MEASURING DROWSINESS WITH THE JDS™

It is widely acknowledged drivers/operators tend to be poor judges of their own level of drowsiness and cannot reliably predict when they are impaired to the point of falling asleep at the wheel. Drowsy drivers who continue driving, despite their condition, can make decisions that put themselves and others at risk. The ability to objectively identify the earliest signs of drowsiness removes uncertainty and subjective bias that can influence a professional operator's judgement, even though they are expected to remain vigilant in the workplace. A unique scientifically-validated scale of alertness has emerged from more than 20 years of research into the physiology of drowsiness. Based on a specific combination of ocular parameters, a single, sensitive measure of dynamic alterations in drowsiness levels has been developed – the Johns Drowsiness Scale (JDS™).

Introduction

It has been well-established the dynamics of blinks, particularly the speed of the eyelids closing and reopening, provides a reliable and direct physiological marker of alertness and drowsiness.[1] Many researchers have shown it is the combination of ocular parameters providing the most reliable characterisation of alertness. The key to quantifying drowsiness is determining the correct combination. What are the variables reliably characterising drowsiness in different people? The commonly used measure of blink rate has been shown to vary widely between people; some blink more frequency when drowsy, others blink less often. Relying on a measure such as PERCLOS (percentage of eyelid closure over time), for example, may limit detection to the very late stages of drowsiness.

The Johns Drowsiness Scale (JDS™)

In recent years, a new method has been introduced for measuring alertness/drowsiness objectively and continuously, based on measurements of the neuromuscular function of muscles in the eyelids during their reflex-controlled movements with each blink. Technology incorporating tiny sensors enabling many different characteristics of those movements to be measured while driving has enabled a unique ten-point scale of drowsiness to be developed, the Johns Drowsiness Scale (JDS™).

The Johns Drowsiness Scale (JDS™) was developed by Dr Murray Johns, a world renowned authority on sleep medicine and sleep research. He also developed the Epworth Sleepiness Scale (ESS), which is now a world standard method for measuring a subject's general level of sleepiness in daily life. The JDS™ was developed specifically for use with Optalert's technology, which uses a system of infrared (IR) reflectance oculography housed in a pair of glasses to monitor eye and eyelid movements, with particular emphasis on the velocity and duration of the upper eyelid during blinks. Recent evidence has shown the JDS™ can be

applied to other sensor technologies capable of measuring eyelid aperture, even at relatively low sampling rates.

Dr Johns, along with fellow research scientist Dr Andrew Tucker developed the proprietary drowsiness detection algorithms based on these new methods for measuring eye and eyelid movements. The system of IR oculography has enabled several ocular variables to be identified that can be used in combination to objectively quantify drowsiness on a scientifically validated scale, the Johns Drowsiness Scale (JDS™).

The JDS™ is a composite scale based on weighted values of many different variables reflecting the short-term variability of blinks and eyelid closures, duration and velocity characteristics, measured each minute. This weighted combination of ocular parameters provides a single, sensitive measure of dynamic alterations in alertness and drowsiness and does not require adjustment for individuals.

The JDS™ is a 10-point scale; a score of 0 = 'very alert' and 10 = 'very drowsy'. Peer-reviewed research has shown as levels of drowsiness increase, the risk of performance failure also increases. The term 'performance failure' refers to the inability of a person to respond appropriately, such as failing to respond to a visual stimulus (for example, responding to a stop signal) or failing to turn the wheel during a bend in the road. A drowsy driving crash will occur if a performance failure coincides with the need to perform a safety critical task.

The risk per minute begins to increase only slightly as JDS™ scores rise above 3.0. This risk increases substantially at JDS™ scores of 4.5 or above. Once JDS™ scores reach 5.0 or more, the risk of performance failure (i.e. the risk of a drowsy crash) is sufficiently high, in fact, several times higher than for an alert driver.

