Paramedic practice in low light conditions: a scoping review

Andrew D Hichisson, Job Title, Clinical Directorate, London Ambulance Service NHS Trust, UK; **George Wilcock**, Job Title, Nuffield Department of Clinical Neurosciences, University of Oxford, Oxford, UK; **Georgette Eaton**, Job Title, Clinical Directorate, London Ambulance Service NHS Trust, UK; **Laura J Taylor**, Job Title, Nuffield Department of Clinical Neurosciences, University of Oxford, Oxford, UK, Oxford Eye Hospital, Oxford University Hospitals NHS Foundation Trust, Oxford, UK; **Jasleen K. Jolly**, Job Title, Nuffield Department of Clinical Neurosciences, University of Oxford, Oxford, UK, Oxford Eye Hospital, Oxford University Hospitals NHS Foundation Trust, Oxford, UK, Vision and Eye Research Institute, Anglia Ruskin University, Cambridge, UK. **Email:** jasleen.jolly@aru.ac.uk AQ1 Please provide job titles of all authors

Abstract

Background: Paramedics undertake visually demanding tasks, which may be adversely affected by low lighting conditions. **Aims:** The study aimed to: identify difficulties paramedics experience carrying out tasks in low light; and establish occupational health standards and adjustments that may improve working practices. **Methods:** A scoping review was undertaken informed by an expert panel of paramedics recruited through social media. A meta-analysis was conducted assessing visual acuity under different light levels. **Findings:** Difficulty in driving and in assessing/treating patients under low light conditions were reported. Sixty relevant studies were identified for review. Visual acuity reduces with decreasing luminance, causing increasing difficulties in performing critical tasks. **Conclusion:** Visual function testing can assess paramedics' visual health and ability to undertake critical tasks. Adjustments may help to improve conditions. Regular occupational health assessments could identify paramedics who need support. Further research should explore levels of visual function and practical adjustments needed for safe clinical practice.

Key words

- Paramedic
- Emergency medical service
- Ambulance
- Driving
- Low luminance visual acuity
- Night-time working

Accepted for publication: Xxxxxxxxxxx

Frontline paramedics working in the prehospital setting undertake visually demanding tasks in challenging environments, including driving under emergency conditions, assessing patients and implementing lifesaving treatment and interventions at variable light levels. The visual conditions within which these tasks must be undertaken are often far from optimal, and the success of critical tasks may be adversely affected by low luminance levels in dark surroundings and while working at night.

It is widely known that visual function decreases as light levels fall (Hiraoka et al, 2015). However, how this affects the ability of paramedics to undertake their role is hitherto unexplored. There are also no standardised regulations for provision of lighting equipment to support staff across different ambulance settings.

This study explored the impact of working in decreased light levels on paramedic practice and discussed modifications to reduce risk.

The review also aimed to identify the scope for evidence-based occupational standards and guidance for paramedic practice in low lighting conditions by identifying the key aspects of visual function that are affected.

Methods

Professional panel

Twitter was used to recruit prehospital paramedics to a professional panel to provide their opinions and discuss their experiences of working in low light conditions.

Discussions took place via direct messaging or email over 11–21 December 2020.

Responses were recorded verbatim. No further probing to clarify or expand answers was done. Transcripts were analysed and themes identified, which then informed the direction of the scoping review.

Editor's note - I think blue text on Ovid could be cut

Scoping review

A literature search was undertaken using scoping methodology (Munn et al, 2018; Tricco et al, 2018). Embase (OvidSP) [2000-01/12/2021] and Medline (OvidSP) [2000-01/12/2020] were chosen, along with Google Scholar. The search strategy is shown in *Table 1*. [AQ2 the PRISMA flowchart (Figure 2) refers to 'registers'. Explain here and in Literature Review section below or remove from Figure 2?]

Peer-reviewed publications of any methodological design were considered eligible if they related to paramedic practice, emergency services, vision, visual acuity (VA) and the subject themes identified by the focus group. Publications were excluded if the population was not relevant to paramedics (animal studies, human populations that were outside paramedic working age i.e. aged <18 or >65 years). As this was a scoping review, no age limits were applied to publication date [AQ3 - edit OK?] to ensure the breadth of literature could be explored. Inclusion and exclusion criteria are shown in *Table 2*. [AQ4 Table includes exclusion/inclusion criteria (eg being in English and surgical focus) not listed here, and omits eg age. Please make the text and the table consistent].

Study findings was collated from included papers using Microsoft Excel.

Meta-analysis

To further understand the effect of luminance levels on VA, data from studies assessing VA under different light levels were collated and a meta-analysis undertaken.

Table 1. Search strategy

Theme 1. Driving	(('driving' OR 'crash') AND (('mesopic' OR 'low light' OR 'low luminance') OR ('night myopia' OR 'accommodation' OR 'aberration') OR ('visual deficit' OR 'visual impairment') OR 'age' OR 'glare'))
Theme 2. Glare	(('driving' OR 'crash') AND (('glare' OR 'glare sensitivity' OR 'disability glare' OR 'discomfort glare' OR 'glare enhancement') OR ('refractive surgery' OR 'LASIK' OR 'PRK' OR 'cataract')))
Theme 3. Colour	(('mesopic' OR 'low light' OR 'low luminance') AND (('colour' OR 'colour vision' OR 'colour spectrum') OR ('purkinje shift' OR 'colour-blind')))
Theme 4. Visual acuity	(('mesopic' OR 'scotopic' OR 'low light' OR 'low luminance') AND ('visual acuity' OR 'hyperacuity' OR 'visual acuity testing'))
Theme 5. Contrast sensitivity	(('mesopic' OR 'scotopic' OR 'low light' OR 'low luminance') AND ('contrast sensitivity' OR 'contrast sensitivity testing') AND ('age' OR 'optical health' OR 'optical disease' OR 'colour'))

Results

Professional panel

Five UK registered paramedics engaged with the social media call and took part in the consultation. While engagement was in a personal capacity, all respondents practised in the same ambulance service NHS trust and all undertook frontline work for at least part of their role.

