The Duration of Eyelid Movements During Blinks: Changes with Drowsiness

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Introduction

The increased duration of spontaneous blinks has been suggested as an early indicator of the drowsy state (Caffier, Erdmann, & Ullsperger, 2003). Blinks have been monitored traditionally by the EOG, video images or magnetic search coils on the eyelids (Evinger, Manning, & Sibony, 1991). A new infrared (IR) reflectance method was used here to measure the duration of each component of blinks (eyelids closing, remaining closed and reopening) when subjects were alert and when drowsy.

Aims

The aims of this investigation were first, to describe briefly the new system for infrared oculography and second, to describe the results of its use for measuring the duration of eyelid movements during blinks in subjects when alert, and again when drowsy and lapsing in a performance test after sleep deprivation.

Methods

Eyelid movements were monitored by a new infrared reflectance method (Optalert™, Sleep Diagnostics Pty Ltd, Melbourne) shown in Fig. 1. Brief infrared pulses (<100 microsec), repeated at a frequency of 500 Hz from a light-emitting diode (LED), are directed up in a 30 degree beam centred on the lower edge of the upper eyelid. The total IR light reflected back from the eye and eyelid is detected by a phototransistor beside the LED. The effect of additional environmental IR light detected immediately before each pulse was subtracted from the output. The resulting pulse height (position) and the change in the pulse height per 50 msec (velocity) are calculated every 2 msec and displayed on a PC screen. The IR transducers are housed in a special frame (like spectacles) with a microprocessor in the arm, controlling the IR pulses and digitising the output from the phototransistor. These frames are light weight (28 g), comfortable to wear for hours at a time, and do not interfere with vision. They can have prescription lenses and/or sunglasses fitted to them.

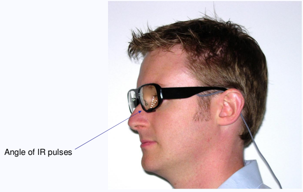

Fig. 1. The system of infrared oculography.

Five healthy subjects (4M: 18-27 yr) performed a 10-min psychomotor vigilance task (Johns Test of Vigilance, JTV, Johns, 2003) in the morning when alert and performing normally, and again after 34-40 hr of wakefulness when drowsy and showing lapses in performance (errors of omission). The JTV requires a push-button response to a visual stimulus lasting 400 msec on a PC screen at random intervals of between 5 and 15 sec. The timing of each stimulus, the subject's response, and the eye movement data are recorded simultaneously on the PC.

Blinks were distinguished from saccades and other movements. The duration of eyelids closing, remaining closed, reopening, and the total blink duration were calculated in software for the first 50 blinks during the JTVs when alert, and for all blinks during the 60 sec before the last error of omission when drowsy. Non-parametric statistical methods were used for analysis.

Results

The outputs from the IR oculography system are shown for an alert subject (Fig. 2) and a drowsy subject (Fig. 3)

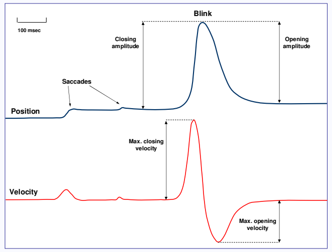

Fig. 2. The eye and eyelid position in uncalibrated units (A) and the velocity of movements (delta A per 50 msec) for saccades and a normal blink in an alert subject.

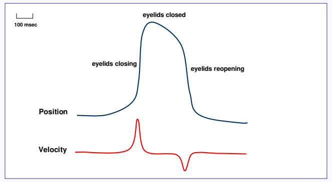

Fig. 3. A long eyelid closure and its velocity in a drowsy subject

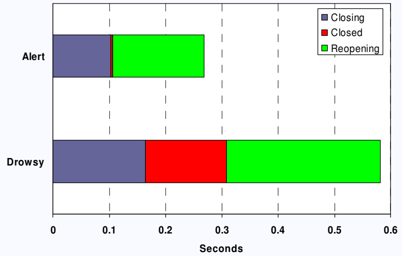

Fig. 4. The mean duration of each component of blinks in alert and drowsy subjects.

The mean duration of eyelid closure increased significantly after sleep deprivation, from 103 +/- 18 msec (SD) to 165 +/- 118 msec (Mann-Whitney U-test, p<0.001)(Fig. 4). The duration of eyelid reopening also increased significantly, from 162 +/- 49 msec to 273 +/- 100 msec (p<0.001). In alert subjects, the eyelids remained closed only very briefly (0.3 +/- 4 msec), but this increased markedly to 144 +/- 506 msec (p<0.001) and was highly variable in the drowsy state. The total duration of blinks (the combination of closing, remaining closed and reopening) in subjects when alert (265 +/- 57 msec) also increased significantly after sleep deprivation (586 +/- 592 msec, p<0.01). These durations are consistent with those measured by the gold standard magnetic search coil technique (Evinger et al. 1991).

The correlations between these different components of the same blinks were quite low. The duration of eyelid closure was only moderately correlated with that of reopening, whether in alert subjects (Spearman's r = 0.32, n = 250, p<0.001) or drowsy (r = 0.32, n = 133, p<0.001). In alert subjects, the duration of eyelids remaining closed was not correlated significantly either with the duration of eyelid closure or of eyelid reopening (Spearman's r = -0.03, n = 250, p = 0.63; r = -0.11, n = 133, p = 0.07 respectively). In drowsy subjects, the duration of eyelids remaining closed was moderately correlated with the duration of eyelids closing (Spearman's r = 0.30, n= 133, p<0.001), but not with the duration of eyelids reopening (Spearman's r = 0.16, n = 133, p = 0.07).

These results indicate that the processes that control the separate components of eyelid movements are somewhat independent. Changes in the duration of blinks reflect changes in either their amplitude or velocity, or both. Reduced relative velocities of eyelid closure and reopening in the drowsy state are described in a companion report.

Conclusions

- **The results of this new IR oculography system are consistent with the durations of blink components measured by the gold standard, magnetic search coil technique.**
- **The duration of each component of blinks (eyelids closing, remaining closed, reopening) increases and becomes more variable with drowsiness.**
- **The low correlations between these separate duration components indicate 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.**
- **We probably cannot rely on any one of these variables alone to characterize the drowsy state, or to predict drowsy lapses in performance.**

References

Caffier PP, Erdmann U, & Ullsperger P. *Eur J Appl Physiol*, 2003; 89: 319-325. Evinger C, Manning KA, & Sibony PA. *Invest Ophthalmol Vis Sci*, 1991; 32: 387-400. Johns MW. *Sleep,* 2003; 26 (Suppl): A51-52.