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Sleep deprivation disrupts visual scanning for driving

Sufficient good quality sleep is a necessity for the human brain to function normally. Sleep is primarily regulated by the in-built biological clock that is synchronised with the day-night cycle of our environment, which prepares the body for sleep at night and maintains daytime alertness. Disruption of this natural cycle is common among shift workers and results in lack of sufficient sleep, often leading to excessive sleepiness. The impact of sleep deprivation can be exacerbated by mental fatigue arising from prolonged engagement in a task, such as driving.

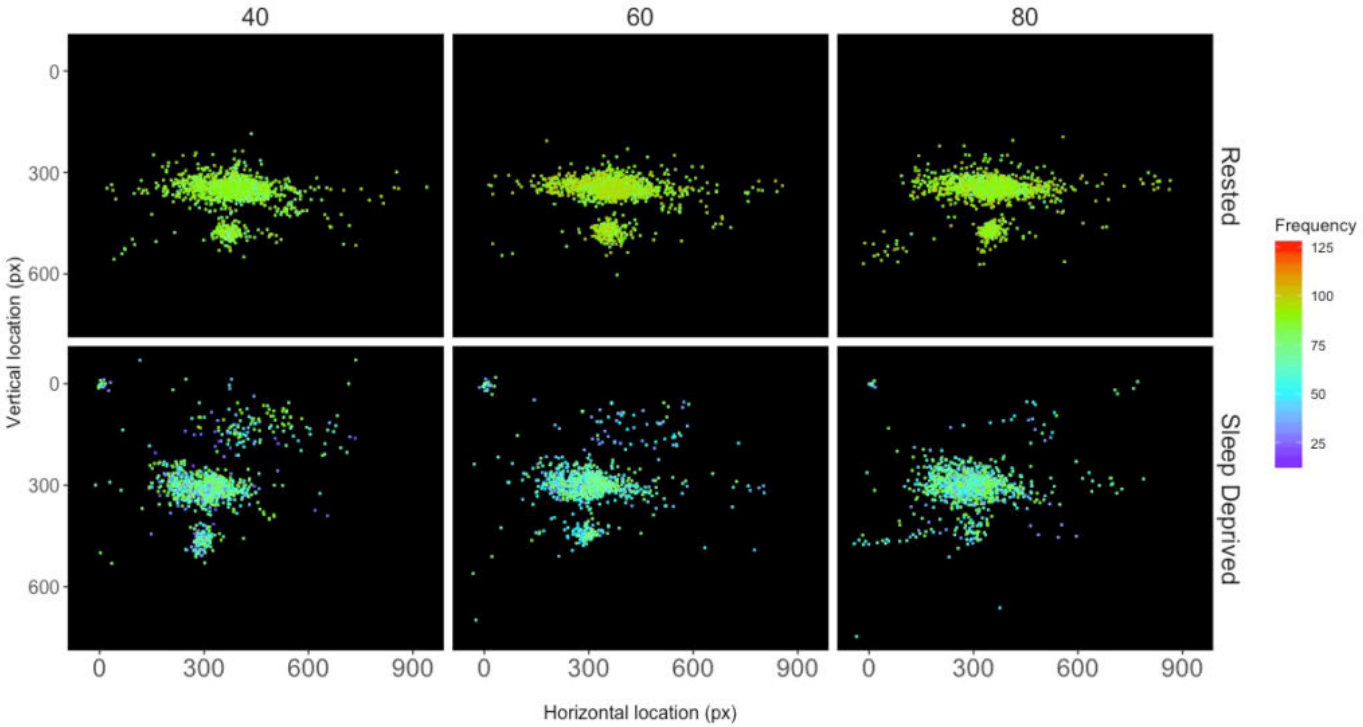

Fig. 1. Spatial dispersion of gaze for rested (top row) and sleep deprived (bottom row) conditions during the driving task, after 40, 60, and 80 minutes of driving. Reproduced from original article published in Scientific Reports.

The most widely recognised process through which sleep deprivation affects driving performance is by increasing drowsiness, where the electrical activity in the brain slows and the eyes are partially or completely closed. Since visual awareness is critical for driving, such changes in eye closure activity increase the risk of collision. Beyond eye closure, sleep deprivation also affects the ways in which the brain automatically scans the visual environment through frequent movement of the eyes. This indicates that even in the absence of drowsiness that alters eye closure, sleep deprived individuals have compromised visual scanning strategies that can affect their awareness of the environment.

Over the past decade, numerous driver drowsiness detection systems have been introduced. In more recent years, the popularity of such systems has increased, and safety regulations are now requiring the integration of such systems into all new vehicles. Most driver drowsiness detection systems rely on eye closure

characteristics, and none have yet examined how visual scanning behaviour changes as a result of sleep deprivation. With the growing sophistication of video-based eye tracking systems that are easily installed in vehicles, incorporating measures of visual scanning behaviour into driver monitoring systems may increase their efficacy in detecting impairment to reduce accidents.

The present study was designed to characterise the impact of sleep deprivation on visual scanning behaviour and examine whether associated changes can predict performance decrement. Participants were asked to drive an instrumented vehicle in a closed circuit under two conditions while their eye movement activity was simultaneously recorded. In one condition, they had a normal night of restful sleep, while in the other they were kept awake for 36 hours prior to completing the driving task. The results revealed that following sleep deprivation, the transition pattern of eye movements became more random with the spatial location of where they are looking becoming increasingly dispersed (Fig. 1). These effects became more pronounced over time suggesting the exacerbating effect of task-induced fatigue. Furthermore, the increase in spatial dispersion of where the drivers were looking predicted lane departure events.

Such results illustrate how sleep deprivation alters the control of eye movements which results in a less structured (thus less useful for the task of driving) visual scanning behaviour. The prediction of lane departure events further demonstrates that impaired visual awareness (e.g. position of vehicle within lane) can directly influence driving performance and increase likelihood of accidents. Thus, incorporating visual scanning measures into driver monitoring systems may enable the detection of impairment prior to the onset of severe drowsiness symptoms such as long eye closures.

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Publication

Stationary gaze entropy predicts lane departure events in sleep-deprived drivers.
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