The UK CAA Colour Vision Regulation – Truly A Grey Area!

A detailed research into whether the UK Colour vision regulation for Commercial Pilots is too restrictive and if so what type of regulation should be used?

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Abstract

In 2018 the UK CAA changed its colour vision regulation for commercial pilots, creating irregularities in EASA Class 1 medicals. The literature review revealed many other issues especially the reliability and validity of the CAD test. If research does not address the problem now, the irregularities could increase in scale and progressively get worse, potentially failing unfairly many high-quality candidates for a Class 1 medical. Authorities like New Zealand, CASA and the FAA are moving towards practical testing methods, which are fairer and demonstrates the now lack of importance in colour discrimination needed as a pilot.

This report investigated whether the UK CAA regulation is too restrictive and if so, what type of regulation should be used. Different regulations within EASA and ICAO were compared with the UK CAA. A sample of 30 aviation professionals with 3 or more years' experience were asked to give opinions and categorise selected regulations. The questionnaire collated that 87% want the UK current regulation replaced with the proposed regulation. In combination with the rest of the data, this demonstrated that the UK regulation was too restrictive and that a practical test should be used.

The UK government state they want to be the best country in the world for aviation however, the UK CAA stand by their CAD test arguing it allows 35% more pilots to pass. The UK CAA still insisting on using only lab-based tests to pass or fail respondents, these tests have shown to be inaccurate according to the literature review. The enactment of Brexit will mean the UK CAA becomes an independent state, giving the CAA the perfect opportunity to implement the proposed regulation recommended to the UK CAA and the DFT, a suitable replacement in which all aviation professionals can agree on.

Glossary of Terms

CAA- Civil Aviation Authority

CAD- Colour Assessment & Diagnosis

CMO- Chief Medical Officer

CVD- Colour vision deficiency

Deutan- A form of Red -Green Colour deficiency where Green is less sensitive

DFT- Department for Transport

Dichromat- A person who has two cones

NAA- National Aviation Authority

PAPI- Precision Path Approach Indicators

Protan - A form of Red -Green Colour deficiency where Red is less sensitive

Trichromat- A person with three cones for detecting colour

Tritan – Yellow/ blue colour deficiency

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Introduction

Colour vision testing is a required part of the ophthalmologist section within a class 1 medical for commercial pilots. (EASA, 2019) (Manual of Civil Aviation Medicine, 2012) 8-12 % of the world population, mostly males have a level of colour deficiency with women only 0.5%. (Nei.nih.gov, 2019) (Nhs. uk, 2020)
93% of pilots are males according to (Aopa.org, 2019).
CVD regulation, therefore, affects a considerable number of respondents. There is increasing evidence that colour vision is not necessary at all within aviation, there is also huge ambiguity and misconception about what type of regulation needs to be implemented. (Cvdpa.com, 2020) (CVDPA, 2010) The problem is that colour vision is an extensive and relatively unknown subject where a lot of myths that derive from old train and marine regulation have been implemented in today's aviation regulation as this existed before flight and have had very little change. (Defence Technology Agency, 2015)
ICAO quotes that 'the problem with colour vision standards for pilots and air traffic controllers is that there is very little information which shows the real, practical implications of colour vision defects on aviation safety'. (Manual of Civil Aviation Medicine, 2012)
There have never been any reported aviation accidents attributed to colour vision. (CVDPA, 2017) Therefore the common question is whether colour vision regulation is actually required for commercial aviation. In 2018 the UK CAA decided to change their colour vision stance, moving away from EASA, thus causing much debate as to whether it has become over-restrictive or is still a necessary safety measure.

The most recent regulation change is seen by some to be taking a step backwards in colour vision regulation, especially when compared with the regulation used in New Zealand, Australia, and the USA. (CVDPA, 2017) (Pape, A, 2015) (Defence Technology Agency, 2015)
This regulation which now differs from the EASA's regulation was legally allowed as the UK CAA changed the guidance material under EASA MEDB.075, which is counted as a soft rule. As long as the state can meet the criteria for the implementing rule that EASA sets via the use of their guidance material, that state may change it. (EASA, 2020) This regulation change is important because the new UK regulation has created many irregularities especially for UK pilots, from observing the regulation and NAA statements these irregularities have been identified:

- Pilots who cannot get a UK class 1 can still fly in and out of the UK with a foreign medical and perform the same job. For example, on an Irish AOC based in Stanstead.
- Pilots in the UK who passed pre-2018 (I.e. via HWL or Anomaloscope) are still allowed to fly commercially in the UK and have not been required to take the CAD test.
- The UK CAA is making qualified pilots with thousands of hours perform the CAD test when transferring to the UK, if they fail the CAD, they will be denied a UK class 1
- The UK CAA had no transition period in changing the regulation and was using mainly the CAD test to pass pilots before the formal regulation change in April 2018.
- There is no consistency between the regulation used in the UK compared to the world.

Colour vision regulation in aircrew causes a lot of debate between academics and regulators, with many problems in terms of uniformity in regulation. (Watson, D., 2014) Many have argued that it does not make sense that one authority can deny someone's class 1 based on a stricter regulation than another authority, especially when using lab-based tests. (Defence Technology Agency, 2015)

These points have identified an important research, to find out if the UK CAA regulation is too restrictive and whether the CAD test used as the sole CVD test by the UK CAA is fit for purpose as this is where the irregularities stem from.

It is, therefore, crucial to find out whether aviation professionals from pilots to aerospace medicine doctors think that this regulation is too restrictive and if so what type of regulation needs to be implemented. This research can then be discussed with the CAA to express the outcome and any necessary changes needed.

To achieve successful and in-depth research, a number of objectives have been set.

1. An introduction into colour vision in aviation and to discuss the statistics and facts in the industry
2. Explain and compare the current testing methods and regulations
3. Explain in-depth about the CAD test -the new test used by the UK CAA
4. To identify the situations that have occurred due to the regulation change by the UK CAA
5. To gather data and opinions to establish whether the UK's current regulation is too restrictive by comparing it to other NAA regulations

6. If so, look at what regulation should be implemented instead, and ask the opinions of industry professionals and pilots

Literature Review

A BACKGROUND INTO COLOUR VISION TESTING IN AVIATION

COLOUR VISION REGULATION HISTORY

Colour vision testing has been a standard requirement in Class 1 medicals for commercial pilots since the beginning of aviation. The requirement came from maritime and train regulation and has been used ever since ICAO was formed. During the first World War the British Royal Flying Corps used medical testing of applicants, 'a great emphasis was laid upon perfect colour vision because of the importance of picking out the colour or markings of hostile machines, recognizing signal lights, and judging the nature of landing grounds. (Gibson, T. and Harrison, M, 1984)

Soon after the Aeronautical Commission established the first international civil aviation CV standards in 1919 stating that:

> 'If he is unable to distinguish pigmentary colors but is able to distinguish the coloured lights used in air navigation, his license may be rendered valid both for flight by night and for flight by day; If he is unable to distinguish either pigmentary colors or the colored lights used in air navigation, his license may only be rendered valid for flights by day, that is to say, for flights effected between sunrise and sunset.'

(Aeronautical Commission. Medical certificates Section V to Annex E - minimum qualification necessary for obtaining certificates as pilots and navigators, 1919)

This regulation implemented over 100 years ago was important as there was no radio communications and aircraft had very basic technology therefore a higher emphasis of understating coloured flares and light signals were needed.

COLOUR VISION IN MODERN CIVIL AVIATION

The requirement today for aircrew to identify coloured signals and flares in the absence of radio communication does not exist. Historical requirements should therefore not be used as a basis for today's standards.

Aviation authorities have quoted that ‘colour signals are almost obsolete and testing for these is now irrelevant’. (Civil Aviation Authority of New Zealand, 2020) (Civil Aviation Safety Authority,2020) (Defence technology Agency, 2015)

The UK CAA’s view is that those coloured light signals are still important in today’s commercial aviation industry. They quote the need for multiple coloured lights with the authority still using colour signals in control towers in case of aircraft radio failures and continuing to teach this within basic pilot training. (CAA, 2009) This old method can always be simply replaced by a requirement for a handheld radio to be carried according to (Civil Aviation Authority of New Zealand, 2020).

Colour vision requirements for aircrew in modern civil aviation have been examined in several different studies from the UK CAA and the FAA. (FAA, 2014) (CAA, 2009) There has always been much debate between academics, regulators and pilots with plenty of contradictions, misinterpretations and confusion.

Colour vision and its regulation have long been argued that it is not necessary within aviation especially in the modern era.

A court case in 2015 set a precedent when a commercial pilot in Australia fought for his right to obtain captaincy based on his ability to safely operate the aircraft as a co-pilot for many years even though he had not achieved a pass in any colour vision test. In Australia, at this time there were restrictions for CVD pilots, which stated that ‘the person couldn’t fly as a captain if they could not pass any CVD testing’. The tribunal found even though he had a major colour defect that ‘He was not likely to endanger the safety of air navigation in the role of Captain’ and ‘his ability to operate aircraft safely with CVD is not in question.’ (O’Brien and Civil Aviation Safety Authority, 2015)

This is a clear example that there is no evidence of the effect on safety in relation to the severity of CVD.

Furthermore, the UK CAA report on CVD in the cockpit quote:

> ‘In almost all situations there were additional sources of information to aid the taking of a particular decision. Very few instances were found in which colour was the sole source of information and therefore likely to be safety-critical in its own right’.

(CAA, 2006)

(Civil Aviation Authority of New Zealand, 2020) provides an example of how colour vision is irrelevant in the cockpit ‘Warning lights are a common example to argue why colour vision is necessary in the cockpit. The colour of the light is irrelevant. What is important is whether the light is on or off’.

This along with the fact there has never been an accident in aviation-related to colour vision is a strong argument to show colour vision is not necessary for the safe duties of flight. (CVDPA, 2017)

The current restriction for pilots in the UK and EASA is that, if the candidate is unable to pass a colour vision secondary test, they may be issued a class 2 with the restriction 'valid by day only'. (EASA, 2020)
However, this in comparison to the CAA's quote about CVD in the cockpit and the Australian tribunal does not correlate. Research shows that the use of colour is redundant or not critical in conveying the information within an aircraft even with the most severe forms of CVD. (Defence technology Agency, 2015) Furthermore, the EASA restriction that pilots who fail CVD testing are only able to safely perform in daytime, does not make sense. A pilot in the daytime would still have to read instrumentations, radios, maps, navigation aids to name a few. If having CVD was of such significance, then they would not be able to fly the aircraft whether it be day or night, An argument to this is that at night there is increased importance in correctly identifying lights to aid with specific tasks. However, unlike in day the luminance of light at night will be increased. Yet, it is important to understand that colour is rarely the sole use of information when flying an aircraft. (Pape and Crassini, 2009)
View Appendix 3 for more expert opinions that elaborate on whether colour vision is needed as a pilot.

