

Modern vehicle headlights dazzle drivers
and may compromise road safety



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Foreword

A problem in need of a solution

“It’s not your eyes; it’s the on-coming headlights”. So might be the imagined conversation of an optician to a patient who’s arrived asking for glasses or treatment because night driving has become something of a nightmare. Optometrists are seeing an increasing number of patients no longer driving at night because of headlight dazzle, which, in winter months, means short days leave very little driving time.

The public know this too. Valerie – a young grandmother – told us of “the most terrifying experience driving home in a mini cooper after dropping off my granddaughter. SUV cars’ glaring lights left me feeling blinded and stunned for at least 5 seconds; the same happens on my way to work even with streetlights”.

Eight out of ten RAC members think something should be done to reduce glare whilst in the United States thousands are signing a petition for action, and the FIA Europe is addressing this modern-day problem. ^{1 2}

Whilst older people – with eyes that adjust more slowly or having the beginnings of a cataract – are particularly affected, this is good reason to take action rather than discriminate against them by making driving a challenge. It’s not just car drivers. As one motorcyclist said, “You should try this with a wet visor!”.

Put simply, new technology’s innovative headlights, which might illuminate the road for the person behind the wheel, are a menace for on-coming vehicles or pedestrians. It’s worse in built up areas, with “sleeping policemen” causing an oncoming car suddenly to angle upwards, but also in country lanes where a car appears round a bend before its supposedly clever computer has dipped or angled the headlight.

These hazards are primarily due to unregulated luminance and blue wavelength light, as existing standards largely predate today’s vehicle designs. However, that is no reason for not enforcing the Highway Code, rule 114 of which states: “You must not use any lights in a way which would dazzle .. other road users”. ³

Despite that, and US data showing up to 15 per cent of accidents are caused by glare from high-beam headlights, our government is deaf to the issue, telling us as that their statistics showed little or no contribution from dazzle on accidents. Not only is this irrelevant (if people are giving up driving because of another car’s lights, diminishing their social life) but unproven, as despite undertaking no .research, the DfT continues to disregard the public’s view. ⁴

¹ RAC. Blinded by the lights, [Press Release](#) - 7 March 2022.

² Meeting with FIA

³ [The Highway Code](#)

⁴ RAC. Blinded by the lights, [Press Release](#) - 7 March 2022.

The Group which produced this report brought together representatives of drivers, of light experts and consumer champions and reviewed information from optometrists, medical experts, transport research and European specialists.

Our first ask of Ministers is that they recognise the problem. The second is that they undertake research and then use the results to set standards for brightness and blue light emissions. The third is to bring together manufacturers, optometrists, drivers, standard setters, transport research experts, insurers, MOT testers and lighting specialists from the UK and beyond, to work with EU and other standard setters to reduce this modern-day menace.

Let's not wait for an accident caused by an on-coming car to realise that some of today's headlights are not fit for purpose, given the dazzle they cause other road users.

Baroness Dianne Hayter

1 Summary and recommendations

1. Vehicle headlights are crucial in enabling drivers to travel safely at night, to identify signs and bends as well as obstacles, cyclists and pedestrians. Proper vehicle lighting also enables a vehicle's visibility in the dark or under bad weather conditions allowing to be visible to other road users. Over the last 20 years, vehicle lighting technology has changed rapidly from halogen, to HID, to LED.
2. In general, using LEDs as light source in vehicle lighting is advantageous in terms of sustainability (long lifetime and robustness, low energy consumption) and safety. However, LED as vehicle light sources lead to complaints from road users on glare. The concerns seem to be mainly caused by high-intensity headlights, but also by dazzling tail-lights, front and rear indicators, fog lights, reversing lights, position lights etc, fitted around the vehicle, all may cause glare concerns.
3. Research published by the RAC, the College of Optometrists (CO) and others reveals that many drivers believe that modern headlights are too bright, leading to disability glare, potentially increasing accidents risks. This perception is not unique to the UK, motoring organisations across the world make similar complaints.
4. In March 2022, the RAC published the results of a survey of 2,700 drivers. They found that 89 per cent of drivers think that some or most vehicle headlights on the UK's roads are too bright, with 88 per cent of these saying they get dazzled by them while driving. Many say that the problem is getting worse, with 63 per cent saying it's happening more often and 64 per cent thinking they risk causing other drivers to have collisions. Sports utility vehicles (SUVs) that sit high off the ground seem to take much of the blame. Around six in 10 drivers of conventional vehicles blame the higher angle of SUV headlight beams.
5. More recently, an article published in The College of Optometrists' professional journal reported that its members are seeing an increase in the number of patients that are no longer driving at night due to headlight dazzle. It said these issues are particularly acute for those older drivers with eye conditions, such as cataracts, due to the impact bright lights have on people with those conditions. They also report a rise in patient complaints of the discomfort that results.
6. The main causes of disability glare are that modern headlights are brighter than those they replace, and their bluer spectrum disables night adapted vision to a greater extent than that of conventional halogen headlights, making them blindingly bright over a greater distance than the halogen lighting they replace. Suspected root causes of glare in road traffic are miniaturisation of the LED light sources and the light beams directly being projected on the eye instead of being diffused by mirror reflection. ⁵

⁵ To add reference: Van Derlofske, J., Chen, J., Bullough, J. D., & Akashi, Y. (2005). Headlight Glare Exposure and Recovery. SAE Transactions, 114, 1974–1981. <http://www.jstor.org/stable/44725225>.

7. This trend might suggest that vehicle headlight design needs a rethink. Optometrists also report that some people believe they have a problem with their eyesight because they are blinded by headlights when, in fact, the reverse is true. LightAware has also received correspondence from people who have that given up driving because of headlight glare and daytime running lights. This will have impacts on the economy, reducing both the number of people who are able to drive for work or make use of leisure and hospitality facilities.

