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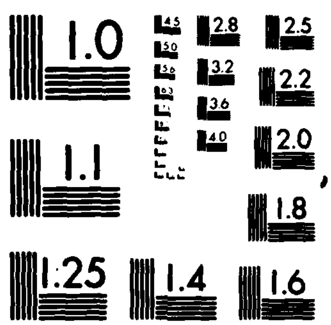

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Final Technical Report
December 1981

EYE MOVEMENTS AND VISUAL INFORMATION PROCESSING

RUTGERS UNIVERSITY
NEW BRUNSWICK, NJ

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Bolling Air Force Base, DC 20332

82

Manuscripts in preparation

Kowler, E. and Sperling, G. Independence of visual search from stimulus onset waveform. To be submitted to Perception and Psychophysics

Kowler, E. and Sternberg, S. Programming of saccades. Will be submitted to Vision Research.

ABSTRACT

Eye movements determine the location and velocity of the retinal image. Thus, to understand how we see it is necessary to understand both how eye movements are controlled and how they affect visual information processing. The proposed research is concerned with both problems. Specifically:

(1) The effect of expectations on smooth eye movements. The eye moves smoothly in the direction of expected future target motion. Experiments will determine: (1) how expectations and guesses about the direction of future motion are formulated and (2) the relative contributions of expectations and retinal image motion to smooth eye movements.

(2) The effect of saccades and saccade-like stimulus perturbations on visual information processing. Saccades continually displace the retinal image, yet we see the world as a single coherent picture. Experiments will find out whether the visual system selectively tolerates rapid lateral displacements, or whether the decision to move the eye is required.

and (3) Programming sequences of saccades. Experiments will show whether sequences of saccades can be pre-programmed, and whether use of such sequences improves performance of visual tasks.

PROGRESS REPORT (January, 1981 - December, 1981)

1. Development of laboratory facilities. The LSI 11/23 computer system was delivered and installed in April, 1981. The system contains a central processor, memory, serial and parallel line interfaces, clock, analog-to-digital converters, digital-to-analog converters, and an electrostatic plotter. Hardware and software interfacing allowing computer control of experiments is underway and should be complete by September 30, 1981. The computer is currently being used for analysis of data collected in 1981 (see descriptions of experiments and results below). The SRI Double Purkinje Image Eyetracker is scheduled for delivery on or about October 1, 1981. An appropriately sized, secure table to hold the tracker is currently under construction.

2. Experiments on the role of saccades in visual information acquisition. Kowler and Sperling (1980) reported that saccade-like stimulus perturbations (abrupt onsets and rapid, lateral displacements) are not necessary for efficient acquisition of visual information (see proposal pp. 2-3). Specifically, they found that performance on a visual search task (identifying the single numeral in an array of alphanumeric characters) was not improved either by increasing the number of abrupt onsets of the display, or by imposing rapid, lateral displacements on the display. This result suggested that the retinal image perturbations produced by saccades are not necessary for efficient information acquisition.

Their conclusion, however, was limited because Kowler and Sperling's stimuli always contained at least one abrupt onset. In order to further test the conclusion that abrupt onsets are not useful, I completed an experiment in which performance on the same visual search task used by Kowler and Sperling was measured for displays with: (1) gradual onsets and abrupt offsets, (2) abrupt onsets and gradual offsets, (3) abrupt onsets and abrupt offsets.

The results obtained support Kowler and Sperling's original conclusion. No evidence for the necessity of abrupt onsets was found. In fact, the waveform of the onset and offset had only minimal effects on performance. The small effects of waveform that occurred do not suggest an important role for abrupt onsets. Performance for displays with gradual onsets was always slightly better than performance for displays containing the same amount of energy, integrated over the total presentation time, with abrupt onsets and offsets. These results for two subjects and two presentations times (150 msec and 250 msec) are summarized in Table 1.

One stimulus variable which did affect overall performance was total energy. Performance was slightly better for the shorter presentations times when total energy was increased by a factor of two. These results, however, do not mean that visual search performance depends on stimulus energy because increasing energy improved performance only during the first two-thirds of the trials. As subjects became more practiced, total energy no longer mattered. This is summarized in Figures 1 and 2, which show how performance changed over trials. Note that total energy never affected performance for the longer (250 msec) presentation time.

These results, taken together with Kowler and Sperling's (1980) results, have implications for the role of saccades in visual information processing. They suggest that the kind of retinal image perturbations produced by saccades are not essential for visual information acquisition. In fact such perturbations hardly affect performance at all, suggesting that saccade-like image perturbations are not harmful either. This is a useful state of affairs. It means that human beings can use saccades at will to fixate regions of interest. They do not have to increase saccade rate in order to keep already fixated regions visible. Also, they do not have to decrease saccade rate to avoid what could be harmful consequences of saccades, such as rapid displacements of the retinal image, or brief decrements in stimulus visibility known to be associated with saccades (*i.e.*, saccadic suppression). Results obtained so far indicate that such perturbations have little, if any, effect on our ability to acquire visual information.