Figure 1. Images depicting risk levels associated with JDS scores. Low risk: 0-4.4, Medium risk: 4.5-4.9, High Risk: 5.0-10

Independent validation of the JDS™

The JDS™ has undergone extensive validation and is the result of more than 20 years of research into the physiology of drowsiness. Independent scientific publications examining the JDS™ are the result of highly controlled, stringent experiments that have undergone the peer-review process by experts in the field

of fatigue measurement and sleep medicine. The JDS™ has been independently validated by Harvard Medical School as the gold standard measure of drowsiness. Further, Optalert's early-warning drowsiness detection has also been recommended by the Australian Department of Defence for military applications and shown to improve operator performance in vehicles over time.

The JDS™ has been validated and calibrated against independent objective measures of performance which is critically important for use in occupational settings. The validity of the JDS™ has been confirmed from separate investigations assessing measures including; reaction time, increasing blood alcohol concentrations, benzodiazepine consumption, driving simulator performance, on-road driving, field-based trials, psychomotor vigilance errors, effects of caffeine, hazard perception, circadian phase and brain electrical activity. Results of Optalert research and product validation has been widely published[2] by both the Optalert Research & Development team and leading research institutions from around the world including; Harvard Medical School (USA), Monash University (Australia), Australian Defence Force and Austin Hospital (Australia).

Independent research has shown JDS™ scores at medium risk levels indicate performance impairment equivalent to a blood alcohol concentration of 0.05, the legal limit on roads in many countries. High risk JDS™ scores correspond to impairment equivalent to a BAC level of 0.08. These levels of impairment are similar to being awake for 17 and 21 hours respectively.

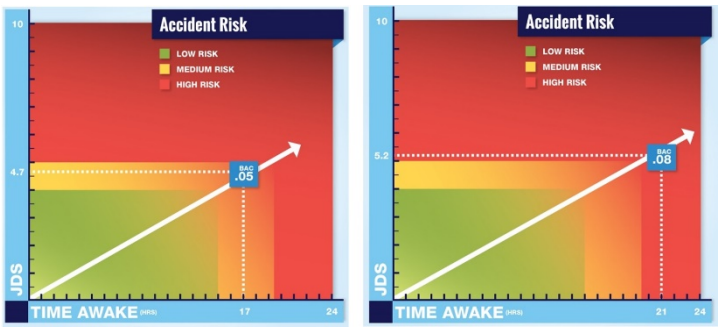

Figure 2. Graphical representation of accident risk equivalence for blood alcohol concentration (BAC), time awake, and drowsiness levels on the JDS™

Recent research findings

Australian Department of Defence, Capability Development Group (CDG)

The Australian Defence Test & Evaluation Office (ADTEO), in conjunction with the Defence Science & Technology Organisation (DSTO) assessed fatigue levels in military personnel and evaluated the effectiveness of Optalert technology as a suitable tool for risk management strategies.

The Report on Defence Trial Number 896 demonstrated Optalert systems contributed to a reduction in drowsiness and improvement in driver performance. Recommendations were made to continue to employ Optalert's technology in a stand-alone role and to investigate the potential use within other military contexts including tri-service driving and watch roles

Defence Trial Number 896: ADF Fatigue Management – Optalert.
Department of Defence, Capability Development Group. Australian Defence Test & Evaluation Office, 2012.

Harvard Medical School & Division of Sleep Medicine, Brigham & Women's Hospital, Boston, USA

The 'Harvard Work Hours Health and Safety Group' is a multi-disciplinary collaborative whose mission is to investigate sleep and work practices among physicians, police officers, and other occupational groups, and implement strategies to improve the safety of patients, workers, and the general public. Optalert technology is a key component of this research and is used routinely during standard sleep medicine and field-based research studies.

Harvard researchers have shown Optalert's technology to be the strongest predictor of drowsiness and an effective tool for monitoring changes in alertness and performance, endorsing Optalert as the gold standard measure of fatigue.