Recommendations

8. The reports discussed here, and in other reports by motoring organisations across the globe, indicate that most drivers find an increasing proportion of headlights too bright and continually complain about glare. The increasing prevalence of full LED headlights may be a contributing factor to this.
9. A major problem in regulating new technology is that people in government tend to work in specialist silos, rather than multidisciplinary teams. To tackle this problem, the UK government needs to bring together car manufacturers, the lighting industry, eye care professionals, neurologists, driving organisations and other interested parties to gain a broader understanding of this problem. It is not sustainable for the UK government and the car industry to say there isn't a problem with modern vehicle headlights when the vast majority of motorists know that there is one.
10. The UK, and other governments, need to develop and set realistic safety standards for vehicle headlights (and other vehicle lighting) and outlaw those that don't achieve those standards. Key issues here are:
 - **Extreme brightness** – the high luminance of LED chips commonly used in vehicle headlights causes discomfort and disability glare, increasing the risk of accidents as well as causing eye pain, headaches and migraine. This is a particular problem for older drivers but other drivers, cyclists and pedestrians are affected too.
 - **Flicker** – although LEDs should not flicker (and most headlights do not) some retrofitted LEDs flicker badly when they are not compatible with vehicle electrical systems. Flicker causes disruption of eye movement (resulting in lower driver performance), headaches and migraines.
 - **Spectrum** – LED vehicle headlights have a high colour temperature with a spike at the blue wavelength. This makes the headlights appear brighter than those of a similar brightness at a lower colour temperature. This also leads to blurred vision for older drivers who may be developing cataracts and people with certain eye conditions. ⁶

⁶ American Medical Association. 2016. Human and environmental effects of light emitting diode (LED) community lighting. Report of the Council on Science and Public Health. Chicago (IL): American Medical Association.

The UK government should:

- Direct the National Institute for Health Protection to sponsor research to establish how vehicle lighting is causing discomfort in older drivers, other susceptible individuals and other road users such as cyclists and pedestrians.
- Use the results of this research to set standards for brightness (glare), flicker and colour temperature for vehicle headlights, including a ban on exceeding a peak luminance threshold to ensure that people can drive safely and reduce the discomfort of other road users and pedestrians.
- Set legal limits for the amount of blue light that vehicle headlights can have in their spectrum by setting standards for their colour temperature.
- Provide garages undertaking MOT tests with guidance and training on how to recognise inappropriate aftermarket installation of LED bulbs and to ensure such cars fail MOT tests.
- The UK government should raise the issue in the Administrative Committee No 2 (AC2) of UNECE WP29 and request GRE, the subsidiary group on light sources, systems and installing requirements of vehicle lights, to revive the informal working group (IWG) on glare prevention. This IWG was hibernated in 2008 and should again be tasked to revisit the applicable UN Regulations and insert supplemental rules that help prevent glare from LED light sources, light assemblies and installation of the LED light sources. The UK government should consider sponsoring this initiative by chairing this UNECE IWG.

2 Vehicle headlights glare is a growing problem for drivers

What drivers think

11. In 2018, the RAC published a survey of 2,061 drivers about car headlights. Its main findings were that:
 - 65 per cent of drivers of all ages were regularly dazzled by modern headlights – even when they are dipped
 - 58 per cent thought that the brightness of modern vehicle headlights is putting drivers at risk.
 - Only 12 per cent of drivers thought that the brightness of new car headlights was just right, 66 per cent thought some models were too bright and 22 per cent feel most of them are too bright.
 - Around 66 per cent of drivers said they often struggle to tell whether the beam is on full or dipped. ⁷
12. In March 2022, a new RAC survey of 2,700 drivers found that nine-in-10 drivers (89 per cent) think some or most car headlights on the UK's roads are too bright, with an overwhelming majority of these (88 per cent) saying they get dazzled by them while driving. ⁸
13. Contrary to what might be expected, younger rather than older drivers were more likely to complain about the apparent brightness of headlights and the effect this has on their driving. Thirty per cent of those aged 17-34 think most are too bright, compared to just 19 per cent of those aged 65 and over. Meanwhile, of those younger drivers who believe some, if not most, car headlights they see are too bright, 70 per cent think the accident risk is increased – while for drivers aged 65-plus the proportion is 62 per cent.
14. This survey also found that the problem of glare from headlights appeared to be getting worse, with 63 per cent of drivers who got dazzled saying that it was happening more often, and 23 per cent claiming they're now dazzled more regularly. Of those who believed headlights are too bright, 64 per cent thought they risked causing collisions.
15. The brightness of car headlights also appeared to be putting motorists off driving at night. Sixteen per cent of those who complain about the intensity of headlights said they avoid driving at night altogether, with women (22 per cent) and those aged 65 and over (25 per cent) much more likely to say they deliberately don't drive after dark than men (9 per cent).

⁷ <https://media.rac.co.uk/pressreleases/motorists-claim-to-being-regularly-left-dazzled-by-modern-vehicle-headlights-2458363>.

⁸ RAC. Blinded by the lights, [Press Release](#) - 7 March 2022.

16. The RAC's research also suggests that the increasing prevalence of vehicles that sit higher on the road, specifically SUVs, could exacerbate the problem for those in conventional cars that sit much lower, such as hatchbacks, saloons and estates. Six-in-10 drivers (61 per cent) of lower vehicles who said they suffered from glare, blamed the headlights on taller vehicles, yet just 28 per cent of drivers of taller vehicles blamed others in similar vehicles.
17. A clear majority of drivers (82 per cent) think something should be done to reduce glare from vehicle headlights.