Four respondents identified as male and one identified as female [AQ5 did they answer 'are you male/female' or were they identifying as a gender? May be an issue as the sexes have differences in eg discriminating between colours and in tracking moving objects]. Wider demographic characteristics were not recorded as this was not part of the intended study design.

Figure 1 shows the areas of practice that are most affected by low-luminance working conditions. These were broadly grouped into two themes: driving; and 'patient assessment/treatment.

The professional panel discussed changes to the

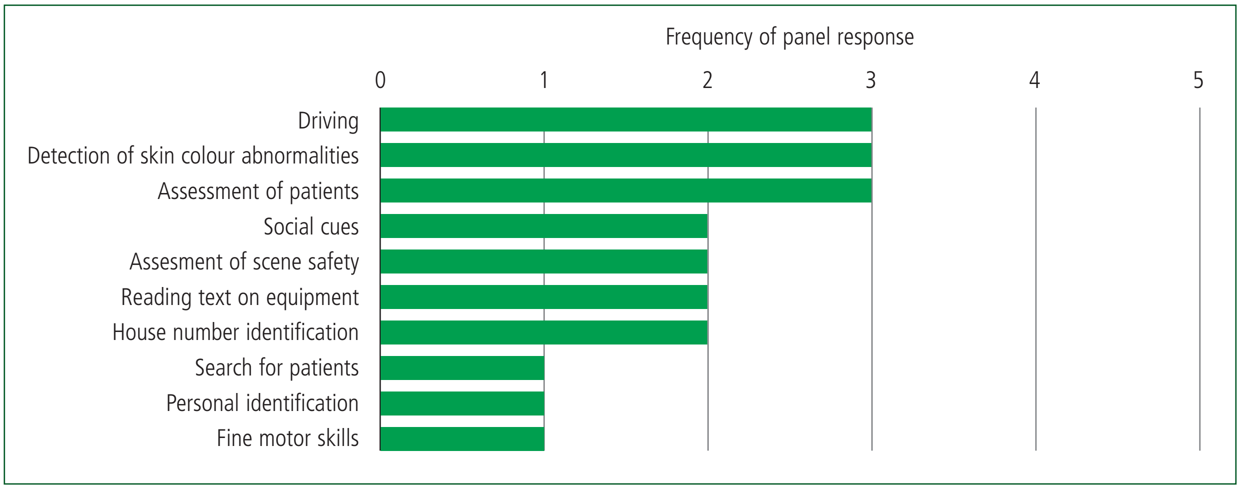

Figure 1. Areas of paramedic practice affected by low luminance working conditions identified by the expert panel

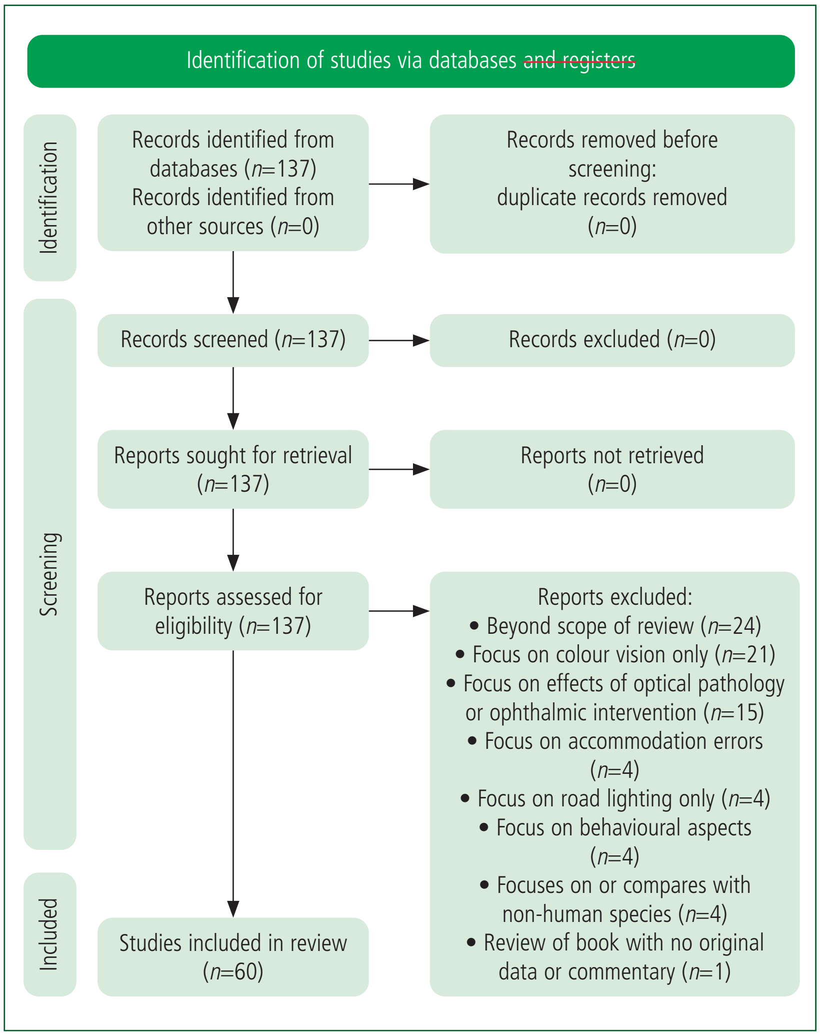

Figure 2. PRISMA flowchart for literature selection

Table 2. Inclusion and exclusion criteria

Inclusion	Exclusion
Human participant Full text in English	Cellular pathology only Surgical focus Behavioural focus Night myopia/accommodation

AQ6 contents differ from main text - see AQ4. Please provide consistent text for table

working environment and equipment/technology provisions that could address the difficulties experienced in low luminance working conditions.

Driving

Driving under emergency conditions and transporting patients to hospital are key features of prehospital care. This became harder at night. In relation to tasks associated with arriving at a scene after nightfall, the panel reported increased difficulties with house number identification, assessment of scene safety and locating patients.

Patient assessment/treatment

The clinical severity of patients presenting to ambulance services is highly variable, but many are critically unwell. The professional panel identified that working in low luminance conditions made assessing and treating patients more difficult.

