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LETTER TO THE EDITORS

LATENCY CHARACTERISTICS OF SMALL SACCADES

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WYMAN and STEINMAN (1973) have shown that subjects use saccades to correct small errors produced by sudden displacements of the fixation target in much the same way that they correct small errors during fixation. Moreover, subjects use different patterns of saccadic response to correct experimentally introduced visual errors just as idiosyncratic eye movement patterns are used during fixation of a stationary target. For example, one subject frequently responded to a leftward step with a burst of small saccades and to a rightward step of the same size with a single saccade that tended to fall short of the displaced target position. This finding suggests that the oculomotor response to a target step is not a fixed characteristic of the oculomotor system but may depend on stimulus conditions or on the nature of the required response. This possibility led us to examine the relative effects of signal characteristics and response variables on the latency of the tracking response. Only the first saccade was studied, because only this saccade is signalled entirely by the visual error introduced by the target step.[1]

METHOD

Horizontal and vertical eye movements were recorded with a two-dimensional contact lens optical lever. This technique, described elsewhere by HADDAD and STEINMAN (1973), records small rotations of the eye free from contamination by torsions of the eye or translations of the head.

The fixation target was a sharply focused green point on an oscilloscope face, seen in darkness. The point was produced by a short persistence phosphor (P-20) whose intensity was set to be 1·6 log units above absolute foveal threshold. Care was taken to eliminate any distinguishable features from the oscilloscope face, which subjects could have used as reference marks to aid in identifying displacements of the target. The target was located 2·04 m directly in front of the subject's right eye and was less than 2′ in extent at this distance. The left eye was covered and closed and the head was held rigidly in place by means of a dental acrylic bite board.

Two subjects—one highly experienced (RS) and the other relatively inexperienced (GH)—participated in the experiments. Subjects were instructed to stay on-target and correct for any changes in target position. The subject started each trial when he felt that he was ready and on-target. After 2 sec of fixation of a centered target, the target stepped either 3·5, 7·1, 14·2 or 28·4′; up, down, right or left. Size and direction of steps were randomly determined. No auditory signal was given to define precisely when the target would step. Each trial ended after 3 sec of fixation of the displaced target. Response latency was measured[2] as the time from the target step to the onset of the first corrective saccade (the first saccade in the direction of the target step).[3]

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[1] Once the eye starts to follow the target, proprioception can contribute to the oculomotor response making interpretation of subsequent saccades more difficult (see TIMBERLAKE, WYMAN, SKAVENSKI and STEINMAN, 1972, for a discussion of this problem).

[2] RC timers (± 1 msec) were started when the target stepped and triggers (of local design) stopped the timers when a saccade occurred. Trigger rates and amplitudes were adjusted functionally, i.e. subjects made saccades and the triggers were set to operate on all saccades and to ignore drifts and physiological nystagmus. These functional trigger settings were subsequently calibrated with a ramp voltage input and found to be 3°/sec of eye rotation for 7 msec, corresponding to a saccade amplitude of 1·3′.

[3] The first corrective saccade was also always the first saccade after the target step with the target step sizes used in this experiment (WYMAN, 1972).

RESULTS

Saccade latency decreased with increasing target step size

Decreases in latency with increasing target step size were modest but consistent. The effect was similar for both subjects except that RS was about 55 msec slower than GH, on the average. The results are plotted as lines connecting trianglesin Fig. 1. Further increases in the size of the target step should have still smaller effects on response latency, even though the curves in Fig. 1 show only a slight tendency to flatten out, because SASLOW (1967), who used a technique similar to ours to measure latency, has shown that latency for much larger target steps (2–8°) is not affected by the size of the target step. In his experiment, latencies for all target steps were about 200 msec. GH is showing signs of leveling off near this value when the target step is only about 0·5°.

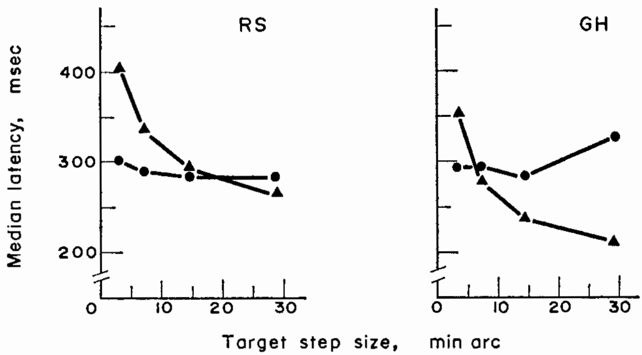

FIG. 1. Median latencies to the first saccade in the direction of the target step for target steps of different magnitude when the subject was instructed to track the target step (triangles) or to use the target step as the signal to go to a continuously visible second target located 14′ below the target that stepped (circles). The left graph shows the data for subject RS; the right graph, for subject, GH.

The measured relationship between the amplitude of the target step and the latency of the subject's response could reflect the speed of processing at some level of the oculomotor system. For example, the visual error produced by a relatively large target displacement (about 30′) may be sensed more quickly by the oculomotor system than the error produced by a 3′ target step. Or perhaps the oculomotor system can program and execute a corrective saccade of appropriate size more quickly for a larger target step. In the next experiment, we attempted to separate the contribution of signal characteristics to response latency from the contribution of response variables by using the different target steps to serve only as the subject's signal to make his saccade. This was done in the following way: The subject viewed the centered oscilloscope point and a continuously visible second target, matched in size, color and brightness to the oscilloscope point and seen as superimposed on the face of the oscilloscope. This second, stationary target was located 14′ below the centered point. The subject was instructed to move his eye to the second target when the centered target stepped. The 16 target steps used in the first experiment served as signals to saccade from the centered position down to the second point. Trials followed the format described in the prior experiment.

Size and direction of the visual signal did not influence first saccade latency

When the subject's response was predetermined, there was no systematic decrease in latency with increasing target step size. The range of median latencies with the different target step sizes was small for both subjects (for RS range = 21 msec; for GH range = 43 msec). These are much smaller than the ranges found when the same subjects actually tracked the target steps (RS's tracking range = 140 msec; GH's range = 144 msec).[4]

In conclusion, it appears that as long as the subject knows the direction and size of the saccade he should make, characteristics of a visual signal that tell him when to respond do not affect the latency of his first corrective saccade. This finding suggests that the relationship between response latency and target step amplitude originates at the programming and execution level of the oculomotor system and that the saccadic response to a large visual error can be generated more rapidly than the response to a small visual error.

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J. NACHMIAS and M. HERMAN showed in an extensive series of experiments (as yet unpublished) performed 8 yr ago that subjects track target steps as small as those tracked in our more recent work. These authors also showed that the latency for responding to small target steps depended on the size of the target step.

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[4] The results were much the same when this experiment was repeated with a variable foreperiod to insure that subjects were actually using the target step as a "go" signal and not simply estimating when the step would occur.

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