

Effects of an Optokinetic Background on Pursuit Eye Movements

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The effects of an optokinetic background on pursuit eye movements was studied in four normal human subjects and seven patients with impaired pursuit and/or optokinetic nystagmus (OKN). Eye movements were recorded by DC electro-oculography and eye movement velocity was analyzed by a digital, microprocessor system. Tracking of a small laser target was performed against a featureless, white screen, a stationary OKN background that filled the entire visual field and an OKN background moving at constant velocity. The OKN background significantly affected pursuit in all subjects. The stationary background or background moving in the direction opposite to that of the laser target impaired pursuit; whereas, the background moving in the same direction as that of the target improved pursuit. The effects of the background on pursuit were greater in subjects with lower pursuit gains during tracking against the screen. An algebraic summation of independently induced pursuit and OKN eye movements could not account for all of the experimental observations. Invest Ophthalmol Vis Sci 24:1115-1122, 1983

Pursuit and the slow component of optokinetic nystagmus (OKN) are smooth eye movements that track objects moving in the visual environment. Pursuit is induced by small objects whose images stimulate the foveal or parafoveal retina; whereas, OKN is induced by large patterns that stimulate large areas of the retina. Both types of eye movements stabilize images on the retina. In naturally occurring situations pursuit and OKN are activated simultaneously. For example, during head movements pursuit and OKN act synergistically with the vestibulo-ocular response (VOR) to stabilize retinal images. If the head rotates to the right, the objects whose images fall on the fovea move to the left and induce a pursuit eye movement to the left. Objects in the visual surround whose patterns fall on the central and peripheral retina move to the left and induce an OKN slow component to the left. Pursuit and OKN are in the same direction as the slow component of the VOR that results from stimulation of the horizontal semicircular canals.

Antagonistic stimulations of pursuit and OKN can occur during tracking of a small object. For example, a bird might be observed at a distance flying to the

right against the background of mountains. The movement of the bird stimulates the fovea and induces pursuit to the right. However, movement of the eyes to the right results in motion of the visual background of the mountains to the left relative to the eyes. Leftward OKN might be stimulated. If the observer's head also rotates to the right while he is attempting to track the bird, the head movement results in a VOR to the left. In this situation, pursuit would be antagonistic to the OKN and VOR.

In most laboratories pursuit targets are presented against featureless backgrounds. However, previous observations in man¹⁻³ have indicated that optokinetic backgrounds can affect pursuit. Merrill and Stark¹ suggested that these effects can be explained by a linear summation of pursuit and OKN eye movements. An OKN pattern consisting of vertical stripes was generated on an oscilloscope screen, and made to rotate horizontally at a constant velocity. A stationary $4 \times 4^\circ$ area in the center of the OKN pattern was produced and a small dot moved in triangular patterns of constant velocity of about $0.8^\circ/\text{sec}$ within the central area. When normal subjects tracked the dot moving in the same direction as the OKN pattern (synergistic stimulations), eye velocity was greater than the dot velocity. The eyes moved ahead of the dot, and backward saccades were made to refixate the target. When the dot and OKN pattern were moving in opposite directions (antagonistic stimulation) eye velocity was less than the dot velocity. The eyes lagged behind the dot, and forward, catch-up saccades were made.

Hood² demonstrated differences in pursuit during tracking against a featureless screen and tracking

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against a stationary OKN background in patients with cerebellar disorders and impaired pursuit. A small dot was made to move in triangular patterns of constant velocity of about 15°/sec. Eye velocity during tracking against the screen was less than target velocity and catch-up saccades were made. However, eye velocity during tracking against a stationary OKN pattern of vertical white stripes against a black background was much less than that during tracking against the screen, and larger catch-up saccades were made. Hood did not observe a similar decrement of pursuit during tracking against the OKN background in normal subjects. Collewijn and co-workers³ demonstrated in normal subjects that pursuit of a small target was impaired during tracking against a large OKN background of random dots, compared to tracking against a featureless background.