The UK CAA colour vision papers have indicated several things a pilot must see to safely operate the aircraft. These include:

- Precision approach path indicator (PAPI).
- Hazard marker beacons
- Signal gun
- Aircraft navigation lights
- Airfield lighting
- Flight deck displays
- Maps

The research into the most important safety-critical colour related task for pilots identified that the PAPI lights were the most important safety task. The CAA quote that

'There are many other tasks that involve the use of colour signals, but they involve larger stimuli, the viewing is under more favourable conditions of light adaptation and other cues make the colour coding less critical'.
Also 'There are other visual tasks that can be classed as safety-critical, but in general these involve larger and brighter lights and are therefore easier to carry out. These tasks either rely on colour discrimination

(such as the red-green parking lights) or, in some cases, the tasks benefit from the use of colour signals as redundant information (such as the “green” runway threshold lights)’.

(CAA, 2009)

Therefore, stating that the PAPI lights, according to the UK CAA, are the only safety-critical task that a pilot needs to identify, to be classified as colour safe.

PAPI LIGHTS --MOST SAFETY-CRITICAL TASK (AS PUBLISHED IN FLIGHT TRAINING NEWS JANUARY 2020 BY AUTHOR)

The PAPI lights an evolution of the VASI (Visual approach slope indicator) developed in the 1950s is an aid for pilots to achieve the correct glide slope for landing. The PAPI has 4 lights in comparison to the VASIs 2. Each light is angled towards the aircrew, showing depending on the angle of view from the cockpit, either a red or white light. Red if too low and white if too high with 2 red and white lights meaning the aircraft is on the perfect approach path. (CAA, 2009)

Figure 1- *PAPI lights at night* (CAA, 2009)

With the PAPI being the most safety-critical task the CAA decided to develop the CAD which is a computer test to determine a respondent’s severity of colour vision deficiency and whether a respondent meets the safety level required to see the PAPI lights. This was achieved by measuring and relating PAPI task performance on a PAPI simulator developed by City University and colour discrimination sensitivity as assessed on CAD, signal lights and several other colour vision tests. (CAA, 2009)

THE ONLY CVD TEST IN THE UK -CAD (PUBLISHED IN FLIGHT TRAINING NEWS JANUARY 2020 BY AUTHOR)

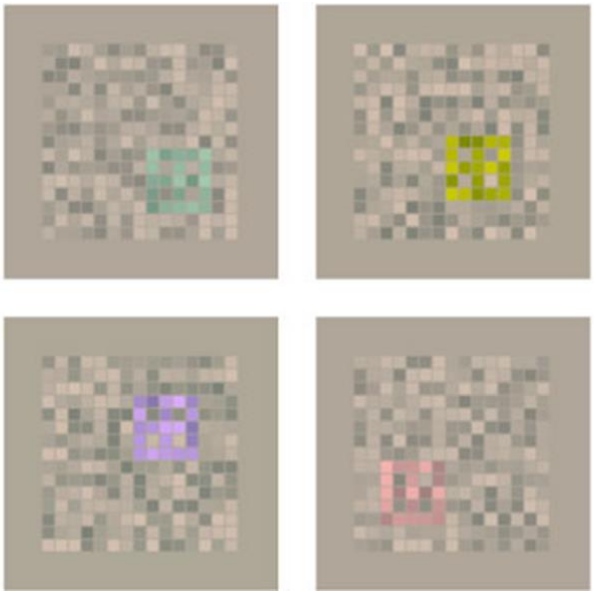


Figure 2-*The CAD test* (CAA,2009)

The CAD test is the only test available for CVD respondents. (CAA, 2019). The test lasts 15 minutes in which a colour square will move to one of four corners against a grey pixel background simulating camouflage technique, the candidate must then press a button to which of the four corners he or she believes the coloured square moved to. The test progressively gets harder with the colour fading against the grey background, even for colour normals. The computer programme works out a score that relates to the respondent's colour vision.

The test is normally taken in a dark condition with a monitor that is automatically calibrated. (City-occupational.co.uk, 2012) (CAA, 2009)

The UK CAA then determined the safe colour vision loss level, 6 SU (Standard units) for Deutans and 12 SU for Protans. (CAA, 2009) A respondent must get a score equal to or lower to pass the test depending on what type of colour deficiency they have. This pass mark developed from the City University's PAPI light test was created to relate the pass mark of the CAD to the most safety-critical task. The idea is that if a respondent can pass the CAD, they could definitely see the PAPI lights. The CAD pass marks are designed to pass 100% of

respondents who have previously passed via the Holmes Wright Lantern, the previous test used by the UK CAA.

The CAA, therefore, says the test is 100% specific and sensitive and passes 35% more pilots. (CAA, 2009)

Five irregularities, listed in the introduction, have stemmed from the CAD test and the UK CAA deciding to implement the CAD as the sole CVD test within their regulation. It is therefore important to understand the challenges of the CAD and PAPIs.

CHALLENGE TO THE CITY PAPI AND THE CAD TESTS (PUBLISHED IN FLIGHT TRAINING NEWS JANUARY 2020 BY AUTHOR)

The DTA 2015 report explains there are *'Four aspects of the validation process are however open to challenge.*

1. The University PAPI simulator was not representative of the colour or intensity of real PAPI lights. Rather the University PAPI simulator modified the colours of the signal lights to exploit lines of colour confusion.
2. City University eliminated the secondary intensity cue that is designed into the real PAPI.
3. Thirdly, simulator lights were only presented for 2-3 seconds, after which the subject was required to state how many red lights had been shown. By comparison the real PAPIs are continuously visible to the observer when interpreting the signal.
4. Finally, the pass mark in the CAD test was adjusted so as to be conservative. A proportion of respondents who were able to read the city University PAPI simulator without error, fall below the prescribed CAD pass mark.
As such the CAD test applies four levels of conservatism with result in a significant proportion of CVD respondents being excluded'.

(Defence Technology Agency, 2015)

Furthermore, concerns regarding the CAD test stems from that it is based on the PAPI. It is pointed out in the submissions that not all airfields have PAPI; it is a redundant aid that is prone to errors, and it is not a requirement for a safe landing. (CVDPA, 2017) (Caa.govt.nz, 2015)

- It is also important to note that the maker of the CAD himself Dr John Babur in the Australian appeal tribunal said "*The CAD system wasn't designed specifically for aviation. It was designed for assessing colour vision." "…the CAD test was not intended in any way to use direct information on operational tasks." "…that does not make the CAD an operational test."* (O'Brien and Civil Aviation Safety Authority, 2015)
- CVDPA have shown a video clip of a CAD test (where Dr Pape was the test subject) to a significant number of highly experienced pilots. Without exception, the response has been that the test resembles nothing any pilot has ever encountered in either normal or abnormal operations in any type of aircraft. The CVDPA stated 'this test does not simulate any operational action or situation.' (CVDPA, 2017) (Pape, A, 2015)

- The pass criteria for the CAD appears to be arbitrarily raised when compared to the pass criteria for the PAPI simulator. (DTA Report 405, 2015)
- Research conducted by City University and the CAA was not subject to any independent review. 'The CAA 2006 and 2009 studies were conducted under contract to the CAA by the City University of London and subsequently published by the CAA'.

(CVDPA, 2017) (Colour Vision Aviators, 2013)

Figure 3 below, a comparison of all the colour vision tests that are used by EASA, it shows that the CAD test only has an average sensitivity of 75.7%, not 100% according to the UK CAA. The HWL and the Spectrolux have very good scores and if conducted correctly are very accurate.

It is important to see scientifically which test is the most specific and sensitive, however, it is important to note this still does not demonstrate whether a candidate can safely perform their duties as a pilot.

(Bailey, K. and Carter, T, 2016)

Table 2.

Summary of test methods investigated

Test	Sensitivity %	Specificity %	CVD classification	Pass %	Summary of studies
HW(A)	83, 86, 86, 88.5, 89, 92, 96, 97, 100 (90.8)	96, 100, 100, 100, 100, 100 (99.3)	Dichromat	0–2 (0.40), 0–20 (4.4)[a]	Two studies compared HW(A) with established CV test battery: one using manufacturer testing and scoring procedure one testing in photopic conditions only. Two studies compared HW(A) with other secondary CV tests, using manufacturer testing and scoring procedure. One study compared HW(A) with simulated signal light test, using manufacturer testing and scoring procedure. Two studies compared pass/fail rates using different testing criteria: one comparing results with seven different scoring criteria one comparing the manufacturer testing criteria with that recommended by CIE.
			Trichromat	8–76.9 (27.7, 18.5, 28.9, 19.7)[a]	
HW(B)	98	92	Dichromat	0	One study compared HW(B) with two other lantern tests, using the Australian Department of Transport testing criteria.
			Trichromat	4	
Beyne	85	50	Dichromat	0	One study compared Beyne with two other lantern types and an anomaloscope using the JAR testing criteria.
			Trichromat	22	
Spectrolux	95	88	Dichromat	0	One study compared Spectrolux with two other lantern types and an anomaloscope using the JAR testing criteria.
			Trichromat	9	
CAD	64, 70 (based on RG CAD threshold limits for aviation), 93.3 (web-based CAD) (75.8)	100	–	–	One study evaluated the web- based CAD, comparing with established CV test battery, using the manufacturer's testing criteria. One study compared CAD with established CV test battery, a lantern test, and a signal light simulator, using experimentally derived pass/fail limits.

Figure 3 *Sensitivity and specificity of each colour vision test* (Bailey, K. and Carter, T, 2016).

The Civil medical institute of the FAA, who also part-funded the CAA research study into the CAD development, decided to independently design an operationally more appropriate PAPI simulation task, which CVD pilots were able to carry out with a high degree of accuracy. (FAA, 2011)

The FAA PAPI light test was designed to be a realistic fielded PAPI utilizing actual PAPI lens material and that used the intensity difference of lights. Respondents were asked to identify signals on the PAPI simulator for both incandescent and LED lighting.

It was found that when examined using incandescent PAPI, a replica of the PAPI lights used by airfields in the UK, **there was no difference in performance between respondents with normal colour vision and those with a colour vision deficiency!**

Furthermore, the move to an LED technology saw the CVD outperform respondents with normal colour vision and achieve perfect scores in the PAPI light test!

