A New Scale of Drowsiness Based on Multiple Characteristics of Blinks: The Johns Drowsiness Scale

Johns MW, Tucker AJ, Chapman RJ, Michael NJ, Beale CA
Sleep Diagnostics Pty Ltd, Melbourne, Australia

Introduction:

Drowsiness is the intermediate state between alert wakefulness and sleep, to be distinguished from fatigue. Although drowsiness is believed to be the cause of many highway crashes, there is no generally accepted method for measuring it in people while they are active.

Johns (1,2) has previously reported on the use of amplitude-velocity ratios for measuring the relative velocity of eye and eyelid movements during blinks, and of eye movements during saccades. These ratios change with drowsiness in ways that do not require calibration for individual subjects

We describe here a new scale, the Johns Drowsiness Scale (JDS), that measures different levels of drowsiness continuously, particularly in people who should remain alert, e.g. while driving. It is based on a combination of oculometric variables, including the relative velocities of eye and eyelid movements, measured by a new method of infrared reflectance oculography (Optalert™) (1,3).

Methods:

Seventy volunteers (male and female, aged 20-69 yr) had their eye and eyelid movements monitored by Optalert™ while performing a visual reaction-time test, the Johns Test of Vigilance (JTV). This is a PC-based test that presents a visual stimulus (change of shapes from circles to diamonds or squares) lasting 400 ms every 5 to 15 sec over 10, 15 or 20 min. The participant responds by pushing a button as quickly as possible, in a simple reaction-time test.

Data were available for 400 min from 38 participants who responded to every JTV stimulus when alert, and another 310 min from 25 of those Ss when drowsy after remaining awake for 24-40 hr and making at least 5% errors of omission (failure to respond within 2 s). Two participants also performed JTVs every 3 hr for 24 hr to demonstrate the effect of time of day on JDS scores. Nineteen subjects performed JTVs while drinking progressively more alcohol during a 6 hr period in the evening, up to 0.12% blood alcohol.

The Optalert™ system calculates the mean and standard deviation each minute for many ocular variables effected by drowsiness. They include the relative velocity and duration of eyelid closure and reopening during blinks, the duration of eyelids remaining closed, the total blink duration, and the frequency and relative velocity of saccades. Most of these variables required $\log_n$ transformation to produce normal distributions. The size and fluctuations of the pupil and the frequency of blinks, that other have used but which were not included here, the former because such measurements were not practical in drivers, the latter because it does not reflect drowsiness reliably.

The JDS (range 0-10) is a composite score based on regression weights from multiple regression analysis predicting alert and drowsy conditions (coded 0 and 10) from the ocular variables, minute by minute. Many made significant independent contributions to that regression, accounting for 63.5% of the total variance ($p<0.001$). Details of the JDS algorithm are proprietary information.

Results:

The mean JDS for subjects when alert was 1.1 ± 1.1 (SD), and when drowsy and lapsing was 6.4 ± 2.3 ($p<0.001$, t-test). (Fig. 1). Thus, the effect size was large. The sensitivity of the JDS was 82.4.0% and specificity 93.9% for detecting each minute of drowsiness that was associated with performance impairment (errors of omission), demonstrated objectively.

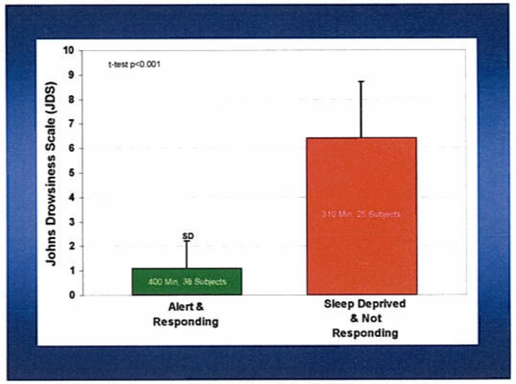

Fig. 1. Mean and standard deviation of JDS scores for alert and drowsy subjects

Typical changes in the JDS with the time of day during a 24 hr period without sleep are shown in Fig.2a for one subject. He performed the JTV every 3 hr, with a progressively increasing percentage of lapses in performance after about 18 hr of wakefulness, ie. after midnight (Fig. 2b), in line with the JDS changes that indicated increasing drowsiness.

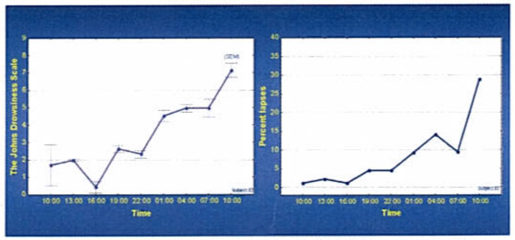

Fig. 2a (left) JDS scores during 24 hr wakefulness, performing JTVs every 3 hr

Fig. 2b (right) Percentage of lapses (failure to respond at all or within 500ms) during JTVs over 24 hr wakefulness

References
1. Johns MW. The amplitude-velocity ratio of blinks: a new method for monitoring drowsiness. *Sleep,* 2003; 26(Suppl.): A51-52.
2. Johns MW & Tucker AJ. The amplitude-velocity ratios of eyelid movements during blinks: changes with drowsiness. *Sleep,* 2005; 28 (Suppl.): A122.
3. Tucker AJ & Johns MW. The duration of eyelid movements during blinks: changes with drowsiness. *Sleep,* 2005; 28 (Suppl.): A122.

Fig 3. shows the mean JDS and the mean RT for each of 222 JTVs performed by 70 Ss at different times and under different circumstances, either when alert, or when drowsy because of sleep-deprivation (51 Ss), or after consuming different amounts of alcohol (19 Ss). There was no standardization of results within subjects. The mean JDS was highly correlated with the mean RT during each test ($r = 0.53 - 0.64$, $p<0.001$), and this relationship was very similar in the different conditions.

Thus, scores on the JDS were highly correlated with the speed of manual response to a visual stimulus under different conditions. Longer reaction times and failing to respond at all were associated with lower velocity and longer duration eye and eyelid movements and longer eyelid closures at the time.

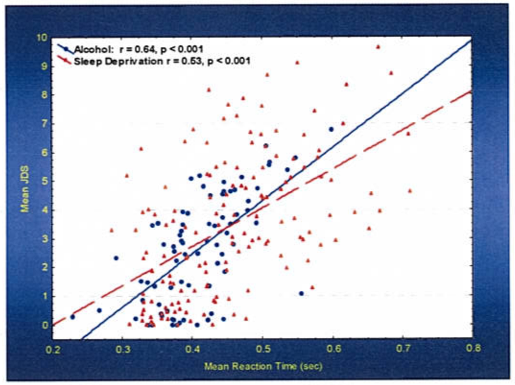

Fig. 3. Mean reaction time versus mean JDS score in 222 JTVs performed by 70 subjects at different times and under different circumstances (51 sleep deprived and 19 alcohol effected).

Conclusions:

The JDS is a new scale for measuring drowsiness (0 to 10) continuously in active people. It is based on a combination of ocular variables, several of which are new, measured automatically by Optalert™.

The JDS does not require adjustment for individual subjects.

The JDS has been validated against objective measures of impaired performance because of either sleep deprivation or alcohol.

The JDS can be used to monitor drivers' drowsiness and warn them before they fall asleep at the wheel and crash.