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Physiology. — “*The Camera silentu*”) of the *Physiological Laboratory at Utrecht*”. By Prof. H. ZWAARDEMAKER.

(Communicated in the meeting of February 26, 1910.)

The extension of the means of communication calls forth nearly everywhere to a higher or lower degree the disadvantages connected with the continual presence of noise. Therefore we want in many instances apartments free from sound, and that at first in those cases in which the continuous existence of disturbing sounds forms an insuperable impediment. Such cases present themselves:

a. in acoustic experiments when the observations have to take place in the proximity of the minimum perceptible;

b. in public consulting rooms for diseases in the ear where through the coming and going of patients the required silence never reigns, and more frequent visits render every minute investigation well nigh impossible, consequently cause also uncertainty of diagnosis, of advice and of decision in case of examination;

c. in modernly built hospitals, which with their smooth walls, naked floors, construction of stone and iron, etc. show a kind of strong resonance, and which, through their many technical ‘institutions’ can never be quiet; the consequence is the impracticableness of a really efficient percussive and auscultatory examination.

Since 1904 a camera silenta ($2.28 \times 2.28 \times 2.20$ M.) has been used for the purpose mentioned under *a* in the Physiological Laboratory at Utrecht¹⁾ and also since that time my advice has repeatedly been asked in the building of new laboratories, polyclinics and hospitals in this country and elsewhere. In connection with this I venture here to pronounce the conviction that an apartment free from sound, intended for one of the three above mentioned purposes, will have to satisfy three conditions in order to preclude disappointment. These conditions are:

1. The inner surface of the apartment has to be covered with

¹⁾ Silentus, adj. occurring in GELLIIUS, in a fragment from LAEVIUS used by “loca”, is, on account of its shortness, preferable to silentiosus.

²⁾ Ned. Tijdschr. v. Geneesk. 1905, Part I, p. 571. Zeitschr. f. Ohrenheilk. Bd. 54, p. 247.

a material that does not reverberate sound; for if this is neglected, not only the involuntary sounds that are made by us, will have a disturbing influence, but we shall also be hindered by the small remainder of sound that might still be left on account of incompleteness in the construction; the resonance of the space that is shut off will itself seize definite parts of the small quantity of noise that arises or penetrates into it and make them audible in a higher degree.

2. The isolation must be brought about by a double wall, with interstices of air of such a trifling thickness that resonance of audible tones is quite out of the question and moreover no other contact is left between the two walls than of a few narrow lead-contacts.

3. The isolation of the outer wall of the building and of its bottom has to be as complete as possible: the first isolation has to take place through a purposely constructed secondary apartment.

The first condition is fulfilled in our laboratory by means of a covering of horsehair some centimeters thick (*trichopièse*), as it is used in telephone-cells. Thanks are due to Dr. BILTRIS of Gent for making me acquainted with this material, which, moreover, procures an excellent isolation of sound.

The second condition is satisfied at Utrecht by making use, in fastening the *trichopièse*, of a wall of porous stone and by constructing outside it a second wall, consisting of corkstone of German manufacture. Plates of peatmoss from Klazienaveen in the province of Drente would have answered the purpose even better.

The third condition requires the exclusive use of lead-contacts. Especially the bottom has to be well provided for. At Utrecht faults have been made in this respect, which could only partly be made up for by the subsequent addition of an extra-covering.

Taking the above-named chief conditions for granted, we shall have to answer the question, whether an apartment free from sound will have to be constructed underground, on a level with the ground or on a higher floor. My answer is decidedly on a higher floor, for the conduction of the sound coming from the bottom is the obstacle which it is most difficult to overcome. An efficient isolation of the bottom can much more easily be brought about on a higher floor than on a foundation. In the first case the only thing one has to do is to provide lead-contacts with the stone beams, which in their turn are not directly connected with the bottom, whilst in the second case, under the most favourable circumstances, short columns con-

sisting of many strata can be made use of, which, however, have a constant direct communication with the ground.

As to the different tones, the most difficult thing appears to be to keep away the low tones. Inaudible vibrations of very slow periodicity are even not at all excluded in our camera silenta, so that a sensitive microphone, conducted to a gold-thread string-galvanometer does not appear to subside, not even when at a complete adaptation of the organ of hearing not a trace of sound is to be observed. (This does not disturb acoustically, but a somewhat faster periodicity would have been a hindrance).

Besides an apartment free from sound ought to have porous walls, for if perfectly impermeable walls are chosen, it will appear that in case of long experiments a ventilation is necessary, which in its turn would require the supply of ventilation-channels, consequently of sound-leaks. For double-door and double-window (the latter in my opinion hygienically indispensable) as a matter of course apparatus are wanted which require much care and a lasting control. When acoustic experiments are made, the supply of sound should come from sound-sources placed outside the apartment, right through a leaden stopper, that the principle that the two walls of the double wall should have none but a lead-contact, is not discounted ¹⁾. Electric light, telephone, supply of air for organ-pipes and sirens through a narrow leaden tube and the necessary conducting-wire to the galvanometer offer no technical difficulties.