The purpose of this study was to investigate the effects of stationary and moving OKN backgrounds on pursuit in normal human subjects and patients with defects of the ocular motor system. We wished to determine if these effects could be explained by simple summations of separately induced pursuit and OKN eye movements.

Materials and Methods

Subjects

Four normal human subjects were studied. They had no history or signs of ophthalmic or neurologic disorders. These subjects were selected from a large group of normal subjects because they had either very high or slightly decreased pursuit gains (eye velocity/target velocity) while tracking a small target against a white, featureless screen. Their mean pursuit gain ± 1 SD while tracking a target moving at 30°/sec was 0.93 ± 0.07 (range 0.82–0.99). Their mean OKN gain ± 1 SD while tracking a large visual pattern of vertical stripes moving at 30°/sec was 0.83 ± 0.07 (range 0.74–0.96). Five patients with cerebellar and/or pontine lesions were studied. The etiologies included familial and acquired cerebellar ataxia syndromes and infarction. These patients were selected because they demonstrated moderately impaired pursuit. Their mean pursuit gain ± 1 SD at a target velocity of 30°/sec was 0.64 ± 0.08 (range 0.52–0.86). Their mean OKN gain ± 1 SD at a drum velocity of 30°/sec was 0.62 ± 0.17 (range 0.47–0.99). Two additional patients with an Arnold-Chiari malformation and congenital achromatopsia were studied. They were selected because they demonstrated markedly impaired pursuit and OKN. Informed consent was obtained before entry into the study.

Eye Movement Recording and Analysis

Eye movements in all subjects were conjugate, and summed, horizontal movements of both eyes were recorded by D-C electro-oculography. Ag-AgCl skin electrodes were placed at the outer canthi of both eyes. Details of the recording and analysis systems have been reported previously.⁴ The electro-oculographic system has a bandwidth of 0–35 Hz (–3 dB) and an average noise level ± 1 SD (root mean square) of $0.10 \pm 0.03^\circ$. Eye position data was displayed on a curvilinear chart recorder (Grass) and was digitized at 200 samples/sec and analyzed by an online, digital microprocessor system (LSI-11). Instantaneous pursuit velocity was measured every 5 msec, and an average pursuit velocity was calculated for every 20 msec interval.

We have observed an effect of eccentric gaze on smooth pursuit in another study.⁵ In that study target trajectories that were centered about eccentric, horizontal positions of gaze were used. We found that pursuit velocity when the eyes were moving toward the center of the orbit could be greater than that when the eyes were moving away from the center of the orbit. To avoid an effect of eccentric gaze in the present study, pursuit velocities were selected when the eyes crossed the center position of gaze during each cycle. Data from four to eight cycles were used to calculate a mean pursuit velocity in each direction. Pursuit gain for each subject was calculated as mean eye velocity/pursuit target velocity. OKN gain was calculated as mean slow component velocity (SCV)/drum velocity.

It was important to identify and remove small amplitude, catch-up saccades from the data. Saccades were identified by an online, computer algorithm, based upon velocity criteria.⁴ Saccades have a characteristic peak velocity-amplitude relationship,⁶ and have much higher velocities than pursuit movements of similar size. Since we wished to identify saccades as small as 1° in amplitude, the minimum velocity criterion for a saccade was 70°/sec. If an eye movement had a velocity of 70°/sec or more for at least 20 msec, it was identified as a saccade. In the computer output of pursuit velocity vs time, small saccades missed by the algorithm were easily detected as abrupt peaks in the velocity tracing. We do not believe that saccadic velocities were included in the calculations of pursuit velocity.

Tracking Tests

A pursuit target was generated by a helium-neon laser (Spectraphysics) and consisted of an intense, red dot of 1° diameter. The target was reflected from a

motorized, mirror galvanometer (General Scanning) and projected onto a featureless, white screen located 1M in front of the subject. The target was made to move in triangular patterns with constant velocities of 5, 15, 30, and 60°/sec with amplitudes up to 30° (peak-to-peak). Subjects were instructed to track carefully the pursuit target.

