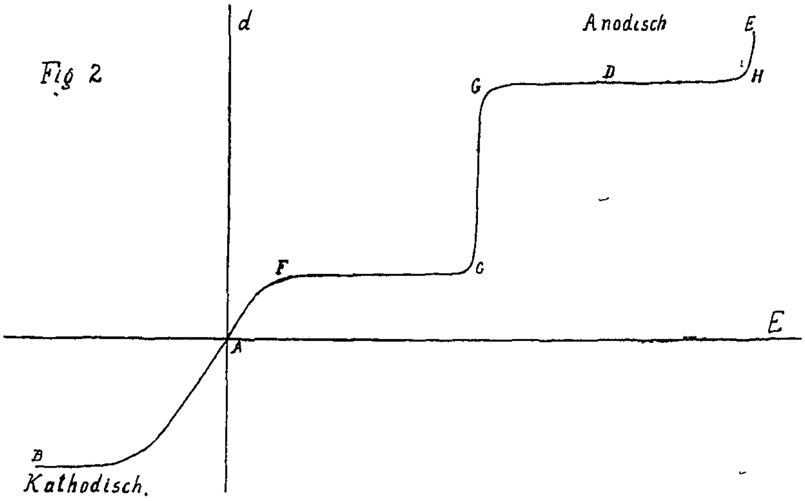
Fig 2




From $A$ to $C$ exclusively $Ag(\overline{CN})_2$ is formed. At $C$ the deposition of $Ag_2(CN)_2$ on the anode begins, from $C$ to $G$ it becomes greater and greater, at $G$ besides the deposition of cyanogensilver on the anode, this compound also begins to precipitate in the liquid; at $D$ the quantities of $Ag_2(CN)_2$ being deposited on the anode and in the liquid are equal, and finally from $H$ to $E$ the cyanogen silver precipitates practically exclusively in the liquid.

It is clear that in practice a current density will be worked with which is smaller than $F$. It is, indeed, possible to make the current density somewhat greater than $F$ without $Ag_2(CN)_2$ being deposited on the anode, but this slight increase of the current density gives a very great increase of polarisation-tension, which can amount to about 0.4 or 0.5 V. A too great current density at the anode, therefore, gives rise here to an appreciable loss of energy.

*Chemical Laboratory of the University.*

*Amsterdam,* October 1916.

**Physiology.** *"An exact method for the determination of the position of the eyes at disturbances of motion."* By Dr. C. OTTO ROELOFS. (Communicated by Prof G. VAN RIJNBERK).

(Communicated in the meeting of October 28, 1916).

In a communication to the Meeting of the 26nd of January 1916 I indicated, in what way it is possible to calculate the position of the axis round which the eye has, as it were, turned, when we know the abduction, deorsumduction and inward rotation, caused by a contraction of the m. obliquus superior. There exists however hardly any suitable method exactly to ascertain the position of the eyes. We shall at all events best succeed, if binocular vision exists (which will, as a rule, be the case for a paralysis or paresis) and we can make use of the position of the double-images for the purpose we have in view.

In the "Zeitschrift fur Augenheilkunde" Vol. XXXV, N°. 4 HESS indicates a method, based on the subjective localisation of the double-images. For clinical purposes this method is as a rule sufficient and highly to be recommended, for physiological investigation it can however not satisfy all the requirements that may be wanted.

I have tried to find a method that is more suitable to a similar purpose of which I intend to give here a description. Binocular vision and good correspondence of the retina is for this method likewise required.

The purpose of the investigation will consequently be exactly to ascertain the position of one of the two eyes, whilst the other eye has obtained a determined direction of regard by looking at an indicated point of fixation.

For this purpose the patient is placed directly opposite a vertical wall, at a distance of at least 3m. Directly in front of the patient, at a level with his eyes, a point $O$ is marked on the wall. Now we suppose, that the distance from $O$ to the point of rotation of the eye is $= a$ and that when the head is erect and at binocular fixation of $O$, both the eyes, are in the primary position, consequently in the position from which the normal eye moves according to the law of LISTING.

As second point we apply to the wall the point $Q$ which must serve as point of fixation. In some cases we can make the points $O$ and $Q$ coincide as Fig. 1 indicates.