An accidental additional advantage of an acoustic apartment with a double wall, double door and double window, duly separated from the outer-walls of the building by means of by-apartments, is this, that it forms a calorimeter. The camera silenta at Utrecht remains without an inhabitant of a constant temperature to within 2 decigrades. By covering the trichopiëse-walls with some meters of extremely fine brasswire (0,1 mm.), a bolometer may be made with a Wheatstone bridge and galvanometer placed in a by-apartment, by which bolometer the rise of temperature that the space undergoes through an inhabitant, may be measured. The production of heat which this causes is determined empirically (D'ARSONVAL). As a respiration-calorimeter, however, the sound-free apartment is not to be used. This is impossible because the walls are porous, and if this is given up, it is no longer free from sound for longer experiments.

A number of investigations may take place in the camera silenta.

¹⁾ The leaden stoppers are 5 cm. thick and possess a central bore, at its narrowest point being 0.4 cm. wide; comp. Onderz. Physiol. Lab. Utrecht (5) VI. p. 138.

Those which have been made in the last six years, are, it is true, not so numerous and extensive as I should wish, but an enumeration with a list of the publications may follow here in order to serve as an example of what is to be reached in a sound-free apartment.

1. The sensation of stillness may be experimented on; unless a perforation of the tympanum exists, a kind of buzzing may be observed, in which at a closer analysis a soft rustling as of the wind in the tops of the trees, accompanied by a high-toned whistling ($\pm g^a$) may be distinguished; persons in whom this physiological ear-buzzing is indistinct, perceive a feeling of oppression¹).

2. The influence of the adaptation may be traced; then appears among others a gradual diminution of the physiological tinnitus aurium, which after a 3 hours' stay in the sound-free apartment has entirely disappeared (BORTOLOTTI), whilst at the same time the feeling of oppression, if existing, gradually increases (MINKEMA); from this one might be inclined to derive that the physiological ear-buzzing, entirely or partly, possesses the character of an after-image²).

3. The phenomenon of accommodation, discovered by HENSEN, may be more closely studied, by conveying to a person standing outside the camera silenta through bone-conduction the tone of a tuning-fork, which then from the person's ear is conducted into the apartment through an auditory tube; whenever a metronome placed outside the apartment is ticking, the sample-person accommodates and the observer bears a strengthened sound (QUIX).

4. From the shortest exposition-time the smallest observable number of sound-vibrations may be derived in the tone of a tuning-fork or that of an organ, conducted to it from the outside; according to BODE this number seems to vary in the scale in a typical manner (DE GROOT³) and VAN MENS).

¹) For my ear the physiological ear-buzzing can be suppressed: *a.* by the ticking of a watch; *b.* by the sound of a tuning-fork of the *c'*-pitch and a sound-force of 68.10^{-3} Erg. per cm^2 and per sec. (Erg. d. Physiol. 1905 p. 452).

²) According to BORTOLOTTI the buzzing returns directly, after one has left the camera for a moment and then returns.

³) II. DE GROOT, Ztschr. f. Sinnesphysiol. Bd. 44 p. 18 and Onderz. Physiol. Lab. (5) X p. 137.

5. The minimum perceptible during the unity of time may be fixed by the scale (MINKEMA ¹⁾).

6. The limit of distinction may be traced and the typical variation it undergoes in the scale (DEENIK ²⁾).

7. The sensation of a report, observed by HENSEN at a sudden intonation or interruption of siren-tones, may be demonstrated in tones of different origin and pitch, with the aid of a sudden opening or closing of a telephone-contact or a sudden opening or closing of a particularly constructed lead cock.

8. The spreading of the sound round a tuning-fork with the situation of the well-known interference-planes may be accurately traced, without making the mistakes that must necessarily arise in apartments with echoing walls.

9. The action of the winding mollusc-shells as to their resonance for buzzes may be proved directly.

10. The sound-extinguishing action of different means of isolation may be traced with perfect security; for reports by dropping steel balls on a steel plate ³⁾ (fall-phonometer of ЗОТН), for tones by electrically touching purely tuned bells; in both cases the instrument put in a small non-resonant space; the walls of this space are covered with the materials that are to be examined, and, on the one side the energy with which the bells are touched, and on the other the distance at which the sound is heard, is defined; the completest isolation with an equal thickness of the walls is got in the case of trichopièse, then follows the peatmoss-plate from Klazienaveen, then the corkstone; other materials that we examined had a considerably smaller sound-extinction.

¹⁾ H. F. MINKEMA, Onderz. Physiol. Lab. (b) VI. p. 134.

²⁾ Meeting of this Academy 3 Nov. 1905.

³⁾ In order to prevent resonance the steel plate has to be soldered upon a heavy piece of lead.