The Amplitude-Velocity Ratios for Eyelid Movements During Blinks: Changes with Drowsiness

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Introduction

The ratio of amplitude to maximum velocity (AVR) of eyelid closure during blinks has previously been shown to increase with drowsiness and to predict lapses in performance of a vigilance task (Johns, 2003). At that time, the AVR was calculated as the change of position of the eyelids during a blink, from eyelids open to eyelids closed, in uncalibrated units (A), divided by the maximum change of position (delta-A) per 10 msec. These two variables are known to be highly correlated in alert subjects (Evinger et al, 1991). Their ratio (AVR) has the dimension of time. This gives a measure of the relative velocity of eyelid movements which does not depend on calibration of the measurements of amplitude or velocity in absolute units (e.g., mm and mm/sec), so long as those measurements for each movement are made at the same time and under the same circumstances.

AVRs for eyelid movements show promise as a method for monitoring and quantifying the drowsy state.

Aim

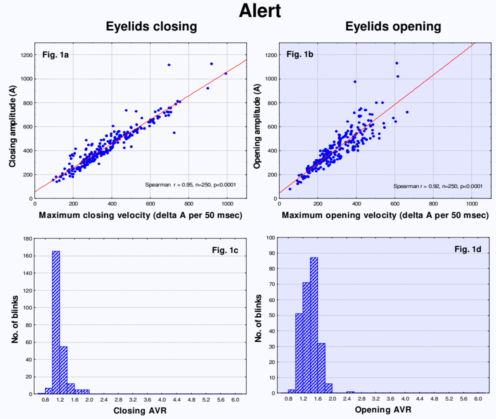
The aim of this investigation was to compare the AVRs for eyelid closure with those for eyelid reopening during blinks in subjects when alert, and again when drowsy and lapsing in a performance test after sleep deprivation.

Methods

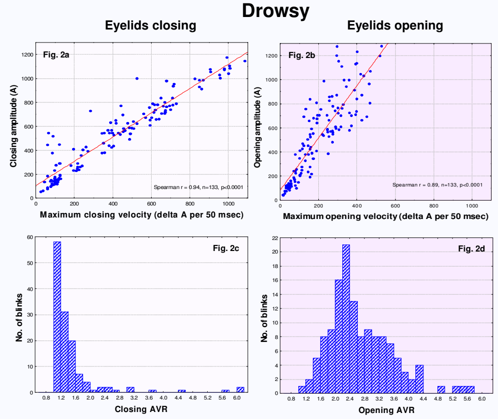
Five healthy subjects (4M: 18-27 yr) performed a 10-min psychomotor vigilance task. They had to push a button as soon as possible after seeing a change of shapes on the screen, each lasting only 400 msec and presented randomly at intervals between 5 and 15 sec. They did this when alert, performing normally, and again after 34-40 hr of wakefulness when drowsy and showing lapses in performance (errors of omission).

Eyelid movements were monitored by an infrared reflectance method (Optalert™, Sleep Diagnostics Pty Ltd, Melbourne) with 500 samples per sec, as described in an accompanying poster. The AVRs for eyelid closure and reopening during blinks were calculated in software for the first 50 blinks during the performance test when alert, and for all blinks during the 60 sec before the last error of omission when drowsy. Velocities were measured here as the maximum delta-A per 50 msec, rather than 10 msec as before. That change was made so that slower blinks in the drowsy state could be more accurately assessed. Non-parametric statistical methods were used for analysis.

Alert



Drowsy



Results: Alert Subjects

The amplitudes and maximum velocities of eyelid closure during blinks in alert subjects are shown in Fig. 1a. Each point represents one blink. These two variables are very highly correlated (Spearman's r = 0.95, n = 250, p<0.001), confirming earlier reports (Johns, 2003; Evinger et al.1991). The comparable correlation between amplitude and maximum velocity for eyelids reopening in the alert state (Fig. 1b) was almost as high (r =0.92, n = 250, p<0.001) but with a different regression slope.

The AVRs for eyelid closure during blinks in alert subjects (Fig. 1c) had a mean of 1.2 +/- 0.2 (SD). The comparable AVRs for eyelid reopening (Fig. 1d) were significantly higher than for closing (1.4 +/- 0.2, Mann-Whitney U-test, p<0.001) i.e., the relative velocity of eyelid reopening is lower than for closing, but this difference is not great in the alert state.

However, the correlation between these AVRs for eyelids closing and reopening within the same blinks, while statistically significant, was surprisingly low (Spearman's r = 0.20, n = 250, p<0.001). That indicates that the process that so closely controls the amplitude and maximum velocity (and hence AVR) for eyelid closure during blinks is somewhat independent of the process that controls eyelid reopening.

Results: Drowsy Subjects

The relationship between the amplitude and maximum velocity for eyelid closure during blinks in the drowsy state is shown in Fig. 2a and the comparable relationship for eyelid reopening in Fig. 2b. There was more variability between individual blinks in the drowsy state, and the regression for eyelid reopening was quite different from that in the alert state. i.e., the relative velocity of eyelid reopening was lower and more variable for most blinks in the drowsy state than in the alert state.

These changes were reflected also in the respective AVRs (Fig. 2c and 2d). With drowsiness, the mean AVR for eyelid closing increased to 1.5 +/- 1.0 (SD) (Mann-Whitney U-test, p<0.001), and the AVR for reopening increased to 2.7 +/- 0.9 (p<0.001). The standard deviations increased even more than the mean values.
In the drowsy state, as also noted above for the alert state, the AVRs for eyelid closure and reopening within the same blinks were not highly correlated (r = 0.28, n = 133, p = 0.001).

Conclusions

- **In alert subjects there is very close control over the maximum velocity of eyelid closure during blinks, in relation to the amplitude of those movements.**
- **The amplitude velocity ratio (AVR) gives a measure of the relative velocity of eyelid movements that does not require calibration.**
- **In alert subjects, the velocity with which eyelids reopen during blinks is also highly controlled, in relation to their amplitude.**
- **In the drowsy state, the AVRs for eyelid closure and reopening both increase (i.e., relative velocities decrease) and they become more variable, however, these changes are not highly correlated.**
- **This indicates that their respective control processes are partially independent.**
- **Drowsiness causes a loosening of the normally tight controls of eyelid movements, and the results of that loosening vary with time and differ between subjects.**
- **Because of lower velocities, the duration of these movements increases with drowsiness, as described in a companion report.**
- **We probably cannot rely on any one of these variables alone to characterize the drowsy state, or to predict drowsy lapses in performance.**

References Johns MW. *Sleep*, 2003; 26 (Suppl): A51-52. Evinger C, Manning KA, & Sibony PA. *Invest Ophthalmol Vis Sci*, 1991; 32: 387-400