Electrooculographic System for the Recording and Two-Dimensional Mapping of Concomitant Eye Movements

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Electrooculogram (EOG) is a simple method of measuring the movements of eyes in human subjects that has been used for quite a long time [1--3]. Both the speed and linear characteristics of saccades and tracing movements of the eyes can be easily assessed by this method. However, it is very difficult to restore the eye movements in the Cartesian coordinate system from an electrooculogram. Currently, there is no system that can restore two-dimensional movements of eyes based on an analysis of the electrooculographic potential. This is probably caused by the absence of simple and accurate algorithms for the analysis of EOG potential changes associated with eye movements upon various derivations.

In this work, we developed a system of derivation of the EOG potential and algorithms for its analysis that allow one to restore the trajectory of eye movements in two-dimensional space.

Modeling of dipole projections of eyeballs during the concomitant movements of eyes at various derivations indicated that the simplest and, at the same time, most informative method involves the use of two active and one "null" electrode as shown in Figure 1. The null electrode should be situated at the midline of the forehead and the active electrodes along the straight lines going from the null electrode via the temporal margins of the orbits. It is very important that the null electrode and the active electrodes be situated at the same distance from the outer margin of the orbits. With this location of silver chlorine electrodes, EOG potentials recorded in two derivations contain complete information on the movements of the eyes in the Cartesian coordinate system.

Recording of EOG potentials using this scheme was conducted with a multichannel measurement DC amplifier with an input resistance of 1 MOhm. Before being input into a computer, the signal was digitized with the frequency 20 Hz.

Figure 2 shows electrooculograms recorded in the first and the second derivations during eye movements at 10@ from the center of the visual field in various directions. It is clear that alterations of the EOG potentials during the movements of the eyes in the first and the second derivations have patterns that allow one to obtain all information necessary to represent the movements of the eyes in a two-dimensional coordinate system.

Our algorithm for analysis of EOG potentials allowed us to automate the two-dimensional mapping of concomitant movements of the eyes. The basic characteristic of the algorithm is that it analyzes the value of the potential increment in the first two derivations rather than the potentials themselves. This makes our method relatively insensitive to electrode potentials and, therefore, more accurate. Figure 3 presents the trajectory of concomitant eye movement restored from these potentials by using our method and visualized on the computer screen.

CONCLUSION

Thus, the system developed (Rospatent priority certificate No. 034148, January 10, 2001) enables one to register and conduct two-dimensional mapping of the trajectory of concomitant movement of the eyes using oculometric potentials, including analysis in real time. Therefore, this system could be applied in medicine and physiology and could also be used in the development of various artificial control units.

REFERENCES

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FIGURE CAPTIONS

Fig. 1. Scheme of electrode positioning for electrooculography: (@A) common electrode; (B@1, B@2) active electrodes; (@B@1-A@) first derivation; (@B@2-A@) second derivation.

Fig. 2. Electrooculograms recorded during eye movements in various directions from the center of the visual field in the first (@1) and second (@2) derivations. Arrows show the direction of movement of the eyes 10@ from the point of visual fixation and vice versa.

Key: 1. @a; 2. @b; 3. @c; 4. @d; 5. @e; 6. @f; 7. @g; 8. @h; 9. 100 @[mu]V; 10. s

Fig. 3. Eye movement trajectory restored from two electrooculograms.