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Reports

Most naturally occurring human saccades have magnitudes of 15 degrees or less.

A. Terry Bahill, Deborah Adler, and Lawrence Stark.

Normal human saccadic eye movements are seldom larger than 15 degrees. In an outdoor environment, 86 per cent of the saccades of three subjects were 15 degrees or less in magnitude.

Although human saccadic eye movements vary in size from a few minutes of arc to 100 degrees, most naturally occurring human saccades are 15 degrees or less in magnitude. Over 70 years ago, Dodge and Cline[1] noted that saccades invoked during a normal reading task are 12 degrees or less in magnitude. When looking at pictures, normal scanpath patterns are constructed from a sequence of saccades similar in amplitude to reading saccades.[2] Lancaster[3] stated that 99 per cent of all eye movements are within 15 degrees of primary position. Three-fourths of the spontaneous saccades of restrained laboratory monkeys were less than 18 degrees.[4] When the angular direction of gaze is changed by a large amount, it is usually accomplished by using a combination of head and eye movements[5, 6]; thus, the eye movements usually remain less than 15 degrees. The purpose of this experiment was to discern the magnitude distribution of normal, human saccades during naturalistic tasks.

Methods. Electro-oculography (EOG), low-pass filtered at 100 Hz., was used to measure horizontal and vertical components of eye movements. AC-coupled differential amplifiers and an FM tape recorder were mounted on a pack frame and carried by the subject. The subject and experimenter then strolled through the campus at the University of California. The data presented here were derived from three normal male subjects. One subject (TB) wore his glasses during the experiment, while the others had normal vision without corrective lenses.

Results. Fig. 1 shows the relative frequencies of occurrence of 913 various sized saccades. Of these saccades, 86 per cent had magnitudes of 15 degrees or less. Microsaccades were omitted since the noise inherent in the EOG technique made it difficult to measure saccades of one degree or less. We estimate that these small saccades were much more numerous than indicated in Fig. 1. There were no significant differences in the shape of the distribution for horizontal, vertical, and oblique saccades, so the data for these three types have been pooled together in Fig. 1: one-fourth of the saccades were horizontal, one-fourth vertical, and one-half oblique. For the restrained monkey,[4] one-fourth of the saccades were horizontal, 5 per cent were vertical, and the rest were oblique. Our criterion for human data was that if the smaller of the horizontal and vertical components was larger than one-tenth of the large component then the saccade was called oblique; the straight vector length, not the actual travelled path length, was chosen as the amplitude.

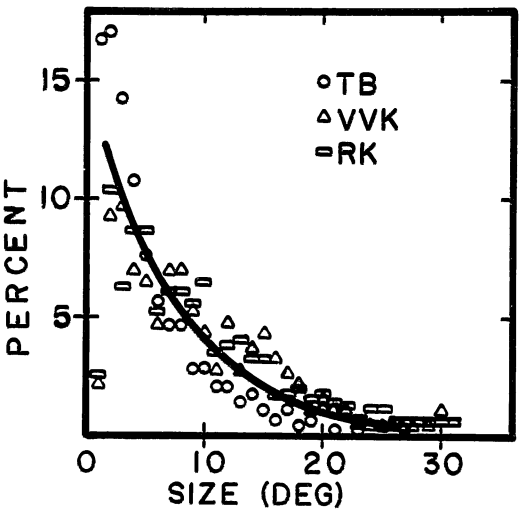

Fig. 1. Frequency of occurrence of various sized saccades for three normal subjects. The solid line representing the equation $Y = 15 \exp(-X/7.6)$, where Y is the per cent occurrence, and X is size of the saccade in degrees, was derived by the method of least squares from all of the data.

Discussion. When reading, looking at pictures, or walking out of doors, most human saccades have magnitudes of 15 degrees or less. This 15 degree saccadic size may be an important physiologic value, for there appears to be a knee in the maximum velocity main sequence curve at 15 degrees. This curve plots the log of the maximum saccadic velocity as a function of the log of the saccadic magnitude and can be approximated in a piece-wise linear fashion with a slope of 0.8 for saccades smaller than 15 degrees and a 0.15 slope for saccades 15 degrees and larger.[7] It is helpful to consider the greatest upper bound of this velocity-amplitude relationship since in this way many factors such as obliquity of the saccade or occurrence of double and overlapping saccades with lower values can be eliminated. Furthermore, at this apparent inflection point the high-frequency burst of motoneuron activity in the

saccadic controller signal undergoes significant changes.

Thus, studies of saccades larger than 15 degrees are helpful in the understanding of the operation of the central nervous system, because they stress the system and demonstrate its operation under difficult conditions. If it is realized that these larger saccades accentuate saccadic abnormalities, then much can be gleaned about the normal operation of the saccadic control system from those studies of both normal and abnormal large saccades. However, if the usual, unstressed operation of the saccadic system is to be studied, then saccades 15 degrees and smaller should be emphasized.

From the Departments of Electrical Engineering and Computer Science and of Physiological Optics, University of California, Berkeley. This research was partially supported by a National Institute of Health grant No. NIH-GM 1418 to T. Bahill. Submitted for publication Jan. 20, 1975. Reprint requests: Terry Bahill, Room 226 Minor Hall, University of California, Berkeley, Calif. 94720.

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