International Refereed Journal of Engineering and Science (IRJES)
ISSN (Online) 2319-183X, (Print) 2319-1821
Volume 11, Issue 1 (January 2022), PP. 01-04

Effect of Light on Driving Safety of Hazardous Materials Transport

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Abstract: *Ensuring the safety of hazardous materials transport is critical for the city and the operation company. Many efforts have been made to investigating factors that affect the safety. We for the first time, to our knowledge, propose that the lighting conditions will put non-negligible affects to the driving safety of hazardous materials transport based on the existing evidence in realm of psychology and neuroscience. We hereby give a comprehensive review of the research findings, including a series of behavioral and psychological experiments, of how light act as a moderator for the cognitive function in the brain. We note that further investigation should be conducted to analyze the effect and mechanism of light conditions affecting driving safety, both at the daytime and the nighttime, and protective measures can be prepared accordingly, including making drivers exposed to specific color of light to stimulate brain arousal and enhance human cognition that will enhance the safety of Hazardous Materials Transport.*

Keywords*: Light Stimulation, Non-visual Effects, Cognitive Level, Hazardous Material Transport.*

Date of Submission: 11-01-2022 Date of acceptance: 26-01-2022

I. INTRODUCTION

Safety is always a crucial factor for transporting hazardous materials (hazmats). As hazmats being flammable, explosive, or highly corrosive, huge property loss and adverse social impact can take place when the safety incidences occur. Therefore, researchers have made many efforts to ensure the safety by analyzing the past accidents occurring during the transport of hazmats [1], [2] and deriving the factors affects the driving safety, for example, human factors, packing and loading Hazmat, the vehicle and facilities. [3], [4] Tools to facilitate safe operation is also developed including the decision support system for risk analysis [5], [6] , and various route planning methods through operations research [7], [8].

However, among all those factors being considered and approaches being implemented, by in-depth interview with the frontline drivers and the operation managers, we identified that there is one factor with its effect underestimated by the scholars and the community – the light.

In this research, we are going to comprehensively review the existing evident from the psychology and neuroscience and offer the perspective that light condition is a critical factor for driving safety. We will first review the existing research of night-driving, and then analyzed how light condition, both at the daytime and at night, affect the driver's performance via the modulation of cognition from the evidence of literature. We then propose our solutions to tackle the problem.

II. STUDIES ON NIGHT DRIVING

The most relevant studies regarding the light conditions are night driving. It have been reported that night driving often has more potential for traffic accidents, attributed to lack of visibility, presence of blind spots in the field of view, and difficulty in anticipating unexpected obstacles. Even experienced drivers are prone to misjudgment due to the visibility and psychological challenges [9], [10]. Therefore, the concept of Adaptive Headlight Control System (AHS) was propsoed, ensuring that the headlights are automatically turned on and adjusted to the proper angle of illumination[11].These devices have been used in higher-end luxury cars such as BMW, Audi and Volvo.

However, despite of researches that have analyzed visual conspicuity measured by reaction times, the deeper mechanisms underlying the phenomena in terms of psychological and cognitive aspects are not studies and introduced to the safety control of hazmats transport. In the following parts, we will review the related literatures from how human percept the world and point out the light is a critical regulator to interpret the driving behavior at various lightning conditions (day & night; sunny & haze days, etc.)

III. HOW HUMAN PERCCEPT THE WORLD WITH NONVISUAL SYSTEM

An important way of acquiring cognition is that humans receive information from the outside world through the visual system and process it in the brain to form cognition.[12] Various advanced monitoring systems to enhance the safe driving was also the "computer vision" enabled devices, by examining the drivers facial and behavioral attributes [13]–[16] and the perception of surrounding environment [17]–[19]. But at the same time, scientists in recent studies have revealed that there is also a "non-visual system" in the brain that is different from the visual system, through the retinal specialized photoreceptor ganglion cells (ipRGCs) and other neuroreceptors to perceive the external light environment, and cause a series of human physiological changes, including hormones, heart rate, sleep, alertness, body temperature and many other aspects[20]. Such neural photoreceptors differ in many ways from the image acquiring, conscious vision of the optic rod and cone cells - they require more light to respond than the cone cells and have thresholds that are much higher than those of visible vision. Through this pathway, light not only serves as a necessary condition for the visual system to receive information that encodes information to be received by the visual system to form cognition, but has itself been discovered by scientists to act as a moderator through the non-visual system to influence cognitive processes in the brain.

A series of behavioral and psychological experiments have shown that specific light can stimulate brain arousal and improve cognition. This effect is correlated with the wavelength of light, the market of exposure, and the duration of exposure. The purpose of this paper is to review and review the existing studies on the effects of light on cognition, which will first review the relevant experimental evidence and then lead to the neurobiological mechanisms by which light affects cognition.

