Congenital colour vision deficiency in healthcare professionals: a scoping review protocol of the impact on clinical practice and patient safety

Authors

Euan Lawson[1], Aqib Khan[1], Quenton Wessels[2], Adam M Taylor[1]
1. Lancaster Medical School, Lancaster University
2. Division of Anatomy, School of Medicine, University of Namibia, Windhoek, Namibia.

Corresponding author:

Dr Euan Lawson
e.m.lawson@lancaster.ac.uk
Senior Clinical Lecturer in General Practice, Lancaster Medical School
ORCID: https://orcid.org/0000-0002-4843-7733

Other authors
Dr Aqib Khan
a.khan50@lancaster.ac.uk
Foundation Year 2 Doctor, University Hospitals Morecambe Bay NHS Trust, Lancaster, UK

Dr Quenton Wessels
qwessels@unam.na
Associate Professor, Head of the Division of Anatomy, University of Namibia
ORCID: https://orcid.org/0000-0001-8539-5459

Professor Adam Taylor
a.m.taylor@lancaster.ac.uk
Professor of Anatomy, Lancaster Medical School, Lancaster University
ORCID: https://orcid.org/0000-0002-4084-0456

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Abstract

360 words

Introduction: Congenital colour vision deficiency (CVD), known as colour blindness, is a common visual problem affecting around 1 in 12 men and 1 in 200 women. It is known that people who have red-green CVD, the most common phenotype, can have difficulty differentiating colours and this can impact on the ability to perform clinical tasks related to patient care. The objective of this scoping review is to understand the extent and type of evidence and the impact on clinical practice and patient safety arising from congenital CVD in healthcare professionals.

Methods and analysis: The scoping review will follow the methodological framework outlined by the Joanna Briggs Institute and by Arksey and O'Malley and we will adhere to the Preferred Reporting Items for Systematic reviews and Meta-Analysis Scoping Review checklist. The following databases will be searched: PubMed, MEDLINE, Web of Science, SCOPUS, LENS.org and TRIP (filtered for low-income countries) with no limit on earliest date and up to 30 November 2024. Grey literature will be identified by planned searches in the Overton Index. All articles related to CVD in healthcare professionals in clinical practice or in training will be included. The study will also include other professionals who may be involved in healthcare but are not involved in direct patient-facing activities. It will be limited to congenital CVD and will exclude the impact of visual impairment and acquired CVD.

There will be an initial search to validate the search strategy. Titles and abstracts will be screened to determine eligibility, and the full text will be reviewed using a data extraction framework. Data will be extracted, collated and then mapped and summarised to present the relevant key findings and outcomes from the papers in tabular and visualised form with a narrative synthesis.

Ethics and dissemination: The scoping review does not need ethical approval and will provide an overview of the impact of congenital CVD on clinical practice and patient safety. This will determine the future need and direction of research in this area and identify methodological challenges and opportunities. The results will be published open access in a peer-reviewed journal.

Registration: The study protocol has been registered with INPLASY. (DOI: 10.37766/inplasy2024.11.0099)

Subject area/keywords (MeSH):

Color blindness; inherited color blindness; color vision defect; physician impairment; diagnosis; clinical skills

Strengths and limitations

- The identification and synthesis of data will be wide, encompassing the global literature and in multiple databases including grey literature.

- Our scoping review is based on the rigorous methodological approach outlined by the Joanna Briggs Institute and the Arksey and O'Malley framework.

- This scoping review is limited to congenital colour vision deficiency and not acquired colour vision deficiency disorders.

- Healthcare is a diverse collective term for an enormously heterogeneous group of professions and interactions with patients and it is possible some might be missed but the search strategy will be tailored to minimise this risk.

