Physiology. — "*Concerning Vestibular Eye-reflexes.*" By Mr. A. DE KLEYN and Mr. W. STORM VAN LEEUWEN. I. "*On the Origin of Caloric Nystagmus.*" (Communicated by Prof. H. ZWAARDEMAKER).

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Although it has long been a matter of common knowledge that a nystagmus is induced by allowing cold or warm water to flow into one ear, and this has been the subject of a considerable amount of experiments with men as well as with animals, the origin of this caloric nystagmus is still a moot point.

Among the various views taken of the subject those of BARANY and BARTELS stand prominent.

BARANY holds that streams in the endolymph evolved by a change of temperature excite the coloric nystagmus, whereas BARTELS inclines to believe that by applying cold water the function of the labyrinth is eliminated entirely or in part and that by applying warm water the labyrinth is stimulated.

It being our purpose to endeavour to clarify our ideas concerning the cause of the caloric nystagmus, we first of all made a series of experiments to ascertain whether the caloric nystagmus may perhaps be provoked by arresting the function of the labyrinth through cold water. The results of this inquiry will be discussed in this paper.

In our investigation we started from the following considerations:

If the caloric nystagmus is brought about by eliminating the labyrinth on the irrigated side, the caloric nystagmus must present the phenomena resulting from an extirpation of the labyrinth.

These phenomena are:

a. The caloric nystagmus would correspond in direction, frequency and nature, exactly with the spontaneous nystagmus occurring after extirpation of the labyrinth.

b. It would be possible to arrest the nystagmus, occurring directly after extirpation of a labyrinth by ejecting cold water into the other labyrinth.

c. When in an animal one labyrinth has been extirpated, a spontaneous nystagmus will ensue, which will disappear again after some time; the nystagmus is then what is termed "compensated".

In this phase of compensation extirpation, or a squirt of cold water into the other ear may excite nystagmus. If a squirt of cold water into the ear is equivalent to elimination of the labyrinth on the same side, then both labyrinths will have been eliminated in case, in the compensatory stage. the unimpaired ear is irrigated. It follows then that the nature, the direction or the frequency of the forthcoming nystagmus can no more be modified by altering the animal's position in space.

d. A concomitant flow of water into the two ears, generally brings forth a condition in which no nystagmus manifests itself. If therefore, squirting cold water into the labyrinth is identical with elimination, a concomitant flow into the two ears cannot provoke a rotatory movement or a deviation of the eyes in case the animal's position in space is altered.

These phenomena have been examined in the following way: *Ad. a.* In order to ascertain whether the caloric nystagmus (which term here always indicates the nystagmus occurring after squirting water, of from 11°—12°, into the animal's ear from a height of 1,5 m.) corresponds completely to the spontaneous nystagmus occurring after unilateral extirpation of the labyrinth, a number of experiments were undertaken. In these experiments the animals (in this series only cats) were tied to an operation board and subsequently the caloric nystagmus was examined in 6 different positions of the animal:

1 ventral position.
2 dorsal position.
3 vertical position, head up.
4 vertical position, head down.
5 lateral position, the irrigated ear up.
6. lateral position, the irrigated ear down.

After this the labyrinth on the side of the irrigated ear was extirpated. The technique of this operation has been described by one of us in another paper. [1]) After the animal recovered from the narcosis, the nystagmus was again examined in the six positions just mentioned. With some animals the examination was repeated the next day. We noted the frequency, the direction and the nature of the nystagmus. The frequency of the nystagmus cannot be accurately demonstrated in these experiments, it being apt to change every moment as well in the spontaneous nystagmus as in the caloric nystagmus. We are entirely ignorant of the cause of it.

[1]) Pflügers Archiv. Bd. 145 p. 549.

Spontaneous eye-movements may come into play here. Sometimes we fancied to note an increased frequency when the animal got restless.

We feel assured, however, that a change of the animal's position can exert an influence upon the nystagmus, so that e. g. the frequency is always less with ventral position than with a dorsal position, and this holds good for the caloric as well as for the spontaneous nystagmus showing itself after a unilateral extirpation of the labyrinth.