(Defence Technology Agency, 2015) (FAA, 2011) (FAA, 2014)

However, the ability of CVD subject being able to read the PAPI should not be surprising, the lights used in the PAPI are designed such that they will not be confused with one another even by a person with CVD. (Defence Technology Agency, 2015)

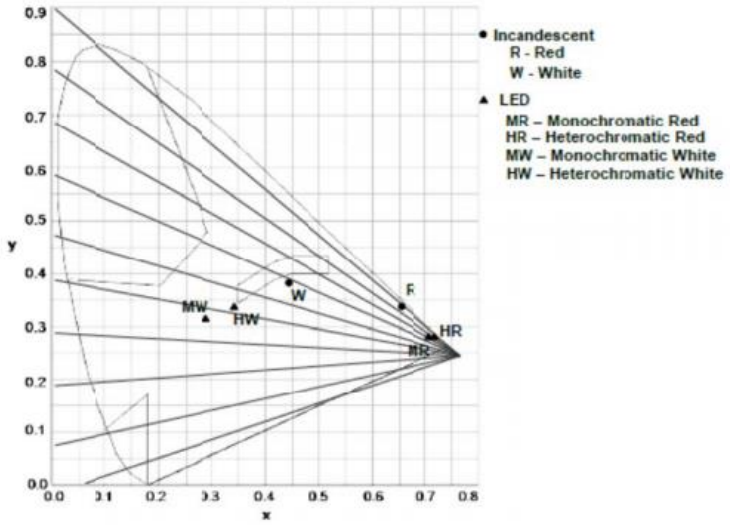


Figure 4-*Colour space and confusion lines for protan subjects, showing that PAPI red and white incandescent and LED lights do not lie on common colour confusion lines* (CIE, 1931)

An important quote from Professor Geoff Stuart of Monash University Accident Research Centre

> *'A recent study by **the FAA tested individuals with various forms of CVD on a more realistic PAPI simulator**. Importantly the colours of the lights corresponded to those of real systems. **Dichromats performed better than normal colour vison respondents**, this was not surprising as the red and white lights in the PAPI would not look the same to dichromats'*.

(Stuart. G, 2015)

The UK CAA test completely removed all intensity differences, in the FAA PAPI simulator the intensity difference was reduced to just 20% - well below that of operational PAPI but **even with this conservative measure, CVD observers still read the PAPI signals as accurately as colour normal observers.**

For more empirical evidence the report from New Zealand provides a more in-depth view of this topic. (Defence Technology Agency, 2015)

COLOUR VISION TESTING

ICAO set the worlds medical regulation and implementing rules that EASA uses. The current regulation requires that pilots have 'the ability to perceive readily those colours necessary for the safe performance of duties.' (Manual of Civil Aviation Medicine, 2012) Clinical tests used by NAAs have been designed to detect the presence and severity of CVD in a respondent however no clinical test yet provides a measure of effect on operating an aircraft. (Defence Technology Agency, 2015) However some argue that this is not needed if an accurate result of the severity of colour vision loss can be shown, this can then be used as a judgment itself on the respondent's ability to perform. (CAA,2006) (CAA, 2009) This could be perceived though as a stigma or lack of education related to colour vision as there is no evidence to suggest that CVD will affect the respondent's ability to perform safely, mentioned by ICAO Manual. (Defence Technology Agency, 2015). Pass marks are assigned to the test options which vary between NAAs, this creates difficulty as a candidate in one state may be issued a commercial medical and in another authority be denied. (Watson, D., 2014)

There is a large variety of testing options for colour vision from Lanterns, Anomaloscopes, colour matching or sequencing and computer tests, all these lab-based tests. This means they cannot determine whether

someone is colour safe for his/her positions as a pilot. Furthermore, the CMO of Australia had recently released a statement in February 2020 which reinforces this.

> *'Research in recent years has shown relying on diagnostic tests alone may be unnecessarily limiting when considering the impact of colour vision deficiency on aviation safety. Advances in technology, operating techniques and human factors training can now mitigate many of the safety risks of colour vision deficiency. Technology to assist pilots has developed significantly and the impact of colour vision deficiency on aviation safety should take these changes into account. These factors have been recognised overseas, most recently in New Zealand where a new approach to colour vision deficiency came into effect in May 2019, which includes an operational colour vision assessment*.'

(The CASA Briefing - February 2020, 2020)

EASA TESTS

Within the EASA regulation Med B.075 there are 3 types of secondary colour vision tests, Lanterns, Anomaloscopes and the CAD. These all lab-based tests and provide fewer options than other ICAO regulations. (Defence Technology Agency, 2015)

Secondary Tests

These are used for any respondent that has failed the Ishihara or another type of screening test

Nagel and other Anomaloscopes

> 'Generally recognised as the best instrument for differentiation of normal trichromats from individuals with red/green colour deficiencies, for differentiation of protan and deutan types amongst the red/green deficient and also recommended for diagnosis and differentiation of the level of deficiency'.

(Procedures for testing colour vision, 1981)

This test is generally accepted as the 'gold standard' for identifying colour vision deficiency and type. (Colour Vision Tests for Aviation: Comparison of the Anomaloscope and Three Lantern Types, 2005).

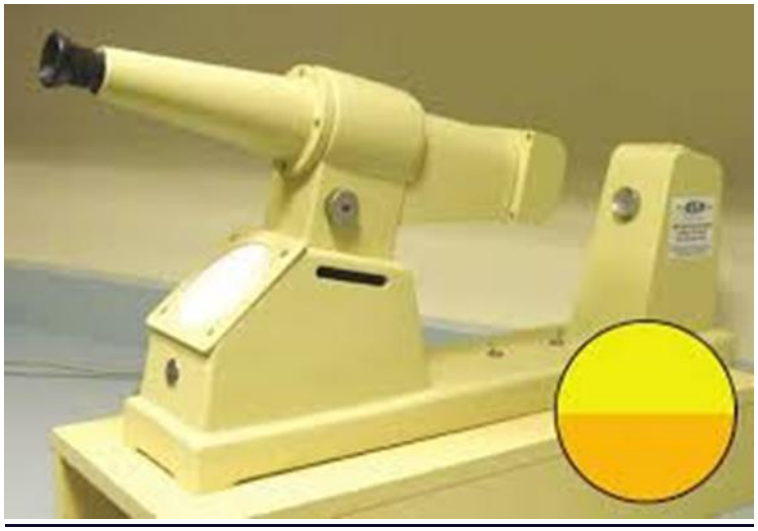


Figure 5-*Example of an Anomaloscope Test* (Colblindor, 2011)

This test is based on colour matching where the respondent views a disk split into two half fields as shown in figure 5 through the device telescope. Scoring explained in Appendix 7. A problem with this test is, it is lab-based, these types of tests do not replicate a real aviation environment and requires an expert to conduct the test, record and interpret the results. Figure 6 demonstrates the complexity of the scoring, anything in blue is considered a pass.

(Report of the Colour Vision Deficiency General Direction Assessment Panel, 2015) (Defence Research and Development Canada, 2017)

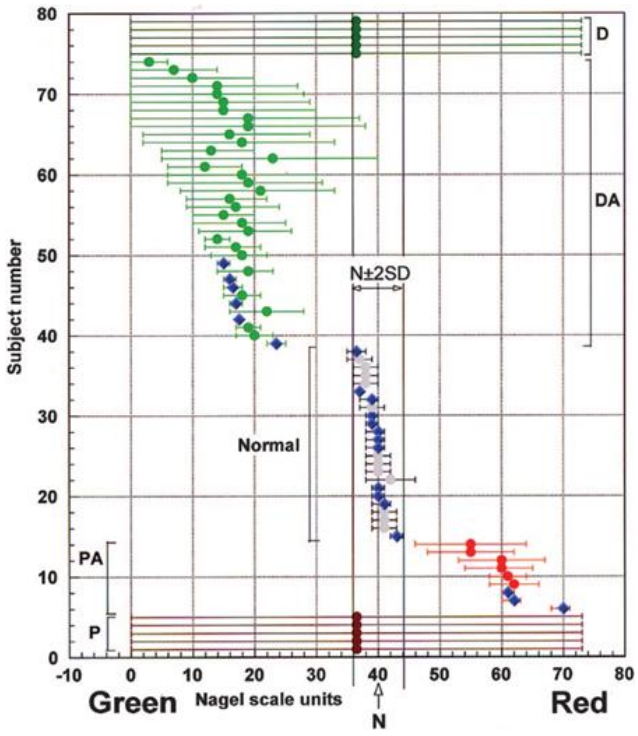


Figure 6 *Anomaloscope results diagram* (Color Vision Tests for Color Vision Tests for Aviation: Comparison of the Anomaloscope and Three Lantern Types, 2005)

Lantern Tests

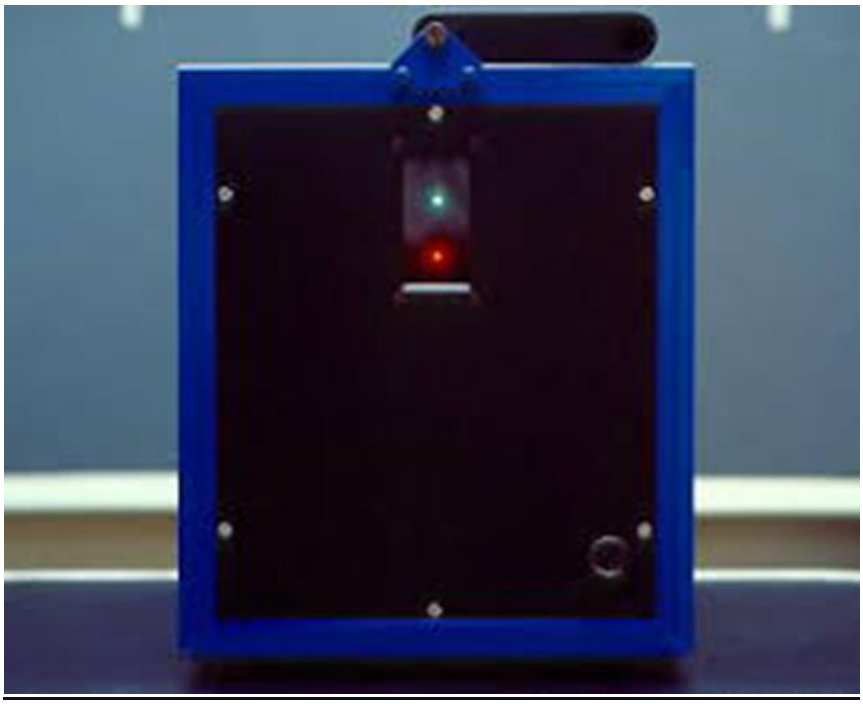


Figure 7-*The Holmes Wright Lantern Type A* (CAA, 2006)

There are three types of lantern tests within the EASA regulation.

The most common being the Holmes Wright Lantern A. There was originally two versions, A and B. A was specifically designed for aviation. (Birch J., Roden M, 1993)

Each type of lantern test varies, using the same colour variants and luminance you would see in aviation; the brightness of the lights varies to give the hardest possible viewing task to replicate bad weather and maximum distance. HWL Testing procedure in appendix 8.

