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THE PERCENTAGE REGISTRATION OF THE SENSITIVENESS OF THE CONDUCTIVE APPARATUS OF THE EAR TO RESONANT IMPULSES OF MINIMUM INTENSITY.

By A. D. STEWART, M.B.,
Aural Surgeon to the Glasgow Public Dispensary.

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Deafness occurs (1), when the transmission of resonant impulses by the several parts of the conductive apparatus of the ear is prevented or impeded; (2), when the resonant impulses, being transmitted, fail to excite a sensation of sound, or its perception, from defects in the nervous apparatus. In the examination of a case in which more or less deafness is the prominent symptom, the first object must therefore be to determine to what extent, if any, the conductive portion of the auditory apparatus is responsible for the existing deafness.

The sensitiveness of the conductive apparatus, in virtue of which that apparatus is influenced by, and transmits resonant impulses of low intensity, is strictly proportional to the inertia of the mass of the apparatus; so that, if the inertia be increased by changes which have taken place in and around the conductive apparatus, the consequent loss of sensitiveness will be indicated by the proportionate rise in the intensity required. Hence, by means of the *minimum intensity* of sound required to overcome the inertia, the sensitiveness of the conductive apparatus may be ascertained, and the amount of any loss thereof determined by comparing the minimum intensity found to be necessary, with that required when the sensitiveness is normal. Since the intensity of sound varies, according to the well known physical law, inversely as the square of the distance from the sonorous body, the maximum distance at which a sound affects the conductive apparatus necessarily depends on the intensity being, at that distance, the minimum capable of overcoming the inertia; consequently, distance, by reason of the intensity which it represents, may be employed, like the intensity itself, to determine the sensitiveness, and is, indeed, the method in actual use for this purpose.* The maximum distance for a given sound, when the sensitiveness of the conductive apparatus is unimpaired, is termed the *normal distance;* while, for the sake of distinction, the maximum distance in the case of a patient, may be termed the *patient's distance.* As the object of the investigation is to ascertain the relation of the sensitiveness of the conductive apparatus of the patient to the normal, it is immaterial whether the numbers employed to demonstrate this denote distance or intensity.

The investigation of the sensitiveness of the conductive apparatus is best carried out by periodic impulses of sound, which are valuable for this purpose by reason of their intensity alone, pitch and quality of sound being here of no importance. Hitherto, the chief objection to the use of the tick of a watch—the sound usually employed—has been the fact that hardly two watches emit, at the same distance, sounds of equal intensity; so that, even when similar results are obtained by several observers, the present method of registration prevents this relation among the results from being recognized—a state of matters exactly paralleled by the confusion which would attend the use of thermometers, each graduated to a scale of its own. The objection is, however, easily overcome by the usual method for the correction of inaccuracies in scientific instruments, by which absolutely uniform results are obtained from a series of instruments, no one of which is in itself accurate. A real or assumed standard for comparison is, of course, essential; in the present instance, an *assumed standard distance* will be employed for the correction of the distances obtained by the use of any watch-sound, and, as already explained, may be virtually regarded as a numerical expression of the standard (*i. e.*, the normal) sensitiveness. Any distance may be arbitrarily assumed as the standard, and will give good results, but no number has seemed to me so thoroughly fitted for this purpose as 100, because it enables the percentage system of expressing

* The closest analogy exists between this method and the use of Snellen's types in the examination of the optical part of the organ of sight.

results to be made use of, the advantages of which are now so well known, and so thoroughly appreciated. The normal sensitiveness of the conductive apparatus, which is the real standard, I propose, therefore, to represent by the *equivalent*, 100 per cent, and variations from the normal, by corresponding percentage equivalents.

In the practical application of this system, it is first necessary to find the normal distance for the sound of the watch to be employed. With the assistance of a few friends, whose ears are normally sensitive to sound, the normal distance is readily determined by measuring the distance from the ear to that point beyond which no sensation of sound can be excited. The circumstances under which the normal distance is determined, must be approximated as closely as possible to those under which it will most frequently be used. If the patient's distance is usually found during the day, amid the noise of the city, the normal distance must be determined under similar surroundings. Having found the normal distance, the next step is to find the patient's distance, which is determined in a precisely similar manner to the normal distance.

