醫工學會誌 : 第10卷, 第3號, 1989
J. of KOSOMBE : Vol. 10, No. 3

研 究 論 文
89－3－10

A Statistical Approach to Analysis of Saccadic Eye Movements

Nam Gyun Kim, Bu Gil Kim

－Abstract－

In this study we propose an approach based on statistical method which use the whole of saccades instead of using a few points of saccades in the quantitative analyse saccades. We computed statistical parameters such as mean velocity, quadratic mean velocity, standard duration, skewness of saccades velocity, flattness factor of saccades velocity, and mean delay by considering eye velocity as a probability density function. The results abtained are the following as : This parameters showed the same trend like that of the main sequence. They were not biased by the systematic errors due to the arbitrary threshold. They were also less sensitive to noise, which was tested through the model simulation. So they are expected to provide a more comprehensive quantitative description of the dynamic properties of saccade in the diagnostic field.

1. Introduction

It is well known that saccades are the fastest eye movements which serve to rapidly redirect the position of the eyes to fixate different objected in the visual world. They are elicited by rapid jumps of small target spot from a central to an eccentric position. Many behaviorally distinct movements such as fast tracking movements, voluntary or involuntary scanning eye movements, eye movements produced during reading and fast phases of nystagmus belong to the class of saccadic eye movements. It has been reported by many authors[2-3] that important pathological situations induce significant modifications in oculomotor responses. So many study have been reported for the quantification of eye movements.

In general, the analysis of saccadic eye movements is to quantify the dynamic behavior of saccades using the main sequence[4] such as amplitude vs. duration and amplitude vs. maximum eye velocity relation. Although the main sequence is a readily applicable tool for characterizing dynamic properties of saccades, we should be aware that it depends on only the correct identification of both degining and end point of saccades. It can be pointed out that maximum velocity is sensitive to the noise affecting the recorded saccaded eye movements.

In this study we propose a statistical approach which is less sensitivite noise and is less dependent on signal processing for the quantitative analyses of saccades. The approach to be presented uses the whole of saccades unlike the main sequence using a few isolated points(beginning and end of saccades).

2. Methods

Measurements were done on 5 subjects with ages ranging from 20 to 40 years. The subjects were seated in a darkened room facing an array of LEDs extending from 30 deg. left to 30 deg. right with their head fixed. For the stimulus, LEDs

〈접수 : 1989년 11월 24일〉

Dept. of Biomedical Engineering College of Medicine Chonbuk National University.

were switched on and off at random intervals to produce symmetrical target jumps of different amplitudes ranging from 5 deg. to 40 deg. with step size 5 deg. and 16 target jumps were produced for each amplitude. For the recording of saccadic eye movements we used classical EOG method. The raw eye position signal were low pass filtered(−3 db at 150Hz) and sampled at a rate 500 Hz. Eye velocity was computed by using the central difference algorithm[5].

For the analyses of saccades we computed the classical parameters at first by following the main sequence. The begining and end points of saccades were identified by comparing eye velocity with a threshold that was adjusted by the operator according to the noise level. Secondly, we computed statistical parameters such as, both mean velocity and quadratic mean velocity(square root of the mean value of squared saccaed velocity)to by compared with maximum velocity, the standard duration(square root of the 2nd order moment of saccade velocity) to be compared with the saccade duration, the skewness of saccade velocity, the fiattness factor of saccade velocity, and the mean delay(delay of the center of gravity of saccade velocity to the stimuius) to be compared with saccade latency, by considering the eye velocity as a probability density function.

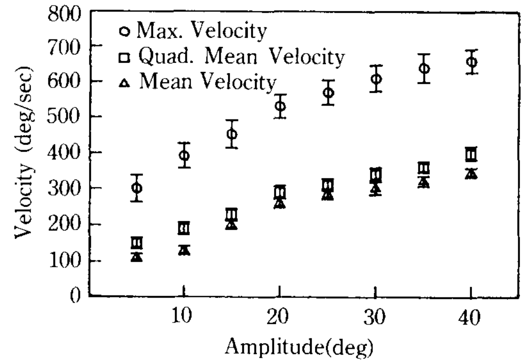

Fig. 1 The average values of the saccade maximum velocity quadratic velocity and mean velocity vs. amplitude.