Fig 1

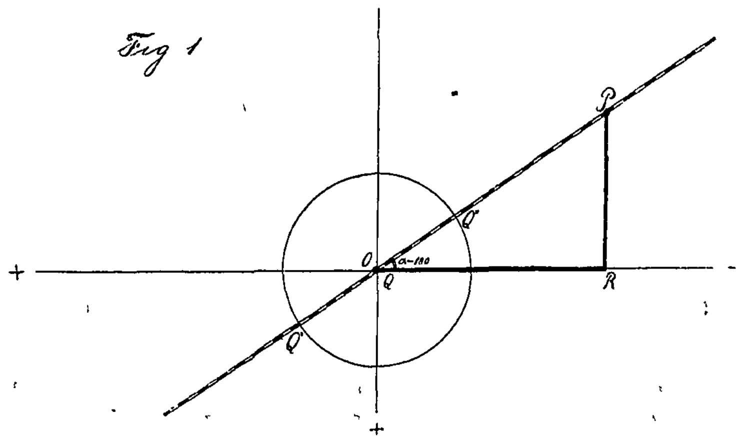
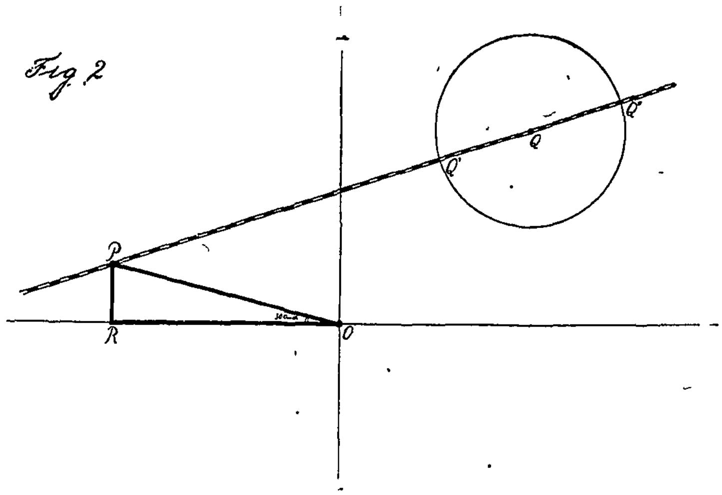


Fig. 2 gives an example of the more general case that these points do not coincide.




The investigation is to be separated into two parts. In the first part we shall describe the investigation into the direction of the line of regard, whilst in the second part the investigation of the rotation of the eye round its line of regard is treated.

The purpose of the first part of the investigation is to find the point $P$, where the line of regard of the examined eye cuts the wall, whilst the other eye fixes the point $Q$.

For this purpose we place exactly for $Q$ a luminous point (short candle-flame) and place before the examined eye the rods of MADDOX in a trial-frame. As long as the investigation lasts the fixing eye must constantly look at the point $Q$. Now the rods of MADDOX in the trial-frame are turned till the luminous red line that the examined eye observes, apparently goes through $Q$.

We know then that the red line on the retina goes through the fovea of the examined eye. Now we remove the flame from $Q$ and move it in a circle round $Q$, whilst the rods of MADDOX before the examined eye have remained unaltered in their places. Twice the patient will then observe that the red line goes apparently through $Q$. The points where the flame is at these moments ($Q'$ and $Q''$) are likewise marked on the wall. We know that we can draw straight lines through the points $Q$, $Q'$, and $Q''$, which will likewise go through the point $P$, on which the line of regard of the eye behind the rods is directed, which we want to find. As on account of the unaltered position of the rods, the observed red line can only move parallel to itself, these three lines which contain all three the point $P$, must coincide. Consequently $P$ must lie on the line $Q'\,Q\,Q''$.

Thereupon we turn the rods of MADDOX in the trial-frame about 90° and now move the flame along the line $Q'\,Q\,Q''$ or its prolongation. At a given moment the red line will again apparently be seen in $Q$. This point is marked and will. as can easily be understood, be the point $P$ we were in search of.

How are we now to describe more accurately the position of the point $P$, which we have found, or the direction of the line of regard? For this purpose we can follow two ways. In the first place we can express the direction of the line of regard in its abduction or adduction and in its deorsumduction or sursumduction.

By abduction and adduction we understand the smallest angle that the line of regard makes with the sagittal plane. If now we seek a formula for the abduction ($A$), then we shall call $OR$ positive, when $R$ lies temporally from $O$, so that the formula is: $tg\,A = \frac{OR}{\sqrt{a^2 + PR^2}}$.

If $OR$ is negative, then $tg\,A$ is negative and there exists adduction.

By deorsumduction or sursumduction we shall understand the smallest angle that the line of regard makes with the horizontal plane. If now we seek a formula for the deorsumduction ($D$) we shall call $PR$ positive. when $P$ lies under the horizontal line, so that the formula is: $tg\,D = \frac{PR}{\sqrt{a^2 + OR^2}}$.