Similarly it is often very difficult to accurately determine the nature of the nystagmus. It happens again and again that the caloric nystagmus in a certain position is perfectly horizontal for some time and suddenly turns rotatory, without any assignable cause. After a change of the animal's position we invariably delayed noting down the nature of the nystagmus for some moments, in order to preclude the chance that the nystagmus brought forth by the change of the animal's position should interfere with the caloric phenomenon. The terms: nystagmus to the left or to the right always mean a nystagmus with the fast component to the left or to the right. From this inquiry it became evident that the direction of the spontaneous nystagmus is not in all positions identical with that of the caloric nystagmus, as it appeared that the spontaneous nystagmus occurring after unilateral extirpation of the labyrinth, has in all positions the fast component turned towards the unimpaired labyrinth, whereas the caloric nystagmus is, with ventral position and with vertical position (head up), turned towards the non-irrigated ear; with dorsal position and with vertical position (head down) it is turned towards the irrigated ear; with lateral position (5 and 6) the caloric nystagmus is mostly towards the same side as with ventral position.

Ad b. Directly after extirpation of a labyrinth a nystagmus reveals itself spontaneously towards the side of the unimpaired labyrinth. As appeared sub *a*, this nystagmus does not vary its direction with a change of the animal's position in space. When both labyrinths are removed during the operation with only a very short interval, no nystagmus will occur. If, therefore, caloric nystagmus should be identical with elimination of the labyrinth, it must be possible to arrest in all positions the nystagmus occurring after unilateral extirpation of the labyrinth, by allowing water to flow into the unimpaired ear. This, in fact, is not the case, as was evidenced by four experiments upon cats, which all yielded similar results. This may be instanced by the following abridged protocol:

31-5-1917. Cat. A flow of cold water 11—12° into the right meatus auditorius from 1,5 m.

Animal in ventral position; horizontal nystagmus to the left side.

Animal: vertical, head down, horizontal and rotatory nystagmus to the right side.

Extirpation of left labyrinth under narcosis of ether; operation finished at 11.15.

11.45. Spontaneous nystagmus to the right side in all positions.

Ventral position, frequency per 10 seconds $\begin{matrix}11\\11\\11\\11\\12\end{matrix}$.

Head down, frequency per 10 seconds $\begin{matrix}14\\15\\15\\18\\16\end{matrix}$.

12.10. A flow into the right meatus.

In *ventral position*, nystagmus to the right side lessens considerably; we did not succeed, however, in removing it altogether.

End. *head down*: nystagmus to the right side (horizontal + rotatory) grows much stronger and rapid. Now the frequency per 10 sec. is $\begin{matrix}24\\23\\25\\23\\24\end{matrix}$.

5.15. Spontaneous nystagmus to the right side in all positions.

Ventral position: horizontal nystagmus, frequency per 10 sec. $\begin{matrix}12\\12\\11\\13\\12\end{matrix}$.

Head down: horizontal + rotatory nyst.; frequency per 10 sec. $\begin{matrix}16\\14\\16\\14\\15\end{matrix}$.

A flow into right meatus.

Ventral position: eyes perfectly quiet. O.S. distinct downwards deviation.

Head down: strong horizontal rotatory nystagmus to the right side, frequency per 10 sec. $\begin{matrix}24\\23\\22\\20\\22\end{matrix}$.

Again in *ventral position* eyes perfectly quiet.

5.30 extirpation of labyrinth on the right with ether-spray.

8.30 not the slightest indication of nystagmus.

It then appeared from this experiment (and the other experiments were conducted in the same way) that after bilateral extirpation of the labyrinth there was no nystagmus, after a unilateral extirpation there was a spontaneous nystagmus which could not in all directions be arrested by a flow into the meatus of the untouched ear. From

this we may safely conclude that the phenomena, associated with the irrigation, cannot be caused by an elimination of the labyrinth. The objection that in these cases the unsatisfactory outcome of the irrigation depended on mere chance, is refuted by the fact that

1. irrigation was very effective before the extirpation of the labyrinth

2. irrigation after unilateral extirpation of the labyrinth in ventral position actually arrested the spontaneous nystagmus and

3. with head down the spontaneous nystagmus was not unaltered, but was considerably stronger.

Ad c. When, in one experiment, both labyrinths are removed, violent movements are observable, but not nystagmus. If, however, we first remove one labyrinth, the spontaneous nystagmus will be seen to vanish after a short interval. When subsequently the second labyrinth is removed, nystagmus returns and that to the side of the labyrinth that was first extirpated. We shall not enter into a discussion here about the question how this nystagmus, first described by BECHTEREW [1]), is originated, and which parts of the central nervous system come into play here for a nystagmus to manifest itself. This is being further investigated at our institute.

