Physiological Aspects of the Nystagmus

found by using Concentric Dual Revolving Apparatus, originated by the Author, which can stimulate simultaneously the Eyes and the Ears

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Preface

Optomotor nystagmus is the prototype of nystagmus, and what is called "optomotor nystagmus" is the *out of mind* eye-movement that some moving objects are cast on the retina as a static image. This eye-movement is influenced in the presence of labyrinth. This "influence" itself is the true vestibulo-oculomotor reflex, that is, labyrinthine reflex which appears in the eye-movement. It is possible to observe nystagmus by caloric test and rotatoric test, but the nystagmus so observed is not "catching the moving in a static form". The examinee becomes unable to catch *even a static body* in a normal form, and is troubled with ataxy and vertigo. In other words, these methods which have been of significance as the test method of vestibular function are simply to observe the nystagmus of labyrinthine origin, i.e., labyrinthine nystagmus, but never to reveal the true labyrinthine reflex. The *concentric dual revolving apparatus* is an epoch-making, unique apparatus originated by the author, by which it is possible to quantitatively determine labyrinthine reflex, with the effect of labyrinth stimulation by revolving angular accelerated velocity on the above-mentioned optomotor nystagmus as the indicator.

This method can be a new, reasonable means for the study of vestibular function. The new findings of nystagmus obtained by the author through this method are described in the present paper.

Introduction

The successive eye-movement which has the rapid phase and the slow phase in a given direction, respectively, i.e., the phenomenon which is generally called "nystagmus" is

caused to occur from such various origins as one which is of totally physiological and optokinetic nature, one which is of patho-physiological nature, e.g., experimental labyrinth stimulation, and one which develops in cases of intracranial diseases and inner ear diseases; however, *experimental nystagmus* is considered to be of significance in the study of the so-called "vestibular function" and in clinical diagnosis of ataxy, and among others, the caloric test is stressed as one which gives the findings of only one of a pair of labyrinth receptors. It is true that this method has a merit of numerically expressing nystagmus caused by stimulation of the labyrinth as the duration time and or beat number, and catches the disturbed side in terms of CP or DP definitely in some cases and presumably in many cases; however, it involves a problem that the method of stimulation employed for it is an inadequate stimulation which can never exist in the daily life. Further, revolving stimulation which is considered to be an adequate stimulation in a way can hardly be said to be an adequate stimulation so long as the methods employed in the past are employed. The formation of a state where nystagmus is caused to occur by labyrinth stimulation itself is not a physiological state of vestibular labyrinth function. Apart from the value as a neurological method but from the standpoint of vestibulo or stato-physiology, the methods of observation of experimental nystagmus introduced in the past are not adequate.

On the other hand, vestibulo-spinal reflex, i.e., labyrinthine reflex which appears chiefly in four extremities, is detected as gait or stepping deviation and deviation of vertical writing representing the difference between the left and the right side of tension of systemic skeletal muscle already caused by labyrinth stimulation which is so weak as not to cause nystagmus, and this is accepted as representing the function of vestibular labyrinth it is well known that vestibulo-spinal reflex is of stato-physiological significance in that it thus considerably quantitatively catches the reaction to weak labyrinth stimulation which does not induce nystagmus.

The author has endeavored for years to systematically catch the ocular reactions to weak labyrinth stimulation which does not cause nystagmus to occur, and he has found a way of approach to a very paradoxical objective of "observing nystagmus under labyrinth stimulation which is so weak as not to cause nystagmus", by devising a new apparatus. In short, the author's method is to observe, record and quantitatively determine vestibulo oculomotor reaction at the *coordination phase* (Fukuda).

Concentric Dual Revolving Apparatus and its Behavior

The apparatus is named the concentric dual revolving apparatus, and has a structure as shown in Fig.1. It comprises an electrically-driven chair which performs revolutions of

Fig. 1

Fig. 2

Fig. 3

uniform velocity, acceleration and deceleration at such a velocity, accelerated velocity and decelerated velocity as desired, and an optic trommel which revolves with the chair. 12 black stripes are marked on the internal surface of the optic trommel, and as shown in Fig.2, work as the optomotor stimulus to the examinee on the chair. In Fig.3 is shown the whole view of the apparatus. This apparatus is featured in that, as shown in Fig.1, the motive power of revolving pulley "R" attached to the chair is conducted to the optic trommel via pulleys r_1 , r_2 and r_3 of " $R/2$ ". In other words, the optic trommel makes two revolutions for each revolution the chair makes. It is further possible by manipulation of the clutch lever to make only the chair revolve. This apparatus makes three movements, i.e., (1) the chair revolves while

the optic trommel stays unmoved, (2) the chair revolves and the optic trommel revolves at two times higher the speed in the same direction, and (3) only the optic trommel revolves.