IV. PERFORMANCE EVALUATION OF STRUCTURES

A series of behavioral and psychological experiments have found that specific light can stimulate brain arousal. Light at night allows for increased cognition and alertness at night. As early as 1990, Campbell and Dawson [21] found that when enhanced lighting (1000lux) was applied during night work, subjects showed increased levels of alertness and cognition during the night shift. The increased cognitive level of light at night may have effects through mechanisms related to the regulation of circadian rhythms, such as the regulation of melatonin levels. This can be supported by direct measurement of melatonin levels and wavelength dependence of light modulation of nocturnal cognitive levels. Cajochen et al [22] used light of different wavelengths but equal photon density (460nm and 550nm) to stimulate young volunteers at night and measured the subjects' behavior, sleepiness index, melatonin secretion and EEG and found that 460nm light had a more pronounced effect on the associated A study by Brainard et al. [23] revealed that light at shorter wavelengths of approximately 460 nm stimulated melatonin secretion from the perspective of melatonin. The study also suggested that melatonin secretion under the influence of light may not be brought about by the cone and rod cells as receptors, since 460 nm is not their sensitive peak. but close to the sensitive region of iPGCs.

In addition to the fact that light exposure at night can modulate cognitive levels, light stimuli applied during the day can also modulate cognitive levels, and this modulation is also wavelength-dependent.

In a study by [24], subjects were exposed to prolonged white light stimuli during daytime wakefulness and their responses were examined by an oddball paradigm task, a test that excluded the visual effects of light and also examined aspects of cognition including auditory perception, attention, and working memory [25] The response speed of subjects under white light stimulation was enhanced relative to controls under dark conditions, and fMRI imaging and PET imaging of the subjects also revealed the brain area activity involved in this cognitive conditioning process.

Further experiments investigated the wavelength dependence, and a study by [24], which organized subjects to receive light stimuli of different wavelengths during daytime wakefulness and assessed subjects' working memory by participants performing an auditory 2-back task (Braver et al, 2001), also found relevant activity in the shorter wavelengths of blue light band (470 nm) , and green light (550 nm) showed a stronger significance compared to green light (550 nm).

The phenomena studied above suggest that light can exert a wide range of modulatory effects on human cognition, that such effects can occur both at night and during the day, and that they manifest a certain transience, occurring when light stimuli are introduced and disappearing after a period of cessation of stimulation. The research on various working conditions provide the useful insight for ensuring safe driving by introducing appropriate cockpit light conditions as the "working environment" for frontline drivers that enhance their cognitive performance.

V. NEUROBIOLOGICAL MECHANISMS BY WHICH LIGHT AFFECTS COGNITION

With the aforementioned phenomena, it is important to understand the neurobiological principles behind the phenomena. Past experiments have often been limited to behavioral and psychological observations and explanations, and with the advancement of technology, the neurobiology of light-regulated cognition has been partially explained by neuroimaging studies, namely using positron emission tomography [26] and functional magnetic resonance imaging (fMRI) [27] techniques. However, there are still many mechanisms that are not yet understood and more research remains to be done. The following is a summary of the possible neurobiological explanations for the effect of light on cognition based on the available information.

First, light rapidly activates subcortical structures associated with alertness. The hypothalamus is an important structure in the human response to changes in external light, and functional neuroimaging studies have shown that the suprachiasmatic nucleus (SCN) and other related structures within this region, such as the dorsal medial hypothalamus (DMH) and the lateral ventricular preoptic nucleus (VLPO), are an important part of the light energy influence on brain activity and may be the first step in connecting the retina to cognitive pathways. [26] Following light-induced enhancement of SCN activity, this signal may be transmitted to the forebrain via a multisynaptic neural pathway via the blue spot nucleus (LC), which receives indirect SCN input from the dorsal medial hypothalamic nucleus (DMH)[28]. the LC is a major source of brain norepinephrine, which is associated with many The LC is a major source of brain norepinephrine, which is linked to many cortical sites and therefore has the ability to modulate light-induced changes in alertness and cognition. Moreover, links between ambient light levels, prefrontal cortex and the LC have been reported [29], and it is in this context that the LC is likely to be the area of the brainstem that enhances activity early after light onset.

The thalamus is involved in light-regulated cognitive processes from the beginning and it will continue to function throughout the process. The thalamus, especially its dorsal and posterior nuclei, such as the medulla, are key structures involved in alertness and cognition in humans [30] and are triggered by the alertness and cognitive tasks performed to generate activity [31]. In the study by [27], the changes in activity detected in the thalamus, induced by light, were directly correlated with light-triggered changes in subjective alertness.