If $PR$ is negative (as in the Fig. 1 and 2) then $tg\,D$ is negative, and there is sursumduction. We have not to take account here of angles larger than 90°. If we wish to indicate the position of the line of regard in the manner as HELMHOLTZ has taught us (inclination of the plane of regard) then the deorsumduction is expressed by the formula: $tg\,D' = \frac{PR}{a}$.

A second method of describing the direction of the line of regard is the following one. In the first place we can calculate the angle, that the line of regard in the position we have found, makes with the line of regard in the primary position, and afterwards the angle that $OP$ makes with $OR$. We shall call these angles respectively $\angle H$ and $\angle \alpha$. For $\angle H$ the formula is: $tg\,H = \frac{OP}{a} = \frac{\sqrt{PR^2 + OR^2}}{a}$.

For $\angle \alpha$ the formula is $\sin \alpha = \frac{PR}{\sqrt{PR^2 + OR^2}}$ and $tg\,\alpha = \frac{PR}{OR}$.

As $\alpha$ can have all values from 0° to 360° we shall agree, that

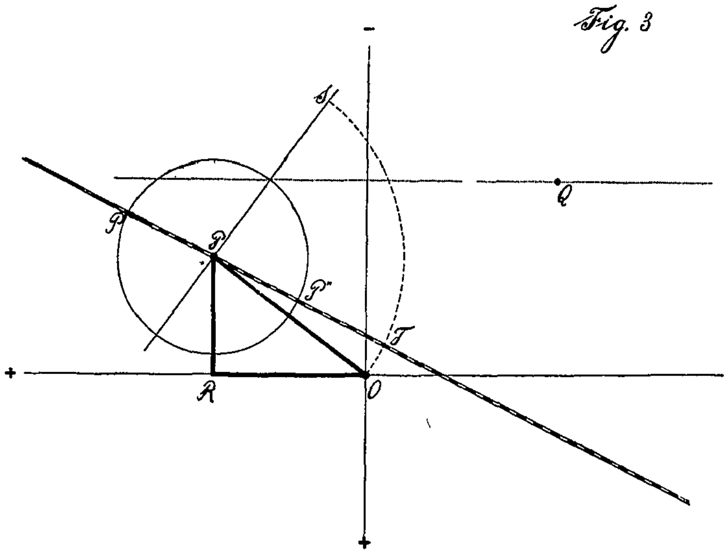
$\angle \alpha$ is calculated from the horizontal plane temporalward downward. In Fig 1 $OP$ lies consequently in the third quadrant, in Fig. 2 in the fourth quadrant. If now we call $OR$ positive, when $R$ lies temporally and $PR$ positive when $P$ lies under the horizontal plane, then two values will in general satisfy the formula for $\sin \alpha$, and also two that for $tg\, \alpha$, but only one value will satisfy both formulas, consequently $\angle \alpha$ is determined.

For the first part of the investigation we have consequently calculated the angles $A$, $D$, $H$ and $\alpha$ from the data $a$, $PR$ and $OR$.

In the second part of the investigation we must learn to know the rotation of the eye round its line of regard. If we call the position that the eye must assume according to the law of LISTING during its different directions of regard the normal position, then we can make it our task to ascertain, if, how much and in what direction the eye has rotated round its line of regard in relation to that normal position.

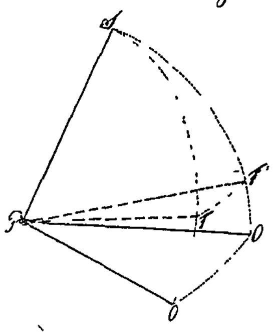
Let $Q$ again be the point of fixation and $P$ the point where the line of regard of the examined eye cuts the wall. Now we place a source of light in $P$ and hold before the examined eye again the rods of MADDOX, as perpendicularly to the line of regard as possible. We now move the rods in their plane so long, till the red line is apparently seen horizontal (as the thin dotted line in Fig. 3 going

Fig. 3




through $Q$ indicates). Leaving the rods in this position we remove the flame from $P$ and move it in a circle round $P$. The points where the flame is, when the red line goes again apparently through $Q$ (namely $P'$ and $P''$) are marked, and it needs no further demonstration, that $P' PP''$ is a line, that is observed by the examined eye as horizontal, i. e. forms an image on the horizontal meridian of the retina. If now we represent to ourselves a plane through the horizontal meridian of the retina and $P' PP''$ and likewise a plane through $OP$ and the meridian of the retina corresponding with it,