Subjects were placed within a 126-cm diameter OKN drum. The interior surface was black with 2.5-cm wide, white vertical stripes placed every 15°. The drum was rotated at a constant velocity of 30°/sec. To test OKN subjects were instructed to fixate upon individual white stripes as they passed directly in front of them ("stare" OKN⁷). Since the laser and mirror-galvanometer were mounted within the drum, the pursuit target could also be projected onto the interior surface of the drum.

The following tracking protocol was used: (1) OKN at 30°/sec, (2) pursuit against the screen, (3) pursuit against the stationary drum, and (4) pursuit against the drum rotating at 30°/sec. In the normal subjects tracking was studied with all pursuit target velocities from 5 to 60°/sec. In the patients tracking was studied at target velocities of 5 to 30°/sec. During pursuit against the OKN drum, subjects were instructed to track the pursuit target and to disregard the apparent motion of the OKN background.

Results

Normal Subjects

In normal subjects the OKN background had significant effects on pursuit. The effects of the visual background on pursuit were related to the pursuit target velocity. The effects were less at lower target velocities and greater at higher target velocities. Figure 1 demonstrates tracking of a normal subject at a target velocity of 15°/sec. During tracking against the screen, pursuit gain was 0.98 to the right and 0.98 to the left. During tracking against the stationary drum, pursuit was slightly-to-moderately decreased (pursuit gains 0.94 and 0.90 to right and left, respectively). The eyes fell behind the target and small catch-up saccades were made. During drum rotation to the right, when the target and drum were moving in the same direction, (synergistic stimulations) pursuit gain increased to 0.99. When they were moving in opposite directions, (antagonistic stimulations) pursuit gain decreased to 0.51. During drum rotation to the left, pursuit gain was 0.99 during synergistic stimulations, and was 0.15 during antagonistic stimulations.

Effects on pursuit in this subject were greater at a higher target velocity of 30°/sec (Fig. 2). Pursuit gains

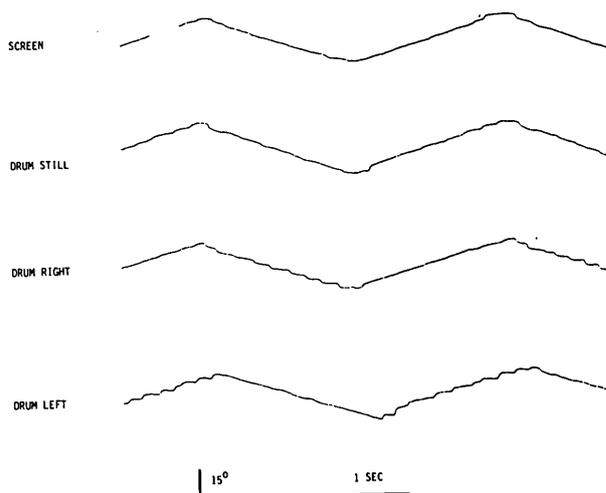


Fig. 1. Smooth pursuit in a normal subject. Laser target velocity is 15°/sec. Deflections up are to the right, down to the left.

were less (0.95 and 0.97 to the right and left, respectively) than at the lower target velocity. Pursuit was markedly degraded during tracking against the stationary drum. Larger catch-up saccades were made, and pursuit gains were only 0.75 to the right and 0.76 to the left. During drum rotation to the right, when the target and drum were moving in the same direction (synergistic stimulations), pursuit was excellent (gain 0.99). However, when they were moving in opposite directions (antagonistic stimulations), tracking

