Vision Research Vol. 19, pp. 1057 to 1059
Pergamon Press Ltd 1979 Printed in Great Britain

RESEARCH NOTE

PURSUIT AFTER-NYSTAGMUS

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(*Received* 20 *November* 1978)

INTRODUCTION

In primates, two types of visual following reflexes—smooth pursuit and the slow phases of optokinetic nystagmus—stabilize images upon the retina. The former stabilizes upon the fovea the image of a small object moving in space; the latter stabilizes upon the retina the image of the entire visual world. Pursuit is predominantly a foveal reflex although movement upon the peripheral retina to a limited extent can also be used (Winterson and Steinman, 1978). In contrast, for maximal optokinetic responses stimulation of the peripheral retina is essential (Dichgans, 1977).

Optokinetic responses are closely allied to those of the vestibular system (Ter Braak, 1936; Dichgans *et al.*, 1973; Waespe *et al.*, 1977; Wallace *et al.*, 1978) and in fact during head rotation the optokinetic system functions to sustain the nystagmus response when the vestibulo-ocular response alone becomes inadequate. One consequence of this alliance is optokinetic after-nystagmus (OKAN), a response in which a relatively long period of nystagmus occurs when the lights are turned off after prolonged, unidirectional, optokinetic stimulation. Functionally OKAN helps null inappropriate postrotatory vestibular nystagmus such as occurs after a constant velocity head rotation.

A problem in ocular motor physiology and neuro-ophthalmologic diagnosis is how to separate the components of eye movements due to the pursuit and optokinetic systems. In what ways are the properties of the two systems similar and different? Since OKAN is a prominent feature of the optokinetic system, we decided to determine if prolonged unidirectional pursuit of a small target is also followed by after-nystagmus. It is.

METHODS

Horizontal eye position was measured during direct current electrooculography (EOG) with electrodes near the outer canthi. Eye position was recorded on analog magnetic tape and displayed on chart paper. The band width of the entire recording system was 0–60 Hz. Subjects were dark adapted and the EOG was calibrated before and after each trial. Gain and baseline stability allowed an overall sensitivity and accuracy of about 1°.

Subjects were instructed to track a dim luminous spot, 0.67° in diameter, rear projected onto a translucent screen located 85 cm in front of the subject. The target was moved horizontally in a repetitive ramp (sawtooth) pattern by a mirror galvonometer in the light path of a slide projector. The excursion of the target was ±25° about zero and ramp velocity was 50°/sec. After 2 min of tracking, all lights were turned off and after-nystagmus was recorded. While in complete darkness the subjects were kept alert with simple mental calculations.

The target was moved across either a dark background or an illuminated acetate overlay on the screen. The acetate supported vertical, 1.7° wide, white stripes, separated by 0.85°. The stripes lay above and below the path on which the target moved and provided a rectangular, stationary background 70° wide and 40° high.

Optokinetic responses were elicited within a revolving optokinetic drum. The drum was 150 cm in diameter. Its interior was covered with a multicolored, plaid pattern. After 2 min of drum rotation at 50°/sec the lights were turned off and OKAN was recorded.

In all tests, subjects were seated with their head stabilized by a chin rest. The order of the tests was varied from subject to subject, and when a subject was available for more than one session, the order was varied from one session to another. All subjects were young adults and had normal visual and ocular motor function.

RESULTS

Fifty deg/sec was chosen as the target velocity since it was the highest velocity that most subjects could consistently track for a long period of time with a gain (ratio of smooth eye velocity to target velocity) of 0.85 or better. A trial duration of 2 min was chosen to obtain a maximum after-nystagmus without fatiguing the subject. Individual trials were separated by 1 hr since after-nystagmus was elicited less reliably with shorter intervals between trials.

A typical record of pursuit after-nystagmus (PAN) for rightward tracking is shown in Fig. 1. When the lights went out, the eyes continued to move for a fraction of a second as if still following the target. A saccade was often then made to the left side of the screen. Subsequently, slow phase movements continued in the same direction as the former pursuit but at a much lower velocity. Fig. 2 shows a plot of individual slow phase velocities versus time for the after-nystagmus depicted in Fig. 1. Such plots of after-nystagmus often contained abrupt changes in slow phase velocity and long tails. These tails had an initial velocity of about 4°/sec and could last as long as 120 sec. However, for the purpose of comparison, we have approximated the initial portion of after-nystagmus by a decreasing exponential function that can be described by a time constant and an initial gain (ratio of the initial slow phase velocity of after-nystagmus to target velocity).

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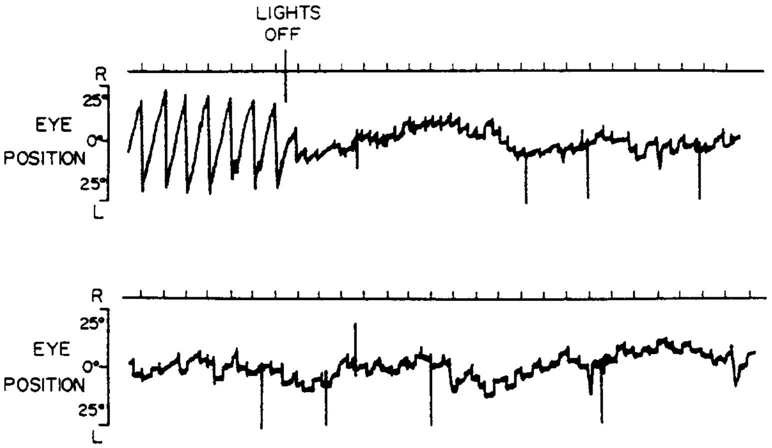

Fig. 1. Recording of eye movements during and after tracking of a small target in a sawtooth fashion on a dark background (target velocity = 50°/sec). Bottom record is continuation of top record. Small spikes just at onset of some saccades are artifactual.