Evidence collected by mobility clubs across Europe support the RAC survey findings

18. Mobility clubs ADAC (Germany), ANWB (Netherlands), Touring (Belgium), NAF (Norway), ÖAMTC (Austria), TCS (Switzerland), AMZS (Slovenia), BIHMK (Bosnia Herzegovina), IAM Road smart(UK), RAC Foundation (UK) are currently conducting a survey to take stock of glare concerns caused by latest vehicle lighting technology. The level of response from the clubs' members is substantial. Preliminary results seem to confirm that the glare concerns are statistically significant in these countries and that club members call for effective measures to substantially reduce glare, caused by road vehicles. The results of the survey may be expected in the first quarter of 2024.

What eye care professionals report

19. In the November 2022 edition of its journal *Acuity*, The College of Optometrists said that its members are seeing an increasing number of patients that are no longer driving at night due to headlights dazzle. They also reported that many people believe they have a problem with their eyesight because they are blinded by headlights when, in fact, their eyesight is fine, the problem is with the headlights.⁹
20. The College has also described more patients reporting problems with glare. It said that a rise in such reports "might suggest that headlight design needs a rethink, lens manufacturers need to find a better solution, and optometrists need to know how best to manage this growing problem".¹⁰
21. These issues are particularly acute for those older drivers with eye conditions, such as cataracts, a clouding in the lens of the eye, due to the impact bright lights have on people with those conditions. Around half of all over-60s have cataracts in one or both eyes. Cataracts make drivers more vulnerable to glare from very bright headlights.
22. Speaking in the *Daily Telegraph* Sai Kolli, a consultant ophthalmic surgeon said, "What happens is that when LED light hits the eye, rather than being perfectly focused on the retina – the layer at the back of your eyeball which sends electrical signals to your brain, enabling you to see – the light gets bounced all over the place". It is one of the reasons why our reaction times in recovering from glaring lights decrease as we age. There are many factors

⁹ *Acuity*, the College of Optometrists, 14 November 2022.

¹⁰ *Ibid.*

that affect the development of cataracts, including age, smoking and diabetes, UV light and blue LED light have also been implicated. ^{11 12}

What researchers report

23. The EU Scientific Committee on Health, Environmental and Emerging Risks (SCHEER) published its opinion on *Potential risks to human health of Light Emitting Diodes (LEDs)* in June 2018. Although the report concluded “there is no evidence of direct adverse health effects from LEDs in normal use by the general population”, for the purposes of the report “general population” excluded children, older people and light sensitive individuals. This has led to the widespread misconception that LEDs are safe for all. ¹³
24. The report also stated: “The SCHEER is concerned about the high luminance sources used on some vehicles, particularly daylight running LED lights that remain on without dimming at night. Current examples appear to be blue-rich, which increases glare and scattering, particularly for older observers. These running lights are a greater glare source in fog than more traditional vehicle lighting. However, the SCHEER is not aware of any risk of direct harm to the eyes from the blue light component of external vehicle LED lighting at normal viewing distances, although if a driver’s vision is impaired this could result in accidents.”
25. Under the heading ‘vulnerable populations’ it concluded that “Children have a higher sensitivity to blue light and although emissions may not be harmful, blue LEDs may be very dazzling for young children. Older people may experience more problems with glare”. The SCHEER report also set out the following adverse health impacts:
- Either discomfort glare or disability glare can be temporarily caused by vehicle LED lights, and particularly daylight running lights and headlights. In particular, older people may experience discomfort with exposure to light that is rich in blue light.
 - Children have a higher sensitivity to blue light and although emissions may not be harmful, blue LEDs (between 400 nm and 500 nm) may be very dazzling and may induce photochemical retinopathy, which is a concern especially for children below three years of age.
 - Some people are sensitive to flicker from LEDs.
 - Light sources that emit more short-wavelength light, as do some types of LEDs, will have a larger effect on the circadian rhythms at equal optical radiance, duration, and timing of exposure. ¹⁴
26. A report by House of Lords Science and Technology Committee published in July 2023 stated, “Research should be carried out in order to establish the level of risk from glare,

¹¹ Robin Haag,*† Nicole Sieber,† and Martin Heßling*Stephen G. Schwartz, Academic Editor Cataract Development by Exposure to Ultraviolet and Blue Visible Light in Porcine Lenses *Medicina* (Kaunas). 2021 Jun; 57(6): 2021.

¹² The Daily Telegraph, May 16, 2023.

¹³ Scientific Committee on Health, Environmental and Emerging Risks (SCHEER), Opinion on Potential risks to human health of Light Emitting Diodes (LEDs), European Union, 2018.

¹⁴ Ibid.

flicker, and dazzle, for example in night-time driving.” The Government has responded that “Road vehicle lighting is subject to comprehensive international legislative requirements that must be satisfied before vehicles can be sold or registered in the UK. However, DfT is considering potential research to quantify the real-world occurrence of glare and dazzle on the road.”^{15 16}

What is glare and why it is important

27. Although the human eye can adapt to a wide range of light levels from bright sunlight to almost total darkness, it cannot adapt in a short space of time. Comfortable vision requires a limited range of light levels at any particular time. Excessive light levels and luminance contrasts can lead to glare. Many light sources, including vehicle headlights, can be a source of glare for dark adapted eyes. Glare can be experienced as disability glare or discomfort glare:

- **Disability glare** affects the ability to see and leads to some degree of temporary loss of vision and is produced by high luminance in a lower luminance scene, for example at night when a car with LED headlights comes over the brow of a hill or goes over a speed bump.¹⁷
- **Discomfort glare** causes irritation, anxiety, visual fatigue, and eyestrain and can adversely affect wellbeing. Depending on an individual’s sensitivity it can also cause dry or watery eyes, itchiness, tense muscles, breakdown of vision, blurred or double vision, headaches and fatigue.¹⁸

28. Vehicle headlights can cause both discomfort and disability glare. Discomfort glare is sometimes described as not impairing to vision; however, it can be startling or distracting to a driver. It can also lead to blinking and squinting and to fatigue reducing driver attention increasing the risk, for example, of not spotting pedestrians. On the other hand, disability glare rapidly impairs visual performance.¹⁹

29. The Royal Society for the Prevention of Accidents (ROSPA) also published information about vehicle lighting and the effects of glare. Its view was that “There will be very few drivers who have not at times experienced being dazzled by very bright car lights, however, it is likely that this results from either poor levelling alignment, use of main beam or use of illegal equipment”.