The HWL has validation since the 1970s and is very good in passing only candidates with a mild colour deficiency that can perform the important safety tasks and passing 100% of colour normal's. Figure 3 shows the test has high sensitivity and specificity scores along with its reliability, easy maintenance and it is simple to administer. Figure 8 shows a comparison between each of the EASA Lantern tests. (Color Vision Tests for Aviation: Comparison of the Anomaloscope and Three Lantern Types 2005)

TABLE II. PROPERTIES OF LANTERNS.

Lantern [and Country of Origin]	Test Distance (m)	Colors of Lights	Number of Apertures	Aperture Sizes (min of arc)	Stimulus Duration (s)	Room Lighting Condition
Spectrolux [Switzerland]	2.5	RGW*	2, vertically separated	4.8	3	light
Beyne type 2 (now Tritest L3) [France]	5	WGRBY*	1	3	1	dim
Holmes-Wright Type A [UK]	6	RGW*	2, vertically separated	0.9	Max. 4 (manual)	normal/dark

*R = red; G = green; W = white; Y = yellow/orange; B = blue

Figure 8 *Comparison of the different Lantern Tests* (Color Vision Tests for Aviation: Comparison of the Anomaloscope and Three Lantern Types 2005)

UK COLOUR VISION REGULATION COMPARED TO THE REST OF THE WORLD

UK COLOUR VISION REGULATION PRE-2018/CURRENT EASA REGULATION (EASA, 2020)

'AMC1 MED.B.075 Colour vision (a) At revalidation and renewal examinations, colour vision should be tested on clinical indication.

(b) The Ishihara test (24 plate version) is considered passed if the first 15 plates, presented in a random order, are identified without error.

(c) Those failing the Ishihara test should be examined either by:

(1) Anomaloscopy (Nagel or equivalent). This test is considered passed if the colour match is trichromatic and the matching range is 4 scale units or less, or if the anomalous quotient is acceptable; or by

(2) lantern testing with a Spectrolux, Beynes or Holmes-Wright lantern. This test is considered passed if the applicant passes without error a test with accepted lanterns.

(3) Colour Assessment and Diagnosis (CAD) test. This test is considered passed if the threshold is less than 6 standard normal (SN) units for deutan deficiency, or less than 12 SN units for protan deficiency. A threshold greater than 2 SN units for tritan deficiency indicates an acquired cause which should be investigated.

(This regulation is still used by other EASA states and has been released in Regulation 2019 Annex I to ED Decision 2019/002/R Page 43 of 113)'

(EASA, 2020)

UK COLOUR VISION REGULATION POST -2018 (CAA.CO.UK, 2019)

UK Alternative AMC to MED B.075 Colour vision (Class 1 and 2)

(c) Those failing the Ishihara test should be examined by:

(1) Anomaloscopy (Nagel or equivalent). This test is considered passed if the colour match shows normal trichromacy, i.e. a matching midpoint of 38-42 scale units and the matching range is 4 scale units or less; or by

(2) Colour Assessment and Diagnosis (CAD) Test. This is considered passed if the threshold is less than 6 SU for deutan deficiency, or less than 12 SU for protan deficiency. A threshold greater than 2SU for tritan deficiency indicates an acquired cause which should be investigated.

The current UK CAA regulation has removed all forms of lantern testing, as well as adapting the Anomaloscope criteria which now only allows colour normal to pass, hence the CAD is the only remaining test available for colour defects to attempt to gain their class 1 medical.

The current UK regulation now differs from all other EASA states.

(Caa.co.uk, 2019)

The reasoning behind the UK CAA decision for the regulation change can be found in Appendix 4 explaining that Lantern tests are now obsolete and no longer used and the Anomaloscope are inaccurate tests. This does not correlate with the evidence however suggesting the Anomaloscope is the ‘Gold Standard’.

ICAO States Colour Vision Regulation -differences in leniency

FAA

pathway is no longer an option to the airman, and no new result will be considered.

An applicant does not meet the color vision standard if testing reveals:

A. All Classes

1. AOC (1965 edition) pseudoisochromatic plates: seven or more errors on plates 1-15.
2. AOC-HRR (second edition): Any error in test plates 7-11. Because the first 4 plates in the test book are for demonstration only, test plate 7 is actually the eleventh plate in the book. (See instruction booklet.)
3. Dvorine pseudoisochromatic plates (second edition, 15 plates): seven or more errors on plates 1-15.
4. Ishihara pseudoisochromatic plates: Concise 14-plate edition: six or more errors on plates 1-11; the 24-plate edition: seven or more errors on plates 1-15; the 38-plate edition: nine or more errors on plates 1-21.
5. Richmond (1983 edition) pseudoisochromatic plates: seven or more errors on plates 1-15.
6. OPTEC 900 Vision tester and Farnsworth Lantern test: an average of more than one error per series of nine color pairs in series 2 and 3. (See instruction booklet.)
7. Titmus Vision Tester, Titmus i400, OPTEC 2000 Vision Tester, Keystone Orthoscope, or Keystone View Telebinocular: any errors in the six plates.
8. Richmond-HRR, 4th edition: two or more errors on plates 5-24. Plates 1-4 are for demonstration only; plates 5-10 are screening plates; and plates 11-24 are diagnostic plates.

B. Certificate Limitation

If an applicant fails to meet the color vision standard as interpreted above but is otherwise qualified, the Examiner must issue a medical certificate bearing the limitation:

NOT VALID FOR NIGHT FLYING OR BY COLOR SIGNAL CONTROL

C. The color vision screening tests above (Section A) are not to be used for the purpose of removing color vision limits/restrictions from medical certificates of airmen who have failed the Specialized Operational Medical Tests below (Section D). See bold paragraph in the introduction of this section (above).

D. Specialized Operational Medical Tests for Applicants Who Do Not Meet the Standard.

Applicants who fail the color vision screening test as listed, but desire an airman medical certificate without the color vision limitation, may be given, upon request, an opportunity to take and pass additional operational color perception tests. If the

Figure 9.1 -*FAA colour vision regulation for commercial pilots* (Faa.gov, 2019)

airmen who have failed the Specialized Operational Medical Tests below (Section D). See bold paragraph in the introduction of this section (above).

D. Specialized Operational Medical Tests for Applicants Who Do Not Meet the Standard.
Applicants who fail the color vision screening test as listed, but desire an airman medical certificate without the color vision limitation, may be given, upon request, an opportunity to take and pass additional operational color perception tests. If the airman passes the operational color vision perception test(s), then he/she will be issued a Letter of Evidence (LOE).

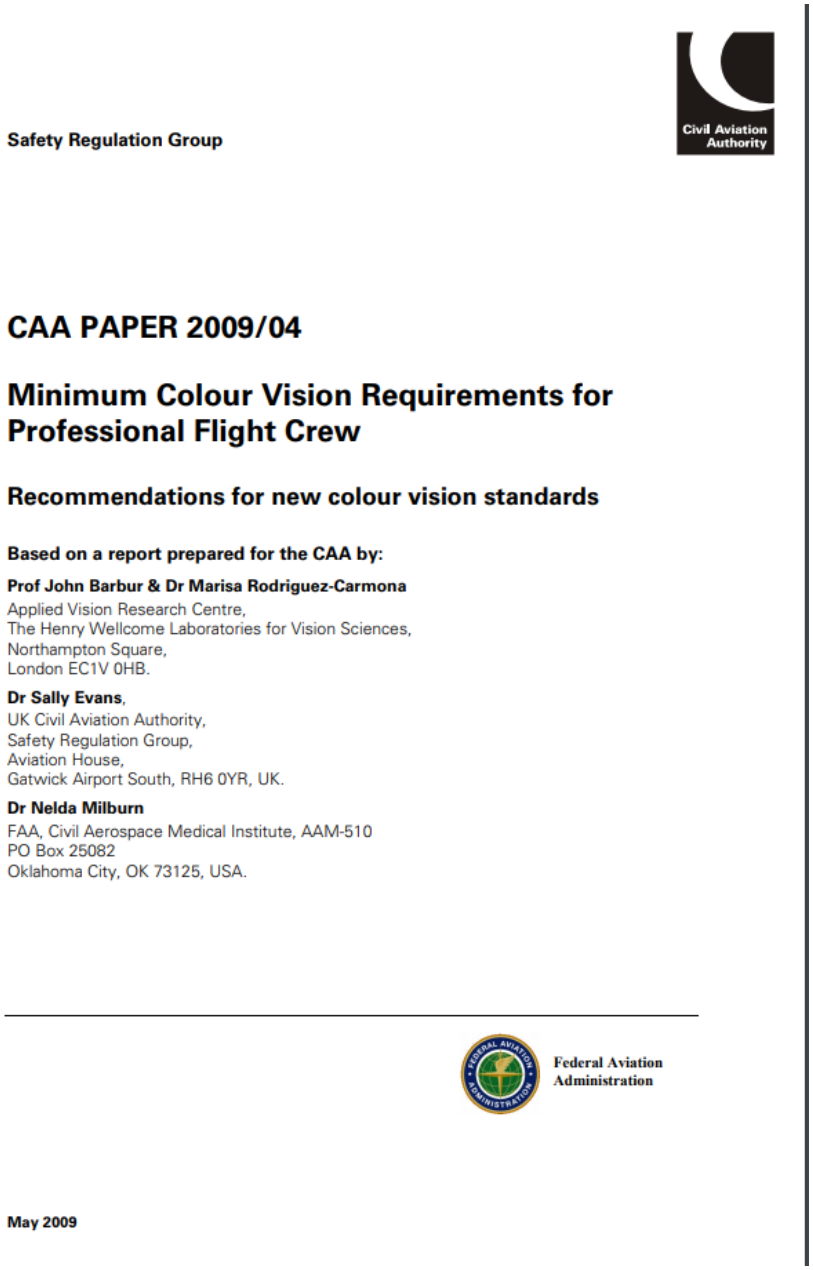
- The operational tests are determined by the class of medical certificate requested. The request should be in writing and directed to AMCD or RFS. See NOTE for description of the operational color perception tests.
- Applicants for a third-class medical certificate need only take the Operational Color Vision Test (OCVT).
- The applicant is permitted to take the OCVT only once during the day. If the applicant fails, he/she may request to take the OCVT at night. If the applicant elects to take the OCVT at night, he/she may take it only once.
- For an upgrade to first- or second-class medical certificate, the applicant must first pass the OCVT during daylight and then pass the color vision Medical Flight Test (MFT). If the applicant fails the OCVT during the day, he/she will not be allowed to apply for an upgrade to First- or Second-Class certificate. If the applicant fails the color vision MFT, he/she is not permitted to upgrade to first- or second-class certificate.

E. An LOE may restrict an applicant to a third-class medical certificate. Airmen **shall not** be issued a medical certificate of higher class than indicated on the LOE. Exercise care in reviewing an LOE before issuing a medical certificate to an airman.

F. Color Vision Correcting Lens (e.g. X-Chrom)
Such lenses are unacceptable to the FAA as a means for correcting a pilot's color vision deficiencies.