On the flip side, the thalamus itself is a key factor in transmitting information to the cortex. The thalamus plays an important role both in the transmission of signals from the retina to the visual cortex and between cortical areas. Thus, the thalamus can modulate the flow of light source information in the brain, triggering a wide range of effects across the cerebral cortex [32].

The neuroscience findings interpret the fact that different light conditions will influence the working performance of the person, drivers included, by making the cognitive modulations through different brain regions.

VI. CONCLUDING REMARKS

Light can exert a modulatory effect on human cognition, and the series of experimental and neuroimaging studies described above give evidence for this effect. This paper reviews the relevant experiments and their results and also summarizes the interpretation of this effect in a neurobiological sense in existing studies. It can be found that the effect of light on human cognition is reflected in the differences in human cognition under different light conditions, and the excitation of different brain regions can be observed. This effect is wavelength-dependent and is related to the nonvisual effects of light, and that this modulation is more pronounced in sensitive regions of the ipGCs: the blue wavelength - compared to the sensitive regions of the visual system. It is now thought that the nucleus accumbens (LC) may be the region of the brainstem that enhances activity early after light onset during this regulation of light-influenced cognition. The thalamus, an essential structure involved in alertness and cognition in humans, plays a role throughout the process.

Further research can be done with a particular focus on the hazmats transport drivers. The existing evidence shown in this literature review is sufficient to lead to the thought that light may play a more prominent role than we estimated in safe driving. This paper provides the first insights, as we know, that proper light conditions should be applied in the cockpit -- not only the headlight for drivers to better “see” by their visual systems, but also the surrounding environment to activate their nonvisual systems for better cognitive performance that leads to an enhanced safety standard.

REFERENCES

[1] J. Yang, F. Li, J. Zhou, L. Zhang, L. Huang, and J. Bi, “A survey on hazardous materials accidents during road transport in China from 2000 to 2008,” *J. Hazard. Mater.*, vol. 184, no. 1–3, pp. 647–653, 2010.

[2] A. Oggero, R. M. Darbra, M. Munoz, E. Planas, and J. Casal, “A survey of accidents occurring during the transport of hazardous substances by road and rail,” *J. Hazard. Mater.*, vol. 133, no. 1–3, pp. 1–7, 2006.

[3] F. E. Bird and L. G. George Jr, “Liderazgo práctico en el control de pérdidas (Loganville, Georgia: Institut Puiblishing of International Loss Control Institute),” 1990.

[4] L. Zhao, X. Wang, and Y. Qian, “Analysis of factors that influence hazardous material transportation accidents based on Bayesian networks: A case study in China,” *Saf. Sci.*, vol. 50, no. 4, pp. 1049–1055, 2012.

[5] V. Torretta, E. C. Rada, M. Schiavon, and P. Viotti, "Decision support systems for assessing risks involved in transporting hazardous materials: A review," *Saf. Sci.*, vol. 92, pp. 1–9, 2017.

[6] R. Asadi and M. Ghatee, "A rule-based decision support system in intelligent hazmat transportation system," *IEEE Trans. Intell. Transp. Syst.*, vol. 16, no. 5, pp. 2756–2764, 2015.

[7] E. Erkut and V. Verter, "Modeling of transport risk for hazardous materials," *Oper. Res.*, vol. 46, no. 5, pp. 625–642, 1998.

[8] B. Y. Kara and V. Verter, "Designing a road network for hazardous materials transportation," *Transp. Sci.*, vol. 38, no. 2, pp. 188–196, 2004.

[9] J. M. Wood, "Nighttime driving: visual, lighting and visibility challenges," *Ophthalmic Physiol. Opt.*, vol. 40, no. 2, pp. 187–201, 2020.

[10] S. Plainis and I. J. Murray, "Reaction times as an index of visual conspicuity when driving at night," *Ophthalmic Physiol. Opt.*, vol. 22, no. 5, pp. 409–415, 2002.

[11] S. Shreyas, K. Raghuraman, A. P. Padmavathy, S. A. Prasad, and G. Devaradjane, "Adaptive Headlight System for accident prevention," in *2014 International Conference on Recent Trends in Information Technology*, 2014, pp. 1–6.

[12] M. Livingstone and D. H. Hubel, *Vision and art: The biology of seeing*, vol. 2. Harry N. Abrams New York, 2002.

[13] M. Selim, A. Firintepe, A. Pagani, and D. Stricker, "AutoPOSE: Large-scale Automotive Driver Head Pose and Gaze Dataset with Deep Head Orientation Baseline.," in *VISIGRAPP (4: VISAPP)*, 2020, pp. 599–606.

