Eyelid Closure, Visual Suppression and Hypovigilance in the Drowsy State: Lapses in Performance With Eyes Open or Closed.

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Introduction:

Hypovigilance in the drowsy state is now recognized as a major factor in road traffic and other accidents. Methods for monitoring drowsiness in such people as truck drivers have been proposed that measure the duration of their blinks and other eyelid closures (1). These methods are based on the self-evident fact that we cannot see when our eyelids are closed because light is blocked from entering the pupils. However, there is an associated premise, usually unstated, that eyelid closure is the only cause of lapses in performance in the drowsy state, ie it is assumed that we would be able to perform visual tasks when drowsy, albeit with reduced speed of reaction, if only our eyelids would stay open.

However, there is always active suppression of vision during saccadic eye movements, when the eyelids are open (2). This suppression, which begins before the saccade and ends soon after it, is central (neural) in nature. There is similar suppression of vision during blinks (3). In this case, vision is inhibited both by central suppression and by coverage of the pupils by the eyelids. We are never aware of the gaps in our perception caused by these episodes of visual suppression that may last for about 50 msec during saccades and 250 msec during blinks in alert subjects. Depending on the frequency of such events, it is normal for us not to be able to see for a total of about 3 seconds per minute. By contrast, we can easily detect a light going out for (say) 100 msec at other times.

Vision is also inhibited when we are drowsy and falling asleep. When we prepare to fall asleep purposely we close our eyes voluntarily and that blocks the entry of light into the eyes. However, vision is also inhibited centrally then, as can be demonstrated by taping open the eyelids and flashing a light in the subject's eyes, to which there may be no response (4). By contrast, there is evidence that drowsy subjects who are trying to stay awake can keep their eyelids open voluntarily for some time, but they may not be able to see, at least intermittently(5), ie in the drowsy state, visual suppression may possibly occur without eyelid closure or saccadic eye movements.

Aim:

The aim of this investigation was to examine the roles of eyelid closure and visual suppression in lapses of performance of a visual psychomotor vigilance task by drowsy subjects. This investigation was facilitated by the development of the Johns Test of Vigilance (JTV) that enabled the subject's eye and eyelid movements to be monitored during the test.

Methods:

Nine healthy volunteers (5F, 4M; 19-64 yr) had their eye and eyelid movements monitored while they performed the 10-minute Johns Test of Vigilance (JTV) 6-8 times each, half when alert and half when sleep-deprived for either 20-24 hr or 30-34 hr. The JTV is a reaction-time test involving a push-button response to a change in shapes lasting 400 msec on a PC screen that occurred at random intervals of 5-15 sec. The infrared reflectance method for monitoring the eyes is described in a companion poster (No. 69). The data for eye and eyelid movements and the subject's responses to the visual stimuli were displayed on the same PC screen which was inspected to establish the relationship between them during all 66 JTVs. This was confirmed by video-camera pictures of the subject's eyes.

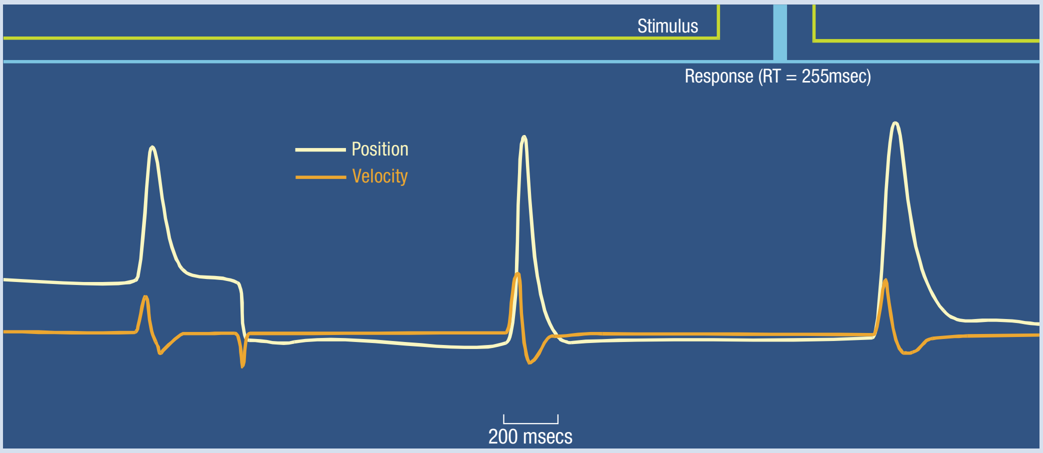
Results:

A total of 3631 stimuli were presented to the 9 subjects, half when they were alert and half when drowsy. The subjects responded to all but 23 stimuli within one sec. Failure to respond at all, or within one sec of the start of the stimulus, was regarded as a lapse in performance or an error of omission. These lapses occurred in only four of the nine subjects, and only when they were drowsy because of sleep deprivation.