G. Any tests not specifically listed above are unacceptable methods of testing for FAA medical certificate. Examples of unacceptable tests include, but are not limited to, the OPTEC 5000 Vision Tester (color vision portion), "Farnsworth Lantern Flashlight," "yarn tests," and AME-administered aviation Signal Light Gun test (AME office use is prohibited). **Web-based color vision applications, downloaded, or printed versions of color vision tests are also prohibited.** Examiners must use actual and specific color vision plates and testing machinery for applicant

Figure 10.2 -*FAA colour vision regulation for commercial pilots* (Faa.gov, 2019)



Safety Regulation Group

Civil Aviation Authority

CAA PAPER 2009/04

Minimum Colour Vision Requirements for Professional Flight Crew

Recommendations for new colour vision standards

Based on a report prepared for the CAA by:

Prof John Barbur & Dr Marisa Rodriguez-Carmona
Applied Vision Research Centre,
The Henry Wellcome Laboratories for Vision Sciences,
Northampton Square,
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FAA, Civil Aerospace Medical Institute, AAM-510
PO Box 25082
Oklahoma City, OK 73125, USA.

Federal Aviation Administration

May 2009

Figure 11 *UK CAA colour vison research study 2009 in conjunction with the FAA* (CAA, 2009)

What's New?

Stage 1
The first stage is the Ishihara colour plate testing. We all know what this means and if you pass, you're deemed colour safe.

Stage 2
Alternative colour vision testing forms the basis for stage 2. This will either be Holmes-Wright Lantern, Farnsworth Lantern, CAD test or the Farnsworth D15. If any of these are passed, the candidate will be deemed colour safe.

Until now, if you failed any of these you're deemed colour unsafe (at least in UK CAA parlance). But what you're actually being told is that yes, you have defective colour vision; nothing more. You aren't being tested in a real-world environment. I know I failed a couple of these tests but rarely ever fail to identify navigation lights on aircraft flying overhead at night, or PAPIs, or aerodrome lighting.

Stage 3
This is where things are now taking a step into the 21st Century. The Operational Colour Vision Assessment (OCVA) appears to be a comprehensive assessment of the individuals ability to correctly identify *information* provided by lights, charts, aircraft systems and more.

It is not a test whereby the individual is required to name a colour, but rather that individual must correctly interpret the *information* that a particular colour is representing.

The day time portion of the assessment will include things such as:

- *'Correctly interpreting aeronautical charts, including print in various colours and fonts, symbols, lines and terrain markings.'* This '*may be performed in daylight or artificial light conditions'*.
- *Correctly interpreting aircraft instrumentation and displays, particularly those with coloured markings, warning lights and coloured displays.*
- Thirdly,*'recognise terrain and obstructions including the surface condition of several emergency landing fields. The applicant should be able to describe surface features and obstructions.'*

The night assessment covers the first two points of the day test, and in addition to identify the location and significance of lights on other aircraft or airfields, including:

The night assessment covers the first two points of the day test, and in addition to identify the location and significance of lights on other aircraft or airfields, including:

- Location and travel of other aircraft in the vicinity
- Runway approach aids relevant to the type of aircraft
- Runway edge, ends, centreline, touchdown zone, taxiway lead off lights
- Taxiway lights
- Holding points
- Obstacles
- Airport beacons

There is no requirement to identify light gun signals. Applicants at this stage will retain a restriction on their medical of:

'Not valid for flight in the vicinity of a controlled aerodrome unless the aircraft is in radio contact with aerodrome control'

In other words, you can flight near an airport as long as you have a working radio.

Read the full contents of the **General Direction here**. The new procedures come into force 1 June 2019 and appear to offer a far more common sense and *task relevant* approach to colour vision testing than any other country.

Figure 12-*New Zealand CAA Colour Vision regulation testing methods for commercial pilots* (Civil Aviation Authority of New Zealand, 2019)

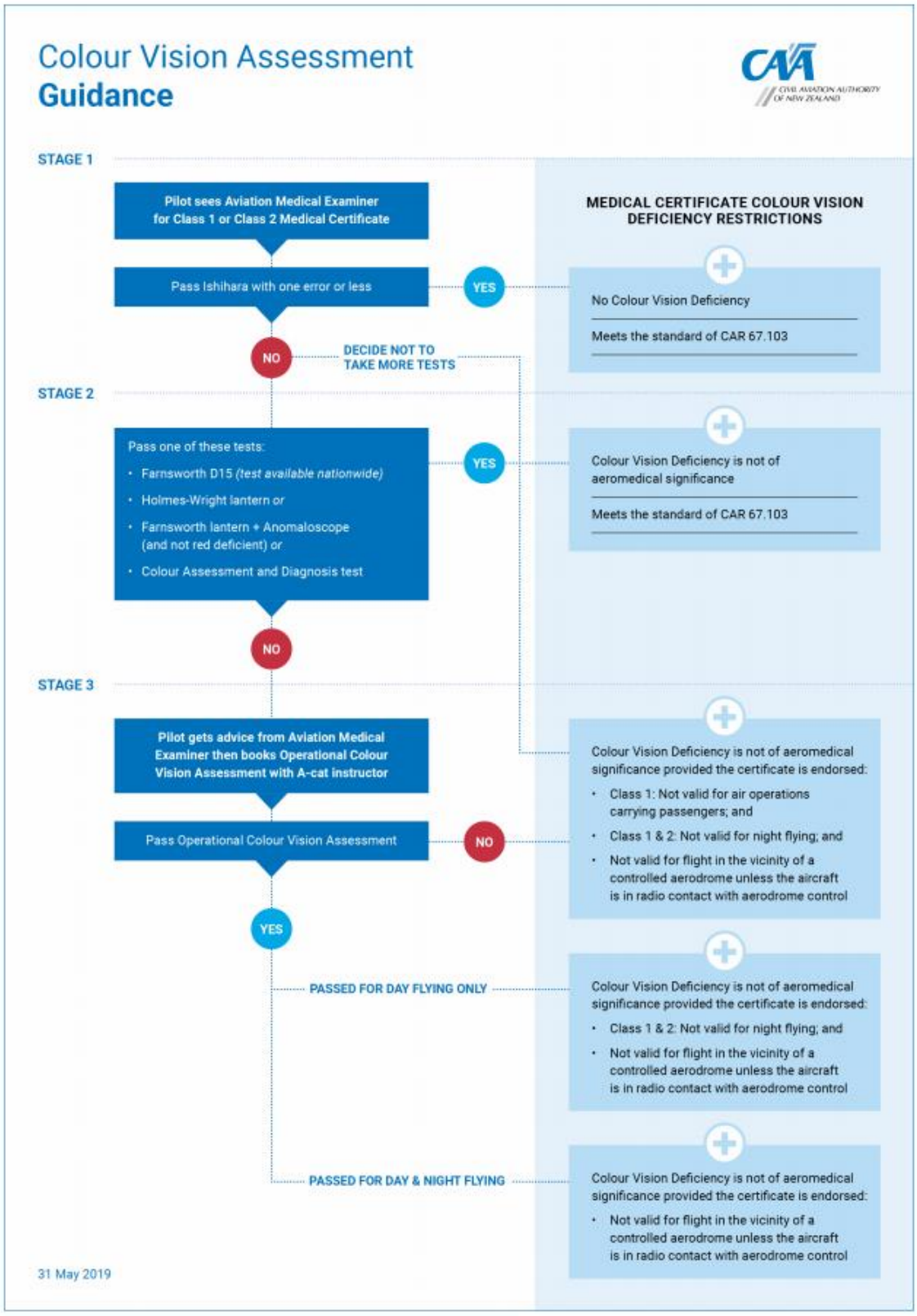
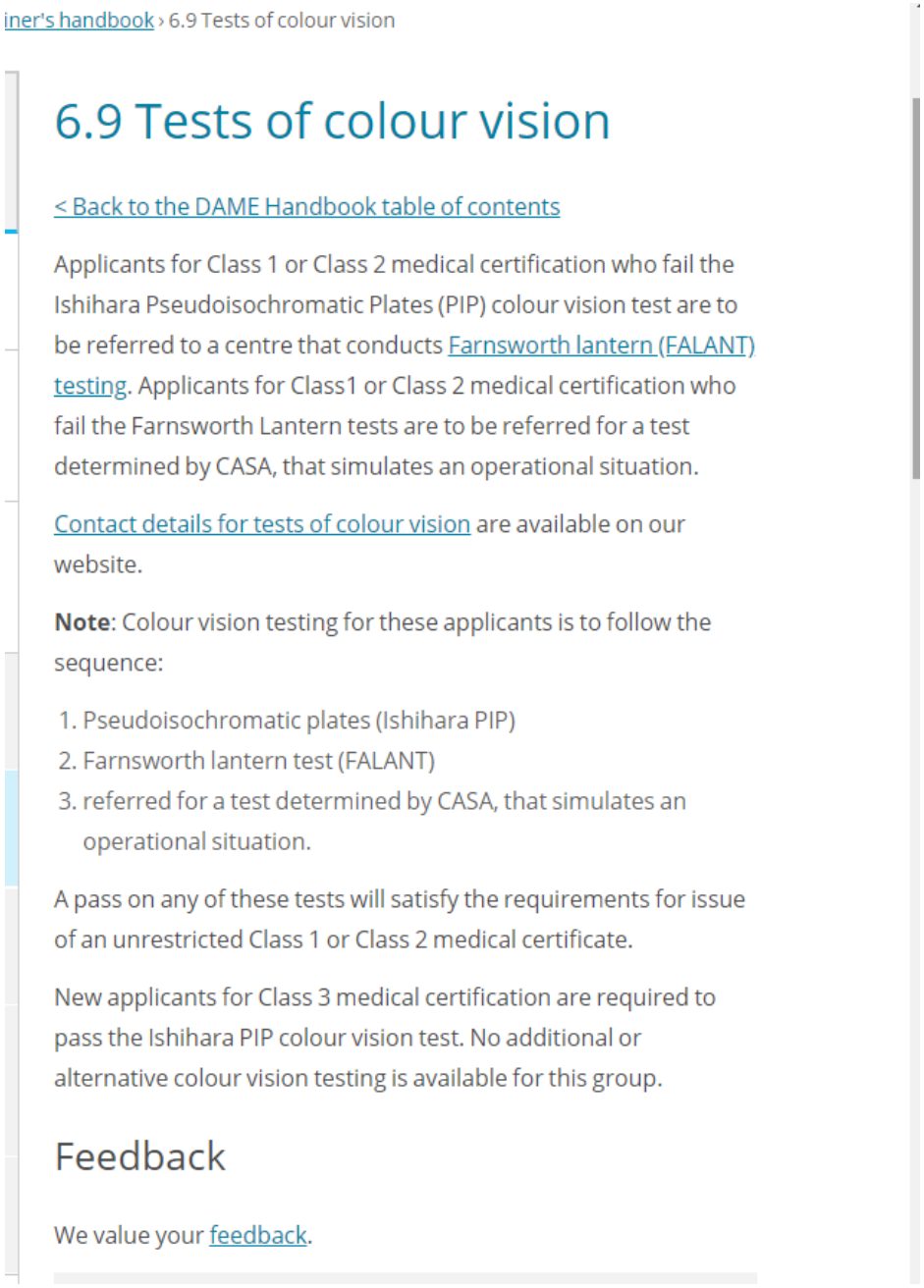


Figure 13 *Civil Aviation Authority of New Zealand colour vision regulation flow chart* (Civil Aviation Authority of New Zealand, 2019)

AUSTRALIA



iner's handbook › 6.9 Tests of colour vision

6.9 Tests of colour vision

< Back to the DAME Handbook table of contents

Applicants for Class 1 or Class 2 medical certification who fail the Ishihara Pseudoisochromatic Plates (PIP) colour vision test are to be referred to a centre that conducts Farnsworth lantern (FALANT) testing. Applicants for Class1 or Class 2 medical certification who fail the Farnsworth Lantern tests are to be referred for a test determined by CASA, that simulates an operational situation.

