at switch 13) is increased slowly at R of section 1 in successive increments until the tone signal becomes audible to the patient through the ear under test. This intensity is recorded as the unmasked hearing threshold for the specific signal frequency for that ear, following which a similar test and record is made for the other ear, or may be deferred until the succeeding method steps are taken for the initial ear, as preferred.

The thresholds for several predetermined unmasked signal frequencies in the desired range (as 300, 900, 1800, and 2700 cycles per second, or frequencies of 250, 500, 1000, 2000, and 4000) may be similarly obtained and recorded for each ear.

(3) Third, a white-noise signal of the noted fixed intensity (loud-noise level) is supplied from generator G' of section 2, and through switch 3, to bone-conduction transducer 9, which supplies a corresponding level of white noise to the skull of the patient to reach the bone structure at the respective ears with substantially equal intensity. A calculated noise level within the skull structure on the order of 40 decibels above the standard threshold has been found to be satisfactory.

This white (masking) noise so decreases the effective acuity of the patient's ears that the threshold values previously obtained for either ear do not apply while the masking noise is present.

(4) The fourth and final testing step is to gradually increase the sound intensity of the tone signal from section 1, for either ear to be tested and at each desired tone-signal frequency, until the tone signal again becomes just barely audible, which intensity is recorded for that ear and frequency as the masked hearing threshold for that ear and frequency. As noted, only one ear may be selected for test initially, following which the essential test steps are taken for the other ear, or the unmasked test may be completed for both ears, if desired, before the masked test is performed for either. In either event, the full test use of the method comprises the making of both the masked and unmasked tests for each of the ears and the recording of the results thereof.

The recorded unmasked thresholds may now be compared with each other as to frequency and ear-to-ear variation, and a similar comparison may be made within the recorded masked thresholds. Finally, the masked and unmasked thresholds may be compared as desired, thus providing the basis for a logical analysis of the patient's condition to be made by a skilled practitioner, who may or may not be the person who makes the herein described tests.

While it is generally preferred that the foregoing four steps taken in the order listed, good results may be obtained if the second recited step is deferred until after the recited fourth step. That is, the masked thresholds for the respective ears and for the desired frequencies for each ear may be obtained and recorded before the unmasked thresholds are obtained and recorded, but the patient reaction may be found to be such that more accurate overall results are obtained when the steps are taken in the order recited.

A practical advantage of the described increasing-signal aspect of the method, which applies to obtaining any recited hearing-threshold reading, is that the patient can signal the threshold value to the tester when the threshold region is reached by an increase in the test-tone intensity (from apparatus of section 1) rather than when the threshold region is reached by reducing test-tone intensity from a level well above audibility. Addi-

5

tionally, it has been found that best results are obtained when the patient is instructed to signal visually to the tester, as by moving a hand, a finger, or the like when he first barely hears the tone signal. It may, of course, be advisable under certain circumstances for the tester to precede the testing steps by holding the headset apparatus a foot or two away from the patient's ears and applying the test-tone signal frequencies through one or the other of the transducers 4, 5 until the patient hears and recognizes the tone frequencies to be employed for test. This preliminary step, when employed, is of course merely to insure that the patient will recognize a test-tone signal upon barely hearing it during the testing operation as hereinbefore described.

It will be understood that the noted intensity of masking noise, or signal, is that of a loud noise which tends to mask or cover up any and all noises ordinarily present within the quarters suitable for tests of the within character. It will be understood, of course, that the variation, for a given ear and a given frequency, between the unmasked threshold and the masked threshold is expected to be on the order of the sound intensity of the masking noise for a normal ear and to be different for an abnormal ear according to the source and extent of the abnormality.