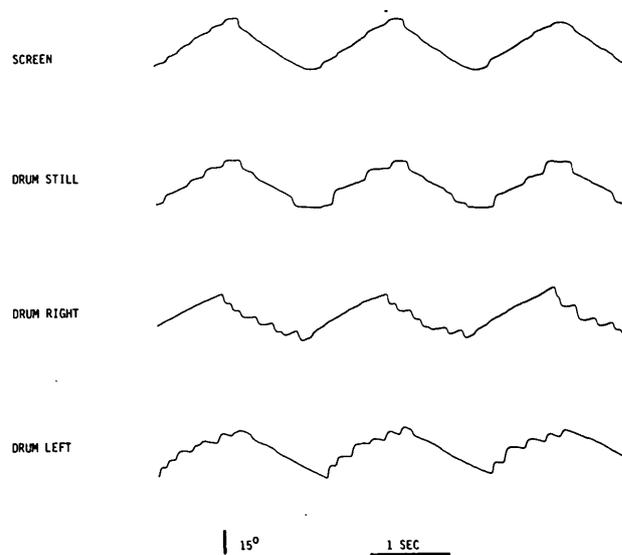


Fig. 2. Smooth pursuit in a normal subject. Laser target velocity is 30°/sec. Deflections up are to the right, down to the left. Note that during tracking in the direction opposite to that of the drum rotation, smooth eye movements are in the direction of drum rotation.

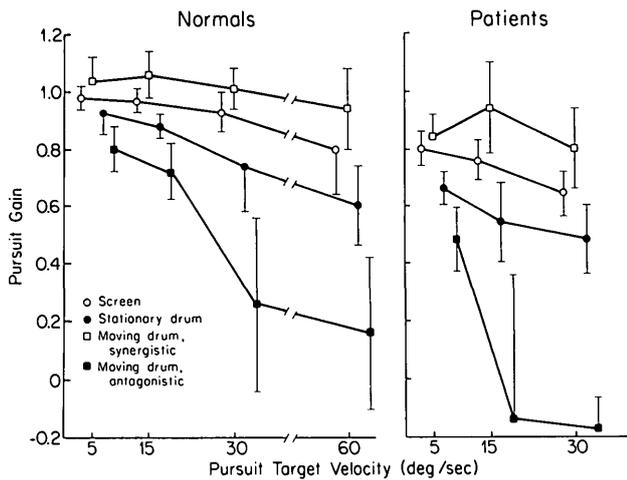


Fig. 3. Effect of target velocity on pursuit gain with different visual backgrounds. Data from normal subjects are shown on the left, and data from patients on the right. Symbols represent mean pursuit gains for the groups ± 1 SD. Open circles represent tracking against the screen, closed circles tracking against the stationary drum, closed squares tracking of target in direction opposite to drum motion (antagonistic stimulations), and open squares tracking of target in same direction as that of drum motion (synergistic stimulations). Note that negative gains indicate smooth eye movements in the direction opposite to that of target motion. Target velocities are 5, 15, 30, and 60°/sec. Data points are clustered close to their respective target velocities.

was severely impaired, and smooth movements were in the direction opposite to that of target motion (gain -0.24). Similar effects on pursuit were present during drum rotation to the left. Pursuit gain was 0.99 during

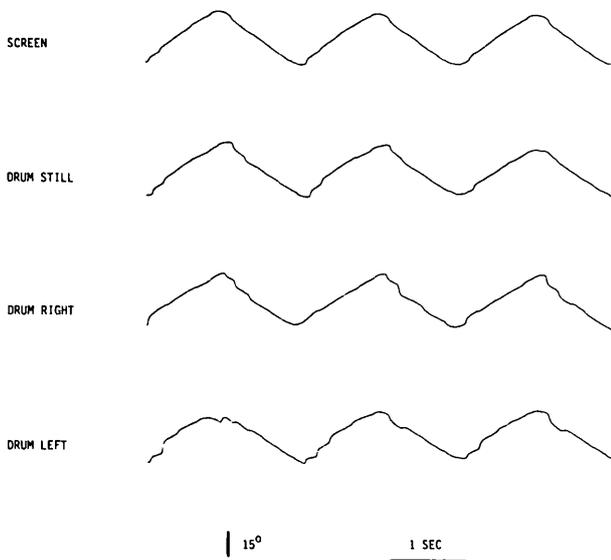


Fig. 4. Smooth pursuit in a normal subject. Laser target velocity is 30°/sec. Deflections up are to the right, down to the left. Pursuit gain against the screen is higher in this subject than in normal subject in Figure 2. Note that effects of the OKN background are less than in Figure 2.

synergistic stimulations and -0.15 during antagonistic stimulations.