Contact details for tests of colour vision are available on our website.

Note: Colour vision testing for these applicants is to follow the sequence:

1. Pseudoisochromatic plates (Ishihara PIP)
2. Farnsworth lantern test (FALANT)
3. referred for a test determined by CASA, that simulates an operational situation.

A pass on any of these tests will satisfy the requirements for issue of an unrestricted Class 1 or Class 2 medical certificate.

New applicants for Class 3 medical certification are required to pass the Ishihara PIP colour vision test. No additional or alternative colour vision testing is available for this group.

Feedback

We value your feedback.

Figure 14-*CASA Colour vision regulation for commercial pilots* (Civil Aviation Safety Authority, 2019)

Canadian Vision Standards – 2016

Ocular muscle balance standards for categories 1 to 3. Lateral phoria limit (no strabismus) is 6□ and the vertical phoria limit is1□ . Applicants who do not meet this standard will be referred for further evaluation. Criteria that the Civil Aviation Medicine Division will consider are fusional reserves, binocular fields, extent of suppression, and absence of diplopia. The applicants may be licensed if diplopia is unlikely.

Colour vision requirements for categories 1 to 3. Colour perception is classified as normal if a patient passes any edition of the Ishihara Colour Vision Test, the AO Standard Pseudoisochromatic Plates, or the AO HRR Colour Vision Test. Minimum passing criterion for the Ishihara and the AO Standard Tests is 83% correct on the screening plates. The passing criterion for the AO HRR test is 100% correct on the first six screening plates. Applicants who fail any one of these tests are administered either the Holmes-Wright Lantern Test or the D-15 test.

If successful in either of these two latter tests, then no restrictions apply. If unsuccessful, then the candidate may be issued a restricted license-day light only with two-way radio. The colour lantern test is no longer acceptable for air traffic control applicants. If they fail the screening plate tests, then they must pass the Farnsworth D-15 test.

Figure 15-*Canadian colour vision regulation for commercial pilots* (Hovis, 2016)

Table 1-*Differences in regulations*

Aviation Authority	Testing options	Stages of testing	Highest Medical certificate possible without passing any tests
UK CAA	1st Stage Ishihara 2nd stage CAD or Anomaloscope (only for colour normal)	2	Class 2 valid for day only
ENAC	1st Stage Ishihara 2nd stage CAD or Anomaloscope (EASA criteria)	2	Class 2 valid for day only
Most EASA states	1st Stage Ishihara 2nd stage CAD, Anomaloscope or Lantern	2	Class 2 valid for day only
FAA	1st stage AOC/HRR, Dvorine, Ishihara, Richmond, Optec 9000, Farnsworth Lantern, Timitus and Richmond HRR. 2nd Stage Operational Medical Test	2	Third class medical -for day only
CASA	1st Stage Ishihara 2nd stage FALANT lantern or CAD 3rd Stage OCVA	3	Class 1 and 2 restricted to co-pilot operations only
CAA New Zealand	1st Stage Ishihara 2nd stage HWL, CAD, Anomaloscope or D15 3rd Stage OCVA	3	Class 1 and 2 valid for day only
TCAA Canada	1st stage AO/HRR, Ishihara 2nd stage HWL or D15	2	Class 2 valid for day only

A discussion in Appendix 10 regarding the restrictiveness of each regulation and the major differences in the above table.

THE OCCUPATIONAL COLOUR VISION ASSESSMENT (OCVA) USED BY NEW ZEALAND AND AUSTRALIAN AVIATION AUTHORITIES

The CASA Chief medical officers' comments enhance and reiterate the view that NAAs should move towards a form of occupational practical colour vision assessment, the CMO states

> *'research in recent years has shown relying on diagnostic tests alone may be unnecessarily limiting when considering the impact of colour vision deficiency on aviation safety. Advances in technology, operating techniques and human factors training can now mitigate many of the safety risks of colour vision deficiency. Technology to assist pilots has developed significantly and the impact of colour vision deficiency on aviation safety should take these changes into account. These factors have been recognised overseas, most recently in New Zealand where a new approach to colour vision deficiency came into effect in May 2019, which includes an operational colour vision assessment. This assessment comprises a ground-based assessment and an in-flight assessment which looks at a pilot's ability to interpret visual information. A separate assessment is done for day flying and for night flying'*

(The CASA Briefing - February 2020, 2020)

Stage 3 - Operational colour vision assessment

Noting that the listed clinical tests are conservative in their nature and hence are difficult to pass with anything more than mild colour vision deficiency, in stage 3 of the testing the applicant may seek to have the restrictions against night flying and working in air operations with passengers removed by undertaking an operational colour vision assessment (OCVA). This consists of a ground and flight assessment, in which the candidate must demonstrate the ability to read and interpret charts, instrumentation, displays, aeronautical lighting, and terrain and conditions. The assessment is carried out initially by day and may be repeated at night for those candidates wishing to remove the night limitation.

As this is a flight assessment, it is desirable that applicants have some experience in piloting aircraft. It is therefore best undertaken part way through training, probably at or about the point where a pilot would normally undertake the PPL flight test or have some night flying experience prior to completing a night rating. Advice on when the assessment should be undertaken should best be made in consultation with an A or B Cat flight instructor, with the final decision on timing to be made by the candidate. Prior to the commencement of an assessment the applicant must produce evidence of their identity.

The applicant may choose to undertake the assessment in the day time only or during the day time and night time. The day OCVA must be completed before the night assessment. If the applicant passes the day time component of the OCVA, they will be permitted to undertake air operations with passengers (if appropriately licenced) and will have restrictions on their medical certificate reduced to –

'Not valid for flight in the vicinity of a controlled aerodrome unless the aircraft is in radio contact with aerodrome control.'

'Not valid for night flying.'

If the applicant passes both the day and night time component of the OCVA, they will be permitted to undertake air operations with passengers and to fly at night (if appropriately licenced and rated) and will have restrictions on their medical certificate reduced to –

Figure 16-*OCVA guidance for respondents* (Civil Aviation Authority of New Zealand, 2019)

This is a valid option for the UK CAA, the testing, research, and implementation of this has already been completed by the various ICAO states, it would be easy for the UK CAA to implement. It would also encourage more flying, increase jobs for pilots/instructors and could move away from lab-based testing that causes so much controversy.

It is, however, important to get the research on whether aviation professionals believe it's necessary to change the current regulation, especially whether they think there are problems with the CAD test and more importantly the UK regulation.

There are some challenges to the OCVA stemming mainly from the UK CAA and in the 2014 Senator Fawcett vs CASA's Director of Aviation Safety and Principal Medical Officer hearing. The CASA director mentions that because a practical flight test happens on one day when the weather, conditions and flying situation are in one state it may not replicate the worst possible conditions the pilot will experience, therefore it can't be used to determine whether a respondent is colour safe or not as the NAA won't be able to determine the safety in all different types of scenarios. Nevertheless, the counterargument to this in which the CVDPA and the Senator argued, was that any flight examination for licensing is based on the day that examiners assess an individual. They decide on that day alone whether the candidate is safe to perform the duties of the licence entitlements. Furthermore, the UK CAA offers a medical flight test for respondents with a condition in one eye, so therefore this argument is an unnecessary barrier. (Rural & Regional Affairs and Transport Legislation Committee, 2014)

THE PROPOSED NEW REGULATION

For the research, a new regulation needs to be developed to replace the current UK regulation if it is deemed to be over-restrictive by aviation professionals. It is also vital to gain an understanding of opinions from aviation experts.

To stay away from the scientific debate as much as possible, the proposed regulation will be developed from existing rules copied from ICAO states and EASA. It is important not to deviate too much from the current regulation as this could be seen as being too lenient, the aim of this is to address the potential perceived problem of the lack of testing options, in which are all lab-based tests and the problems with the CAD that have caused much debate in the literature. Furthermore, adjustments can be made from the research collated.

A new proposed Class 1 Colour Vision regulation for the UK CAA

MED.B.075 Colour Vision

Screening test

Ishihara test (24 plate version) is considered passed if the first 15 plates, presented in a random order, are identified with a maximum of one error.

This test is then required for each renewal unless a candidate has passed via one of the secondary testing method or practical tests.

If a candidate has failed the Ishihara, they are then required to pass one of the secondary testing methods for an issue of a class 1, a candidate may sit multiple tests and is only required to pass one method.

Secondary tests

(1) Anomaloscopy (Nagel or equivalent). This test is considered passed if the colour match is trichromatic and the matching range is 4 scale units or less, or if the anomalous quotient is acceptable: or by

(2) lantern testing with a Spectrolux, Beynes or Holmes-Wright lantern. This test is considered passed if the applicant passes without error a test with accepted lanterns. Any other type of Lantern test result should be sent to the relevant aviation authority for review: or by

(3) Colour Assessment and Diagnosis (CAD) test. This test is considered passed if the threshold is less than 6 standard normal (SN) units for deutan deficiency, or less than 12 SN units for protan deficiency. A threshold greater than 2 SN units for tritan deficiency indicates an acquired cause which should be investigated: or by

(4) Farnsworth D15. This test is considered pass if there are no errors

A candidate that has passed one of the secondary tests is considered as colour safe and can be issued with a class 1 medical certificate , they do not have to resit this test in their career , a medical notice should be put on record they have passed via one of these tests.

If a candidate is not able to pass any of the secondary tests, then they are able to sit an Operational colour vision assessment (OCVA).

OCVA:

This consists of a ground and flight assessment, in which the candidate must demonstrate the ability to read and interpret charts, instrumentation, displays, aeronautical lighting, and terrain and conditions.

The assessment is carried out initially by day and may be repeated at night for those candidates wishing to remove the night limitation. As this is a flight assessment, it is desirable that applicants have some experience in piloting aircraft.