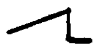
Further quantitative analyses of these results and a ms are in preparation.

3. Experiments on programming sequences of saccades. A common assumption in studies of tasks requiring use of saccades to scan visual displays is that saccades are planned one at a time. Experiments are underway to determine whether subjects can pre-program sequences of saccades. The experiment already begun is modeled after Sternberg

et al.'s (1978) study of pre-programming of sequences of motor responses used in typing and speech. Sternberg *et al*. (1978) found that characteristics of individual responses (latency of the first response and time between responses) are a function of properties of the sequence as a whole (*e.g.*, sequence length). Their finding suggests that observers prepare all the motor commands for the sequence before response execution begins.

I found similar results for saccades. Two subjects were presented with either 1, 3 or 5 stationary point targets. They were instructed to look from point to point as quickly as possible. The mean latency of the first saccade increased with the number of points presented. This result, shown in Figure 3, suggests that motor commands for the entire sequence of saccades are pre-programmed before the first saccade occurs. It now becomes feasible to propose to study characteristics of saccadic programming, for example, the effect of programs on performance of visual tasks (see proposal pp.50-57).

Table 1. Proportion correct reports of the identity and location of the single numeral for two different presentation times (TIME), four different waveforms (WAVE) and two subjects. Each score is based on approximately 300 observations.

		Subject	
TIME	WAVE	EK	BF
150 ms		.68	.57
		.72	.56
		.75	.60
		.68	.53
250 ms		.81	.78
		.84	.79
		.89	.74
		.82	.68

Note: Trials consisted of a sequence of 9 frames, only one of which contained a numeral. Presentation time refers to the time between onsets of successive frames.

Figure 1. Visual search performance as a function of practice over trials. Subject EK. Upper functions for 250 msec presentation times; lower functions for 150 msec presentation times. Symbols indicate waveform:

