Huygens Institute - Royal Netherlands Academy of Arts and Sciences (KNAW)

Citation:

H. Zwaardemaker, On hearing apparatus examined after Lord Rayleigh's mode of arrangement, in: KNAW, Proceedings, 16 I, 1913, Amsterdam, 1913, pp. 492-498

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Physiology. — "*On hearing-apparatus examined after Lord* RAYLEIGH*'s mode of arrangement.*" By Prof. H. ZWAARDEMAKER.

(Communicated in the meeting of September 27, 1913).

In an earlier publication [1]) we were guided by the principle that, before endeavouring to find a fitting apparatus for a diseased organ of hearing, we should first of all examine its auditory range in the zone a_1 to e_3. The apparatus has to supply the deficiency of the organ. The experimental part of our previous researches was performed with a microphone (in camera plumbica [2])) and a string-galvanometer. Lord RAYLEIGH's mode of arrangement is unquestionably a better method.

§ 1. *Non-resonating arrangement.*

ZERNOV placed Lord RAYLEIGH's small mirror [3]) obliquely to the sound-wave and encircled it by a gauze screen. In this way all resonance is prevented; however, the sensitiveness is relatively small. That was why I took an afferent tube of the dimensions of the auditory canal and drew up before it a funnel, whose tone of resonance lies beyond the speechzone and whose mouth corresponds in width with the auricle. Hereby resonance is excluded, except such as the human ear is always subject to. The place where the measuring mirror is suspended corresponds to that of the tympanic membrane, with this difference that in the case of stationary waves, there is always a node on the membrane and a loop on the mirror, for the former is strongly damped by the auditory ossicles, whereas the latter is damped only by the air [4]).

The width of the artificial auditory canal is 6 mm., the diameter of the mirror, used in the experiment, is 4 mm. It is placed at an angle of 45° immediately in front of the canal. To keep off the streams of air a small plug of cotton-wool is put in the afferent tube. The stopped wooden pipes, sounded with maximum power without causing a deflection or an anomalous vacillation, yield the following results as registered at 1 m's distance in the camera silenta (mirror completely stationary; absence of resonance; the wall of the

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[1]) "On hearing-apparatus" Nederl. Tijdschr. v. Geneesk. 1912. II. p. 1101.

[2]) "Eine Camera plumbica für Mikrophone". Zeitschr. für biol. Technik. Bd. II. S. 340.

[3]) ZERNOV used a magnet to ensure a constant position of rest. I adopted a simpler method by applying a flat Wollaston fibre. (See these Procs. XVI p. 195.

[4]) VIOLLE, Acoustique, 1892, p. 108.

room thickly padded with horsehair): a_1 3 (5), ais_1 5, b_1 1 (3), c_2 1 (5), cis_2 2 (3), d_2 1 (2), dis_2 1, e_2 1, f_2 1, fis_2 1, g_2 3 (2), gis_2 $2^1/_2$ (1), a_2 4 (2), ais_2 3 (2), b_2 2, c_3 2, cis_3 1, d_3 1, dis_3 1 (2), e_3 4 (6) [1]).

The procedure is quite simple. At a distance of 1 m. the organ pipe is sounded twice, tone for tone, once with the hearing apparatus, another time with the comparison-funnel. The reinforcement is expressed in the ratios of both numbers.

§ 2. *Hearing-apparatus with selection, without the aid of foreign energy.*

In the publication alluded to above, an endeavour was made to classify hearing apparatus as follows: 1. contrivances substituting a deficient conducting apparatus, 2. apparatus bringing the sound generator nearer to the listener, 3. apparatus affording an enlarged receiving capacity, 4. apparatus reinforcing a certain group of tones, 5. apparatus reinforcing through foreign energy.

For shortness sake only the last two groups are discussed in the present paper.