Advice on when the assessment should be undertaken should best be made in consultation with an A or B Cat flight instructor, with the final decision on timing to be made by the candidate. Prior to the commencement of an assessment the applicant must produce evidence of their identity. The applicant may choose to undertake the assessment in the day time only or during the day time and night time. The day OCVA must be completed before the night assessment.

Figure 17.1-*Proposed regulation by* (Author, 2020)

the candidate. Prior to the commencement of an assessment the applicant must produce evidence of their identity. The applicant may choose to undertake the assessment in the day time only or during the day time and night time. The day OCVA must be completed before the night assessment.

If the applicant passes the day time component of the OCVA, they will be permitted to undertake air operations with passengers (if appropriately licenced) and will have restrictions on their medical certificate reduced to – 'Not valid for flight in the vicinity of a controlled aerodrome unless the aircraft is in radio contact with aerodrome control.' 'Not valid for night flying.' If the applicant passes both the day and night time component of the OCVA, they will be permitted to undertake air operations with passengers and to fly at night (if appropriately licenced and rated) and will have restrictions on their medical certificate reduced to – 'Not valid for flight in the vicinity of a controlled aerodrome unless the aircraft is in radio contact with aerodrome control.'

(Operational Colour Vision Assessment - Guidance for Candidates Page 3 of 6 Civil Aviation Authority of New Zealand)

Figure 18.2-*Proposed regulation by* (Author, 2020)

THE REASONING BEHIND EACH TESTING STAGE IN THE PROPOSED REGULATION

Table 2-*Reasoning for each testing state in the proposed regulation*

Stage	Reasoning
Screening test	The Ishihara was chosen as it is the most common screening test with all NAAs. However, the difference to the current EASA regulation is that you are allowed to make one error in the 24-plate edition, this is to allow for nervousness, incorrect lighting conditions or distorted plates. To have a regulation which allows for no errors seems unnecessarily harsh and many ICAO states outside of EASA allow for one or more errors, the FAA allowing 7 errors on the same test. (Faa.gov, 2019) This seems to be a perfect balance, however, research conducted will tell.
Secondary test	The EASA regulation misses one test that nearly all ICAO NAAs use, the Farnsworth D15. This has been added to the regulation, furthermore, clarification that 'only one test has to be passed' has been added, as the UK CAA does not state how the regulation should be interpreted and EASA says it's

	for the individual states to apply and interpret. If the regulator does not include this, it causes unnecessary confusion. (EASA, 2020) Figure 19 shows the D15 test, it passes only people with a mild colour vision deficiency and is accessible, cheap and easy to use, with many years of validity throughout multiple different ICAO states. (Almustanyir, 2018)
OCVA	This is the answer to the potential problem that there is no practical test element and only lab-based tests. Lab-based tests according to the literature are over-restrictive and do not determine whether someone with CVD can safely fly the aircraft. This stage has been reproduced from (Civil Aviation Authority of New Zealand, 2019).

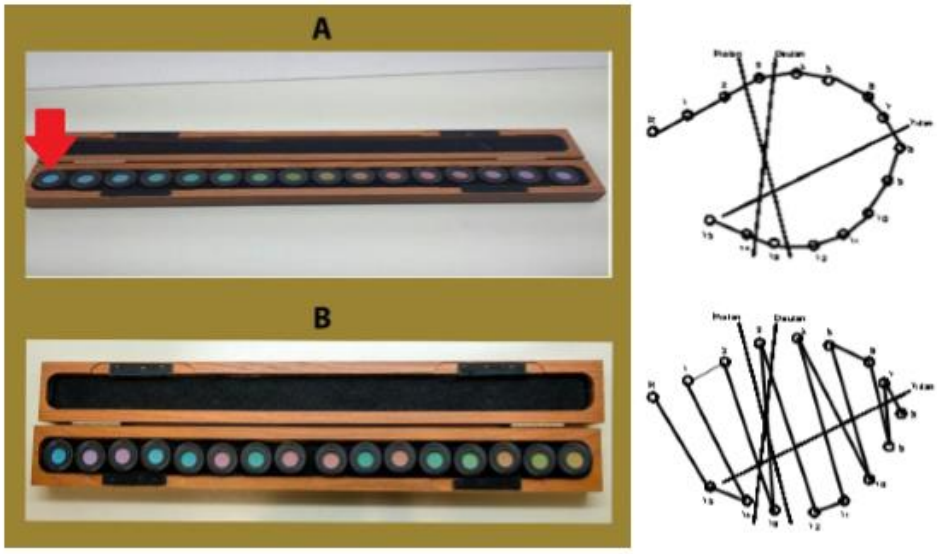
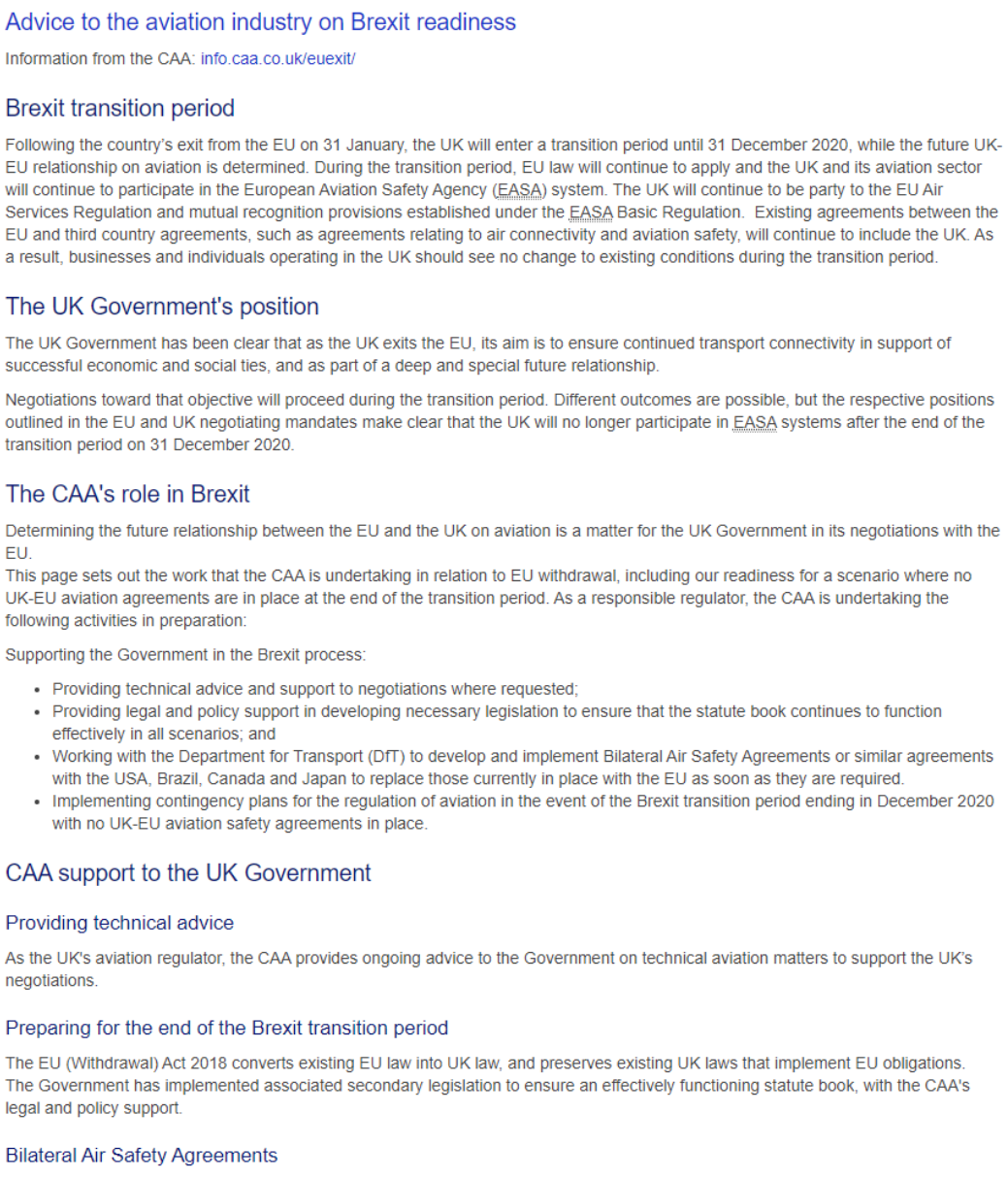


Figure 24. The Farnsworth-Munsell D15 colour test. (A) CVN F-D15 test arrangement and results drawn on the sheet. The red arrow indicates the reference cap. (B) F-D15 test with arrangement of a subject with a moderate to severe protan colour vision deficiency and the corresponding score sheet.

Figure 19-*Farnsworth D-15 Colour vision test and score sheet* (Almustanyir, 2018)

BREXIT- LEAVING EASA

It was declared on the 6th of March 2020 by the secretary state for transport Grant Shapps, that the UK would be leaving EASA at the end of the Brexit transition period. The UK CAA transitions into its own state and can create its own laws. The UK quotes that it wants to be the best country for aviation in the world, therefore this will be the perfect opportunity to implement a new type of colour vision regulation if it is deemed necessary from the primary research. (CAA, 2020)



Advice to the aviation industry on Brexit readiness

Information from the CAA: info.caa.co.uk/euexit/

Brexit transition period

Following the country's exit from the EU on 31 January, the UK will enter a transition period until 31 December 2020, while the future UK-EU relationship on aviation is determined. During the transition period, EU law will continue to apply and the UK and its aviation sector will continue to participate in the European Aviation Safety Agency (EASA) system. The UK will continue to be party to the EU Air Services Regulation and mutual recognition provisions established under the EASA Basic Regulation. Existing agreements between the EU and third country agreements, such as agreements relating to air connectivity and aviation safety, will continue to include the UK. As a result, businesses and individuals operating in the UK should see no change to existing conditions during the transition period.

The UK Government's position

The UK Government has been clear that as the UK exits the EU, its aim is to ensure continued transport connectivity in support of successful economic and social ties, and as part of a deep and special future relationship.

Negotiations toward that objective will proceed during the transition period. Different outcomes are possible, but the respective positions outlined in the EU and UK negotiating mandates make clear that the UK will no longer participate in EASA systems after the end of the transition period on 31 December 2020.

The CAA's role in Brexit

Determining the future relationship between the EU and the UK on aviation is a matter for the UK Government in its negotiations with the EU.
This page sets out the work that the CAA is undertaking in relation to EU withdrawal, including our readiness for a scenario where no UK-EU aviation agreements are in place at the end of the transition period. As a responsible regulator, the CAA is undertaking the following activities in preparation:

Supporting the Government in the Brexit process:

- Providing technical advice and support to negotiations where requested;
- Providing legal and policy support in developing necessary legislation to ensure that the statute book continues to function effectively in all scenarios; and
- Working with the Department for Transport (DfT) to develop and implement Bilateral Air Safety Agreements or similar agreements with the USA, Brazil, Canada and Japan to replace those currently in place with the EU as soon as they are required.
- Implementing contingency plans for the regulation of aviation in the event of the Brexit transition period ending in December 2020 with no UK-EU aviation safety agreements in place.