¹⁵ <https://publications.parliament.uk/pa/ld5803/ldselect/ldsctech/232/23202.htm>.

¹⁶ Government Response to the House of Lords Science and Technology Committee Report: The neglected pollutants: the effects of artificial light and noise on human health.

¹⁷ The Lighting Handbook. London, Society of Light and Lighting, 2009.

¹⁸ Stone PT. A model for the explanation of discomfort and pain in the eye caused by light. *Lighting Research and Technology*, 41, 2009, 109-121.

¹⁹ The Royal Society for the Prevention of Accidents (ROPSA). <https://www.rospsa.com/media/documents/road-safety/road-observatory/Vehicles-Vehicle-lighting.pdf>.

Why LED vehicle headlight glare can be particularly problematic

30. A specific problem with LED vehicle headlights is that light is not distributed evenly across the headlight's beam but is concentrated in the centre (on the axis). This means that vehicle headlights that appear dimmed on approach can suddenly become blinding if the centre of the beam shines directly into a driver's eyes, for example when a vehicle travels over the brow of a hill, round a bend, or over a bump. This is made worse by manufacturers taking advantage of the high luminance of LED chips to make very small headlights with a very narrow piercingly bright centre to the LED beam. This may reduce safety by increasing LEDs headlights' capacity to create disability glare.
31. Because of their small size, LED headlights can be made up from multiple units and portions of the lamp can switch on or off automatically depending on road conditions. This is known as matrix lighting or adaptive beam headlights (ADB). In theory this could give drivers maximum 'main beam' lighting for the prevailing conditions without dazzling oncoming drivers.
32. In 2015, the U.S. Department of Transportation National Highway, Traffic Safety Administration published the results of an extensive evaluation of ADB. They concluded:
- In many cases ADB illuminance levels exceeded that of lower beam mode in the location of other vehicles. In most cases, the ADB systems consistently produced the same or greater glare than the lower beam of that vehicle.
 - ADB adaptation times measured in response to a suddenly appearing oncoming vehicle were reasonable. However, adaptation times in some other dynamic manoeuvre scenarios seemed subjectively long.²⁰
33. This backs up the perception of drivers, on rural roads, that matrix lighting is more likely to blind oncoming drivers. This is because human drivers can see approaching vehicles on a dark country road and dip full beam headlights, even if the other vehicle is round a bend or over the brow of a hill. Matrix lighting systems don't have human anticipation and only switch off when they 'directly sense' the oncoming headlights - too late to avoid blinding the oncoming driver. Also, if you are a cyclist or pedestrian, matrix headlights may not recognise you at all and you are completely dazzled.

How glare may compromise road safety

34. There is evidence that discomfort glare can lead to reduced driver performance. One study found that a relatively low glare source caused a significant drop in detecting simulated pedestrians along the roadside and made participants drive significantly slower on dark and winding roads. Older participants showed the largest drop in pedestrian detection performance and reduced their driving speed the most.²¹

²⁰ Mazzae, E. N., Baldwin, G. H. S., Andrella, A., & Smith, L. A. (2015, July). Adaptive driving beam headlighting system glare assessment Washington, DC: [National Highway Traffic Safety Administration](#).

²¹ Relation Between Glare and Driving Performance. Jan Theeuwes, Johan W. A. M. Alferdinck, and Michael PerelView Relation Between Glare and Driving Performance Human Factors: The Journal of the Human Factors and Ergonomics Society, Volume 44 , Issue 1.

35. When drivers are exposed to the centre of a LED headlight beam their pupils rapidly constrict to adjust to the bright light. But the dilation of the drivers' pupils to readjust to darkness happens more slowly, meaning people 'drive blind' for a time. In addition, the bluer spectrum of light from LED headlights disables the night adapted vision of the human eye to a greater extent than that of conventional halogen headlights – pupil size is more strongly correlated to blue light than yellow light. ²²
36. The Royal Society for the Prevention of Accidents says: "Between the ages of 15 and 65, the time it takes to recover from glare increases from one to nine seconds." While a younger driver may recover from glare relatively quickly, a vehicle traveling at sixty miles an hour can travel over 250 yards in 9 seconds. This headlight-caused night-blindness is one reason many older people choose not to drive at night. Recent research also suggests that LED headlights may actually be less effective in foggy low light conditions. ²³
37. Although the focus of our report is on safety, one should not ignore the significant impact of LED headlight glare preventing older people and those with light sensitivity from driving at night. It can lead to social exclusion, which results in serious consequences for their mental and physical health. It will also lead to reductions in economic activity if people are unable to take up employment or access leisure activities and the hospitality sector. RAC research from 2022 found that 16 per cent of drivers who complain about the brightness of headlights said they had given up driving at night altogether, a figure rising to 25 per cent of those aged 65 and over. ²⁴

Road traffic accidents data up to 2021 does not show an increase in accidents caused by headlights

38. In the Department for Transport's road collisions, vehicles and casualties statistical dataset, one of the contributing factors to accidents that is monitored is 'dazzling headlights'. The latest collated statistics refer to 2021 and include 10 years of data (Exhibit 1). This does not appear to show any increase in accidents caused by collisions, although it must be borne in mind that the last two years were severely affected by Covid restrictions (March- June 2020, September– November 2020. January– July 2021).
39. In the USA, the number of traffic accidents caused by glare from the high-beam headlights of oncoming traffic at night accounts for 12 per cent to 15 per cent of all traffic accidents. ²⁵

²² J Cogn. 2018; 1(1): 16. Pupillometry: Psychology, Physiology, and Function Sebastiaan Mathôt.