Most of the ear-trumpets used by deaf people belong to the apparatus mentioned sub 4. In them the reinforcement is occasioned not only by selection, but also by the widening of the receiving surface and by shortening the distance from the speaker. This is a peculiar feature of GUYE's apparatus, which is largely used in our country. Tested by Lord RAYLEIGH's mode of arrangement it yields the following results, illustrating the reinforcement of every single tone: (see table 494).

The most reliable of these determinations is the one in the first column. With the old method the results were liable to be misleading in virtue of undue selection of certain tones. With our method this is out of the question, there being no other resonance than that which is always present in the human ear itself (meatus, auricle).

The specimen of GUYE's apparatus that we examined this time, reinforces the discant of the speechzone; the one investigated in 1912, acted similarly upon the bass as we found by electric measurement. An improved specimen of modern type (copper spiral along the border of the inner receiver, the inside of the latter being covered with velvet) also intensifies the discant more than the bass. It appears that the new models are discant-intensifiers and that their influence is distributed evenly over a wide range. To make assurance double sure, I subjoin the results of a measurement in the camera silenta, i.e. free from all room-resonance.

[1]) The figures in brackets apply for determinations made in another room.

. GUYE's hearing-apparatus New model of large size (receiving funnel 191 cm²).

Table showing how many times the sound is reinforced as compared with a receiving funnel of about the width of the auricle (21 cm²).

	Free from resonance. In a common room.	Insertion of an oblique membrane of Japanese rice-papier.	With the aid of microphone and string-galvanometer compared with a circular aperture of 1 cm. diameter.
e_3	8	1	25
dis_3	19	9	49
d_3	50	29	36
cis_3	60	14	25
c_3	30	11	4
b_2	35	11	2
ais_2	22	20	2
a_2	18	40	2
gis_2	20	27	2
g_2	30	20	16
fis_2	20	23	9
f_2	5	4	9
e_2	5	9	49
dis_2	5	1	12
d_2	3	33	9
cis_2	2	9	1
c_2	2	4	2
b_1	3	5	1
ais_1	8	6	1
a_1	10	3	1

In theory it is especially the average that exceeds considerably the amount of reinforcement generated by enlargement of the receiver. To all appearance this is due to the distribution of the energy and to the peculiar faculty of the resonator to attract sound. This phenomenon is most distinct when we choose hearing-apparatus whose receiver has the width of the comparison-funnel i.e. the width of the auricle.

GUYE's hearing apparatus tested in the camera silenta (its reinforcement compared with a funnel whose width is nine times smaller).

e_3 10	fis_2 62
dis_3 19	f_2 **65**
d_3 21	e_2 20
cis_3 6	dis_2 2
c_3 **30**	d_2 2
b_2 34	cis_2 5
ais_2 13	c_2 2
a_2 14	b_1 6
gis_2 18	ais_1 4
g_2 29	a_1 4

average 18

N.B. Considering the size of the receiver of GUYE's apparatus we could have looked only for a ninefold reinforcement. The actual reinforcement, however, is eighteenfold. This is accounted for partly by the shorter distance from the sound-generator to the measuring apparatus, to a great extent it is attributable also to resonance.

Reinforcing influence of German hearing-apparatus (pleophone n°. 2). The receiver has the same width as the comparison funnel. (21 cm²).

Measurement in an ordinary room.

e_1 1	fis_2 6
dis_1 1	f_2 **18**
d_3 5	e_2 13
cis_3 9	dis_2 10
c_3 **33**	d_2 4
b_2 25	cis_2 3
ais_2 2	c_2 5
a_2 1	b_1 3
gis_2 2	ais_1 2
g_2 **10**	a_1 3

N.B. Average reinforcement 7.8 times. However, not nearly so regular as in GUYE's apparatus.

Less conspicuous, but still very distinct is the resonance reinforcement with a number of hearing apparatus I examined some time ago by means of microphone and string-galvanometer and which I have now measured again by Lord RAYLEIGH's mode of arrangement.