Specific tasks affected by lower luminance included detection of skin colour abnormalities, recognising social cues and reading text on equipment and medication. These are all essential tasks that may negatively affect the treatment provided to patients if not done accurately [AQ7 add ok?]. However, any relationship between this and patient outcomes is unexplored.

The panel also highlighted that provision of lighting equipment is unregulated and varies between both ambulance trusts and vehicles.

Suggestions for improvement

Suggestions from the professional panel to improve driving were limited. The use of a dark mode to reduce the glare from the mobile data terminal was suggested as was using the low-power mode for blue lights at night-time, which may reduce ambient light reflections. Encouraging the public to make house numbers more visible was also suggested.

Increasing scene luminance was considered the most important way to reduce difficulties in assessing and treating patients. The panel suggested this could be best achieved by improving the availability, performance and regulation of both vehicle-based and personal-issue lighting equipment. Portable devices such as hand and head torches and portable scene lighting, as well as fixed equipment on ambulance vehicles, were recommended.

Literature review

One hundred and thirty-seven papers were identified through searching databases (*Figure 2*) [AQ8 add a sentence about using PRISMA methodology and include a reference]. After screening against inclusion and exclusion criteria (*Table 1*), sixty relevant full-text studies were identified.

The explanations for increased difficulty in driving at night and undertaking patient assessment and treatments are broad.

Key findings were intuitively grouped into the headings below.

Visual acuity and low luminance

VA is the measurement of the ability to resolve fine details and is typically assessed using high-contrast letter charts. It is intuitive and extensively discussed that the ability to observe fine details degrades in low light, and this is in concordance with decreasing VA in reduced light conditions (Low, 1946; Kaido et al, 2007; 2018; Hiraoka et al, 2015).

Various factors influence low-luminance vision (Mandelbaum and Sloan, 1947; Conner, 1982; Barbur and Stockman 2010; Wilkinson et al, 2020; Wood et al, 2021a), and eyes tend to become short-sighted under low-luminance conditions (Arumi et al, 1997), with a change of approximately one dioptre reported in dark conditions as a result of night myopia (Charman, 1996).

It has also been reported that vision can become blurred in low light conditions because of spherical aberrations (Lápez-Gil et al, 2012) and poor accommodation (Leibowitz and Owens, 1975; Artal et al, 2012).

Exposure to an object or image in low light conditions for longer durations leads to improved visual acuity but not to the same level as during daylight conditions (Heinrich et al, 2020).

AQ9 did any study look at effect of pupil size affecting acuity? Or wasn't this relevant here?

Driving and low luminance

Driving statistics suggest that, after alcohol, night-time driving is the leading cause of road traffic collisions (RTCs) (Williams and Preusser, 1997; Åkerstedt et al, 2001).

This is likely to be multifactorial (Owens et al, 2007) owing to factors such as age (Morgan et al, 1995; Owens et al, 2007; Shanmugaratnam et al, 2010), fatigue (Åkerstedt et al, 2001) and reduced light levels (Cohen et al, 2007; Owens et al, 2007). A decrease in night-time RTCs has been directly correlated with increased street lighting (Jackett and Frith, 2013). In addition, eye-scanning patterns and visual perceptions are altered in low light (Rackoff and Rockwell, 1975), which could impact assessment and interpretation of hazards or the viewing of road signs.

Assessing daylight VA in isolation does not adequately determine the ability to drive safely in low light conditions (Gruber et al, 2013) and glare sensitivity along with reduced vision fields are better predictors of RTCs (Rubin et al, 2007).

It is important to consider that, because of ambient lighting [AQ10 add 'the use of headlamps'?], driving is not undertaken in complete darkness. However, low luminance and driving while experiencing night-time myopia (>0.75 dioptres sphere myopic shift) have been attributed to a statistically significant (P=0.044) increase in night-time RTCs (Cohen et al, 2007). This suggests it may be appropriate to mandate the requirement of refractive correction for small refractive errors to optimise vision during night-time driving and improve road sign and hazard visibility.

There is a dearth of literature investigating emergency driving, vision and low luminance. The impact of blue flashing lights on driving visibility and perception as well as their impact on other road users is unknown. Accidents involving ambulances on rural roads has been associated with greater injury severity (Weiss et al, 2001) [AQ11 do you mean 'great severity' or that they are more severe than in other vehicles or circumstances/setting?]. These roads are typically poorly lit, although further investigation is needed to understand the impact of luminance alongside other contributing factors such as road conditions and road familiarity.

A study investigating the impact of luminance on driving on a circuit showed that decreasing luminance reduced the ability to recognise road signs, identify road hazards and maintain higher speeds (Wood and Owens, 2005). However, rather than VA changes, longer scan times are required to identify hazards at night that would normally be identified almost instantaneously during the day are suggested as a contributing feature [AQ12 should this sentence be: 'Identifying hazards at night that would normally be recognised almost instantaneously during the day requires longer scan times rather than changes to VA, and these longer times may contribute to this loss of ability'?] (Rackoff and Rockwell, 1975).

Glare and its impact on driving

Glare can be defined as the loss of retinal image contrast as a result of intraocular light scatter (Aslam et al, 2007) from structures including the retina, lens and cornea (Yuan et al, 1993).

There are two key types: discomfort and disability glare. Disability glare causes a decrease in vision and can be a source of imminent danger (van den Berg, 1991; Aslam et al, 2007). Discomfort glare does not impair vision but makes viewing less comfortable. Although this does not cause danger, it can lead to long-term problems such as headaches, neck pain and eye strain, particularly with long periods of repeated exposure (van den Berg, 1991). This can have a significant impact on all tasks requiring vision as some forms of glare can be extremely disabling (Aslam et al, 2007).

There are several common ophthalmic conditions and procedures that predispose individuals to experiencing heightened glare. These include cataracts, certain types of contact lens and having undertaken refractive procedures such as LASIK (Lasa et al, 1993; Rubin et al, 1993). Therefore, this is an issue that cannot be ignored by paramedics.

Increased difficulty in driving, including in lane control and cornering, as a result of glare has been identified in simulated conditions; of particular concern is being less able to detect pedestrians (Ranney et al, 2000; Theeuwes et al, 2002). It has

Figure 3. Effect of the Purkinje shift

AQ13 do you have permission to reproduce this image and, if so, should it be credited to someone?

also been established that sensitivity to glare is a better predictor of RTCs than visual acuity during photopic (daylight) conditions (Rubin et al, 1993).