²³ Sefer, T., Ayaz, R., Ajder, A. et al. Performance investigation of different headlights used in vehicles under foggy conditions. Sci Rep **13**, 4698 (2023). <https://doi.org/10.1038/s41598-023-31883-3>.

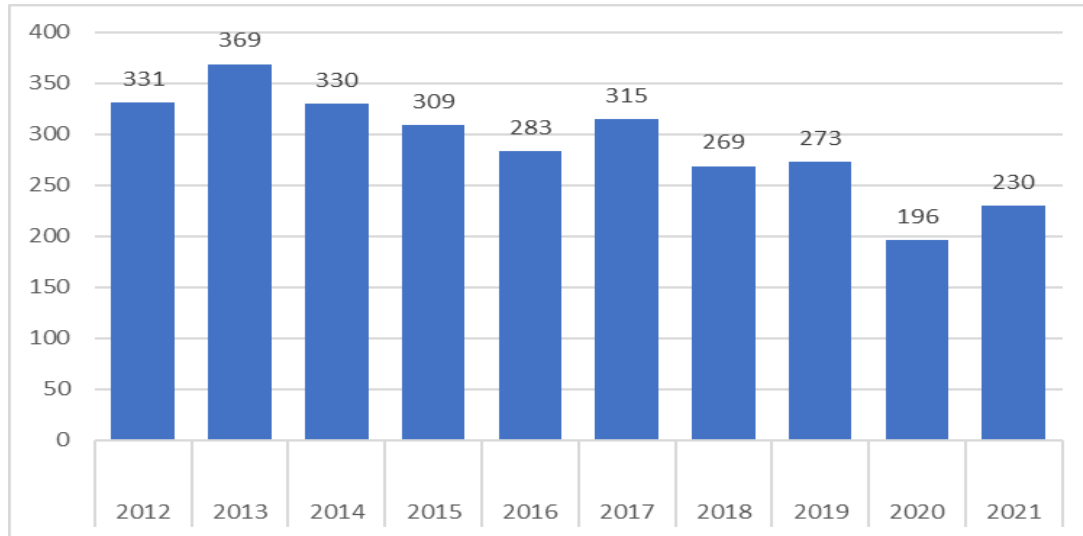
²⁴ <https://media.rac.co.uk/pressreleases/blinded-by-the-lights-nearly-one-in-four-drivers-think-most-car-headlights-are-too-bright-3166996>.

²⁵ Janoff M. Toward Development of a Visibility Model for Roadway Lighting Design. J. Illum. Eng. Soc. 1993;22:122–130. doi: 10.1080/00994480.1993.10748026.

Exhibit 1

Number of collisions where ‘dazzling headlights’ were noted as a contributory factor

Collisions appears to be falling, but 2020 and 2021 are affected by covid lockdowns.



Department for Transport, road collisions, vehicles and casualties statistical dataset.

40. The Department for Transport’s (DfT) position is: “There is no evidence to suggest there is an underlying road safety issue associated with modern vehicle lighting, understandably there may be occasions where due to road geometry the driver of an oncoming vehicle may experience temporary discomfort. Whilst we acknowledge that the downward trend in Police recorded collision statistics has not continued in very recent years, there is absolutely no proven link to the advances in vehicle lighting technology. Some advances have potential to address the basic lighting problem that has vexed headlamp designers for many years: providing good visibility with a minimum of glare when two vehicles meet. Manufacturers are working on adaptive front lighting systems, which automatically adapt the headlamp beam”.
41. Given the huge amount of legislation over the years devoted to improving road safety - seatbelts, banning drink driving, not using mobile phones while driving, as well as improved safety design, it is important to ensure that all vehicle headlights are fit for purpose, given their potential to dazzle other road users.

3. The existing regulatory regime needs updating

The Road Vehicles Lighting Regulations 1989 are out of date

42. The Road Vehicles Lighting Regulations 1989 sets out the current requirements for the installation and performance of vehicle headlights. They include tables which provide an overview of which schedule covers the installation and performance requirements for each type of light. ²⁶
43. These schedules include provisions on the minimum wattage and intensity required for different types of headlights used in various types of vehicles. The reason for using minimum wattage is that this standard was mainly designed to ensure that headlights were bright enough for safe night driving, rather than preventing glare.
44. Because vehicle headlights have become increasingly efficient since 1989, ensuring that lighting is bright enough is no longer a significant issue, cyclists nowadays use LED lamps that are brighter than the vehicle headlights of the time. We increasingly have issues with excess brightness and glare, which are not addressed by these regulations. The technology has moved on, but the regulations haven't.

The Highway Code includes rules to help prevent glare

45. The Highway Code is set a set of rules for road users and is therefore aimed at drivers rather than manufacturers. Many of the rules in the code are legal requirements and disobeying them is committing a criminal offence. For those rules that are not legal requirements, not complying can still have consequences as the code can be used in court proceedings to establish liability. ²⁷
46. A number of rules in the Highway Code relate to headlamps and headlights. These include:
- Rules 114 and Rules 113–115: Lighting requirements
 - Rule 226: Driving in adverse weather conditions (overview)
 - Rule 235: Driving in adverse weather conditions (fog)
 - Rule 239: Waiting and parking (parking)
 - Rules 110 to 111: Flashing headlights.²⁸
47. In particular rule 114 states "You MUST NOT use any lights in a way which would dazzle or cause discomfort to other road users, including pedestrians, cyclists and horse riders." This poses the question of what the position of an SUV driver would be whose headlights caused disability glare in a smaller car leading to the latter having an accident.