Reinforcing influence of German apparatus, compared with that of a control-funnel of 21 cm².

(Measurement in the camera silenta).

	Pleophone N⁰. 3 (receiver 28 cm².)	Cornet	Continophone (width = control-funnel)	Rex (receiver 34 cm².)	Ideal-Taschen
e_3	1	1	1	1	1
dis_3	2	2	1	1	1
d_3	1	1	2	1	1
cis_3	1	1	1	2	1
c_3	1	2	1	5	3
b_2	3	3	1	10	4
ais_2	5	3	1	16	1
a_2	9	2	3	15	3
gis_2	16	1	5	9	3
g_2	8	6	7	5	13
fis_2	3	5	2	1	37
f_2	1	2	3	1	1
e_2	1	1	4	1	1
dis_2	2	10	1	1	1
d_2	4	70	3	6	1
cis_2	8	70	5	13	2
c_2	15	40	18	31	2
b_1	17	2	27	7	1
ais_1	13	2	14 5	5	
a_1	17	5	10 3	3	?
Average	6.4	11.4	5.5	6.7	4

It is remarkable that two maxima of resonance occur in all these apparatus. I suppose there is still a third, very low or very high, and therefore lying beyond the lower or the upper limit of the speechzone. If this is the case it would fall in with the fact that such an apparatus is always composed of two resonating cavities, which invariably yield three maxima, as I pointed out elsewhere [1]).

As stated before the same apparatus was tested in 1912 with the aid of microphone and string-galvanometer. The reinforcements then detected were of the same order and the resonance-maxima were generally found at the same points (only Ideal-Taschen showed considerable deviation). The common average of electric measurements I found to be 14; of non-resonance measurements 10 in an ordinary room and 7 in the camera silenta.

As to uniformity the reinforcement is far from satisfactory, because the amount of damping of these resonators must not be excessive, of course: considerable damping would destroy the reinforcing faculty.

§ 3. *Hearing-apparatus with foreign energy.*

The average reinforcement produced by resonating hearing-apparatus cannot be strong even without any damping. For a strong intensification electric energy is required. The sound is made to impact on the microphone, which is in circuit with the telephone; hereby the electric energy is converted into acoustic energy. The gain thus effected is sometimes so great, that by potent damping we are enabled to expand the resonance of the membrane, which we have to take to boot.

Thus in a perfect way we readily obtain the average reinforcement of GUYE's apparatus. The following table shows the results of a comparison with the usual control-receiver, whose width is precisely equal to that of the ordinary microphone of aural surgery. The width of the opera-aurophone is $2^1/_2$ times as great, because a funnel is placed before the microphone.

Far more striking results can be obtained. Then, however, a noise of "boiling" often reveals itself in the microphone, which is immediately associated with too extensive amplitudes of the sound-vibrations at the highest resonance of microphone- and telophone-membranes, in tune with each other. During the measurement this disturbance expresses itself in a restless to- and fromotion of the mirror. As yet no damping contrivance has been devised to overcome this disorder.

[1]) "Multiple resonance" Ned. Tijds. v. Geneesk. 1913 II p. 647. When tryng to detect the 3rd maximum in the pleophone I found it lying rather beyond e_3.

Reinforcement of electric apparatus, determined in non-resonant arrangement.

	Megalophone of FLATAU	Opera-aurophone
e_3	35	100
dis_3	35	50
d_3	25	60
cis_3	25	75
c_3	25	100
b_2	25	150
ais_2	15	156
a_2	1	140
gis_2	15	40
g_2	10	165
fis_2	2	110
f_2	7	80
e_2	10	140
dis_2	17	120
d_2	13	120
cis_2	16	34
c_2	25	24
b_1	18	30
ais_1	13	70
a_1	11	23
Average:	17.5	80

Together with the so-called accessory noises (crackling) it materially limits the use of the electric hearing-apparatus.