The time that has to elapse after the first extirpation of a labyrinth before a nystagmus can reveal itself after the second extirpation, is varying, but after a few days it is sure to appear.

If directly after the unilateral extirpation of the labyrinth water is sent through the meatus on the unimpaired side, the spontaneous nystagmus resulting from the unilateral extirpation of the labyrinth can be arrested in the ventral position by the irrigation as described above. A repetition of this procedure at different intervals after the extirpation of the labyrinth will prove that the spontaneous nystagmus cannot only be arrested in a ventral position, but also that after some time a nystagmus toward the opposite side is evolved by a flow of water i e. towards the side of the first extirpation of the labyrinth. In this phase we may look for the spontaneous nystagmus detected by BECHTEREW, as quoted above, when the second labyrinth has been removed. If, therefore, irrigation is identical with elimination of the labyrinth, then the latter compensation-nystagmus must correspond entirely to the nystagmus obtained when some days after the unilateral extirpation of the labyrinth, the meatus of the unimpaired ear is irrigated. It appears, however, that

[1]) Pflüger's Archiv Bd. 30 p. 312.

there is not such marked concordance, as can be evidenced in the following way:

Of a cat the *right* labyrinth is extirpated; a nystagmus occurs to the *left* side. This nystagmus disappears after a few days. A flow through the meatus of the unimpaired *left* side yields nystagmus to the *right* side in *ventral position*; but on changing the position of the animal a change of the direction of the nystagmus is produced; in a dorsal position e. g. it is always to the left. If on the same day the left labyrinth is extirpated, the BECHTEREW-nystagmus to the right side appears, whose direction cannot be changed by changing the position of the animal (nor indeed can its nature or frequency).

This, then, also proves that a flow of cold water cannot completely arrest the function of the labyrinth.

Ad d. If the function of the labyrinth were arrested by ejecting cold water into the meatus, there could not be any vestibular reflexes after ejecting it into the two meatus simultaneously. Rabbits are highly serviceable for an inquiry into this matter, these animals making hardly any spontaneous eye-movements, besides having very strong eye-reflexes. We, therefore, experimented upon rabbits to see whether after ejecting water into both ears rotatory movement or deviation could be provoked through changing the animal's position in space. From an investigation made by V. D. HOEVE and DE KLEYN it appeared that in normal rabbits the greatest difference in rotatory movement of the eyes may be observed, when first the animal is examined with its head down and then with its head up.

We subjected five rabbits to the following experimentation.

First of all we ascertained whether no nystagmus at all was discernible after water had been ejected into both ears. This was necessary, as it was evident that with some animals the effect of the irrigation is not quite the same on both sides, so that a slight nystagmus still remains. Such animals were of course not suitable for an investigation. When this inquiry had been made, a photograph was taken of the head of the animal in two positions, without irrigation, viz.

animal vertical, head down
animal vertical, head up.

In order to determine the intensity of the rotatory movement a cross was burned into the cornea after cocainization. This, according to VAN DER HOEVE and DE KLEYN's experience, somewhat slackened the rotatory movement, so that it is somewhat less marked in our experiments than is usually the case with normal rabbits. Consid-

ering, however, that we only endeavoured to ascertain whether or no with bilateral irrigation a rotatory movement occurred, this did not matter at all. So when the two photographs had been taken prior to the irrigation, a simultaneous flow of cold water into both meatus of the animal was performed, and when no nystagmus was distinguishable any more, again two phothographs were taken of the head, in two positions. A measurement of the rotatory movement, caused by the change of position could now be made on the photographs. The difference between the movements in the two positions (head down and head up) amounted to

Exp.	Without irrigation	after bilateral irrigation
1	66,5°	57°
2	70°	65°
3	59°	61°
4	88°	98°
5	63°	78°

From this table it is obvious, then, that after a flow of cold water into the two meatus of rabbits a strong rotatory movement is still effected by a change of the animal's position in space, perhaps as strong as with normal animals.

For the present we refrain from theoretical speculations on the basis of these experiments. Our object in publishing our experience was only to prove that the caloric nystagmus cannot possibly be provoked by a complete elimination of the labyrinth by cold water.