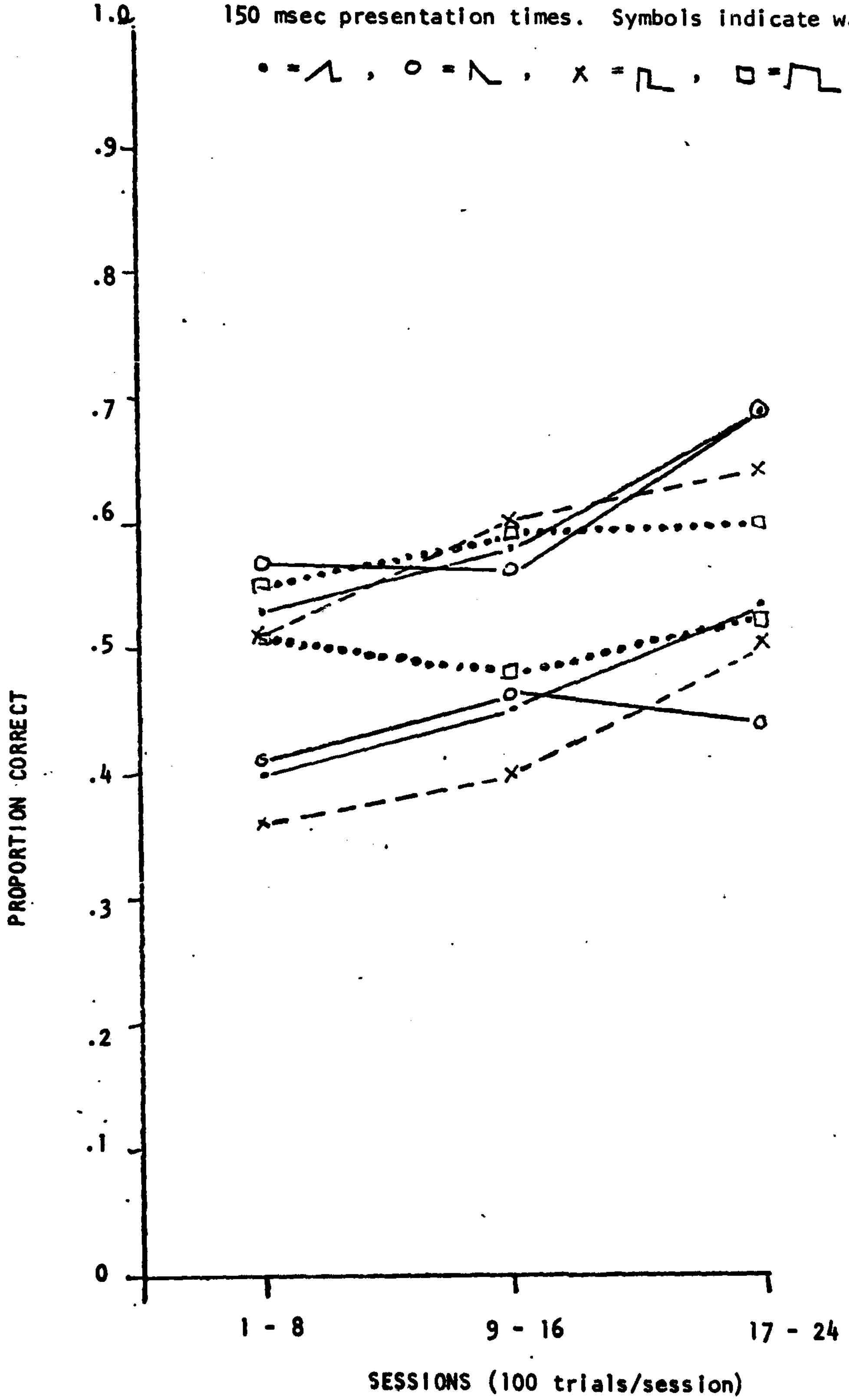


Figure.2. Visual search performance as a function of practice over trials. Subject BF. Upper functions for 250 msec presentation times; lower functions for 150 msec presentation times. Symbols indicate waveform:

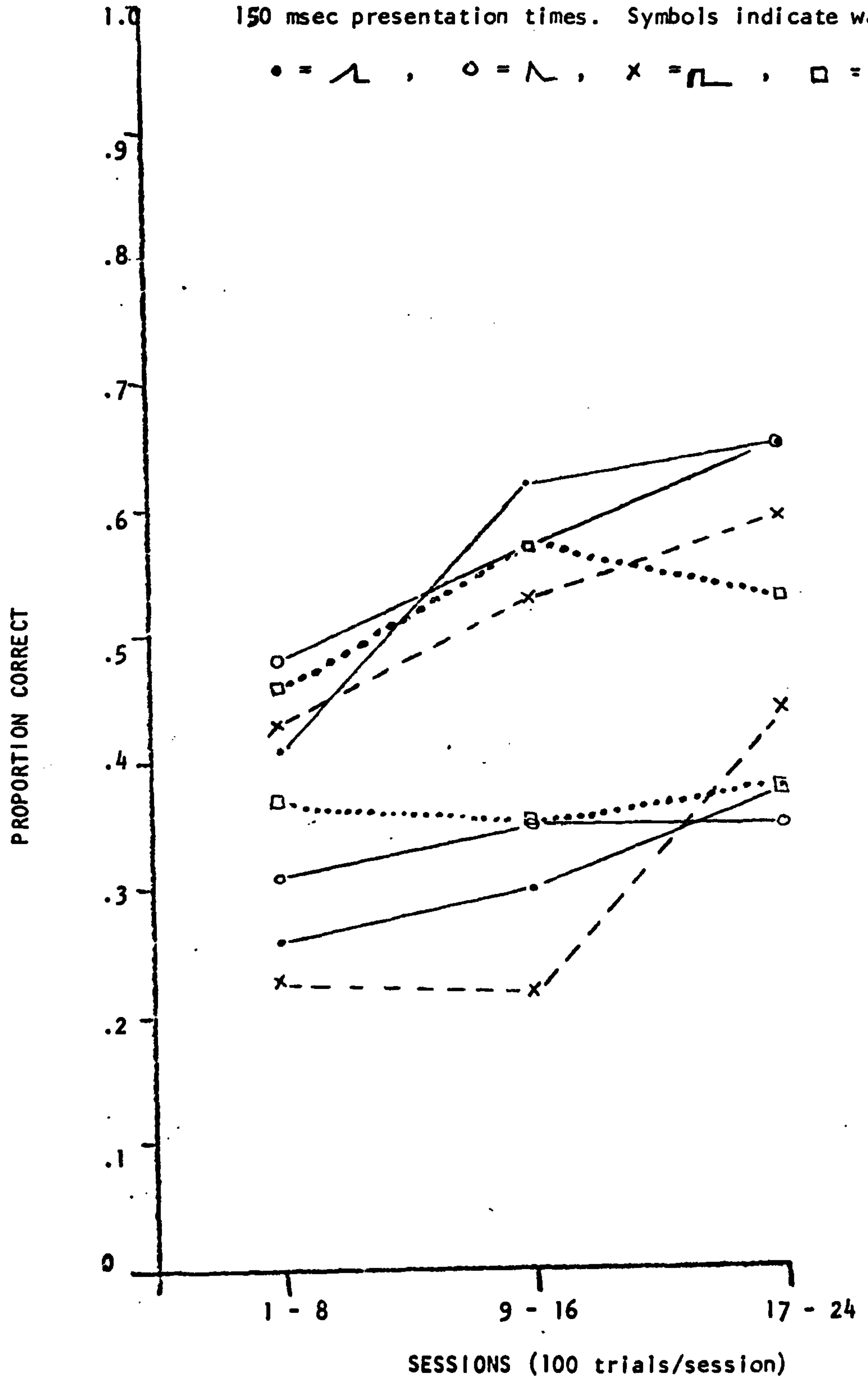


Figure 3. Mean latency of the first saccade in a sequence as a function of the number of points ... acting as targets for saccades. Solid lines for subject DF; dashed lines for subject RS