From these two data—the normal and the patient's distance—the percentage equivalent for the sensitiveness represented by the latter can be calculated. When the observations are only occasional, nothing more than a sum in simple proportion is required; for example, let the normal distance for the sound of a watch be 56 inches, and let the patient's distance, determined with the same watch sound, be 24 inches, required the percentage equivalent for the sensitiveness represented thereby.

$$\text{As } 56 : 24 :: 100 : x$$

where $x = 42{\cdot}85$. The sensitiveness of the conductive apparatus to resonant impulses would, therefore, be represented in this case as 42·85 per cent, and the loss 57·15 per cent.

When numerous observations are regularly taken, it is more convenient to construct a table for every watch used, showing, at a glance, the percentage equivalent corresponding to the patient's distance. In the proportional statement above, the first and third terms are constants, for that particular watch-sound, so that if the third term be divided by the first, the quotient, multiplied by the variable second term, yields precisely the same result as in the ordinary proportional method above. This coefficient when applied to the distances obtained by the use of a watch-sound, becomes the *coefficient of correction* for all distances possible with that sound, because by means of it, the results are corrected for the assumed standard distance. The construction of those tables is facilitated, therefore, by employing in the calculation the coefficient of correction instead of the ordinary proportional method. The rules may be summarised as follows :—

(1.) The *quotient* obtained from the division of the standard distance (100 inches) by the normal distance is the coefficient of correction.
(2.) The product of the multiplication of the coefficient of correction and the patient's distance is the corresponding percentage equivalent.

Thus, in the example previously employed, if 100 be divided by 56, the quotient, 1·7857, becomes the coefficient of correction for all distances obtained by the use of that watch-sound, and if this number be multiplied by 24, the patient's distance given, the result is 42·85 per cent as before.

In proceeding to construct a table of percentage equivalents for the distances obtained by the use of a watch-sound, the number of inches attainable is set down in sequence in one column of the table, and, in another column, opposite each number in the first, the corresponding percentage equivalent.

As a considerable number of calculations are required in constructing these tables, the liability to error is much diminished, and the arithmetical work lightened by the use of logarithms instead of simple numbers. The rules for the use of logarithms in these calculations are as follows :—

(1.) The *difference* between the logs. of the standard and the normal distances, is the log. of the coefficient of correction.
(2.) The *sum* of the logs. of the coefficient of correction and the patient's distance, is the log. of the corresponding percentage equivalent.

Using the same example as before, the full working-out by this method is as follows :—

Log. 100 (standard distance),	=	2·0000
Log. 56 (normal distance),	=	1·7482
Log. of coefficient of correction,	=	·2518
Log. 24 (patient's distance),	=	1·3802
Log. of percentage equivalent,	=	1·6320

The antilogarithm of which is 42·85 per cent.

Once the coefficient of correction for any watch-sound, or its logarithm, is known, only the 2nd rule in each method is required. The following table is partially constructed in illustration of the foregoing description:—

WATCH, No. 1.

Normal distance,	=	56 inches.
Coefficient of correction,	=	1·7857 or
Log. of do. do.,	=	·2518.

Patient's Distance.	Percentage Equivalent.
$\frac{1}{2}$	·89
1	1·78
2	3·57
3	5·35
...	...
56	100·00

As soon as the patient's distance is determined, a reference to the table at once shows the corresponding percentage equivalent. The signs already in use to denote the fact that the sound is only audible on contact $(+c)$, or not on contact $(-c)$, on pressure $(+p)$, or not on pressure $(-p)$, may be employed in reporting cases, to supplement the table, noting at the same time the normal distance of the watch used, thus $\frac{+p}{56}$

