Acute Effects of Alcohol on Saccadic Eye Movements

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Abstract. Four components of 20° horizontal saccadic eye movements, i.e., latency, mean and maximum velocities, and duration were measured in 16 students under the influence of alcohol and also in a control situation. The experimental procedures were standardized and automated as much as possible. Latency (simple eye reaction time) was not influenced by alcohol in blood concentrations of 0.056 – 0.16 %. Mean and maximum eye velocities decreased by about 9 % and duration of saccades increased by 11 %. The maximum changes occurred 90 – 120 min after the start of alcohol ingestion. The changes in velocities and durations correlated more closely with feelings of intoxication than with blood alcohol concentrations. There were great intra- and intersubject variations in reactions to alcohol. The close resemblance between the effects of certain psychotropic drugs, alcohol, fatigue, and decreased attention on eye movement control suggest that all these may act upon the same nervous structures in the brain stem.

Key words: Alcohol — Eye movements

Ethanol is known to have harmful effects on motor performance in man (Goldberg, 1966; Wallgren and Barry, 1970; Franks et al., 1976). Standing steadiness and manual dexterity, among other things, are known to be disturbed by alcohol. Similar effects have been observed in connection with fatigue, many drugs, and poisons (Rashbass, 1961; Dichgans et al., 1973; Bahill and Stark, 1975).

The disruptive effects of alcohol on ocular motility have been known for a long time. Earlier studies have shown that after ingestion of alcohol, maximal saccadic velocities drop (Franck and Kuhlo, 1970), positional alcoholic nystagmus types I and II appear (Aschan, 1958), and smooth pursuit movements of the eyes become inefficient and jerky (Wilkinson et al., 1974). Some authors conted, however, the disturbances of eye movements after ingestion of alcohol may simply reflect intrasubject variability of fatigue (Boghen et al., 1974).

This study was undertaken to find a sensitive and quantitative neurophysiological measure for detecting effects of small doses of alcohol on motor performance, and to distinguish effects of alcohol and fatigue from one another. We have found that some components of saccadic eye movements constitute such a measure. Furthermore, they can be easily quantified and are beyond voluntary control (Baloh et al., 1975a, b). We have also made studies of the effects of alcohol on EEG, smooth pursuit eye movement, simple and choice reaction times of the eyes and hands, and visual-evoked potentials. Preliminary reports of these results have appeared elsewhere (Lehtinen et al., 1976, Niemi et al., 1977). A preliminary report of the present study has also been published (Lehtinen et al., 1977).

Materials and Methods

Subjects. Sixteen healthy students, nine females and seven males, 19 – 30 years old, served as paid volunteers. All were accustomed to drinking socially. Ten subjects had normal vision and the rest had their eyesight corrected by lenses.

Experimental Design. All subjects served as their own controls. Each underwent two sessions: a control session, and about 1 week later, a test session. During both sessions they underwent the same test sequence, except for alcohol.

The experimental session was organized as follows: the subjects had a standard breakfast, one glass of milk and two warm sandwiches, at 9 a.m. after a night of good sleep (according to their own report). After the instructions had been given, the first recording was made at 10 a.m. (time point 1). Thereafter, four more recording runs were made at 1/2-h intervals (time points 2 – 5). The drinking period started immediately after the first run and lasted 30 min. During the test session the subjects consumed a mixture of vodka and juice corresponding to 1 g ethanol per kg body weight. During the control...
session subjects consumed juice only. Blood samples were taken from fingertips immediately after each recording run and also during the control session. Blood alcohol concentrations (BAC) were later analyzed by gas chromatography. The maximum values in different subjects varied from 0.056 - 0.116%. The experimental session lasted up to 4 h, during which the subjects were kept alert as much as possible by discussion and by psychological testing procedures. Two subjects reported being a little tired before the tests, others were normal or more alert than normal.

Recording of Saccades. The mean horizontal eye position and saccadic eye movements were recorded with DC skin electrodes (IMI™) applied to the outer canthi of both eyes. The subjects were seated in a chair with the head fixed mechanically and instructed to fix their gaze on the red light-emitting diode (LED) 10° right of the center on the screen and then on the new LED 20° to the left of the original one when it was turned on. A small tape recorder and a special steering circuit were used to produce a standard, pseudorandom sequence of 20 jumps between the two LEDs. The intervals between jumps ranged from 0.5 - 1.5 s. The sequence of the first ten saccades, lasting 10 s, was analyzed. The steering signal was used to produce voltage spikes which were added to the EOG (electro-oculography) signal before amplification. The EOG signals were amplified with a DC preamplifier (upper frequency limit 70 Hz/-3dB, input impedance 1 MΩ) and recorded on FM tape. For monitoring, saccades were also recorded with an ink-jet EEG recorder (ELEMA-Schöndander). The magnetic recording was later converted to digital form at the rate of 200 samples/s, using the 8-bit A-D converter of a Didac 4000 multichannel analyzer. The digitized signal was punched on paper tape and analyzed by a timesharing computer.

Data Analysis. In the computer analysis, the jump indicator spikes were first identified, using rising-speed and duration criteria. The signal was then treated with a simple harmonic digital filter of the form

\[ Y_i = Y_{i-1} + 0.25 \cdot 0.5 \cdot Y_i + 0.25 \cdot Y_{i+1} \]

Saccades beginning within 0.1 - 0.5 s after the jump indicator were then identified by applying minimum velocity and duration criteria (40°/s and 30 ms). Faulty saccades were identified by their calculated amplitude and visual inspection of the ink recording. Those accepted were used for calibration. Their average was considered to be 20° and the accepted saccades had to be within 17° - 23°. The SD of saccade amplitudes was taken to be a measure of the magnitude of under- and overshoots.

The following measures were calculated for each saccade (Fig. 1):

- Latency, i.e., the time interval from the rising point of the jump-indicating spike to the beginning of the saccade; duration of the saccade; mean velocity (amplitude/duration); and maximum velocity. The computer printout included these measures for every identified and accepted saccade and also the basic statistics. The computer program, designed by one of us (V.J.), was a modification of those used by Baloh et al. (1975b).

Subjective Evaluations. Tiredness, intoxication, and decrease of eye movement control were estimated by the subjects themselves on a continuous scale from 1 to 20. The upper end of the scale indicated maximal drunkenness, minimal tiredness, and minimal loss of subjective eye movement control. The subjects indicated their opinions by marking a cross on the line depicting the variable in question.

Statistical Analysis. The paired t-test was used to determine whether there was a significant change in variables measured at each time point. The product-moment correlation coefficient r was calculated to test possible correlations.

To see if BAC or feeling of intoxication could explain differences in measured variables between test and control situations, covariance analysis was performed. Only those subjects were included whose BAC was higher at time point 3 than at 2, and higher at time point 4 than at time point 3. Two persons were thus excluded from the analysis. For every subject at each time point the difference between control and test situations in a measured variable was calculated and a linear regression function was fitted to the differences, using BAC or feeling of intoxication as the explaining variable. F-statistics were calculated to test significance of the regression coefficient. To test how much of the remaining variance was due to interindividual variability or time point, F statistics were also calculated.

Results

Simple Reaction Time of the Eyes (Latency). Latency describes the simple reaction time of the eyes to a light signal coming from a predetermined direction. Thus, the subject does not need to make a decision about the direction in which he must turn his eyes when the signal