Concentric Dual Revolving Method and its Features

For convenience of explanation, stimulation of the right labyrinth will be described below.

Rotacceleratory stimulation type I:

As shown in Fig. 4 B, revolving only the chair clockwise at accelerated velocity gives rise to stimulation of the right labyrinth, and the stimulation by the optic trommel occurs relatively in the opposite direction, and the absolute level of accelerated velocity becomes equal with the accelerated velocity of revolution of the chair.

Rotacceleratory stimulation type II:

As shown in Fig. 4 C, the chair revolves in the same way as under Rotacceleratory stimulation type I, but because the optic trommel revolves in the same direction as the chair but at two times higher the speed than the latter, the labyrinth stimulation is equal with that under Rotacceleratory stimulation type I, but the stimulation by the optic trommel takes place in the opposite direction. In other words, the examinee

Fig. 4

undergoes stimulation by the optic trommel in the form of difference between the speed of revolution and acceleration of optic trommel and the speed of revolution and acceleration of the chair. Since the chair revolves in the same way as under Rotacceleratory stimulation type I, the optomotor stimulation which the examinee receives is equal as a relatively value with that under Rotacceleratory stimulation type I but in the opposite direction.

Control : It is possible to observe the rightward optomotor nystagmus and the leftward one under unilateral labyrinth stimulation by the methods under rotacceleratory stimulation types I and II, but for quantitatively determining the effect of labyrinthine stimulation, it is necessary to employ the findings upon stimulation by the optic trommel only as the control (Fig. 4 A).

The method introduced in the present paper is to extract the true vestibulo-oculomotor reflex by means of comparing the findings under rotacceleratory stimulation types I and II for the levels of labyrinth stimulation at various accelerated velocities, with the corresponding findings in the control, i.e., to catch the labyrinthine reflex, employing the optomotor nystagmus as carrier.

Method of Recording and Analysis

An electronystagmograph is used for recording, but since the objective is to observe the optomotor uprising, it is convenient to make the time constant less than 0.03 for purposes of counting the beat number of nystagmus.

It is desirable to observe histogram and correlations of pulse by the use of medical data computer for analysis, but in the present paper is introduced a simple method under which the beat number is counted by directly reading the electronystagmogram, and the findings graphically shown.

In Fig. 5 are shown the findings by stimulation of right labyrinth at $0.25^\circ/\text{sec}^2$, which indicate variations in the number of beat of nystagmus for each $10^\circ/\text{sec}$. increase in revolving angular velocity of the chair. This graph only indicates that there is a difference in number of beat of nystagmus between rotacceleratory stimulation type I and type II. The number of beat of nystagmus upon stimulation by the optic trommel in the control

Fig. 5

Fig. 7

Number of beat of nystagmus in case of concentric dual stimulation*
 Number of beat of nystagmus in the control (by stimulation of optic trommel only)* = Vestibular index

Fig. 6

(*provided that these are the sum of number of beat of nystagmus for each 10° variation in angular velocity, respectively.)

which is recorded on electronystagmogram is counted; calculation is then made by the following formula, and the value so obtained is named the vestibular index. (Fig. 6)

In other words, if the value is 1, the labyrinthine reflex is silent, and if larger than 1, it represents acceleration, and if smaller than 1, suppression. The findings are entered in such a form as shown in Fig. 7.

Results

Normal healthy adults who did not show optic DP were employed as the subjects. The findings upon stimulation of the right side only, with accelerated angular velocities of labyrinth stimulation at $0.25^\circ/\text{sec}^2$, $0.5^\circ/\text{sec}^2$, $2^\circ/\text{sec}^2$, $5^\circ/\text{sec}^2$ and $10^\circ/\text{sec}^2$ are described. In order to infer the effect of training, the findings in class A auto racers upon stimulation at $10^\circ/\text{sec}^2$ are supplementarily shown. The findings are all graphically shown as the vestibular index described in the preceding chapter.