Mean pursuit gains in the normal subjects are shown on the left side of Figure 3. Gains at all target velocities and with all visual backgrounds are shown. Increased effects on pursuit gain at higher target velocities is demonstrated. Tracking against the screen is represented by open circles. Pursuit gain decreased at velocities of 30 and 60°/sec. Tracking against the stationary OKN drum is shown by closed circles. Pursuit gains against the drum were less than those against the screen at all target velocities. The differences between pursuit gain against the screen and against the stationary and moving OKN backgrounds were tested by the Student's t-test for paired observations. The differences between tracking against the screen and tracking against the stationary drum were not significant at a target velocity of 5°/sec, but were significant at 15, 30, and 60°/sec ($P \leq 0.05$).

Tracking with the laser target and drum moving in opposite directions (antagonistic stimulations) is represented by closed squares. The moving background markedly decreased pursuit gains at all target velocities. The differences between tracking against the screen and tracking with antagonistic stimulations were not significant at 5°/sec ($P = 0.2$), but were significant at 15°/sec ($P = 0.05$), and at 30 and 60°/sec ($P < 0.01$). Tracking with the target and drum moving in the same direction (synergistic stimulations) is shown by open squares. Pursuit gains were only slightly increased by synergistic stimulations. The effect on pursuit gain was much less than that of antagonistic stimulations. The differences between tracking against the screen and with synergistic stimulations were significant only at 60°/sec ($P = 0.05$).

The large standard deviations in Figure 3 are indicative of a large variability of data between subjects. Part of the variability can be attributed to differences in the pursuit systems among the subjects. Pursuit is thought to result from a closed-loop tracking system. If the eyes fall behind the target, a retinal error signal (probably a velocity error) is generated, and the velocity of the eyes is increased. If the system is unable to precisely track the target, pursuit gain values decrease. The normal subjects in this study were chosen to include subjects with a range of pursuit gains. A suggestion of a correlation between pursuit gain and the magnitude of the effects of the background on pursuit was found in the normal subjects. Subjects with high gains tended to demonstrate smaller effects; whereas, subjects with lower gains showed greater effects. Therefore, variability in effects would be expected.

Figure 4 shows tracking of another normal subject

at a target velocity of 30°/sec. Pursuit gains against the screen were higher than those of the normal subject in Figure 2, and the effects of the OKN backgrounds were less than those in that subject. The pursuit gains against the screen were 0.98 and 0.99 to the right and left, respectively. Pursuit was only slightly impaired during tracking against the stationary drum and antagonistic stimulations. The smooth eye movements during antagonistic stimulations are still in the direction of the laser target motion; whereas, they were in the direction of the drum motion in Figure 2.

Patients

The OKN background also had significant effects on pursuit in the patients. These effects were generally greater than those in the normal subjects, especially during antagonistic stimulations. Figure 5 demonstrates tracking in a patient with olivo-ponto-cerebellar degeneration. During tracking against the screen at target velocities of 15°/sec, pursuit gains were 0.85 and 0.71 to the right and left, respectively. Tracking against the stationary drum decreased pursuit (gain 0.60 right, 0.65 left). Synergistic stimulations during drum rotation to the right improved pursuit markedly, such that eye velocity exceeded target velocity (gain 1.21) and small, backward saccades were made to the target. Antagonistic stimulations during drum rotation to the right resulted in smooth movements in the direction opposite to that of target motion, and the calculated pursuit gain had a negative value (gain -0.66). Synergistic and antagonistic stimulations were also effective in modifying pursuit eye movements during drum rotation to the left. Synergistic stimulations increased pursuit gain to 0.97, and antagonistic stimulations decreased the gain to -0.45.

Mean pursuit gains in the patients (excluding the two patients with the Arnold-Chiari malformation and congenital achromatopsia) are shown in the right side of Figure 3. Pursuit against the screen is represented by open circles. Pursuit gains were less than those of the normal subjects at all target velocities. Tracking against the stationary drum (closed circles) decreased pursuit gain. The differences between tracking against the screen and stationary drum were significant at all target velocities ($P \leq 0.05$).