²⁶ The Road Vehicles Lighting Regulations 1989. <https://www.legislation.gov.uk/uksi/1989/1796/contents>

²⁷ <https://www.gov.uk/guidance/the-highway-code/introduction>

²⁸ [The Highway Code](#) Lighting requirements (113 to 116).

Improved MOT testing could reduce the number of cars with poorly adjusted headlights

48. An MOT is a regular check to make sure that a vehicle meets road safety and environmental standards. During an MOT test, headlights are checked for the beam pattern that the bulb emits and if that falls outside defined criteria that is considered a major non-compliance and therefore an MOT failure.
49. In 2016 the DVSA stated that “headlamp aim consistently tops the MOT compliance survey as one of the most likely items to be assessed incorrectly by testers”, suggesting this is not an easy thing to test accurately.²⁹
50. In addition, new vehicles have HID headlamps. This is because they comply with European type approval regulations. The UK cannot refuse to register a vehicle with a European type approval. These approvals relate to ECE Regulation 98 (for the HID headlamps which are tested on a rig in a laboratory) and ECE Regulation 48 (lighting installation on the vehicle).
51. For the after-market, a used vehicle cannot obtain type approval because this only applies to new vehicles. However, DfT does not think it reasonable simply to ban HID in the aftermarket. Instead, the department makes analogies with new vehicles. It seems reasonable to require HID in the after-market to meet the same safety standards as those for new vehicles. The same level of safety should apply.
52. Section 4.1.4. ‘Compliance with requirements’ sets out some restrictions regarding LEDs. It states that existing halogen headlamp units on vehicles first used on or after 1 April 1986 must not be converted to be used with HID or LED bulbs. However, it also states that complete replacement headlamp units may be constructed with these light sources. That means that a halogen bulb cannot be replaced with an LED bulb, however, it could be replaced with a whole headlamp unit if manufactured with LEDs.

Use of aftermarket bulbs

53. As explained above, a halogen headlamp bulb replaced with an LED bulb would be an MOT failure, assuming the MOT technician recognises that it is an aftermarket part, and the part is in place at the time of the MOT. Car owners can purchase LED bulbs from major retailers and evidence from product reviews indicates that some purchasers are using them to have brighter headlights on public roads.
54. Halogen headlights also use reflectors to create beam patterns, while LEDs use projectors. If an LED bulb is placed in a halogen housing, it will be hard to replicate the beam pattern and the resulting poor beam alignment could cause glare for other drivers. In addition, buying ‘off-brand’ LED bulbs is more likely to lead to differences in current between the car and the bulb causing flickering.

²⁹ <https://mattersoftesting.blog.gov.uk/the-mot-headlamp-aim-test-is-changing/>.

Appendices

Appendix 1 Acknowledgements

This report was produced by a group chaired by Baroness Dianne Hayter. Dr John Lincoln of LightAware drafted this report on behalf of the group.

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The report also draws on input from the College of Optometrists, SMMT, FIA Europe, Jonathan Fong of the ABI and Nicole Winchester of the Lords Library.

Appendix 2 LED vehicle headlights are very different from their predecessors

55. Halogen headlights were the most popular type of bulb before the introduction of LEDs. They use a combination of gases and a tungsten filament in a glass tube to produce around 700 to 1,200 lumens with a colour temperature of around 3000K. LED vehicle headlights are a semiconductor light source and work quite differently (Exhibit 2).

Exhibit 2

LED vehicle lights are a semiconductor light source

A light-emitting diode (LED) is a semiconductor that emits light when current flows through it. Each LED emits light of only one particular colour. In vehicle headlights, this is usually blue, to make white headlights, a powerful blue LED is shone on to compounds called phosphors that absorb blue light and emit yellow light. This yellow light combines with the blue light and appears white to the eye.

Most white-light sources emit a range of wavelengths, which, when combined, produce the colour of light perceived by the human eye. The resulting shade of white depends on the blend of phosphors and is measured on the colour-temperature scale. Colour temperature is conventionally expressed in Kelvins, using the symbol K, a unit of measure for absolute temperature. It is measured on a numbered scale, where the higher the number, the 'cooler,' or bluer the light, the lower the number, the 'warmer,' or yellower the light. Colour temperatures of different forms of lighting include:

- 2400K – Standard incandescent lamps
- 2550K – Soft white incandescent lamps
- 3000K – **Halogen headlights**, warm white LED street lights
- 4000K – Neutral white LED street lights (the most commonly used type)
- 5000K – Cool white LED street lights, Tubular fluorescent lamps
- 6000K – **LED Vehicle Headlights**, Bright sunlight.

It should be noted that colour temperature only provides an approximate comparison and that the colour spectrum of 6000K vehicle headlights is very different from sunlight.

Early "white" LEDs were very blue and harsh on the eye. Adding more phosphors to a 'white' LED makes its light look warmer and less harsh, but at the expense of reduced efficacy.

Unlike other forms of lighting, LEDs are highly directional with light emitted in an arc of around 60 degrees, rather than 360 degrees common in other lighting. LED light is usually emitted from a small, flat, surface, rather than a large, curved one.

LED light is not distributed evenly across its beam but concentrated on its axis. This causes problems of glare if the centre of the beam shines directly in people's eyes. In addition, glare from external LED lighting can be felt over much greater distances.

56. Individuals across the UK (and beyond) have complained that LED vehicle headlights are much bluer and brighter than the halogen headlights they replace. They usually have a brightness of 3,000 to 6,000 lumens and a colour temperature of 6000K. However, the LED Auto website reported "normally they would be 4000 Lumen, 5000 Lumen, or 6000 Lumen.

