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ALERT TO THE PROBLEM

It stands to reason that if both drivers and pedestrians are more alert that will make our roads safer. But can this be achieved through better (or just different) highway lighting? An innovative research project is looking for answers

By Aysheh Alshdaifat, Nima Hafezparast Moadab, and Professor Steve Fotios

This article is about the non-visual effects of road lighting on pedestrians and drivers when travelling after dark. It is based on research being conducted by two University of Sheffield PhD students, working within the LightCAP project.

The LightCAP project is a European consortium led by Eindhoven Technical University. Aysheh Alshdaifat's work is focusing on pedestrians, while Nima Hafezparast Moadab's research is more focused on drivers.

Non-visual effects are the biological and behavioural responses to light rather than direct visual responses, such as the ability to detect and identify an object.

Non-visual responses include the synchronisation of circadian rhythms to the 24-hour cycle of light and dark and hormone activation. In combination, these can result in changes of mood and sleepiness. This work is concerned with alertness, in other words the state of being ready to see, understand, and act in a particular situation.

Alertness is impaired by factors including sleepiness and cognitive workload and, in this work, we are investigating the degree to which these effects can be mitigated by road lighting.

RISKS OF IMPAIRED ALERTNESS

Impaired alertness may lead to a potential hazard being unseen or seen, but not so quickly and hence with less time for avoiding action. In turn, this can lead to increases in the frequency and/or severity of road-traffic collisions or to pedestrian trip and slip accidents.

Sleepiness, as most of us will be well aware, is the state of being tired and wanting to sleep. Sleepiness can negatively affect risk-taking, impulsivity, attention, and decision-making. For drivers, sleepiness at the wheel interferes with driving skills and diminishes a driver's ability to react.

Cognitive workload is the dynamic relationship between the resources required to carry out a task and one's ability to supply those resources.

Cognitive workload when driving has increased in recent years with the introduction of in-vehicle information technologies and a rise in traffic intensity. Drivers with higher levels of cognitive workload are less likely to anticipate hazards; they may fail to identify objects in their line of sight and are slower to take evasive action when it is needed.

Enhancing alertness can make both pedestrians and drivers more aware of potential hazards. Our research is investigating the degree to which light is able to enhance alertness in the context of road lighting after dark in the evening, in other words when the natural circadian rhythm is for us to become more sleepy and therefore less alert.

We can expect light to affect alertness through two pathways, by suppression of melatonin release in the evening and by activating regions of the brain associated with cognitive performance and alertness.

Any alerting effect of light will vary according to factors including the duration of exposure (for road users, this is the duration of their journey), the intensity and spectral power distribution of light, and the timing of light exposure (for example, whether in the morning or the evening). From previous work we know that short wavelength (blue) light is particularly effective at inducing non-visual responses.

However, while previous studies have

demonstrated that light affects measures of alertness, those studies have not represented typical exposure to road lighting.

For example, the test participants were first adapted to dark conditions followed by exposure to bright test lighting. Our work is concerned with travel in the evenings, where the pattern of exposure is reversed. In other words, adaptation first to interior lighting (in the home or office) followed by driving or walking after dark under road lighting; from bright to dark rather than from dark to bright.

EVENING ALERTNESS

An experiment was conducted in November evenings (starting at 9pm) when the body starts to prepare for sleep.

Test participants were first exposed for two hours (the adaptation phase) of lighting typical domestic situations (2700K, 25 lux vertical illuminance at eye level) whilst seated.

For the next hour (the test phase) they were exposed to one of four lighting conditions, with half the participants remaining seated and the other half walking on a treadmill to measure the impact on alertness of physical activity.

The four lighting conditions in the test phase are shown in Table 1 (overleaf). The non-visual effect of road lighting is characterised by its 'Melanopic Equivalent Daylight Illuminance' (EDI), the circadian metric adopted by the CIE [1].

Four measures were recorded to establish the state of alertness, repeated at intervals of about 30 minutes throughout the experiment.

These were: melatonin levels (from saliva

Highway lighting

CONDITION	CCT (K)	VERTICAL ILLUMINANCE AT THE EYE (LX)	MELANOPIC EDI (LX)	REPRESENTED SITUATION
C1	2700	8	3.4	Typical road lighting
C2	5800	8	10.4	Same illuminance as C1 but higher CCT
C3	2700	25	10.7	Same spectrum as C1 but higher illuminance, to match EDI of C2. Same lighting as the adaptation phase
C4	2700	0.5	0.5	Dark environment

Table 1. Lighting conditions during the test phase of the experiment

samples), reaction time to an acoustic stimulus (press the button quickly when you hear the beep), self-reported sleepiness, and skin temperature.