1) Revolving labyrinth stimulations with angular accelerated velocities at $0.25^\circ/\text{sec}^2$, $0.5^\circ/\text{sec}^2$ and $2^\circ/\text{sec}^2$ (Fig. 8):

Fig. 8

The vestibular index by rotacceleratory stimulation type I was larger than 1, and that by rotacceleratory stimulation type II, smaller than 1. The findings shown in Fig. 8 are from the same subject, where the vestibular index by rotacceleratory stimulation type I was $0.25^\circ/\text{sec}^2 > 0.5^\circ/\text{sec}^2 > 2^\circ/\text{sec}^2$, but that by type II was reversed.

Fig. 9

2) Revolving labyrinth stimulations at $5^\circ/\text{sec.}^2$ and $10^\circ/\text{sec.}^2$ (Fig. 9):

The vestibular index was smaller than 1 in almost all cases by either rotacceleratory stimulation type I or type II.

3) Revolving labyrinth stimulation of class A auto racer at $10^\circ/\text{sec.}^2$ (Fig. 11):

Direction of Nystagmus		
(1) the so-called subliminal rot. stimul.		
	Type I	Type II
nystagmus in course of preparation (conceivable)	----->	----->
optokinetic nystagmus	----->	-----<
total appearance	----->	-----<
(2) over-liminal rot. stimul.		
	Type I	Type II
perrotatoric nystagmus	----->	----->
optokinetic nystagmus	----->	-----<
total appearance	----->	-----<

Fig. 10

Fig. 11.

The vestibular index to rotacceleratory stimulation type I was larger than 1 in general, and that by type II was smaller than 1: however, the latter was far closer to 1, compared with that under 1) and 2) above.

Summary

A vestibular index of larger than 1 means that fixation eye-movement accelerated, and a value of smaller than 1 means that fixation eye-movement is suppressed. Since a vestibular index of 1 represents only the optomotor stimulation, i.e., the value without labyrinth stimulation, in cases where it has been systematically proved that the findings are not 1, the findings represent labyrinthine reflex which appears in the eye-movement. So long as nystagmus is originally the fixation function it is reasonable to observe the effect of labyrinth on it, and the methods employed in the past which ignore the true picture of nystagmus, such as experimental nystagmus test, may be accepted from the standpoint of neurology and functional anatomy, but cannot be accepted from the standpoint of static physiology.

To summarize the findings by the apparatus and method newly developed by the author, there was an apparent difference between the findings by rotacceleratory stimulation type I, i.e., by the method in which only the chair revolves, and the findings by rotacceleratory stimulation type II, i.e., by the method in which stimulation is performed by rotating both the chair and the optic trommel, and nystagmus was accelerated by rotacceleratory stimula

tion type I, and suppressed by rotacceleratory stimulation type II at angular accelerated velocity of labyrinth stimulation below $2^{\circ}/\text{sec.}^2$. The suppression and acceleration were most prominent at $0.25^{\circ}/\text{sec.}^2$, however, and became less at $0.5^{\circ}/\text{sec.}^2$ and $2^{\circ}/\text{sec.}^2$ in the said order. Although stimulation at less than $0.25^{\circ}/\text{sec.}^2$ could not be carried out because of capacity of the apparatus, it may be said that the smaller the labyrinth stimulation, the larger the effect of labyrinth stimulation on fixation function would be, within the findings so obtained. Such a level of stimulation was the level which had been said to be subliminal or liminal, with no nystagmus occurring during revolution in many cases, and it was, therefore, impossible to carry out a systematic observation with nystagmus as indicator. It was because labyrinthine nystagmus was employed as the only objective, however, and as given in the present paper, if optomotor nystagmus, i. e., the normal function of fixation of vision were employed as the indicator, it would be possible to definitely and quantitatively catch labyrinth stimulation. This may be considered to be the same as that labyrinthine reflex which appears in four extremities and trunk in response to weak labyrinth stimulation is caught by vertical writing and stepping tests.

Experiments were also carried out on stimulation at $5^{\circ}/\text{sec.}^2$ and $10^{\circ}/\text{sec.}^2$. These are the level at which nystagmus usually appears during revolution. Even in this case, there is an apparent difference between rotacceleratory stimulation type I and type II, and the former appears to be somewhat better in fixation eye-movement. However, the findings totally differed from those at less than $2^{\circ}/\text{sec.}^2$ in that the vestibular index was less than 1 for both rotacceleratory stimulation type I and type II i. e., the fixation function was always suppressed by labyrinth stimulation. The labyrinth was already losing its function even at such a level of stimulation. In other words, since it can be surmised that vision can be well fixed on objects in the absence of labyrinth, the level of labyrinth stimulation which is applied at stoppage of revolution under the post-rotatoric nystagmus observation should be said to be such a level at which the labyrinthine function is destroyed.