6000 Lumen is extremely bright as we know. But we still can find some LED car headlights bulbs marked with 8000 Lumen, 10000 Lumen or even 12000 Lumen. That is really unbelievable".³⁰

Because LEDs are so different from their predecessors the metrics used to measure glare need to change

57. While currently used lighting metrics suggest that glare should be comparable to that from earlier lamps, the public is increasingly unhappy with modern vehicle headlights. One reason for this is that the metrics currently used to measure glare are based on earlier generations of headlights (primarily, halogen lights), where the luminance was limited by the technology, thus making regulation unnecessary. The introduction of LED headlights with increasingly sophisticated optics has resulted in the same or greater amount of light being emitted from a significantly smaller area. As a result, the luminance of headlights (perceived as brightness) has increased significantly, leading to the need for regulation.
58. In a similar way, colour separation within the headlight beam can beam cause distracting patterns to oncoming traffic (seeing coloured flashes as the oncoming headlight is viewed from constantly changing angles),³¹

United Nations Economic Commission for Europe guidance and international compliance revised metrics on glare need to take account of LEDs

59. The United Nations Economic Commission for Europe (UNECE) hosts the world forum for harmonization of vehicle regulations in Working Party 29 (WP29). Its objectives include:
- allowing the market introduction of innovative vehicle technologies, while continuously improving global vehicle safety
 - enabling decreasing environmental pollution and energy consumption
 - fostering and facilitating cross-border trade, since provisions established under the 1958 agreement include the reciprocal acceptance of approvals of vehicle systems, parts and equipment issued by other contracting parties. The 1998 Agreement allows collaboration with major other economies like the USA, China and India.

GRE is the subsidiary group of WP29 that works on international approval legislation regarding vehicle Lighting and Light-Signalling. Until 2008, there was an informal working group established under GRE, that was dedicated to glare prevention. This group was hibernated and would need to be resurrected to develop glare counter measures, that all contracting parties of the 1958 and 1998 agreements will help protect consumers in their regions and countries against the adverse design aspects of LED light sources and modern light system installation.

³⁰ <https://www.ledoauto.com/> se article [here](#).

³¹ axial colour of an automotive headlamp lens," Applied Optics, vol. 56, pp. 5106–5111, Jun 2017. <https://opg.optica.org/ao/abstract.cfm?uri=ao-56-17-5106>.

60. To ensure that vehicle lighting is fit for purpose, all components must conform to UK, European and UNECE regulations. The lighting system fitted to most modern European vehicles must comply with the requirements of the type approval process. Representative vehicles are assessed and vehicle manufacturers are required to ensure that the mass-produced vehicles match the specification of the tested vehicle. Compliance with the required standards is verified before a vehicle can be registered in the UK. European approval legislation of vehicle lighting, light signalling and installing light systems is entirely relying on reference to the UNECE requirements. Vehicles that falling out of scope of approval legislation covering categories³² M, N, L and T, are falling in the scope of the Machinery Directive 2006/42/EC³³, varying range between personal mobility devices, pedelecs up to excavators and mobile cranes. The lighting requirements for these vehicles are not existing at the European level but are based on national legislations. All these vehicle types are switching to LED light sources.
61. The assessment process is witnessed by an independent approval authority who oversee the testing, certification and production conformity in line with regulatory requirements. The authority is appointed by respective member states and an approval issued by one authority will be accepted in all the member states. The Vehicle Certification Agency (VCA) is the designated UK Approval Authority for all type approvals to automotive EC Directives and most UN Regulations.
62. In terms of vehicle lighting, the individual lamps are assessed as components to ensure that they meet the required colour, intensity and light distribution. Subsequently the installation of the lamps in the vehicle is also assessed to ensure that the component approvals are valid, the required number is fitted in the correct position and that they meet the required angles of visibility. The vehicle lighting regulations for vehicles sold in Europe are developed at the United Nations in Geneva. The harmonisation of standards in this way allows vehicles to be sold without restrictions and ensure that vehicles are compatible across borders.
63. These mechanisms should, in theory, ensure consistent vehicle build quality across the UK and Europe. However, as we have shown earlier, LEDs are so different from their predecessors as light sources and the metrics used to measure LED glare are no longer fit for purpose. The mechanisms are unlikely to solve the problems of LED glare until new metrics are agreed upon.
64. The UN Regulations that should be scrutinized and supplemented with additional measures to prevent glare:
- UN Regulation No. 48 - Installation of lighting and light-signalling devices
 - UN Regulation No. 53 - Installation of lighting and light-signalling devices for L3 vehicle
 - UN Regulation No. 74 - Installation of lighting and light-signalling devices (mopeds)
 - UN Regulation No. 86 - Installation of lighting and light-signalling devices for agriculture vehicles
 - UN Regulation No. 128 - Light Emitting Diode (LED) light sources

³² Passenger cars, medium and heavy passenger busses, light and medium delivery vans, trucks, light 2-, 3- and 4-wheeled vehicles, agricultural vehicles

³³ OJ L 157, 9.6.2006, p. 24–86

65. Moreover, lighting systems equipped with LED light sources from vehicles frequently travelling on the road that fall in the scope of type-approval such as agricultural vehicles and L-category vehicles as well as machines falling out of scope of approval legislation, like e.g. personal mobility devices, pedelecs, excavators, road repair machinery etc shall all be subject to appropriate safety requirements to reduce glare from road vehicles.

Light Sensitivity and light disability

Light sensitive individuals can be badly affected by glare from LED headlights. The causes of light sensitivity are many and varied and the list below is not exhaustive but gives an indication of the range of people affected.