Eight of 11 subjects tested showed PAN when tracking a small target moving on a dark background, 6 of 8 tested showed PAN when tracking on a stationary, striped, illuminated background and 7 of 7 showed OKAN. Several subjects were tested several times. As an example of intrasubject variability, one individual, in whom PAN was elicited on four separate occasions, had a relatively narrow range of gains (0.21–0.26) and a broader range of time constants (5–15 sec).

In an attempt to systematically compare PAN elicited with and without a background and OKAN, we measured responses of five individuals to each of the three types of stimuli. The results are shown in Table 1. In most subjects, the gain of OKAN was consistently higher than that of PAN and there was also a trend for PAN to have a higher gain when the target moved on a stationary illuminated background. However, the after-nystagmus time constants showed no consistent pattern of variation that could be related to the nature of the tracking task.

DISCUSSION

Our study demonstrates the existence of a previously unreported ocular motor phenomenon—pursuit after-nystagmus (PAN). PAN was found in most subjects (73%) although its intensity and especially the time course of decay were exceedingly variable. PAN occurred regardless of whether the target moved on a dark or high contrast patterned background. Comparison of OKAN and PAN in the same individual indicated that the initial slow phase velocity of OKAN was usually greater but no significant difference in time constants was apparent.

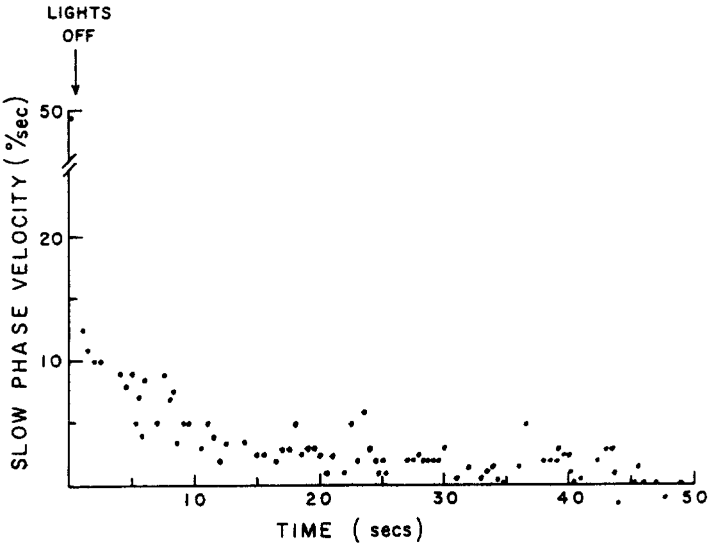

Fig. 2. After-nystagmus slow phase velocities versus time from record shown in Fig. 1.

Table 1. Comparison of after-nystagmus during different visual tracking tasks

SUBJECT	MEASURE	PURSUIT	PURSUIT ON STRIPES	OPTOKINETIC DRUM
ls	gain	0.36	0.47	0.61
	TC	4.5	10.0	4.5
lg	gain	0.12	0.45	0.60
	TC	5.0	2.0	8.5
dz	gain	0.24	0.13	0.25
	TC	5.0	4.5	9.0
ss	gain	0.18	0.26	0.23
	TC	10.0	6.0	4.0
rw	gain	0.29	0.35	0.73
	TC	4.0	2.0	3.5
Mean (S.D.)	gain	0.24(.09)	0.33(.14)	0.48(.23)
	TC	5.7 (2.4)	4.9 (3.3)	5.9 (2.6)

Gain = ratio of the initial slow phase velocity of after-nystagmus to target velocity.
Time constant (TC) = time in secs at which the slow phase velocity is 37% of its initial value. This computation is made after excluding the contribution of any long tails of slow phase velocity.

What neural mechanism generates PAN and what, if any, is its functional significance? On the one hand, PAN could simply be a scaled down version of OKAN and reflect the action of the proposed storage mechanisms that normally produces OKAN (Raphan *et al.*, 1977). On the other hand, PAN could reflect a different neural mechanism that helps the central nervous system compensate for ocular motor imbalances created by neurological lesions. The central nervous system's first line of defense against unwanted drift of the eyes is the pursuit system. Normally the latter detects the motion of an image upon the fovea and generates an eye velocity command nearly equal to that of the original velocity of the image on the fovea so that the net image velocity is nearly zero. In the case of image movement produced by drift of the eyes themselves, the pursuit command could in effect null the unwanted drift and permit steady fixation.

One can thus envision an adaptive mechanism by which the central nervous system monitors the output of the pursuit system. If prolonged unidirectional pursuit is detected this adaptive mechanism assumes that a lesion must have occurred causing the eyes to drift, and creating image movement upon the fovea. Therefore, this adaptive mechanism generates a bias in the direction of prolonged pursuit to help null the presumed ocular motor drift. Such a mechanism would presumably operate during any prolonged unidirectional pursuit and thus reveal its action as PAN if the lights were shut off after prolonged unidirectional tracking. The time course of decay of PAN would then reflect the time course of decay of the bias created by this adaptive mechanism. Our findings do not permit us to distinguish the exact mechanisms causing PAN but none the less point out a new ocular motor phenomenon of potentially significant theoretical and clinical interest.

Acknowledgements—We thank Vendetta Matthews for editorial assistance and Scott Schnee for helping with preliminary experiments. This work was supported by a National Institute of Health research grant (EY01849) and Teacher Investigator Award (NS 11071) to Dr Zee.

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