Slow (pendular) eye movements that are known to occur during sleep onset were recorded at times in these subjects when drowsy. When slow eye movements happened to coincide with the presentation of a visual stimulus all subjects were nonetheless able to respond within one sec. Slow eye movements were not present during any of the 23 lapses in performance.

In retrospect, the subjects were not aware of failing to respond to any stimulus that they had seen, but were aware of having dozed off at times when drowsy.

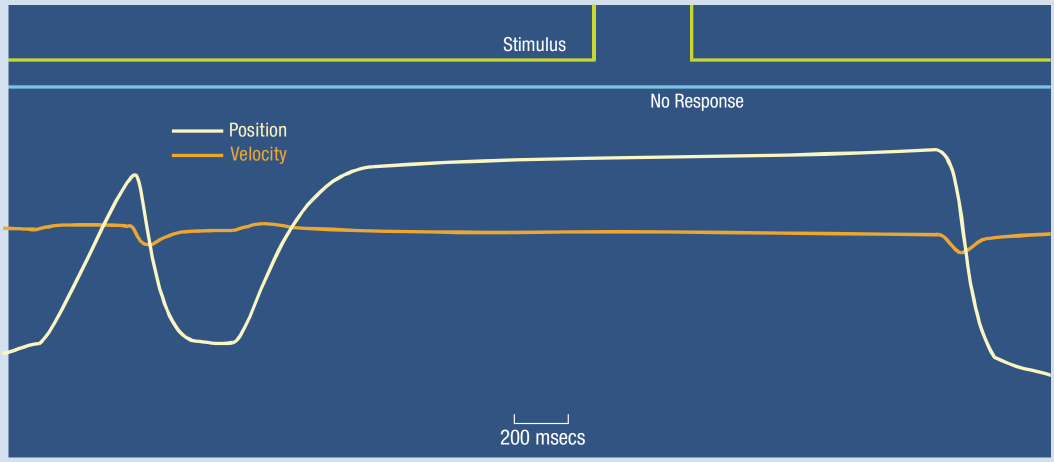
Fig 1 shows three normal blinks and a saccade (and their velocities) in an alert subject. The subject's reaction time to this visual stimulus, which happened to be presented between blinks, was 255 msec and normal.



Optalert: Normal blinks and saccade, with normal response to stimulus

Fig. 1

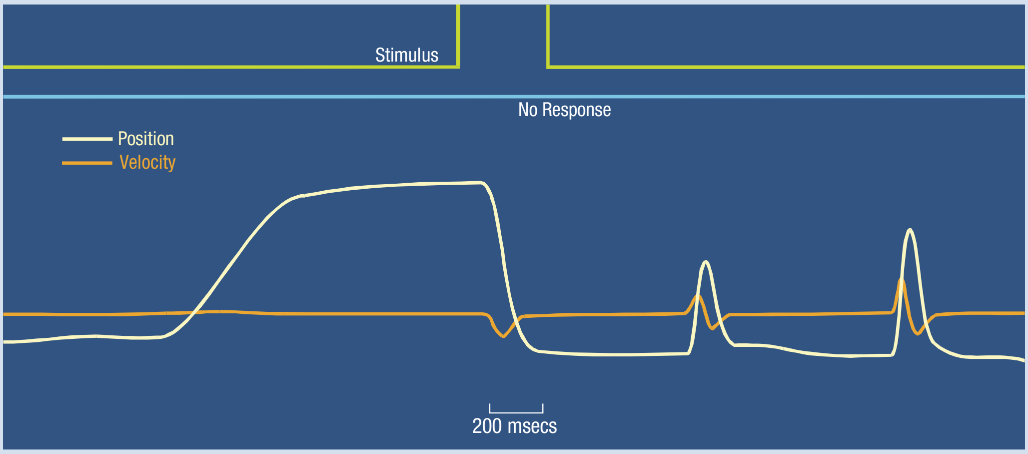
Fig 2 shows an abnormally slow blink followed by a prolonged eyelid closure which lasted 2.9 sec in a drowsy subject. There was no response to the stimulus which happened to be presented while the eyes were closed.