Fig 4



then in normal cases, the angle between these two planes must be equal to $\angle POR$. We must however take into consideration, that the angle between the mentioned planes is not expressed in the angle $OPT$, because the wall does not stand perpendicularly to the secant line of the two planes, namely the line of vision (coinciding nearly with the line of regard). If we represent to ourselves however a plane in $P$ perpendicular to the line of regard and further a globe constructed with $P$ as central point and $PO$ as radius (vide Fig. 4) then it is easy to see, that in the rectangular spherical triangle $ST'' T$ $tg\ SPT' = cos\ S\ tg\ SPT$ or $cot\ O'PT' = cos\ H\ cot\ OPT$.

If we call $\angle O'PT' = \angle \beta$, then the difference between $\angle \beta$ and $\angle POR$ indicates the rotation we wanted to find.

$$tg\ (POR-\beta) = \frac{tg\ POR - tg\ \beta}{1 + tg\ POR\ tg\ \beta} = \frac{PR - RO tg\beta}{RO + PR tg\beta}$$

and as $tg\ \beta = \dfrac{tg OPT}{cos\ H}$ the rotation ($R$) is expressed by the formula

$$tg\ R = \frac{PR\ cos\ H - RO\ tg\ OPT}{RO\ cos\ H + PR\ tg\ OPT}.$$

Consequently we have to calculate $tg\ OPT$. If we no longer regard $T$ as the point of intersection of $P'P''$ with the spherical surface, but as the point of intersection of $P'P''$ with the perpendicular to $P'P''$ passing through $O$, then: $tg\ OPT = \dfrac{OT}{PT}$.

We must however carefully pay attention to the marks ($\pm$) in order to find the exact value for the rotation. In concurrence with the first part of the investigation we shall call $PR$ positive, when $P$ lies under the horizontal line and $RO$ positive when $R$ lies temporalward from the vertical line. If now we express $\angle POR$ in its tangent, $tg\ POR$ is positive, when $P$ lies under the horizontal line and temporalward from the vertical line or over the horizontal line and noseward from the vertical line.

We shall likewise call $OT$ positive when $O$ lies under the line

$PT$ and $PT$ positive, when $T$ lies temporalward from $P$; consequently $tg\ OPT$ will be positive, when $O$ lies under $PT$ and temporalward from $P$ or over $PT$ and noseward from $P$.

If now we apply this rule, we shall find a positive value for the rotation, when the upper part of the vertical meridian of the retina inclines too much temporalward, a negative value when it inclines too much noseward.

For all our calculations we have consequently to measure on the wall: $OR$, $PR$, $OT$ and $PT$, whilst the distance from the eye to the wall must be known.

Now we can ask how the axis lies, round which the eye would have to come from the primary position into the position we have found.

Some formulas for its calculation have been given in the communication mentioned above. I think it a good plan to repeat these formulas again, not only because this gives me an opportunity to correct a few troublesome printer's errors, but likewise because I can call attention to the fact, that these formulae do not serve exclusively to find the axis of the m. obliquus superior, but that they are of a much more general signification. In the former communication the rotation was called positive, when the upper part of the vertical meridian of the retina inclined nose-wardly; in connection with what is generally understood by positive cyclophory, I suppose, I have been obliged to rectify this likewise.

The formulas mentioned run consequently:

$$sin\ H = \sqrt{sin^2 A + sin^2 D}$$

$$tg\ \mu = \frac{tg\ {}^1/_2 H}{sin\ {}^1/_2 R} \quad (\mu \text{ is always less than } 90^c).$$

$$cos\ \lambda = -\frac{sin\ \mu}{sin\ H}(sin\ D\ cos\ {}^1/_2 R - sin\ A\ sin\ {}^1/_2 R)$$

$$cos\ \nu = -\frac{sin\ \mu}{sin\ H}(sin\ D\ sin\ {}^1/_2 R + sin\ A\ cos\ {}^1/_2 R)$$

in which $H =$ the angle between the line of regard in the position we have found and the primary position, $A =$ Abduction, $D =$ = Deorsumduction, $R =$ Rotation temporalward. $\lambda =$ angle of the anterior half of the axis of motion with $x$-as (temporalward). $\mu =$ = angle of the anterior half of the axis of motion with $y$-axis (forward. $\nu =$ angle of the anterior half of the axis of motion with $z$-axis (upward). The sign before $\mu$ indicates the direction in which the eye has rotated.