- **Eye conditions** including:
 - Coloboma - the lower portion of some eye tissues is missing
 - Ocular albinism –people are born with a lack of pigment in the eye.
 - Aniridia –the iris is missing from birth.
 - Cataracts – clouding of the lens inside the eye.
 - Macular degeneration – destruction of the area in the eye responsible for central, detailed vision.
 - Uveitis – inflammation inside the eye
 - Inherited retinal dystrophies such as retinitis pigmentosa.
 - Corneal dystrophies which cause changes in the cornea
 - Glaucoma – the pressure inside the eye is too high
 - Keratoconus – where there are changes in corneal shape, strength and thickness.
- **Neurological conditions**
 - **Migraine** - For many migraineurs (32 – 40 per cent) light-sensitivity is intricately linked to their condition.
 - **Autistic spectrum conditions** Many people on the autistic spectrum have sensory issues that can be either over-developed (hypersensitive) or under-developed (hyposensitive). Both can affect how people experience environments. Fluorescent lighting has been shown to have a particularly negative affect on individuals on the autistic spectrum and flickering LED lighting can be distressing.
 - **Epilepsy** – individuals with epilepsy can be affected by flashing LED lighting
- **Dermatological conditions** - People who suffer from Xeroderma pigmentosum (XP), and some people with chronic actinic dermatitis (also known as chronic photosensitive dermatitis) have their conditions made worse by LED lighting, whether as a car occupant or as a pedestrian,
- **Lupus** - Lupus is an autoimmune disease in which the body's immune system mistakenly attacks healthy tissue. Lupus sufferers who cannot go out in sunlight may be effectively trapped in their homes at night as well by LED street lighting and LED headlights.

Appendix 3 Glossary

Vehicle headlight types

There are three common headlight bulb types, laser headlights are very new:

- **Halogen:** This was the most popular type of bulb, but it is rapidly being replaced by LED. It uses a combination of gases and a tungsten filament in a glass to tube to produce around 1,300 lumens.
- **Xenon:** high intensity discharge (HID) headlights heat gases and rare metals to generate a bright white or blue glow. They are up to three times brighter than halogen bulbs with the same wattage but have failed to become an industry standard.
- **LED:** Light emitting diodes (LEDs) are rapidly taking over from halogen as the common type of bulb. LEDs are brighter than halogen bulbs of the same wattage. LEDs are more expensive to manufacture than halogen bulbs.
- **Laser headlights** - are a new technology which is finding its way into the vehicle headlights in upmarket brands such as high-end BMW and Audi cars. They incorporate tiny lasers, which are fired onto phosphors to create a white light, which is then reflected by internal mirrors onto the road. They are up to four times brighter than their LED equivalents and able to illuminate the highway 600 metres ahead of the vehicle, double that of conventional LED high beams. They operate like matrix LED headlights, where internal mirrors are tuned to avoid oncoming vehicles.

Measuring light emissions from vehicle headlights

- **Illuminance (Ev):** The amount of light that hits a surface.
- **Luminance (Lv):** The perceived amount of light emitted from an object. Luminance is also referred to as brightness.
- **Lumen (lm):** The total amount of visible light emitted from a light source. It's the unit to measure luminous flux.
- **Luminous Flux (Φ_v):** The amount of light emitted in every direction and measured in lumens.
- **Luminous intensity (Iv):** Amount of visible light emitted from a source in a particular direction per unit solid angle. The candela is the SI unit for luminous intensity.
- **Candela (cd):** The unit measurement for light intensity. A candela measures the amount of luminance intensity from any point in a single direction.
- **Nits:** Are usually used to measure screen brightness a 'nit' is one candela per square meter. Although not an official unit, they provide a practical way of measuring brightness for display devices.
- **Lux (lx):** A unit of measurement for illuminance which is a measure of how much luminous flux is spread out over a given area providing measure of the intensity of illumination on a surface at a particular distance from the source. Examples are:
 - 0.0001 Starlight

- 0.25–1 Full moon
- 80 Typical indoor lighting
- 500 A well-lit office
- 1000 Overcast day outdoors
- 10,000 Daylight
- 100,000 Intense, direct sunlight.
- **Colour temperature (K)** Colour temperature is conventionally expressed in Kelvins, using the symbol K, a unit of measure for absolute temperature. It is measured on a numbered scale, where the higher the number, the ‘cooler,’ or bluer the light, the lower the number, the ‘warmer,’ or yellower the light. Colour temperatures of different forms of lighting include:
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 - 3000K – Warm white LED street lights, **Halogen Headlights**
 - 4000K – Neutral white LED street lights (the most commonly used type)
 - 5000K – Cool white LED street lights, Tubular fluorescent lamps
 - 6000K – Bright Sunlight, **LED Headlights**.

Blue-light hazard (BLH)

A term used to describe the potential for a photochemical injury of the retina (photoc maculopathy); i.e., not a “thermal” injury. The sensitivity function, or action spectrum, $B(\lambda)$, is defined over the wavelength range of 300 - 700 nm, but the peak effectiveness of this injury occurs at approximately 435 - 440 nm, which is in the violet-blue region of the optical spectrum.

Retinal thermal hazard (RTH)

A term used to describe the potential for a thermal injury to the retina. The sensitivity function, or action spectrum, $R(\lambda)$, is defined over the wavelength range of 380 - 1,400 nm, but the peak effectiveness of this injury occurs at approximately 435–700 nm. The exposure limit (EL) for this hazard is dependent on the angular subtense, α , of the source and the exposure duration, t .

Photopic sensitivity

This relates to the sensitivity of the human eye which peaks at the wavelength of 555 nm; the sensitivity function is defined as $V(\lambda)$. Technically, this typical, or average response is that of the “CIE Standard Photometric Observer” (CIE 2016).