As in the normal subjects, antagonistic stimulations (closed circles) had the greatest effect of pursuit. Pursuit gain was decreased at all target velocities. Gains were negative, ie, smooth movements were in the direction of drum motion rather than in that of target motion, in three of the five patients at 15°/sec

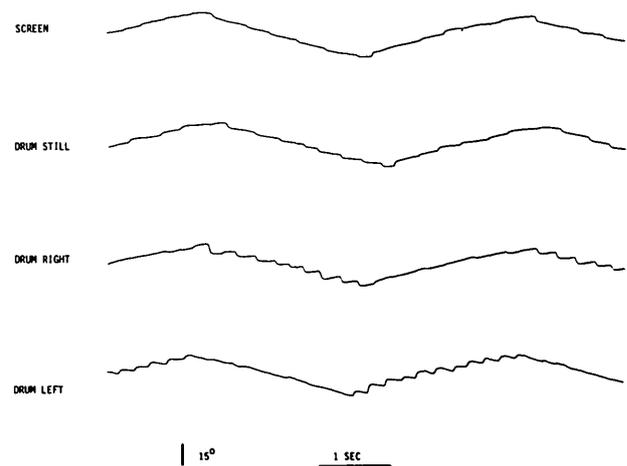


Fig. 5. Smooth pursuit in a patient with olivo-ponto-cerebellar degeneration. Deflections up are to the right, down to the left. Laser target velocity is 15°/sec. Note that effects of the visual backgrounds are greater than in the normal subjects shown in previous Figures.

and in four of the five patients at 30°/sec. The differences in gains between antagonistic stimulations and tracking against the screen were significant at all target velocities ($P < 0.01$). Synergistic stimulations increased pursuit gain, but this effect was much less than that of antagonistic stimulations. The differences between synergistic stimulations and tracking against the screen were not significant at 5°/sec ($P = 0.5$), but were significant at 15 and 30°/sec ($P = 0.05$). As in the normal subjects, part of the large variability in data appeared to be due to the variability in pursuit gains against the screen among the patients.

Observations in the two patients with an Arnold-Chiari malformation and congenital achromatopsia suggested that correlation might exist between OKN gain and the effects of the OKN background on pursuit. In these patients OKN gains were much lower than those in the normal subjects and in the other patients. The effects on pursuit were much less than those expected in patients with decreased pursuit gains. In the patient with the Arnold-Chiari malformation, OKN gains were 0.28 and 0.37 to the right and left, respectively. At a target velocity of 15°/sec, pursuit gain against the screen was 0.69 to the right and 0.30 to the left. Gains against the stationary drum were similar (0.70 right and 0.31 left). Antagonistic stimulations did not decrease gains (0.65 right and 0.31 left). Synergistic stimulations had little effect on the pursuit gains (0.58 right and 0.42 left).

Observations in the patient with congenital achromatopsia provide a striking example of a possible correlation of OKN gain and the effects of the OKN background on pursuit. In this disorder there is a

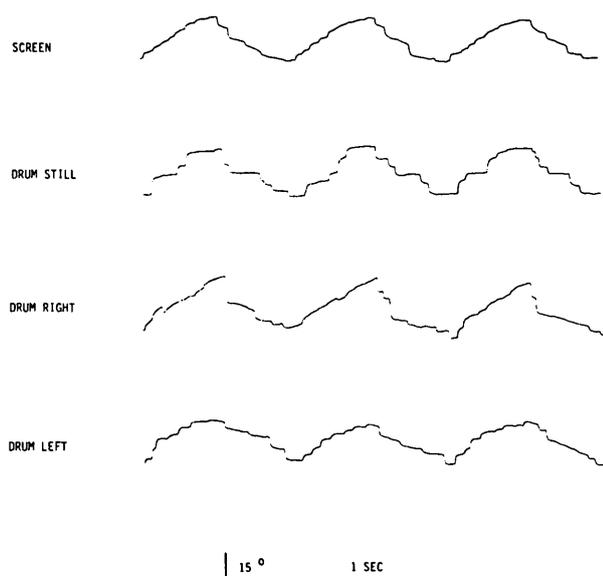


Fig. 6. Smooth pursuit in a patient with congenital achromatopsia. The right eye is occluded, and the left eye is viewing. Laser target velocity is $15^\circ/\text{sec}$. OKN gain was much greater to the right than to the left. Note that synergistic stimulation improves pursuit only during drum rotation to the right.