Additionally, glare in bright light may result in slower driving times (Theeuwes et al, 2002), which could increase response times and therefore affect patient outcomes. Evidence to support this as a potential cause of colours to [AQ14 - edit OK?] assessing or treating patients has not been identified.

Colour vision and low luminance

Colour vision is adversely affected by decreased luminance (Zele and Cao, 2015; Kelber et al, 2017) because of the shift from trichromatic, cone-mediated vision that occurs in bright light conditions to monochromatic, rod-mediated vision at low light levels.

Degradation of colour is not equal for all wavelengths. Red colours (longer wavelengths) are affected more than blue colours (shorter wavelengths) following dark adaption, ~~with dark adaption,~~ since spectral sensitivity between long-wavelength cones and short-wavelength rods and cones [AQ15 should this just be 'rods'?] is different (Long and Garvey, 1988).

The threshold for colour vision varies substantially between colours and individuals. Yellow colours can be identified down to 10^{-3}cd/m^2 background luminance and blue colours down to 10^{-2}cd/m^2 background luminance but only when a contrasting cue is provided (Kelber et al, 2002) so this is unlikely to be a true reflection of real-world colour vision. In comparison, Roth et al (2008) reported no correct identification of colour at a luminance level of 0.007cd/m^2.

Of particular note is the Purkinje shift, whereby red objects become darker while blue colours are enhanced (*Figure 3*) (Barlow, 1957). This may have an adverse effect on performance in emergency driving. In simulated driving conditions, it has been demonstrated that the ability to distinguish the colour red diminishes as luminance decreases (Alferdinck, 2006). This may be relevant in respect of street features such as warning signs and traffic lights. Although not evidenced in the literature found in this review, it can also be hypothesised from this that a 'washout' effect may be exhibited with the use of blue lights, making road features less distinguishable.

Approximately 5% of men have a red-green colour vision defect. There is no evidence that these individuals are at a disadvantage for paramedic duties as many tasks are based on comparisons between colours (Verhulst and Maes, 1998).

Difficulties in identifying skin colour changes was highlighted by the professional panel discussion as being particularly problematic. Clinically, blue skin changes observed in cyanosis are of immediate concern and needs to be identified early. The loss of ability to distinguish skin colour changes in low luminance conditions is unexplored.

Vision scientists have long been aware of the concept of colour rendering, where lamps of differently coloured hues have different effects on vision and dark adaptation levels (Verhulst and Maes, 1998). This has resulted in street lamps in many locations being changed from yellow sodium to LED lighting, which emits shades closer to natural light (Alferdinck, 2006; Masuda and Uozato, 2014). Selection of hue and luminance of any lighting devices issued needs careful consideration to enable optimal performance and patient care by paramedics.

Contrast sensitivity and low luminance

Contrast sensitivity is the lowest observable difference between an object and the background. Seeing the difference between two areas that are similar, such as the edge of the pavement against the road or skin lesions with subtle pigmentation changes, can be difficult.

The ability of the visual system to discern contrast is complex and changes with shifts in object and background luminance levels (Wood et al, 2021b). Overall, contrast sensitivity decreases with age (Gillespie-Gallery et al, 2013). For paramedics aged <40 years, the effects are unlikely to be significant in practice (Puell et al, 2004a; 2004b). However, after this age and towards the current retirement age in the UK of 66, it is plausible that reduced contrast sensitivity may affect the visibility of a range of paramedic activities.

Low luminance contrast sensitivity changes cannot be predicted from standard VA tests. Identifying contrast sensitivity changes may be better achieved by performing targeted testing in low luminance conditions (Ginsburg et al, 1982; Hertenstein et al, 2016). The effect on vision may be linked to the effect on response to glare rather than decline in contrast sensitivity alone (Puell et al, 2004b). Appropriate lighting and lighting set-ups can in some circumstances improve contrast sensitivity and reduce glare.

Of relevance to paramedics, work conducted in editor's note - is Fig 4 going to be redrawn? Text is v small

pilots shows that scotopic contrast sensitivity is a better predictor of performance on occupational tasks than standard photopic VA measures (Ginsburg et al, 1982). Using such measures in paramedic occupational assessments may allow better predictive measures.

Photopic contrast sensitivity measurements cannot predict performance of contrast sensitivity under low light conditions (Hertenstein et al, 2016; Owsley et al, 2020) under laboratory or real-world conditions.

There is no literature investigating the relevance of visual contrast sensitivity on paramedic practice.

Individual considerations

Consideration should also be made for individual factors, such as age (Brown et al, 1987; Sturr et al, 1990; Fraade-Blanar et al, 2018) and optical health (Congdon et al, 1995; Helgesen et al, 2004; Schallhorn et al, 2009), which may influence the success and safety of tasks undertaken in low luminance conditions.

For example, in endotracheal intubation in simulated conditions, the quality of view during direct laryngoscopy was shown to be directly affected by age-related VA changes (Mathews et al, 2021). Although this could be compensated for by changing the viewing angle and using adjuncts, its potential significance when combined with low luminance should be considered.

The rates of common conditions such as diabetes and glaucoma are increasing in the population (Flaxman et al, 2017). Even at early stages, these conditions will cause changes in visual perception which can be mitigated with some simple measures and must be accounted for to maintain a high-quality service and healthy paramedic workforce.

Meta-analysis

To understand further how VA changes with reducing luminance, a meta-analysis was conducted including seven studies that assessed VA at different luminance levels (Pesudovs et al, 2004; Barrio et al, 2015; Hiraoka et al, 2015; Lin et al, 2015; Bartholomew et al, 2016; Pluháček and Siderov, 2018; Freundlieb et al, 2020). A forest plot of mean logMAR VA reported at difference luminance levels was created (*Figure 4*).

Three studies (Pesudovs et al, 2004; Barrio et al, 2015; Lin et al, 2015) reported a range of VAs between 0.0 and 0.5 logMAR for 0.75cd/m^2, suggesting VA at this luminance level varies. VA dropped off significantly below 0.38cd/m^2. This is in agreement with previous findings, where 100–1.0cd/m^2 VA remains within normal limits and becomes impaired only when luminance falls below 1.0cd/m^2 (Rabin, 1995).

