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FINAL TECHNICAL REPORT on instrumentation grant AFOSR-89-0191.

RESEARCH TITLE: DURIP - Improved eye monitoring capabilities
for studies in visual cognition.

PRINCIPLE INVESTIGATORS: Dr. Robert Fendrich and Dr. M.S.
Gazzaniga

Dear Sirs:

My apologies for getting this report to you late. The problem was that due to an oversight, a ccpy of the documentation stating the need for this report was not forwarded from the college funding office to me. Until they received a notice that the final report was overdue, I was not notified that one was required.

EQUIPMENT ACQUIRED.

One Generation 5.5 Double Purkinje Image Eyetracker, purchased from Fourward Technologies (San Diego, California) for a cost of \$65,000.

The instrument, manufacturer and price are as specified in the grant application.

The Eyetracker was installed at Dartmouth by Fourward Technologies in February of 1989, and is currently fully operational.

RESEARCH PROJECTS UTILIZING THIS EQUIPMENT.

We have interfaced the new ^{image} eyetracker with a Hewlett-Packard 1310 large screen display and IBM PC/AT computer. The IBM contains a Data-Translation high speed D/A-A/D board and a vector drawing board. Specialized software has been developed to analyze the characteristics of both pursuit and saccadic eye motions. The investigations described below are representative subset of the studies we are conducting with the eyetracker. These investigations are being carried out in conjunction with Dr. Patricia Reuter-Lorenz of the Dartmouth Medical School Program in Cognitive Neuroscience and Dr. Howard Hughes of the Dartmouth College Dept. of Psychology.

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Research specified in the grant proposal.

A. An investigation of the role of oculomotor system in covert shifts of spatial attention.

This investigation is now nearing completion. It has been proposed that movements of spatial attention are mediated by states of oculomotor readiness - that is, by oculomotor programs which are set to move the eyes to the attended region, but not actually executed. We evaluated this hypothesis by comparing the effect of spatial precues on manual and oculomotor reaction times. In separate blocks of trials, subjects were required to (1) press a button (while maintaining central fixation) when a target was presented on a CRT screen or (2) jump their eyes to fixate that target. There were four possible target locations, two in each visual field. A precue indicated the spatial location where the target would appear 75% of the time; on the remaining (invalid precue) trials the target appeared at one of the 3 alternative locations. If oculomotor programs are used to deploy spatial attention, the performance decrement - i.e reaction time "costs" - produced by the invalid precues should follow the same pattern for the two types of responses. The Purkinje image tracker was used to time the saccadic responses, and insure proper fixation in both the saccadic and the manual response conditions. Two experiments have been carried out.

In one experiment, we used a peripheral precue - a luminance increment at one of four target locations. We found the overall cost produced by the invalid precues was identical (at 40 msec.) in the two response conditions. However, the pattern of costs produced by the different cue-target pairings is strikingly different for the two types of responses. For manual responses, cost are relatively large when the target is presented farther

from the fovea than the cued position. For the saccadic responses, on the other hand, costs are relatively large when the target is presented closer to the fovea than the cued position. This dissociation is consistent with the view that attentional orienting mechanisms can be independent of oculomotor programs.

In a second experiment (now about 80% complete), we employ the identical paradigm but use a central precue - arrows - to indicate the probable target location. With this central precue, the pattern of costs produced by the invalid cues is appears to be quite different from the pattern obtained with peripheral cues. With central precues, there are no clear differences between the pattern of costs produced in the two response conditions. Costs are substantially larger when the cue and target appear in different visual fields than when they occur in different location in the same visual field, an effect which did not appear with peripheral cues. However, the effect of the relative cue-target eccentricity found with peripheral cues is absent with central cues. These results suggest that (1) covert mechanisms of covert orienting are not identical for central and peripheral cues and (2) that with a central but not peripheral precue a common mechanism may be influencing the latency of manual and oculomotor responses.

B. Illusions during stroboscopic displays.

Previous investigators have reported that if two points or short line segments in apparent motion are presented vertically aligned on a CRT display, and one is presented slightly before the other, the stimulus which is presented second is seen as lagging spatially behind the first. We have extended this observation to more complex displays, in which moving lines and geometric figures are drawn by sequentially plotting multiple points on the screen. We have found that when such images are placed in apparent motion (by drawing the display at successive horizontal screen positions), there are large and stable distortions of seen image. These distortions occur because the regions of the image that are drawn later in each "frame" are displaced spatially backwards from the regions drawn earlier. To illustrate, if a "X" is plotted on the screen with a vertical line passing through its center (over a time course of about 30 msec.), and the line is plotted after the X, the line will appear to displace backwards from the center of the X during apparent motion of the display. In addition, if the line is plotted vertically from its bottom to its top, it will appear to lean obliquely backwards. Finally, these distortions can influence the apparent length of lines along the axis of motion: lines shrink when they move in the same direction as they are being plotted, and stretch when they move in the opposite direction. The magnitude of these distortions depends upon (1) the rate at which

the images are drawn, and (2) the rate of apparent motion.