maldevelopment of retinal cone photoreceptors, resulting in poor visual acuity and complete loss of color vision.⁸ Patients with congenital achromatopsia have been shown to demonstrate a directional asymmetry of OKN during monocular stimulation, that is similar to directional selectivity of OKN in avoate animals,^{9,10} but that is not present in normal human subjects. With one eye covered and the other eye viewing, motion of OKN patterns in the temporal-to-nasal direction of the visual field of the viewing eye elicits greater OKN than motion in the nasal-to-temporal direction in the visual field.

In our patient with congenital achromatopsia tracking tests were performed with each eye occluded. Drum rotation in the temporal-to-nasal direction had large effects on pursuit; whereas, drum rotation in the nasal-to-temporal direction had little, consistent effect. Figure 6 demonstrates tracking at $15^\circ/\text{sec}$ with the left eye viewing. With the left eye viewing, OKN gain was 0.50 to the right (temporal-to-nasal direction) and 0.10 to the left (nasal-to-temporal). Pursuit gains while tracking against the screen were 0.74 and 0.65 to the right and left, respectively. Tracking against the stationary drum reduced pursuit gains in both directions (right 0.04, left 0.02). Drum rotation to the right, which produced a relatively high OKN gain (0.50), significantly increased pursuit gain to the right (0.86, synergistic stimulations), compared to gains to the right during tracking against the screen and against the stationary drum. However, drum ro-

tation to the right did not significantly decrease pursuit gain to the left (0.04, antagonistic stimulations), compared to gain to the left against the stationary drum (0.02).

Drum rotation to the left, which produced a low OKN gain (0.10), did not increase pursuit gain to the left (0.36, synergistic stimulations), compared to the gain to the left during tracking against the screen (0.65). However, the pursuit gain to the left was greater than that during tracking against the stationary drum (0.02). Drum rotation to the left did not decrease the pursuit gain to the right (0.20, antagonistic stimulations), compared to the gain to the right during tracking against the stationary drum (0.04). However, the gain was decreased compared to the gain to the right during tracking against the screen (0.74).

Directional effects were also observed with the right eye viewing. OKN gains were 0.50 to the left (temporal-to-nasal direction) and 0.17 to the right (nasal-to-temporal direction). Pursuit gains while tracking against the screen were 0.34 and 0.37 to the right and left, respectively. Pursuit gains against the stationary drum were similar to those against the screen. Drum rotation to the right did not alter pursuit gains. However, drum rotation to the left decreased pursuit gain to the right to 0.01 (antagonistic stimulations) and increased the gain to the left to 0.58 (synergistic stimulations).

Discussion

In most clinical tests and experimental paradigms of smooth tracking attempts are made to study pursuit and OKN in isolation. Small targets that stimulate the fovea are used to induce pursuit, and large patterns that stimulate large areas of the retina are used to elicit OKN. However, in most naturally occurring situations the fovea and peripheral retina are stimulated simultaneously, and both types of smooth tracking could be induced. Our studies demonstrate that the visual background can significantly affect tracking of a small target. Our experimental paradigms do not match closely visual stimuli that are likely to be encountered in the environment. The OKN drum presents a high contrast grating and the OKN background and the pursuit target are at the same distance from the observer. However, it is reasonable to expect that effects similar to those found in our study, but of lesser magnitude, are present during tracking in the environment.

The optokinetic background moving in the opposite direction to the pursuit target (antagonistic stimulations) dramatically degrades pursuit tracking.

