THE TURNING TEST WITH SMALL REGULABLE STIMULI

IV. THE CUPULOGRAM OBTAINED BY SUBJECTIVE ANGLE ESTIMATION

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As has been explained in some previous papers (van Egmond, Groen and Jongkees, Hulk and Jongkees, Groen and Jongkees) it is possible by administering a number of rotatory stimuli of various strengths to obtain a diagram which gives a good impression on the function of the semicircular canal system in its total physiological sphere. To make such a diagram it is possible to make use of the duration of both after-nystagmus and after-sensation (nystagmus cupulogram and sensation cupulogram) at the turning test, after subliminal acceleration at the beginning and abrupt stopping at the end.

There is another method at our disposal to obtain an impression on the function of the cupula in a very short time by using a very subjective technique. However, this method asks too much of the introspective observation of the examined subject to be usable for all patients. If, however, the patient is able to give us the information which we need, we get a very fine check on the curve obtained in the normal way. The point in this instance is to follow exactly the subjective angular velocity during the after-sensation. In this way we learn the sensation at every situation of the stimulation quantitatively. Essentially we get in a continuous line those data which we try to obtain point by point in cupulometria.

The test is performed in the following way : The subject is subjected to a known stimulation. A rotatory sensation (after-sensation) is caused and the patient gets the impression of turning round with a definite angular velocity. We ask him to indicate when he believes to have been rotated 360°, 180° or 90° as far as possible, until he stops. He indicates this last point also. We also determine his threshold for angular impulses in the normal way (*loc. cit.*) and with those two experiments it is possible to build up the whole cupulogram. Let us for instance suppose that a subject has been subjected to the influence of an impulse of 60°/sec.

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After three seconds he has the impression of having covered 180°. The average velocity is 60°/sec. at $1\frac{1}{2}$ seconds after the stopping. The next 180° need 5 seconds to be passed. The average velocity is 36°/sec. at $5\frac{1}{2}$ sec. (3 + 5/2 sec.). The next 90° are covered in his mind in 10 seconds ; average velocity 9°/sec. at 13 sec. (3 + 5 + 10/2 sec.). After 22 seconds he has lost every rotatory sensation. His threshold for angular impulses appears to be at 2·5°/sec. This is the velocity reached at 22 seconds. An illustration of this case is given in Figure 1. Also the normal sensation cupulogram of the same subject is given there.

Two things are striking here. In the first place that the course of the diagram obtained by the subjective estimation of the angular velocity is completely parallel with the sensation cupulogram, and secondly that the absolute value of the subjective estimation at extrapolation towards t = 0, that means to the moment on which the stimulus is given, balances very well with the real magnitude of the given stimulus. Mostly this subjective measuring is a little too high (up to about 50 per cent.).

The formula for the deviation of the cupula is given by Groen on the basis of mechanical considerations regarding the laws of oscillation (see Figures 3A and 3B).

Approximately :

$$x = C\frac{\Theta}{P}\left(e^{-\frac{D}{P}t} - e^{-\frac{P}{\Theta}t}\right)$$

Hence

$$t = \frac{P}{D}\ln\frac{\Theta C}{Px}$$

$$\frac{D}{P} = \frac{1}{10}\ \text{sec.}^{-1}\ \text{approx.} \qquad \frac{P}{\Theta} = 10\ \text{sec.}^{-1}\ \text{approx.}$$

and

$$\frac{D}{\Theta} = 1\ \text{sec.}^{-2}$$

Here C indicates a certain stimulus in °/sec. The deviation of the cupula x causes a certain subjective angular velocity, which is measured. The declining of the subjective angular velocity is the same as the declining of x with t.

The magnitudes of $\frac{P}{\Theta}$ and $\frac{D}{\Theta}$ are found as an average value of a number of normal subjects (van Egmond, Jongkees and Groen*).

We therefore may conclude that the subjective sensation of our subjects is able to give us (though indirectly) some quantitative data on the magnitude of the rotatory stimulus administered to that patient. Figure 2 shows us a number of such cupulograms based on the subjective valuation of the covered angle with the normal sensation cupulogram of

* P = frictional torque at unit angular velocity. Θ = moment of inertia. D = directive force per unit angle.

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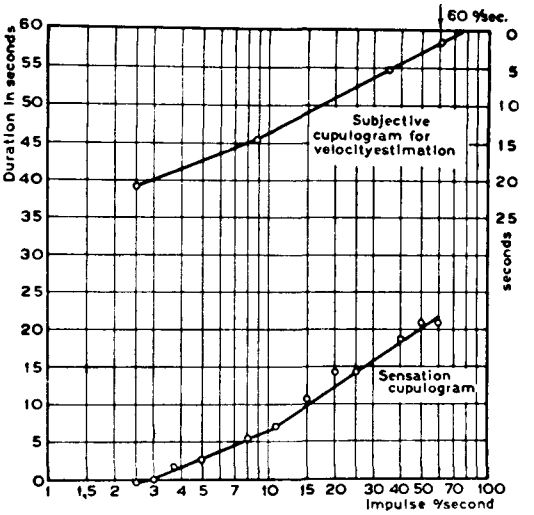


FIG. 1.

A cupulogram taken in the normal way as compared with a cupulogram obtained by the subjective estimation of the covered angle during the after-sensation after the turning test.