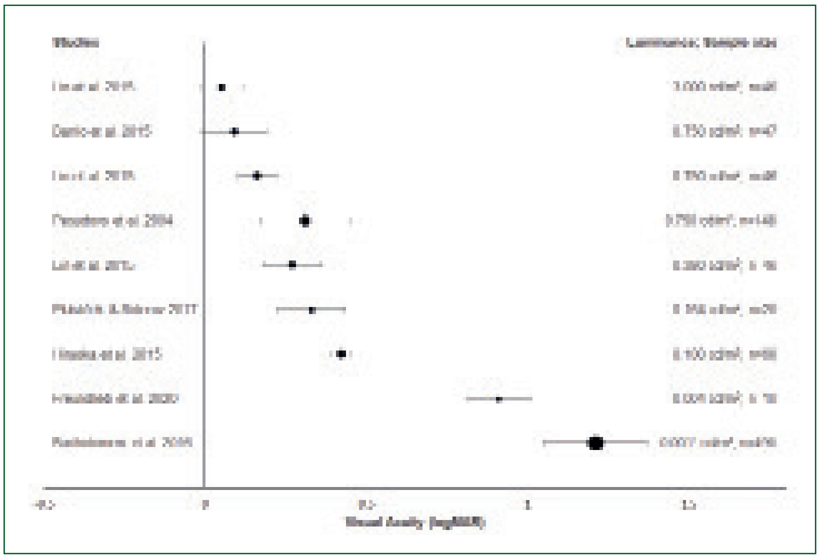

Figure 4. Forest plot of mean logMAR visual acuity reported at difference luminance levels

These findings suggest that, in low-luminance conditions (<1.0cd/m^2), paramedic activities requiring attention to fine details are likely to be hindered and would benefit from additional lighting to maintain good vision for such tasks.

Discussion

The main difficulties paramedics experience when working in low light conditions are in driving and patient assessment/treatment. Multiple factors affect visual abilities in low light conditions so multiple solutions are required.

The effects of low light on driving are likely to be magnified when driving an ambulance vehicle in emergency conditions where faster driving speeds must be maintained. However, the enhanced training that emergency drivers receive may offset some of this risk.

To the best of the authors' knowledge, there is no published data on the location and cause of ambulance driving incidents during night-time conditions. Analysis of such driving incidents could provide insight into risk reducing strategies.

Glare may be of practical relevance to paramedics. Sources of glare while driving ambulance vehicles could include oncoming traffic and street lighting, reflections from flashing blue lights, illuminated satellite navigation equipment and the mobile data terminal. Dirty windscreens and a low sun position can also cause significant glare.

There are no standardised occupational health standards relating specifically to paramedics in the UK. [AQ16 - edit OK?] The Health and Care Professions Council regulates allied health professionals including paramedics in the UK and

Key points

- Visual acuity reduces as the level of luminance decreases
- Paramedics report difficulty in undertaking critical tasks, including driving and assessing/treating patients, during low lighting conditions
- Standardised occupational health assessments should be developed and undertaken regularly to identify paramedics who may need additional support to work in low luminance conditions
- Adjustments to working practices and the introduction of tailored lighting equipment may help to alleviate the difficulties experienced by paramedics and improve patient safety
- Any changes to working practices should be supportive, with the aim of keeping paramedics working for as long as they wish to while maintaining the safety of patients

standards are generic (HCPC, 2014), as is the driving standard set by the Driving and Vehicle Licensing Agency (2021) which concentrates on VA and visual fields. Neither of these [AQ17 edit OK?] do consider other visual factors such as sensitivity to glare, contrast sensitivity and colour vision, which may affect driving and clinical practice. Some of these are assessed as part of occupational health checks for other professions such as pilots and train drivers. However, as far as the authors are aware, no occupational standards focus specifically on low light conditions.

In addition, assessments are generally only undertaken on initial employment and are not routinely repeated to consider changes associated with age or development of health conditions. This review has identified that many aspects of visual function, including colour vision and contrast sensitivity, are impacted by low luminance, along with environmental factors such as glare. Current assessments are insufficient to fully assess the effectiveness and safety of paramedic practice in low lighting conditions.

Recommendations

To overcome the difficulties identified in this review, the authors recommend that national paramedic occupational health standards are developed for low light working with visual function assessments established to ensure adherence to these. Assessments should be designed to simulate realistic working conditions by incorporating testing in a variety of lighting conditions as well as assessing response to glare.

A collaborative working group between optometry and ambulance trusts and clinicians is required to develop an array of tests to probe visual function to provide evidence-based support for the workforce. In recognition that visual function may change throughout a paramedic's career, especially as age increases, a full range of assessments that examine visual function in a range of lighting conditions should be undertaken at appropriate intervals.

Occupational support should be tailored to individual paramedics and conducted supportively to ensure an open culture where self-referral is encouraged when there are changes in personal health. To avoid concern and distress, a sensitive approach is needed with the underlying aim of retaining and supporting experienced paramedics to work in the prehospital environment for as long as they wish to and are able to do so safely. To support paramedics, a package of evidence-based adjustments should be made available. In exceptional circumstances, this could include duties that avoid driving at night. Adaptations to working practices should be practical and cost efficient.

Adjustments may be needed for all paramedics to ensure safety when working in low light conditions. In the UK, there are no restrictions on the speed of emergency response during night-time working (Association of Ambulance Chief Executives, 2018) and no distinctions made between luminance levels. While evidence is limited and further research is required to confirm whether a higher risk of night-time RTCs may be linked to reduced VA, driving at slower speeds may be necessary for safety to be maintained. This could potentially increase response times and, ultimately, affect the outcomes

CPD Reflection Questions

- What are your experiences of working in low lighting conditions? Do you have to make any adjustments to your practice to compensate for any difficulties?
- Do you know who to approach for support if you are experiencing problems in undertaking your role in low lighting conditions? Would you feel confident and safe to ask for further support?
- What lighting equipment is available to help you fulfil your role? What additional equipment, if any, would you like to see introduced?

of critically unwell patients; careful consideration for resource planning would therefore be needed if guidelines are amended. Excessive glare from vehicle-based or portable equipment should be considered before implementation and may be corrected with low-cost filters and software changes.