[14] C. Morris and J. J. Yang, "A machine learning model pipeline for detecting wet pavement condition from live scenes of traffic cameras," *Mach. Learn. with Appl.*, vol. 5, p. 100070, 2021, doi: https://doi.org/10.1016/j.mlwa.2021.100070.

[15] N. Das, E. Ohn-Bar, and M. M. Trivedi, "On performance evaluation of driver hand detection algorithms: Challenges, dataset, and metrics," in *2015 IEEE 18th international conference on intelligent transportation systems*, 2015, pp. 2953–2958.

[16] S. Kaplan, M. A. Guvensan, A. G. Yavuz, and Y. Karalurt, "Driver behavior analysis for safe driving: A survey," *IEEE Trans. Intell. Transp. Syst.*, vol. 16, no. 6, pp. 3017–3032, 2015.

[17] L. Zhu, D. Ji, S. Zhu, W. Gan, W. Wu, and J. Yan, "Learning Statistical Texture for Semantic Segmentation," 2021.

[18] Z. Liu and L. Zhu, "Label-guided Attention Distillation for lane segmentation," *Neurocomputing*, vol. 438, pp. 312–322, 2021.

[19] Y. Liao, J. Xie, and A. Geiger, "KITTI-360: A Novel Dataset and Benchmarks for Urban Scene Understanding in 2D and 3D," *arXiv Prepr. arXiv2109.13410*, 2021.

[20] M. W. Hankins and R. J. Lucas, "The primary visual pathway in humans is regulated according to long-term light exposure through the action of a nonclassical photopigment," *Curr. Biol.*, vol. 12, no. 3, pp. 191–198, 2002.

[21] S. S. Campbell and D. Dawson, "Enhancement of nighttime alertness and performance with bright ambient light," *Physiol. Behav.*, vol. 48, no. 2, pp. 317–320, 1990.

[22] C. Cajochen, J. M. Zeitzer, C. A. Czeisler, and D.-J. Dijk, "Dose-response relationship for light intensity and ocular and electroencephalographic correlates of human alertness," *Behav. Brain Res.*, vol. 115, no. 1, pp. 75–83, 2000.

[23] G. C. Brainard *et al.*, "Human melatonin regulation is not mediated by the three cone photopic visual system," *J. Clin. Endocrinol. Metab.*, vol. 86, no. 1, pp. 433–436, 2001.

[24] G. Vandewalle *et al.*, "Wavelength-dependent modulation of brain responses to a working memory task by daytime light exposure," *Cereb. cortex*, vol. 17, no. 12, pp. 2788–2795, 2007.

[25] A. A. Stevens, P. Skudlarski, J. C. Gatenby, and J. C. Gore, "Event-related fMRI of auditory and visual oddball tasks," *Magn. Reson. Imaging*, vol. 18, no. 5, pp. 495–502, 2000.

[26] F. Perrin *et al.*, "Nonvisual responses to light exposure in the human brain during the circadian night," *Curr. Biol.*, vol. 14, no. 20, pp. 1842–1846, 2004.

[27] G. Vandewalle *et al.*, "Daytime light exposure dynamically enhances brain responses," *Curr. Biol.*, vol. 16, no. 16, pp. 1616–1621, 2006.

[28] G. Aston-Jones, S. Chen, Y. Zhu, and M. L. Oshinsky, "A neural circuit for circadian regulation of arousal," *Nat. Neurosci.*, vol. 4, no. 7, pp. 732–738, 2001.

[29] M. M. C. Gonzalez and G. Aston-Jones, "Light deprivation damages monoamine neurons and produces a depressive behavioral phenotype in rats," *Proc. Natl. Acad. Sci.*, vol. 105, no. 12, pp. 4898–4903, 2008.

[30] C. M. Portas, G. Rees, A. M. Howseman, O. Josephs, R. Turner, and C. D. Frith, "A specific role for the thalamus in mediating the interaction of attention and arousal in humans," *J. Neurosci.*, vol. 18, no. 21, pp. 8979–8989, 1998.

[31] J. T. Coull, M. E. P. Jones, T. D. Egan, C. D. Frith, and M. Maze, "Attentional effects of noradrenaline vary with arousal level: selective activation of thalamic pulvinar in humans," *Neuroimage*, vol. 22, no. 1, pp. 315–322, 2004.

[32] C. M. Sylvester, K. E. Krout, and A. D. Loewy, "Suprachiasmatic nucleus projection to the medial prefrontal cortex: a viral transneuronal tracing study," *Neuroscience*, vol. 114, no. 4, pp. 1071–1080, 2002.