Introduction

Vision is a key sense utilised by humans and our ability to see in colour relies on specific photoreceptor cells. There is evidence that it is the sense most valued by the general public.[1] The light detectable by the human eye falls between the ultraviolet and infrared wavelengths of the spectrum. The specialised photoreceptor cells required for vision fall into two categories: rods and cones. Rods display high sensitivity to light, but this comes at a cost to spatial resolution. Their sensitivity to light is because they contain only a single photopigment – rhodopsin.[2] There are approximately 90 million rods in each human eye and they are twenty times greater in number than cones.[3,4]

The cones display a high spatial resolution, but low sensitivity to light, enabling colour vision.[5] The sensitivity reception difference between the cell types is shown in the fact that a single photon of light can activate a rod cell, but several hundred are needed to activate a cone cell. This process is assisted by only a small number of rod cells connecting to a single bipolar cell whereas many cone cells attach to a single bipolar cell further enhancing the sensitivity differences between the two retinal cell types.[6,7]

Once is there is sufficient light the cones become the dominant cell type in depicting vision with three specific cell types responding to light at different wavelengths; short wavelengths (blue), medium wavelengths (green) and longer wavelengths (red).[8] The ability to detect different colour wavelengths is a result of the cone cells expressing cone opsins.[7]

Colour vision deficiency – phenotypical variation

Some individuals may find themselves unable to distinguish colours across the visible light spectrum resulting in the inability to fully distinguish between colours. Anomalous trichromacy, based on the normal trichromatic theory where vision is perceived colours (red, green and blue), is where there is trichromatic vision but there is deficiency in the ability to perceive one of the three light wavelengths.[9] People affected are regarded as being colour vision deficient (CVD) although the term ‘colour blind’ is in common usage.

The most common deficiency is in the ability to distinguish red and green, of which there are two sub-types: deuteranomaly and protanomaly.[10]

Deuteranomaly is the most common type and results in reduced sensitivity to green light causing certain greens to appear red. The impact of this deficiency is typically mild and may not result in significant impact on everyday activities. Where there is complete inability to see green this is known as deuteranopia. *Protanomaly* results in reduced sensitivity to red light causing certain greens to appear red and complete inability to see red results in protanopia.

Where the blue cones are impacted, this is tritanomaly; it is often known as ‘blue-yellow’ CVD and is much rarer than the red-green deficiencies. It is more often acquired and when it is congenital the genetic defect is on chromosome 7 rather than being sex-linked. It results in difficulty distinguishing between green and blue, amongst other effects.

These deficiencies can display a spectrum of symptoms where the effects are so mild that the sufferer may have near normal vision approaching that of a trichromat, or could have a much more significant impairment that places them closer to that of a dichromat. Where there is a total deficiency in any of the cone types, this results in deuteranopia, protanopia and tritanopia, respectively. Each of these is the result from the deficiency of a given cone; red cone deficiency results in deuteranopia, green cone deficiency in protanopia and blue

cone deficiency results in tritanopia. Tritanopia is rare but manifests across most colours in the spectrum and makes them duller.

Colour vision deficiency prevalence and causes

The prevalence with ethnicity also varies with white populations having higher reported prevalence than others, and Africans having the lowest.[11,12] However, whilst many studies have investigated colour vision deficiency in populations, the available prevalence studies still represent modest snapshots of populations within any given country, region or across the globe.

Colour-vision deficiency in the workplace

With the high levels of CVD in the population, the impact and tracking of its effects in the workplace is somewhat limited, with the exception of a small number of professions that have strict requirements on the ability to differentiate the colours of the spectrum in order to safely undertake their role. The most notable of these professions include airline pilots and air traffic controllers, professional transport drivers, marine captains/pilots, various aspects of the armed forces and emergency services as well as some electrical professions. Many of these professions have restrictions due to safety requirements, but there are other professions which will be impacted as a result of CVD such as fashion, hospitality and decoration. It is well recognised that there are many individuals with CVD who are not aware that they have the condition or the severity of it though this has not been systematically researched.[13–15]

Many of these requirements are legacy and recent studies have shown that modern technologies in fields, such as aviation, have led to means that demonstrate that CVD is not always a cause for being unable to perform that job, or alterations to the colouration of electrical wiring away from colours that are problematic (red/green) for those with CVD. The other issues are also that many of these requirements are not universal and show differences across the globe, in aviation for example work to analyse the requirements for being able to pilot an aircraft have shown that across 92% of the aviation activity across the globally there is huge disparity in what constitutes requirements that permit/deny the ability to obtain a relevant licence.[13]