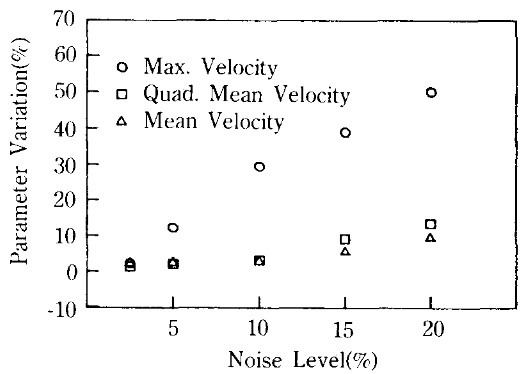

Fig. 2 The variation of each parameter vs. Noise level.

3. Results

Fig.1 shows the average values of saccadic maximum velocity, mean velocity and quadratical mean velocity vs. saccade amplitude for one typical subject. In this figure, the values of both the classical and statistical parameters mainly depended on saccade amplitude. We could ovserve slight difference with different eccentricity. We could observe the maximum velocity increase with amplitude showing saturation trend for the larger amplitudes. This corresponded to the results already described by many authors.[6-7] The statistical parameters represented the similarity like the classical one, and comparable standard deviation. We could take similar consideration when comparing the saccade latency with the mean delay and the saccade duration with the standard duration. The statistical parameters were comparable with the classical one in inter-subject variability. We could also abserve the increase of skewness with amplitude from about 0.2 for deg. saccade to 0.5 for 40 deg. and increasing dissymmetry between the acceleration and the deceleration phases. These results confirmed the earlier suggestion in the literature[8-9] with slight difference that skewness increased with amplitude. The flatness factor showed an almost constant value of about 2.3 indepenedently on amplitude and symmetry, which meaned that the velocity profile remained sharp.

Fig.2 represents the variations of each parameter vs. noise level in the simulation of 10 deg. saccade in order to show the effect of noise on each parameter. In this figure we could find that statistical parameters were less sensitive to noise. It resulted from using the whole of saccade in stead of a few points of saccade. For this simulation we used the 6th order model of the oculomotor plant described in literature.[10)] A Gaussian white noise was added to the output of the model. The simulated noise saccades were submitted to the same processing like real saccades. The velocity parameter were compured for different values of the signal to noise ratio.

4. Conclusion

In this study, we have attempted a statistical approach to quantify the saccade dynamic by using whole saccade instead of a few points. With this approach we could find that they are not biased by the systematic errors introduced in the classical parameters by use of arbitrary thresholds. The statistical parameter seems to give a more complete description of the saccade than the traditional parameter, due to their strict dependency on the profile of saccade velocitiy. The statistical parameters also were less sensitive to noise as a result of their dependency on the whole saccade. This fact also was discovered through the simulation of 10 deg. saccade by using the model described in literature.[10)] This approach could justify the increased computer efforts needed to evaluate them. This approach is expected to give us much interests in the quantification of pathological saccades.

References

1) Ron S., Robinson D.A., Skavensky A. A. : "Saccades and the Quick Phase of nystagmus", Vision Res.,12 : 2015—2022,1972.
2) Leigh R.J.,Zee D.S. : "The Neurology of Eye Movements", Philadelphia ; Davia,1983.
3) Schmid R., Zambarbieris D. : "Eye Movements Analysis in Neurological Diagnosis", Report of Center of Bioengineering, University of Pavia, 1979.
4) Bahill A.T., Ciark M. R. and Stark L. : "The main sequence, a tool for Studying Human Eye Movements",Math. Biosci.,24 : 191—204, 1975.
5) Bahill. T., Kallman J.S., Liebrman J. E. : "Frequency Limitations of the Two Points Central Difference Differetiation Algorithm", Biol.Cybernet., 45 : —14,1982.
6) Baloh R.W., Stills A.W., kumley W. E., Honrubia V. : "Quantitative Measurement of Saccade Amplitude, Duration, and Velocity", Neruology, 25 : 1065—1070, 1975.
7) Schmidt D., Abel L.A., Dell 'O' so L.F., Daroff R.B. : "Saccadic velocity characteristics : intrinsic variasility and fatigue",Aviat. Space Environ.Med., 50 : 393—395,1979.
8) Van Opstal A.J., Van Gisbergen J.A.M. ; "Skewness of Saccadic Velocity Profiles : A Unifying Parameter for Normal and Slow saccades",Visin Res., 27 : 731—745,1987.
9) Smit A.C., Van Gisbergen J.A.M.,Cools A.R. : "Arametric Analysis of Human Saccades in Different Expertimental Paradighms", Vision Res., 27 : 1745—1765, 1987.
10) Bahill A.T. : "Bioengineering : Biomedical, Medical and Clinical Engineering",Prentice Hall, Englewood Cliffs,N.J.1,1981.