It is possible to account for these illusions by arguing that pursuit eye motions are producing retinal image distortions. Other investigators have argued against this, claiming that such illusions can occur in the absence of pursuit. We have found, however, that when an observer fixates very rigorously (which we verify with the eyetracker), or we use feedback from the eyetracker to eliminate the retinal displacements produced by pursuit, the distorted percepts are generally eliminated. Under these conditions, what is characteristically seen are multiple veridical images flashing across the CRT screen.

Under certain circumstances, however, some of these illusory distortions (such small displacements between points or line segments) are reported despite rigorous fixation. This appears to occur when the spacing and timing of successively drawn stimulus segments favors a parsing together of stimulus elements from different picture frames. Changing the spacing or timing parameters of the displays to increase the isolation of successive frames eliminates the perceived distortion during fixation.

We are now beginning to carry out more parametric examinations of the contributions of parsing and pursuit to these motion dependent distortions. In addition, we are investigating two ancillary findings that have emerged in the course of the studies carried out to date: (1) rapid reversals in the direction of pursuit eye motions may be possible in the course of saccadic eye motions, and (2) the motion "deblurring" filter that has been reported to operate during the perception of continuously moving objects may not be activated by stroboscopic motion (even though that motion appears continuous).

Other research.

We are making use of the Purkinje image tracker in two additional investigations of basic visual and oculomotor processes.

A. Interference by stationary grating on the pursuit of moving gratings.

When observers view a high frequency sinusoidal grating (5 cpd) which is drifted across a stationary low frequency grating (.5cpd), the presence of the low frequency grating often disrupts the coherence of the perceived motion of the high

frequency grating. This observation led us to investigate how well subjects are able to engage in oculomotor pursuit of the moving grating. We have found the stationary low frequency grating generates a loss of pursuit gain, relative to a condition where that grating is not present. This loss of pursuit gain increases as the velocity of the high frequency grating increases: in our experiments, the loss averages 14% with a .2°/sec. grating velocity (temp. freq. = 1 Hz.) and 72% at a 3°/sec. velocity (temp. freq. = 15 Hz.). At velocities greater than 3°/sec. most subjects are unable to initiate any pursuit.

However, when the low frequency grating is drifted and the high frequency grating is stationary, for low frequency grating velocities ranging from 2 to 20°/sec. (temp. freq = 1 to 10 Hz.), there is little or no loss of pursuit gain. This asymmetry could reflect the presence of a low spatial bandpass characteristic in the inputs to the motion processing and/or smooth pursuit system.

At lower velocities of the low frequency grating, however, the stationary high frequency grating does begin to produce a loss of pursuit gain: 12% when the drift rate is 1°/sec., and 35% when the drift rate is .3°/sec. This has led us to speculate that the temporal frequency of the stationary background during pursuit may play a role in modulating the interference effects. We are currently engaged in an investigation of these phenomena.

B. Pursuit eye motions in callosotomy patients.

In primates, the left hemiretina of each projects to the right hemisphere of the brain, while the right hemiretina projects to the left hemisphere. Thus, each hemisphere receives information from the contralateral side of space. However, evidence from animal studies and neurological patients suggests that the hemispheric control of pursuit is ipsiversive: that is, the left hemisphere controls pursuit to the left, and the right hemisphere controls pursuit to the right. Thus, to pursue a stimulus leftward in the left visual field (or rightward in the right visual field) should require a hemispheric interaction. In the monkey, this interaction appears to occur across the splenium of the corpus callosum, where a fiber pathway from MT in each hemisphere (an area apparently dedicated to processing motion information) projects across to MST (a probable oculomotor control area) in the opposite hemisphere.

If pursuit in humans involves a similar hemispheric interaction across the splenium, human callosotomy patients may be impaired in their ability to engage in the ipsiversive pursuit of lateralized targets. To evaluate this possibility, we have presented such patients with targets lateralized just to the left

or right of their fovea, and used the eyetracker to horizontally stabilize those targets. In normal observers, such offset stabilized targets tend to elicit smooth accelerating eye motions which chase the retreating stimulus. We have also observed such eye motions in callosotomy patients, indicating that each hemisphere is at least capable of ipsiversive pursuit. A more quantitative analysis of the quality this pursuit is planned, to determine if it is poorer than that elicited in normals. Informally, it seems to us that this may be the case; the pursuit elicited in the patients appears erratic and is fragmented by numerous small saccades. Formal measurements and analyses are needed however, to give substance to this impression.

Sincerely Yours,

Robert Fendrich

Robert Fendrich, PH.D.