One area that is under-researched yet could have important implications is the impact of CVD on the healthcare profession. The nature of the field sees colouration of bodily fluids, interpretation of imagery and other samples by colouration, as well as labelling of cables, tubes and stickers with colour to enable professionals to rapidly distinguish between identically shaped objects that are used for different purposes.[16,17] Blood collection vials are a typical example of where CVD has the potential for impact on patient care.[18] Similarly, detection of some patient symptoms may also be impacted/missed where there is discolouration of the skin in cyanosis, jaundice, pallor or erythematous rashes. There is some evidence that blood test strips and urine dipsticks, presence of blood or bile in bodily fluids, and the recognition of some clinical signs may present challenges for healthcare professionals with CVD.[16,17,19]

In some Southeast Asian countries CVD is screened for as part of the entry process into medical programmes and can even be a reason for rejection onto the course, such as is the case in Indonesia.[20] Other countries in this region use this as a tool to raise awareness to the individuals that they have CVD, enabling them to understand the implications it may have on their studies and future practice. In countries such as the UK and USA, there is no requirement of CVD screening as part of enrolment onto medical or healthcare programmes and the true extent of CVD prevalence and impact on patient care is not fully known.

There is some limited evidence in this field but the coverage of the research is patchy and it is not clear what areas of CVD have been explored in relation to the provision of healthcare and which require further consideration. Overall, a scoping review was deemed as the most appropriate methodology. A preliminary search of MEDLINE, the Cochrane Database of Systematic Reviews and *JBI Evidence Synthesis* was conducted and no current or underway systematic reviews or scoping reviews on the topic were identified.

Methods and Analysis

The proposed scoping review will be conducted in accordance with the Joanna Briggs Institute (JBI) methodology for scoping reviews [21] and the Arksey and O'Malley framework.[22] This framework lays out five stages that should form the structure of a scoping review: Stage 1 is identifying the research question; Stage 2 is concerned with identifying relevant studies; Stage 3 is the selection of eligible studies; Stage 4 is charting the data; and Stage 5 is the collating, summarising and reporting of the results.

The study protocol has been registered with INPLASY. (DOI: 10.37766/inplasy2024.11.0099)

Stage 1: identifying the research question/s

1. The scoping review will assess the evidence on how congenital colour vision deficiency in healthcare and allied professionals can impact clinical practice.
2. What are the potential impacts on patient safety?

Stage 2: identifying relevant studies

This will be done using the PCC framework: population, concept, context.

Population. The population for this scoping review is healthcare professionals in clinical practice or in training. The study will include other professionals who may be involved in healthcare (such as laboratory technicians) but are not involved in direct patient-facing activities. A list of relevant healthcare professions has been produced from the UK Government's National Careers Service website.[23] (See Appendix 1.) This has the advantage of avoiding a strict definition and encompassing a wide range of roles in the sector.

Concept. The concept is congenital colour vision deficiency (colour blindness). It will be limited to colour vision deficiency and will exclude the impact of visual impairment alone and acquired colour vision deficiency.

Context. The context is how congenital colour vision deficiency can impact clinical practice and we will explore the potential effect on patient safety.

The search strategy aims to be comprehensive in including all published studies. The study will include all available global studies and is not limited to geographic location or gender. The initial search strategy will not limit papers by language. An initial limited search of MEDLINE will be undertaken to identify articles on the topic and test the search strategy. (See Appendix 2) The keywords contained in the titles and abstracts of relevant articles, and the index terms used to describe the articles will then be used to develop a full search strategy for databases that will include: PubMed, MEDLINE, Web of Science, SCOPUS, LENS.org and TRIP (filtered for low income countries). We will search the Overton Index for grey literature. The search strategy, including all identified keywords and index terms, will be adapted for each included database and/or information source. The reference list of all included sources of evidence will be screened for additional studies.