It has been found that the threshold shift produced by a fixed intensity of masking noise is relatively low at the lower frequencies and noticeably increases with frequency, at least to a certain point in a selected frequency range. Accordingly, those test purposes which require rather uniform threshold shift over the last noted frequency range as related to normal-ear response, may be fulfilled by including a compensating filter (within, or suitably associated with, generator G of section 2) which gives a relatively large masking noise intensity at the lower frequency ranges and a compensatorily decreasing level for high frequency ranges. Such filter means form no part of the instant invention and are therefore not illustrated herein.

It will be understood, of course, that the method herein disclosed of applying the test signal from section 1 to the auditory canals of the ears under test is preferred primarily because of the obvious selectivity of this method with respect to the two ears of the patient. If that selectivity is not desired, the tone signal may be applied to the surrounding air generally (as by the conventional so-called loudspeaker). The disclosed method, of course, has the advantage that a tester who may spend a considerable time testing patients selectivity is spared from hearing test-tone signals to any considerable extent. Similar considerations apply to the selection of the bone-conduction transducer to supply the desired volume of masking noise to the patient's skull. A noise of similar intensity applied through the air to the ears of the patient would be so loud as to be very obnoxious to the tester himself where several patients are being tested in succession, as well as tending to penetrate the walls of the enclosure to be a source of complaint from persons in surrounding offices, for example.

While I have described above the principles of my invention in connection with specific method, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of my invention.

I claim:

1. The method of testing a person for sensori-neural hearing loss by the degree to which air-conducted tones are masked by white noise delivered by bone conduction directly to the cochlea of the ear under test which comprises:

delivering air-conducted pure tones to the ear under test and increasing the intensity of each said tone to threshold level;

delivering white noise of fixed intensity to the skull by bone-conduction at a point midway between the ears of said person;

6

then increasing the intensity of each said pure tone to threshold level in the presence of said white noise; and indicating the intensities of each said pure tone.

2. The method of testing a person for sensori-neural hearing loss by the degree to which air-conducted tones are masked by white noise delivered by bone conduction directly to the cochlea of the ear under test, which comprises:

delivering air-conducted pure tones to the ear under test at the threshold intensity level of each said tone and imposing white noise of fixed intensity to the skull via a bone conduction pathway through a point midway between the ears of said person to shift the threshold intensity level of each identical air-conducted pure tone.

3. The method of testing the character and extent of the impairment of a deafened person's hearing which comprises:

delivering the quiet threshold intensity of at least one air-conducted pure tone to the ear under test by varying the intensity of said tone until the said tone is just heard by the person and

shifting the said pure tone threshold intensity by applying bone-conducted white noise at a medial point between the ears of said person.

4. The method of testing the hearing of a patient, which comprises applying a test tone signal by air conduction to at least one ear of the patient during a relatively quiet interval and also during a relatively noisy interval, varying the intensity of the test tone signal during each said interval until response of the patient indicates that the threshold intensity of the test tone signal is reached, and producing the said noisy interval for the patient by applying masking noise to the cochlea of his said one ear by way of a bone-conduction path through a point midway between the ears of the patient.

5. The method of claim 4, wherein the said step of varying the test-signal intensity during either said interval comprises increasing the intensity from a sub-threshold value until its threshold value is indicated by response of the patient.

6. The method of testing hearing acuity of a patient, which comprises applying a bone-conduction masking noise signal to the skull of the patient at a location such that it reaches both ears about equally, at the same time applying an air-conducted test signal to an ear of the patient, and varying the intensity of at least one said signal until response of the patient indicates that the threshold value of the air conducted test tone signal is reached in the presence of the bone-conducted masking noise signal.

7. A method according to claim 6, wherein the said noise signal is maintained at a fixed relatively high masking intensity while the test signal is varied in increments of intensity until the patient indicates threshold value.

8. A method according to claim 6, wherein the said threshold value is determined for each of a plurality of air-conducted test-signal frequencies dispersed over the nominal hearing range, air-conducted threshold determinations are made separately with and without the said masking noise signal, and air-conducted threshold determinations are made separately for the respective ears of the patient.

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