Adjustments to the working environment of paramedics could reduce the difficulties experienced when treating patients in low light conditions and, potentially, lead to better clinical outcomes. All panel respondents said that equipment to increase scene luminance would improve their ability to treat patients. Therefore, a review of the lighting equipment included within the ambulance inventory should be undertaken in conjunction with lighting engineers to determine whether additional equipment would be beneficial.

Whether this is vehicle based, such as fixed or portable flood lighting, or personally issue hand and head torches should be informed with the involvement of all stakeholders. Consideration should be given to the risk of exacerbating some of the problems experienced such as excessive glare, over illuminating the scene and losing contrast. This is especially important for activities requiring assessment of skin colour.

Limitations

The sample size of the professional panel was small and, although this had not been the intention, all worked for the same ambulance service NHS trust so may not be representative of the full range of paramedics working in the UK or internationally. The respondents shared similar experiences but it cannot be inferred that these experiences are universal.

The scoping review revealed limited research into evidence-based occupational standards and associated visual function in paramedic practice. Therefore, the literature search was expanded to include visual function scenarios highlighted by the professional panel that could be extrapolated to paramedic practice.

As a result, the authors can make only limited conclusions and recommendations for further investigation more tailored to paramedic practice.

Although this study has focused on paramedic practice, many of the difficulties presented with difficult working conditions in low light extend to other emergency services such as the fire service and police, as well as to work undertaken in war zones. While these were beyond the scope of this article, they also deserve attention.

Conclusions

This study is the first to explore the experiences of paramedics working in low-luminance conditions.

Visually demanding tasks are hindered by low light conditions. Despite broad and frequent low luminance working conditions in paramedic practice, there is a lack of evidence to inform occupational requirements for low light working. More research is needed to create occupational standards and inform personal occupational assessments to ensure that paramedics are supported to undertake their role safely and effectively so they can enable optimal patient care.

These findings could be relevant to other emergency service workers. **JPP**

Conflict of interest: None.

References

Åkerstedt T, Kecklund G, Hörte LG. Night driving, season, and the risk of highway accidents. Sleep. 2001;24(4):401–406. https://doi.org/10.1093/sleep/24.4.401

Alferdinck JWAM. Target detection and driving behaviour measurements in a driving simulator at mesopic light levels. Ophthalmic Physiol Opt. 2006;26(3):264–280. https://doi.org/10.1111/j.1475-1313.2006.00324.x

Artal P, Schwarz C, Cánovas C, Mira-Agudelo A. Night myopia studied with an adaptive optics visual analyzer. PLoS One. 2012;7(7):1–6. https://doi.org/10.1371/journal.pone.0040239

Arumi P, Chauhan K, Charman WN. Accommodation and acuity under night-driving illumination levels. Ophthalmic Physiol Opt. 1997;17(4):291–299. https://doi.org/10.1016/S0275-5408(96)00091-9

Aslam TM, Haider D, Murray IJ. Principles of disability glare measurement: an ophthalmological perspective. Acta Ophthalmol Scand. 2007;85(4):354–360. https://doi.org/j.1600-0420.2006.00860.x

Association of Ambulance Chief Executives. Emergency ambulance response driver handbook. 3rd edn. Bridgwater: Class Publishing; 2018

Barbur JL, Stockman A. Photopic, mesopic and scotopic vision and changes in visual performance. In: Dartt DA (ed). Encyclopedia of the eye. Volume 3. Oxford: Academia Press; 2010: 323–331. https://doi.org/10.1016/B978-0-12-374203-2.00233-5

Barlow HB. Purkinje shift and retinal noise. Nature. 1957;179(4553):255–256. https://doi.org/10.1038/179255b0

Barrio A, Antona B, Puell MC. Repeatability of mesopic visual acuity measurements using high- and low-contrast ETDRS letter charts. Graefes Arch Clin Exp Ophthalmol. 2015; 253(5):791–795. https://doi.org/10.1007/s00417-014-2876-z

Bartholomew AJ, Lad EM, Cao D, Bach M, Cirulli ET. Individual differences in scotopic visual acuity and contrast sensitivity: genetic and non-genetic influences. PLoS One. 2016;11(2): 1–16. https://doi.org/10.1371/journal.pone.0148192

Brown AM, Dobson V, Maier J. Visual acuity of human infants at scotopic, mesopic and photopic luminances. Vision Res. 1987;27(10):1845–1858. https://doi.org/10.1016/0042-6989(87)90113-1

Charman WN. Night myopia and driving. Ophthalmic Physiol Opt. 1996;16(6):474–485. https://doi.org/10.1016/0275-5408(96)00024-5

Cohen Y, Zadok D, Barkana Y et al. Relationship between night myopia and night-time motor vehicle accidents. Acta Ophthalmol Scand. 2007;85(4):367–370. https://doi.org/10.1111/j.1600-0420.2006.00875.x

Congdon N, Quigley HA, Hung PT, Wang TH, Ho TC, Glovinsky Y. Scotopic sensitivity screening. Arch Ophthalmol. 1995;

113(9): 1138–1143. https://doi.org/10.1001/archopht.1995.01100090064024

Conner JD. The temporal properties of rod vision. J Physiol. 1982;332(1):139–155. https://doi.org/10.1113/jphysiol.1982.sp014406

Driver and Vehicle Licensing Agency. Visual disorders: assessing fitness to drive. London: DVLA; 2021. https://www.gov.uk/guidance/visual-disorders-assessing-fitness-to-drive#higher-standard-of-visual-acuity--bus-and-lorry-drivers (accessed 16 December 2022) [AQ18 this goes to a section called 'Higher standard of visual acuity—bus and lorry drivers'. Is this what you want to cite? Do the bus/lorry driver rules apply to ambulance drivers?]