In some normal subjects and patients this motion of the background actually reversed the direction of smooth tracking. Movement of the background in the same direction as that of the pursuit target (synergistic stimulations) also affected pursuit. Improvement of pursuit during synergistic stimulations over that in tracking on a featureless screen was particularly striking in patients with defective pursuit. However, in patients and normal subjects the effect of background motion was greater during antagonistic stimulations. A motionless background also degraded pursuit.

We believe that there is a correlation between the magnitude of the OKN background effect on pursuit and the pursuit gain against the screen. The effects might increase as the performance of the closed-loop pursuit system and its gain decrease. This correlation could explain some of the observations in this study. In the normal subjects and patients, the effects on pursuit increased with increasing target velocity. Pursuit gain in most subjects normally decreases with increasing target velocity. Effects were greater in the patients than in the normal subjects. Pursuit gains against the screen were lower in the patients. Finally, a trend was present within the groups of normal subjects and patients, in which subjects with lower pursuit gains had greater effects by the background. However, when the changes in pursuit gain against the OKN backgrounds were compared to the pursuit gains against the screen, only a moderately strong linear correlation was found. For example, at the target velocity of 15°/sec, Pearson's correlation test of gains during antagonistic stimulations and tracking against the screen revealed a correlation coefficient of 0.7.

Our observations have not allowed us to determine the specific mechanisms by which the OKN background affects pursuit. The visual stimuli consist of a small target, that is located at or near the fovea, and a large, structured pattern that stimulates the fovea and peripheral retina. From our observations it is clear that both stimuli affect the output of the ocular motor system. We constructed a simple model in which two, separate systems responded to the velocity of the small target (pursuit system) and to the velocity of the large pattern (OKN system). A simple algebraic summation of the outputs of the two systems could not occur, if there was no interaction of the velocity inputs to the systems. If the stimuli were independent, equal effects of antagonistic and synergistic stimulations would be predicted. However, one of the most striking observations was the large difference in effects from the two types of stimulation.

To account for the unequal effects of antagonistic and synergistic stimulations in our study, we assumed

that an interaction of visual stimuli occurred in our model. We assumed that the input to the optokinetic system was the relative velocity of the OKN background on the retina. For example, if the drum is rotating at 30°/sec to the right and the eyes and small target are moving to the right and left at about 15°/sec, the relative background velocity will be 15°/sec during tracking to the right (synergistic stimulations). It will be 45°/sec during tracking to the left (antagonistic stimulations). Therefore, unequal effects of synergistic and antagonistic stimulations will be expected. However, this model does not account for the observations at target velocities at 5°/sec and 60°/sec. At 5°/sec the difference between the relative background velocities is too small to account for the large difference between synergistic and antagonistic effects in the normal subjects and patients. At 60°/sec the mean pursuit gain during synergistic stimulations in the normal subjects was 0.94. This represents an eye velocity of about 56°/sec. When the drum and laser target move in the same direction, the eyes move ahead of the drum (drum velocity is 30°/sec). The relative background velocity is in the opposite direction to that of movements of the eyes and target. The model will predict a decrease in pursuit gain. However, pursuit gain was slightly increased by synergistic stimulations at 60°/sec, compared to pursuit gain against the screen.

There is no direct evidence for separate pursuit and OKN systems in man. Observations from clinical studies^{8,10,11} have provided interesting, indirect evidence for the presence in man of a separate, brainstem OKN system, similar to that in afoveate animals. However, if such a system exists, it is usually dominated by the pursuit system. It is possible that in our tests a single, pursuit system is stimulated simultaneously by both types of visual stimuli. The pursuit system may respond to each stimulus in a weighted fashion. The weighting may depend upon instructions to the subject and interactions between the stimuli.

Although the mechanisms underlying the effects of the OKN background on pursuit are not known, tests of pursuit against patterned backgrounds might become useful clinical tests in the future. A patterned background can have definite effects on pursuit, and the magnitude of the effects are greater in subjects with decreased pursuit gain. Therefore, tracking against patterned backgrounds might be a sensitive test in detecting defects in the pursuit system.

Key words: eye movements, pursuit, optokinetic nystagmus, ocular motor pathways, eye movement recording, electro-oculography, congenital achromatopsia

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