Figure 1 (right) shows that melatonin levels increased with time during the experiment, as is expected during the evening. Figure 2 shows the melatonin levels under each lighting condition in the test phase. If the higher melanopic content of C3 (25 lux, 2700K) was sufficient to enhance alertness, this would be seen as a lower level of melatonin than for the other lighting conditions. However, it is not: the differences were not suggested to be significant. The same conclusion was drawn from analyses of the other three measures.

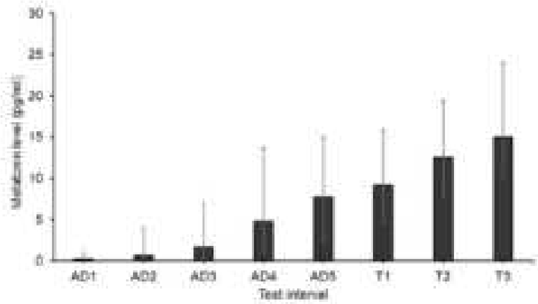


Figure 1. Melatonin levels recorded through the experiment

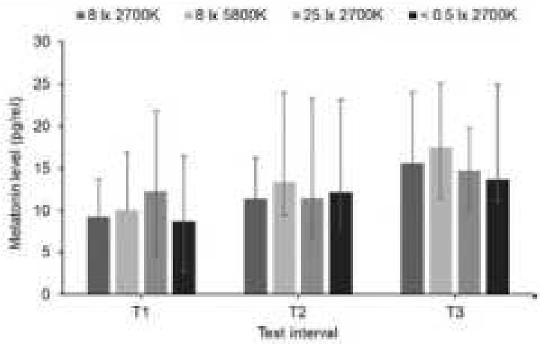


Figure 2. Melatonin levels recorded through the test lighting phase of the experiment under each lighting condition

ARE WE CERTAIN?

The aim of study at PhD level is to learn how to conduct rigorous research. In other words, to ask the question 'Are we certain?' when looking at the results of an experiment.

The results of this experiment did not suggest any differences in alerting effect between the four lighting conditions used in the test phase, confirming the conclusions reported in previous work [2,3]. Are we certain? Not yet. Two further experiments are currently being conducted to provide further validation.

In one experiment, representing the pedestrian context, the first experiment is being repeated but with more extreme conditions. The lighting includes one condition of much higher short wavelength content (giving a melanopic EDI of 100 lux) than used in the first experiment.

Both participants are walking on treadmills, but with their walking speed increased to a level considered to lie in the moderate exercise zone as characterised by their heart rate.

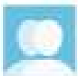
The other experiment, representing the driving context, is using a scale model of a road scene in which test participants, as drivers, are required to detect hazards which move or suddenly appear.

This is done in parallel with auditory and visual distractions to add cognitive load. There were four lighting conditions: representing a low road surface luminance, a higher luminance, and the addition of dim or bright in-vehicle blue lighting, suggested to improve driving performance.

SUMMARY

The findings of this work do not suggest that road lighting of illuminances and spectra typical of current practice offer any benefit in improving the alertness of road users.

We place confidence in this finding by replication and extension of our original experiment and by comparisons with the work of other researchers.



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[1] Commission Internationale de l'Éclairage. 'CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light'. CIE S 026/E:2018. Vienna: CIE, 2018. Available online at: https://cie.co.at/publications/cie-system-metrology-optical-radiation-iprgc-influenced-responses-light-0 [2] Bhagavathula R, Gibbons R, Hanifin J, Brainard G. 'LED Roadway Lighting: Impact on Driver Sleep Health and Alertness'. NCHRP Research Report 2021. Available online at: https://nap.nationalacademies.org/catalog/26097/led-roadway-lighting-impact-on-driver-sleep-health-and-alertness [3] Gibbons RB, Bhagavathula R, Warfield B, Brainard GC, Hanifin JP. 'Impact of solid state roadway lighting on melatonin in humans'. Clocks & Sleep 2022; 4(4): 633-657. Available online: https://www.mdpi.com/2624-5175/4/4/49