Assessment of Drowsiness Based on Ocular Parameters Detected by Infra-Red Reflectance Oculography
Anderson C, Chang A, Sullivan JP, Ronda JM, Czeisler CA (2013), Journal of Clinical Sleep Medicine, 9 (9): 907-920

Infra-red reflectance oculography reveals changes in drowsiness, and is commensurate with gold standard laboratory measures
Anderson C, Chang A, Ronda JM, Czeisler CA (2011), Journal of Sleep Research, 20 (Suppl.1): 36

Real-time drowsiness as determined by infra-reflectance oculography is commensurate with gold-standard laboratory measures: A validation study
Anderson C, Chang A, Ronda JM, Czeisler CA (2010), Sleep, 33 (Suppl.1):A108

Monash University - School of Psychology, Psychiatry & Psychological Medicine

The Sleep Health and Sleep Disorders research group is using Optalert's technology to investigate the contribution of sleep regulatory processes on waking function, health and safety, with particular emphasis on the occupational risks of drowsy driving

Peer-reviewed research findings appearing in the international *Journal of Sleep Research* showed shift-working nurses experienced high levels of drowsiness and

associated driving performance impairments following night-shift. Optalert systems were used to objectively measure drowsiness levels during commutes to and from work. This research also confirmed the well-established notion that subjective ratings of drowsiness before a drive do not reliably predict subsequent hazardous driving events.

Objective and subjective measures of sleepiness, and their associations with on-road driving events in shift workers
Ftouni S, Sletten TL, Howard M, Anderson C, Lenne MG, Lockley SW, Rajaratnam SMW (2012), Journal of Sleep Research, 22(1), 58-69.

Austin Hospital – Institute for Breathing & Sleep (IBAS)

IBAS Director, Dr Mark Howard has provided a formal statement outlining some of the published research undertaken at IBAS. Dr Howard writes, "[Optalert's] Johns Drowsiness Scores were related to crashes and attention lapses" and "recent studies have demonstrated [Optalert's] Johns Drowsiness Scale can identify excessive drowsiness levels experienced by drivers who have experienced sleep restriction, alcohol ingestion, and benzodiazepine ingestion."

Cross institutional studies with Harvard Medical School, Liberty Mutual Research Institute of Safety and Monash University have used Optalert's technology to demonstrate shift workers are at an increased risk of fatigue-related driving incidents following night shifts.

Drowsiness, impaired driving performance and critical driving events among shift workers driving an actual motor vehicle after night-shift work
Lee M, Howard ME, Horrey WJ, Liang Y, Anderson C, Shreeve M, O'Brien C, Czeisler CA (2013). Sleep, 36(Suppl 1): A63

The Long Road Home: Driving Performance and Ocular Measurements of Drowsiness Following Night Shift-Work
Horrey WJ, Liang Y, Lee ML, Howard ME, Anderson C, Shreeve MS, O'Brien C, Czeisler CA. (2013). Proceedings of the 7th International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design. Bolton Landing, New York.

Sleep, Alcohol, Drugs and Driving
Howard M, Stevens B, Swann P, Wilkinson V, Barnes M, Jackson M (2010). Sleep & Biological Rhythms, 8: A4

Intellectual property
Optalert has developed a suite of patents providing intellectual property protection for our technology that is the culmination of decades of research and investment in product development and commercialisation.

For further technical information, readers are encouraged to refer to the following Optalert patents:

1. Johns, Murray. Alertness Monitor. US Patent 7,071,831, 2002
2. Johns, Murray. Measuring Alertness. US Patent 7,791,491, 2006
3. Johns, Murray and Brown, Aaron. Alertness sensing spectacles, US Patent 7,815,311, 2006
4. Johns, Murray. Alertness Monitor, US Patent 7,616,125, 2009
5. Johns, Murray. Incapacity monitor. US Patent 8,311,284, 2007
6. Johns, Murray and Hocking, Christopher. Alertness Sensing Device. US Patent pending 20110121976, AU Patent 2009270333, ZA Patent 2011/00067, 2009
7. Johns, Murray and Tucker, Andrew. Fitness for Work Test, US Patent pending 20130215390, AU Patent 2011326327, 2011
8. Tucker, Andrew; Morgan, Trefor; and Coles, Scott. Monitoring Drowsiness. AU Patent App 2014902364, 2014

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[1] For more information on how blink dynamics are related to alertness and drowsiness, please refer to whitepaper titled "In the blink of an eye"

[2] A comprehensive list of all relevant peer-reviewed papers and scientific validation information are available upon request