Now that the proposed system of registration, and method for obtaining uniform results from a series of ordinary watches has been fully explained, a comparison between it and the system of registration at present in use may be here conveniently introduced. For the purpose of rendering the contrast conspicuous, suppose that three separate observers examine, each with his own watch, the right ear of a patient, with a view to determine the sensitiveness of the conductive apparatus, and that their results when found, appear as follows, stated in inches:—

(1.) $\frac{24}{56}$ (2.) $\frac{261}{609}$ (3.) $\frac{135}{315}$

These fractions may be taken as examples of the present system of illustrating the relation of the sensitiveness of the conductive apparatus of the patient to that of the normal, the denominator of each fraction being the normal distance, and the numerator the patient's distance. If these results, instead of being considered finite, were regarded as readings obtained from inaccurate instruments, and therefore requiring correction before being published, the principal objection to the fractional system, as a method of recording a scientific fact, would then be removed. Taking the three results reported above, and correcting them for the proposed standard, the following is the result:—

$$\left.\begin{array}{c}\frac{24}{56}\\[2ex]\frac{261}{609}\\[2ex]\frac{135}{315}\end{array}\right\}\text{ are each } = 42{\cdot}85 \text{ per cent.*}$$

In conclusion, I have only a few words to say on the selection of the most suitable normal distances for the investigation of the different degrees of deafness, a subject of considerable practical importance. Undoubtedly, any sound, no matter what its normal distance is, may be used, but not equally well in all cases. As long as the patient's distance is infinitely small, relatively to the normal distance employed, a sound of long normal distance is better adapted for the investigation of the case than one of short normal distance, since the patient's distance, although infinitely small in each case relatively to the normal distance, is, in the former, absolutely large enough

* The calculations by the various methods are appended for the last two examples, the first having been already given in full.

(2.)	609	:	261	: :	100	:	42·85
(3.)	315	:	135	: :	100	:	42·85

(2.)	100	÷	609	=	0·1642	×	261	=	42·85
(3.)	100	÷	315	=	0·31746	×	135	=	42·85

(2.)	Log. 100 (standard distance),	=	2·0000
	Log. 609 (normal distance),	=	2·7846
	Log. of coefficient of correction,	=	$\bar{1}$·2154
	Log. 261 (patient's distance),	=	2·4166
	Log. of percentage equivalent,	=	1·6320

the antilogarithm of which is 42·85 per cent.

(3.)	Log. 100 (standard distance),	=	2·0000
	Log. 315 (normal distance),	=	2·4983
	Log. of coefficient of correction,	=	$\bar{1}$·5017
	Log. 135 (patient's distance),	=	2·1303
	Log. of percentage equivalent,	=	1·6320

the antilogarithm of which is 42·85 per cent.

—being seldom less than several inches—to render the determination comparatively easy. On the other hand, when the patient's distance is large, in relation to the normal distance employed, a sound of short normal distance is better adapted for the investigation of the case than one of long normal distance, since the patient's distance, being then confined within readily accessible limits, is rapidly and easily determined. In the progress of a case, when the relation of the patient's distance to the normal passes from the first into the second phase, the sound of long normal distance first employed should give place to that of short normal distance, for the reason assigned. In the investigation of cases of great deafness, therefore, a watch sound having a normal distance of about 50 feet should be employed, and one of about 5 feet, for moderate or slight deafness. As soon as the patient's distance reaches 10 feet with the first watch, its use should be discontinued in favour of the second, with which the examination is to be continued until the sensitiveness is normal. The substitution occasions no interruption in the percentage registration, $\frac{10}{50}$ and $\frac{1}{5}$ being each equal to 20 per cent.

For general purposes a watch sound having a normal distance of about 20 feet will be found most suitable. The recently invented *Hörmesser* of Politzer may be admirably adapted for the investigation of cases of great deafness, but the extreme length of its normal distance (50 feet, less 7 inches), precludes its employment in other degrees of deafness. The watches used should be furnished with a "stop," by means of which the sound may be interrupted at pleasure, without the patient's knowledge; the same result, however, may be less perfectly attained, by reversing the hand which holds the watch, so that the hand is interposed between the watch and the ear of the patient.

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