Flaxman SR, Bourne RRA, Resnikoff S et al. Global causes of blindness and distance vision impairment 1990–2020: a systematic review and meta-analysis. Lancet Glob Health. 2017;5(12):e1221–e1234. https://doi.org/10.1016/S2214-109X(17)30393-5

Fraade-Blanar LA, Ebel BE, Larson EB et al. Cognitive decline and older driver crash risk. J Am Geriatr Soc. 2018;66(6):1075–1081. https://doi.org/10.1111/jgs.15378

Freundlieb PH, Herbik A, Kramer FH, Bach M, Hoffman MB. Determination of scotopic and photopic conventional visual acuity and hyperacuity. Graefes Arch Clin Exp Ophthalmol. 2020;258(1):129–135. https://doi.org/10.1007/s00417-019-04505-w

Gillespie-Gallery H, Konstantakopoulou E, Harlow JA, Barbur JL. Capturing age-related changes in functional contrast sensitivity with decreasing light levels in monocular and binocular vision. Invest Ophthalmol Vis Sci. 2013;54(9):6093–6103. https://doi.org/10.1167/iovs.13-12119

Ginsburg AP, Evans DW, Sekule R, Harp SA. Contrast sensitivity predicts pilots' performance in aircraft simulators. Am J Optom Physiol Opt. 1982;59(1):105–109. https://doi.org/10.1097/00006324-198201000-00020

Gruber N, Mosimann UP, Müri RM, Nef T. Vision and night driving abilities of elderly drivers. Traffic Inj Prev. 2013;14(5):477–485. https://doi.org/10.1080/15389588.2012.727510

Health and Care Professions Council. The standards of proficiency for physiotherapists. London: HCPC; 2014. https://www.hcpc-uk.org/standards/standards-of-proficiency/physiotherapists/ (accessed 16 December 2022) [AQ19 This main text refers to occupational health standards for AHPs in general, not for physiotherapists. Check this is the correct reference. If you want to keep it, check the year - the standards in this citation were drawn up in 2013, and updated in 2015 then in 2022]

Heinrich SP, Blechenberg T, Reichel C, Bach M. The 'speed' of acuity in scotopic vs. photopic vision. Graefes Arch Clin Exp Ophthalmol. 2020;258(12):2791–2798. https://doi.org/10.1007/s00417-020-04867-6

Helgesen A, Hjortdal J, Ehlers N. Pupil size and night vision disturbances after LASIK for myopia. Acta Ophthalmol Scand. 2004;82(4):454–460. https://doi.org/10.1111/j.1395-3907.2004.00278.x

Hertenstein H, Bach M, Gross NJ, Beisse F. Marked dissociation of photopic and mesopic contrast sensitivity even in normal observers. Graefes Arch Clin Exp Ophthalmol. 2016;254(2):373–384. https://doi.org/10.1007/s00417-015-3020-4

Hiraoka T, Hoshi S, Okamoto Y, Okamoto F, Oshika T. Mesopic functional visual acuity in normal subjects. PLoS One. 2015;10(7):1–10. https://doi.org/10.1371/journal.pone.0134505

Jackett M, Frith W. Quantifying the impact of road lighting on road safety—a New Zealand Study. IATSS Res. 2013;36(2):139–145. https://doi.org/10.1016/j.iatssr.2012.09.001

Kaido M, Dogru M, Ishida R, Tsubota K. Concept of functional visual acuity and its applications. Cornea. 2007;26:S29–S35. https://doi.org/10.1097/ICO.0b013e31812f6913

Kaido M. Functional visual acuity. Invest Ophthalmol Vis Sci. 2018;59:DES29–DES35. https://doi.org/10.1167/iovs.17-23721

Kelber A, Balkenius A, Warrant EJ. Scotopic colour vision in nocturnal hawkmoths. Nature. 2002;419:922–925. https://doi.org/10.1038/nature01065

Kelber A, Yovanovich C, Olsson P. Thresholds and noise limitations of colour vision in dim light. Philos Trans R Soc Lond B Biol Sci. 2017; 372(1717)20160065: https://doi.org/10.1098/rstb.2016.0065

Lápez-Gil N, Peixoto-de-Matos SC, Thibos LN, González-Méijome JM. Shedding light on night myopia. J Vis. 2012;12(5):1–9. https://doi.org/10.1167/12.5.4

Lasa MSM, Podgor MJ, Datiles MB, Caruso RC, Magno BV. Glare sensitivity in early cataracts. Br J Ophthalmol. 1993;77(8):489–491. https://doi.org/10.1136/bjo.77.8.489

Leibowitz HW, Owens DA. Anomalous myopias and the intermediate dark focus of accommodation. Science. 1975;189(4203):646–648. https://doi.org/10.1126/science.1162349

Lin RJ, Ng JS, Nguyen AL. Determinants and standardisation of mesopic visual acuity. Optom Vis Sci. 2015;92(5):559–565. https://doi.org/10.1097/OPX.0000000000000584

Long GM, Garvey PM. The effects of target borders on dynamic visual acuity: practical and theoretical implications. Perception. 1988;17(6):745–751. https://doi.org/10.1068/p170745

Low FN. The peripheral visual acuity of 100 subjects under scotopic conditions. Am J Physiol. 1946;146(1):21–25. https://doi.org/10.1152/ajplegacy.1946.146.1.21

Mandelbaum J, Sloan LL. Peripheral visual acuity. With special reference to scotopic illumination. Am J Ophthalmol. 1947;30(5):581–588. https://doi.org/10.1016/0002-9394(47)92311-8

Masuda K, Uozato H. Effect of colour illumination from street lights on scotopic visual acuity. Invest Ophthalmol Vis Sci. 2014;55(13):6238. https://iovs.arvojournals.org/article.aspx?articleid=2271921

Mathews AM, Stein C, Richter M. Age-related laryngoscopic visual acuity. Afr J Emerg Med. 2021;11(2):218–222. https://doi.org/10.1016/j.afjem.2020.12.002

Morgan R, King D. The older driver—a review. Postgrad Med J. 1995;71:525–528. https://doi.org/10.1136/pgmj.71.839.525

Munn Z, Peters MDJ, Stern C, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. BMC Med Res Methodol. 2018;18(1):1–7. https://doi.org/10.1186/s12874-018-0611-x