From the above considerations, in human cases where labyrinth stimulation at larger than $2^{\circ}/\text{sec.}^2$ is applied, "the labyrinth is an obstacle", leading to fixation hypofunction; i. e., "the optical acuity is degraded", and the findings in class A auto racers upon stimulation at $10^{\circ}/\text{sec.}^2$ offered the basis for denying the above surmise. The vestibular index was larger than 1 for rotacceleratory stimulation type I definitely improving the fixation function, and it was only little smaller than 1 even for rotacceleratory stimulation type II. The promotion of fixation function in the racers who are training to become united with the car, catching the outside conditions that fly behind almost always under consciousness at unmeasurably varying speed and acceleration, owes to the improvement

of labyrinthine function. If it were that only the eyes are improved by training, the vestibular index would be less than 1, and the labyrinth would promote and assist the fixation function. And the theory by Fukuda et al. that the training in revolution makes optomotor nystagmus a response increase, has been numericalized by the author's experiment.

The problem that still remains is concerned with the suppression of fixation eye-movement under rotacceleratory stimulation type II. No paper has been found which indicates that the labyrinth suppresses fixation function as far as the author has investigated. Needless to say, fixation dysfunction in cases where the function is destroyed such as labyrinthine nystagmus is out of the question, but consideration should be given to the fact that such a weak labyrinth stimulation as at $0.25^{\circ}/\text{sec.}^2$ causes suppression. This phenomenon should be considered attributable to the social environments. It would be for the reason that although the effect that "the surroundings turn relatively in the opposite direction when one revolves", i.e., rotacceleratory stimulation type I, is not rare but similar effects often encountered in daily life, adaptation to the environments is not sufficient. Since generalization of transportation machine at present has placed a number of people in similar environments, it may be considered that the adaptation function to the environments would gradually improve. The decrease in suppression as noted in the findings of auto racers implies this effect. In any event, in investigating the cause of accident by a car taking over another car at high speed, it is necessary to take into consideration the physical condition of suppressed fixation function in rotacceleratory stimulation type II.

As stated above, the author has developed a reasonable method of quantitatively determining labyrinthine reflex which appears in the eye-movement, and attempted to calculate the vestibular index on some findings as a new means for physiological study of vestibular labyrinth; the author, however, considers that there are many problems yet to be solved for immediate application of the method for clinical purposes.

Conclusion

The author has devised a method of quantitatively determining labyrinthine reflex with optomotor nystagmus, i.e., fixation eye-movement as indicator, i.e., quantitative concentric dual revolving method, given explanations of an example of its content and apparatus, showed the results of quantitative determination of labyrinthine reflex, i.e., vestibulo-oculomotor reflex upon stimulation of labyrinth at various levels of angular acceleration,

and also given considerations to the correlations of labyrinthine function to optomotor nystagmus.

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Bibliography

- 1) **Fukuda, T.** : Stato-kinetic Reflexes in Equilibrium and Movements. Igaku-shoin Tokyo (1957)
- 2) **Adler, F. H.** : Physiology of the eye. The C. V. Mosby CO. Saint Louis (1965)
- 3) **Jongkees, L. B. W.** : Über die Untersuchungsmethoden des Gleichgewichtsorgans, Fortschr. Hals-Nasen-Ohrenheilk. I : 1-147 (1933)
- 4) **Hagiwara, H.** : Physiology of the Eye. Igaku-shoin Tokyo (1966)
- 5) **Amenomori, Y., Baba, A. and Tahara, K.** : Study on Human Equilibrium during the Acceleratory Optokinetic Stimulation. Reports Prepared for the 18th Meeting of Jap. Soc. of Vestibular Research, 18, (1966)
- 6) **Amenomori, Y., and Tahara, K.** : Some Findings about Vestibulo-oculomotor Reflex, using "Concentric Dual Revolving Apparatus, Amenomori-Type". Report Prepared for the 19th Meeting of Jap. Soc. of Vestibular Research, 19, (1966)
- 7) **Amenomori, Y., Tahara, K. and Yamamoto, D.** : Some Findings about Vestibulo-oculomotor Reflex, using "Concentric Dual Revolving Apparatus, Amenomori-Type". (2nd Report) Report Prepared for the 20th Meeting of Jap. Soc. of Vestibular Research, 20, (1967)
- 8) **Amenomori, Y.** : A Physiological Aspect of Nystagmus. Jap. Jour. Otol. (Tokyo) **71** : (3) (1968)