Optalert: No response to a stimulus in a drowsy subject during prolonged eyelid closure.

Fig. 2

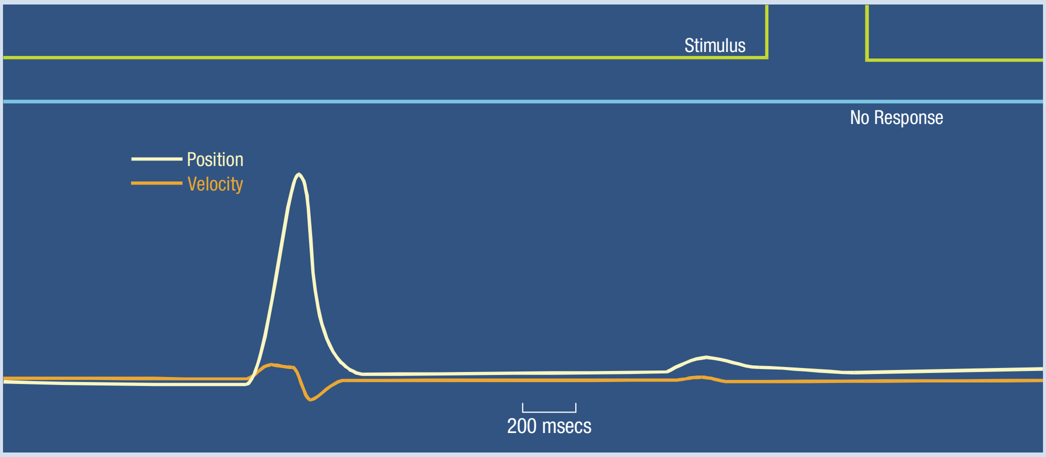
Fig 3 shows that a drowsy subject did not respond to a stimulus presented at the end of a long eyelid closure, even though the eyes were open for much of the stimulus time, sufficient for that stimulus to have been seen by an alert subject. This suggests that visual suppression that would have accompanied the blink/eyelid closure continued for some time after the eyelids were reopened.



Optalert: No response to a stimulus in a drowsy subject with eyes open after long eyelid closure

Fig. 3

Fig 4 shows an abnormally slow, but not prolonged blink. This is followed by failure to respond to a visual stimulus, even though the eyes were open at the time. This is further evidence that, in drowsy subjects, visual suppression can occur in the absence of a blink or saccade. It was not possible to decide when that episode of visual suppression either began or ended.



Optalert: No response to a stimulus in a drowsy subject with eyes open.

Fig. 4

Considering all 23 drowsy lapses, the eyelids were closed throughout the stimulus for 5 lapses, open for the whole time for 9, and open for some of the time, long enough for the stimulus to have been seen by an alert subject, for another 9 lapses.

That is, prolonged eyelid closure was a sufficient explanation for 5 of the 23 lapses, but not for 18 (78%) of them. Intermittent, central suppression of vision must be considered as a major cause of such lapses in the drowsy state, in addition to long eyelid closures.

Discussion:

The results showed that, in drowsy subjects who are trying to stay awake and to perform a visual psychomotor vigilance task, lapses in performance (errors of omission) occurred more often when the eyelids were open than when closed at the time.

Long eyelid closure, by itself, is an important cause of some lapses. However, central visual suppression that occurs normally during saccades and blinks and which is part of the sleep-onset process, must be considered as an important cause of many lapses when the eyelids are open.

Such lapses occurred only after sleep deprivation and only in some subjects.

The lapses did not occur during periods of slow eye movement.

In a companion poster (No. 69) it is shown that the velocity of eyelid movements, assessed in relation to their amplitude by amplitude-velocity ratios, became slower in the 30-sec before each lapse. This may provide a useful method for predicting imminent performance failure, even when the eyelids are open.

The results may have serious implications for those methods for monitoring drowsiness, such as PERCLOS (1), that rely only on the detection of long eyelid closures.

References:

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