Owens DA, Wood JM, Owens JM. Effects of age and illumination on night driving: a road test. Hum Factors. 2007;49(6):1115–1131. https://doi.org/10.1518/001872007X249974

Owsley C, Swain T, Liu R, McGwin G, Kwon MY. Association of photopic and mesopic contrast sensitivity in older drivers with risk of motor vehicle collision using naturalistic driving data. BMC Ophthalmol. 2020;20(1):1–8. https://doi.org/10.1186/s12886-020-1331-7

Pesudovs K, Marsack JD, Donnelly WJ, Thibos LN, Applegate RA. Measuring visual acuity—mesopic or photopic conditions, and high or low contrast letters? J Refract Surg. 2004;20(5):508–514. https://doi.org/10.3928/1081-597x-20040901-20

Pluháček F, Siderov J. Mesopic visual acuity is less crowded. Graefes Arch Clin Exp Ophthalmol. 2018;256:1739–1746. https://doi.org/10.1007/s00417-018-4017-6

Puell MC., Palomo C, Sánchez-Ramos C, Villena C. Mesopic contrast sensitivity in the presence or absence of glare in a large driver population. Graefes Arch Clin Exp Ophthalmol. 2004a;242(9):755–761. https://doi.org/10.1007/s00417-004-0951-6

Puell MC, Palomo C, Sánchez-Ramos C, Villeno C. Normal values for photopic and mesopic letter contrast sensitivity. J Refrac Surg. 2004b;20(5):484–488. https://doi.org/10.3928/1081-

597X-20040901-12

Rabin J. Luminance effects on visual acuity and small letter contrast sensitivity. Optom Vis Sci. 1995;71(11):685–688. https://doi.org/10.1097/00006324-199411000-00003

Rackoff NJ, Rockwell TH. Driver search and scan patterns in night driving. Transportation research board special report. 1975;156:53–63. http://onlinepubs.trb.org/Onlinepubs/sr/sr156/156-005.pdf (accessed 16 December 2022)

Ranney TA, Simmons LA, Masalonis AJ. The immediate effects of glare and electrochromic glare-reducing mirrors in simulated truck driving. Hum Factors. 2000;42(2):337–347. https://doi.org/10.1518/001872000779656453

Roth LSV, Balkenius A, Kelber A. The absolute threshold of colour vision in the horse. PLoS One. 2008;3(11):1–6. https://doi.org/10.1371/journal.pone.0003711

Rubin GS, Adamsons I, Stark W. Comparison of acuity, contrast sensitivity, and disability glare before and after cataract surgery. Arch Ophthalmol. 1993; 111(1):56–61. https://doi.org/10.1001/archopht.1993.01090010060027

Rubin GS, Ng ESW, Bandeen-Roche K et al. A prospective, population-based study of the role of visual impairment in motor vehicle crashes among older drivers: the SEE study. Invest Ophthalmol Vis Sci. 2007;48(4):1483–1491. https://doi.org/10.1167/iovs.06-0474

Schallhorn SC, Tanzer DJ, Kaupp SE, Brown M, Malady SE. Comparison of night driving performance after wavefront-guided and conventional LASIK for moderate myopia. Ophthalmology. 2009;116(4):702–709. https://doi.org/10.1016/j.ophtha.2008.12.038

Shanmugaratnam S, Kass SJ, Arruda JE. Age differences in cognitive and psychomotor abilities and simulated driving. Accid Anal Prev. 2010;42(3):802–808. https://doi.org/10.1016/j.aap.2009.10.002

Sturr JF, Kline GE, Taub HA. Performance of young and older drivers on a static acuity test under photopic and mesopic luminance conditions. Hum Factors. 1990; 32(1):1–8. https://doi.org/10.1177/001872089003200101

Theeuwes J, Alferdinck JWAM, Perel M. 2002. Relation between glare and driving performance. Hum Factors. 44(1):95–107. https://doi.org/10.1518/0018720024494775

Tricco AC, Lillie E, Zarin W et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med. 2018;169(7):467–473. https://doi.org/10.7326/M18-0850

van den Berg TJTP. On the relation between glare and straylight. Doc Ophthalmol. 1991;78(3–4):177–181. https://doi.org/10.1007/BF00165678

Verhulst S, Maes FW. Scotopic vision in colour-blinds. Vis Res. 1998;38(21):3387–3390. https://doi.org/10.1016/S0042-6989(97)00339-8

Weiss SJ, Ellis R, Ernst AA, Land RF, Garza A. A comparison of rural and urban ambulance crashes. Am J Emerg Med. 2001;19(1):52–56. https://doi.org/10.1053/ajem.2001.20001

Wilkinson MO, Anderson RS, Bradley A, Thibos LN. Resolution acuity across the visual field for mesopic and scotopic illumination. J Vis. 2020;20(10):7. https://doi.org/10.1167/jov.20.10.7

Williams AF, Preusser DF. Night driving restrictions for youthful drivers: a literature review and commentary. J Public Health Policy. 1997;18(3):334–345. https://doi.org/10.2307/3343314

Wood LJ, Jolly JK, Buckley TMW, Josan AS, MacLaren RE. Low luminance visual acuity as a clinical measure and clinical trial outcome measure: a scoping review. Ophthalmic Physiol Opt. 2021a;41(2):1–11. https://doi.org/10.1111/opo.12775

Wood LJ, Jolly JK, Andrews CD et al. Low-contrast visual acuity versus low-luminance visual acuity in choroideremia. Clin Exp Optom. 2021b;104(1):90–94. https://doi.org/10.1111/cxo.13087

Wood JM, Owens DA. Standard measures of visual acuity do not predict drivers' recognition performance under day or night conditions. Optom Vis Sci. 2005;82(8):698–705. https://doi.org/10.1097/01.opx.0000175562.27101.51

Yuan R, Yager D, Guethlein M et al. Controlling unwanted sources of threshold change in disability glare studies: a prototype apparatus and procedure. Optom Vis Sci. 1993;70(11):976–981. https://doi.org/10.1097/00006324-199311000-00016

Zele AJ, Cao D. Vision under mesopic and scotopic illumination. Front Psychol. 2015;5(1594):1–15. https://doi.org/10.3389/fpsyg.2014.01594