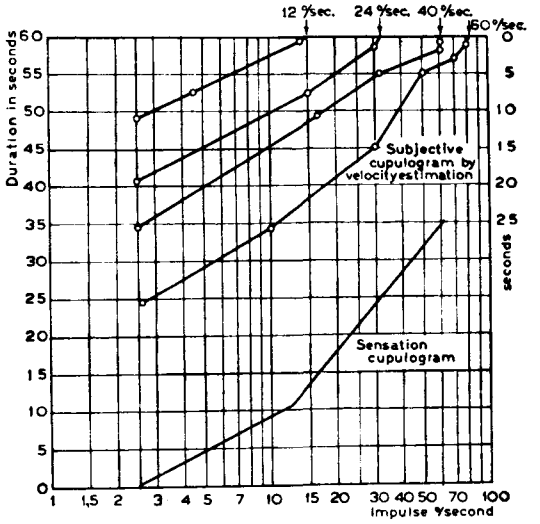


FIG. 2.

In one person the sensation cupulogram (lower curve) and the subjective cupulogram by angular velocity estimation are compared. The stimulus used to take the subjective cupulogram and its strength are indicated by an arrow at the zero point of the diagram.

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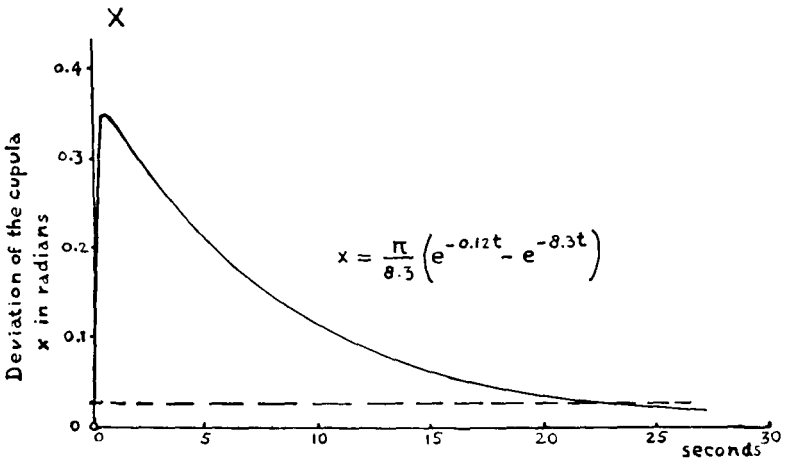


FIG. 3A.

The deviation of the cupula (ordinate, linear scale) after an impulse of π radians (180°) per second is plotted as a function of time (abscissa). The dotted line indicates the threshold of rotatory sensation. The graph is constructed on the base of a theoretical formula, with the average values found in normal subjects (see text).

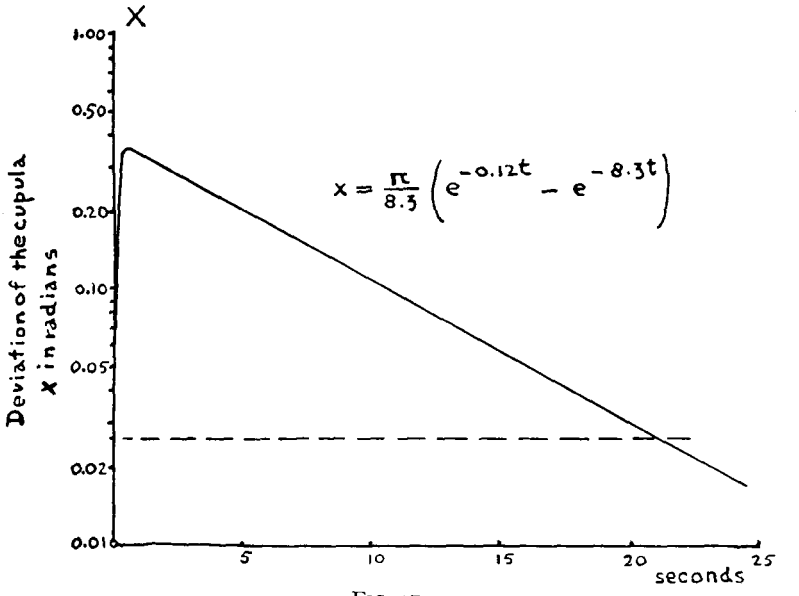


FIG. 3B.

The same as Fig. 3A with a logarithmic scale in the ordinate. The curve of 3A becomes a straight line, cf. the subjective cupulogram. To compare the ordinates of the subjective cupulogram (Figs. 1 and 2) and the theoretical cupula deviation (Figs. 3A and 3B) it must be kept in mind that they are proportional, i.e. a cupula deflexion of $\frac{\pi}{8.3}$ rad. causes a subjective angular velocity of π rad./sec. Thus the factor of proportionality is $\frac{1}{8.3}$

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the same subject underneath. The deviation from the straight line, which we sometimes find in the sensation cupulograms of normal people, return in the same way in this subjective cupulogram and likewise differences in the curves for turning clockwise and anti-clockwise. The quantitative nature at extrapolation (with the above-mentioned restriction) is also very clear.

Summary

By making a subject estimate the subjective angular velocity during the after-sensation after the turning test, it is possible to obtain a fluent cupulogram which not merely resembles even in particularities the normal sensation cupulogram, taken discontinuously, but also appears to determine with satisfactory certainty the magnitude of the stimulating impulse. For clinical use this method is not often serviceable. In those cases in which it is possible to take this diagram, it is an easy and quick check on the sensation cupulogram.

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