Studies published since 1794 will be included. This is the date of John Dalton's initial report deficiency and is the first published study on colour vision deficiency.[24]

Stage 3: selection of eligible studies

The inclusion criteria are wide and the geographical scope is global but studies will be limited to those published in English or where there is an available translation. The inclusion and exclusion criteria are summarised in Table 1. Following the search, all identified citations will be collated and uploaded onto Zotero and the Rayyan platform and duplicates removed. Titles and abstracts will then be screened by two independent reviewers for assessment against the inclusion criteria for the review. Potentially relevant sources will be retrieved in full and their citation details imported.

The full text of selected citations will be assessed in detail against the inclusion criteria by two or more independent reviewers. Reasons for exclusion of sources of evidence at full text that do not meet the inclusion criteria will be recorded and reported in the scoping review.

Any disagreements that arise between the reviewers at each stage of the selection process will be resolved through discussion, or with an additional reviewer/s. The results of the search and the study inclusion process will be reported in full in the final scoping review and presented in a Preferred Reporting Items for Systematic Reviews and Meta-analyses extension for scoping review (PRISMA-ScR) flow diagram.[25]

Table 1. Inclusion and exclusion criteria

Theme	**Inclusion criteria**	**Exclusion criteria**
Geographical	All	None
Time	Earliest literature (first published study in 1794) to 30 November 2024	None
Language	English	All other languages
Populations	Healthcare professionals and allied professions as defined by list and included as keywords in the search strategy	Other professions not defined as healthcare or allied professionals
Concept	People with congenital colour vision deficiency	Literature related to acquired colour vision deficiency Literature related to visual impairment alone without colour vision deficiency
Context	Studies related to clinical practice or where patient safety could be a factor	Other studies not exploring either clinical practice or patient safety
Type of study	Published and peer-reviewed literature. Grey literature including policy reports from established agencies	Non-peer reviewed literature Unpublished literature

Stage 4: charting the data

Data will be extracted from papers included in the scoping review by two independent reviewers using a data extraction tool developed by the reviewers. The data extracted will include specific details about the participants, concept, context, study methods and key findings relevant to the review question. (See Appendix 2)

The draft data extraction table will be modified and revised as necessary during the process of extracting data from each included evidence source and there will be an intermediate consistency check to ensure. Modifications will be detailed in the scoping review. Any disagreements that arise between the reviewers will be resolved through discussion, or with an additional reviewer/s. If appropriate, authors of papers will be contacted to request missing or additional data, where required.

Stage 5: collating, summarising and reporting of the results

The aim of the scoping review is to find all available evidence and understand the extent and range of the research in this area. It should then also allow research gaps to be identified. We will assess the quality of the reviewed studies using JBI checklists. (https://jbi.global/critical-appraisal-tools) but reporting of the findings will be narrative. Results will be presented in tabular form and a descriptive summary of the findings will link the findings and results to the aims of the scoping review.

Patient and public involvement

There has been no public involvement though one author, EL, has lived experience of having congenital colour vision deficiency (protanopia) and working as a healthcare professional.

Ethics and dissemination

This study will not include humans or animals as participants. Data will be sourced from published literature and does not require ethic approval.

This scoping review will offer insights into the current evidence around congenital colour vision deficiency and clinical practice. This has potentially important implications around patient safety and will be of interest to various stakeholders. The full results of the scoping review will be submitted for open access publication in a relevant journal to ensure that the findings are freely available to the public, educationalists, clinicians, researchers and policymakers.

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Competing interests statement

EL is colour vision deficient, known to have protanopia, and is a fully licensed medical practitioner in the UK. AT, AK, QW have no conflict of interest in this project and are not colour vision deficient.

Authors' contributions

Guarantor is Euan Lawson.

EL – initial conceptualisation, development and design of methodology, project administration, writing

AT – initial conceptualisation, development and design of methodology, project administration, writing

QW – development and design of methodology, writing – review and editing

AK – development and design of methodology, writing – review and editing

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