CAA support to the UK Government

Providing technical advice

As the UK's aviation regulator, the CAA provides ongoing advice to the Government on technical aviation matters to support the UK's negotiations.

Preparing for the end of the Brexit transition period

The EU (Withdrawal) Act 2018 converts existing EU law into UK law, and preserves existing UK laws that implement EU obligations. The Government has implemented associated secondary legislation to ensure an effectively functioning statute book, with the CAA's legal and policy support.

Bilateral Air Safety Agreements

Figure 20-*UK CAA statement on Brexit* (CAA, 2020)

PURPOSE OF THIS RESEARCH

This research will identify whether the UK CAA regulation is too restrictive, though the literature review has clearly indicted it as a problem, opinions from aviation experts will be crucial as evidence to support this.
A more practical regulation replacement has been developed and this will be critiqued to identify whether it is suitable and if it's necessary.

Methodology section

INTRODUCTION

This conclusive research uses a mix methodology approach to find out if the UK CAA regulation is too restrictive and if so what type of regulation is suitable. (Pride and Ferrell, 2007)

UNDERSTANDING RESEARCH

(Burns, 1997) defines research as 'a systematic investigation to find answers to a problem'.

According to (Kumar.R, 2011) research covers 3 procedures to obtain an answer to a question which cannot yet be solved without data.

1. The research has to be unbiased and objective
2. Contains a framework of philosophies
3. Uses procedures, methods and techniques which are reliable and have been tested for validity

Subjectivity vs objectivity

The aim of the author is to be impartial and draw to conclusions based on fact rather than opinion. It is important to not hide any information to enhance the outcome of the research towards a vested interest. This is defined as objectivity, however, it can be said there is no such thing as objectivity, as quoted by (Heinz von

Foerster, 1984) 'Objectivity is the delusion that observations could be made without an observer.' Subjectivity is when opinions and feelings shape the research. According to (Kumar.R, 2011) subjectivity is conditioned by your educational background, philosophy, experience and skills. While striving to be objective it must be accepted there will be some form of subjectivity in all research.

METHODOLOGICAL APPROACHES

The Research Onion is the theoretical framework chosen for this research, to provide an effective methodology aiding the reader to understand the direction of the study. (Saunders et al, 2007). The onion is a useful tool as it can be applied to any type of methodology, it is a clear, accurate and has a logical flow for justification. (Bryman, 2012)

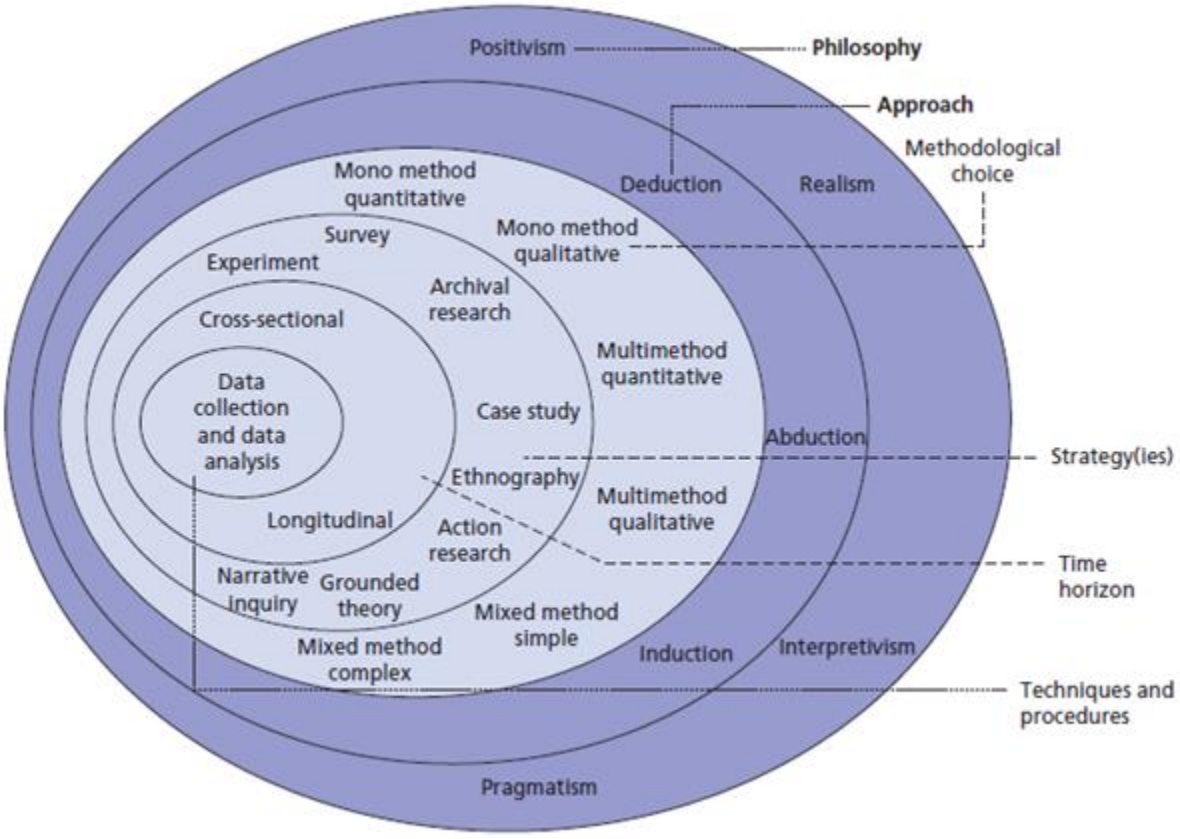


Figure 21-*The Research by Onion* (Saunders, M., Lewis, P. & Thornhill, A, 2012)

The report will go through each layer of the onion, identifying the research approach that was selected, to achieve the aims of this research and provide justification, thus providing an effective research methodology.

PHILOSOPHIES -THE WORLD VIEW

A research philosophy refers to a set of beliefs concerning how reality is perceived (Bryman, 2012). It is important to understand the philosophy selected allowing the reader to comprehend the approach as well as to understand the different thought processes in society.

The two main paradigms that underpin social research are Positivism and Interpretivism. (Punch, K, 2005) Positivism and Interpretive research can be distinguished as objective versus subjective (Burrell & Morgan, 1979)

Table 3-Types of philosophies and how they relate to the research

Philosophy	Description	Whether it relates to the research
Positivism	The view that everything comes from factual knowledge through observation. This philosophy believes that science is not the same as common sense and common sense shouldn't be used. (Wilson, J, 2010)	The research assesses the differences between each regulation, this is factual information, however, the research also aims to get the opinions of the aviation experts regarding their thoughts of the regulation, this quantitative only format does not fit all the aims of this research, therefore a positivism approach was not chosen.
Realism	Represented in two forms, direct and critical. Direct realism is described as "what you see is what you get" and Critical realism is a philosophy in which humans understand the sensations and images that can portray information in a different perspective. (Novikov, A.M. &Novikov, D.A, 2013) (Saunders, M., Lewis, P. & Thornhill, A, 2012)	Whilst colour vision regulation can have many perspectives this philosophy does not allow for a mixed approach which would allow it to collect both qualitative and quantitative data and hence it was not selected for the research.

Interpretivism	This philosophy usually focuses on meanings and understandings as a perceived reality, it also emphasised that a person has knowledge which cannot be separated and there is, therefore, a link between the researcher and their reader. (Collins, H, 2010)	This philosophy encourages some qualitative research and would be useful for gaining an understanding of the views from aviation professionals with a deep explanation rather than just collating standalone data that may not have any context and might render the data useless. (Collins, H, 2010) Therefore this is only partly related to the research, this was not selected.
Pragmatism	This philosophy accepts that there are many ways of interpreting information, no single point of view can give all the answers to every question. Pragmatics can include both positivism and interpretivism approaches. (Saunders, M., Lewis, P. & Thornhill, A, 2012)	It is necessary to use a mixed approach like this to achieve the research aims. This was an ideal philosophy as it combines both Positivism and Interpretivism allowing for both types of data to be collected thus removing the limitations faced with only choosing one method. This method will provide context and reasoning to quantitative data collected regarding the UK regulation restrictiveness.

Pragmatism was the chosen philosophy of this research as it lends to a mixed-methods approach, the main weakness of the mixed-method approach is that it can be quite open and this is not easy to use as a research method, especially since it requires knowledge two types of research and how to utilize both best in order to mitigate their individual weaknesses. (Johnson & Onwuegbuzie, 2004).

APPROACH

Deductive is used to develop a hypothesis based on existing theory and which follows to a research method in which tests this hypothesis. (Wilson, J, 2010) The Research onion shows a deductive approach lends itself to

more positivism psychology and is useful when collecting quantitative data. It is said to follow the path of logic most closely, this is valuable when testing whether the current UK CAA regulation is too restrictive.

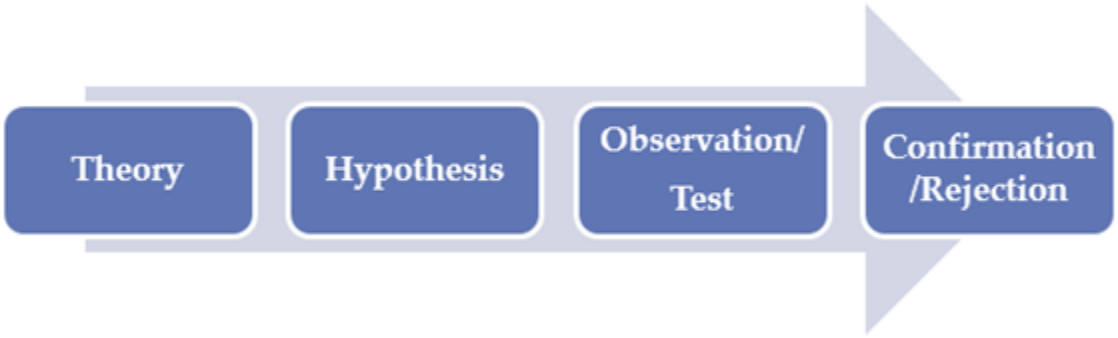


Figure 22-*Deductive Approach flow diagram* (Research-Methodology, 2019)

Inductive starts with tests/observations and proposes theories at the end of the research linking it back to the observations. (Goddard, W. & Melville, S, 2004) The research can be altered in any direction after the research process has been conducted. The main aim of this approach is to search for patterns from the data to create theories and provide context.

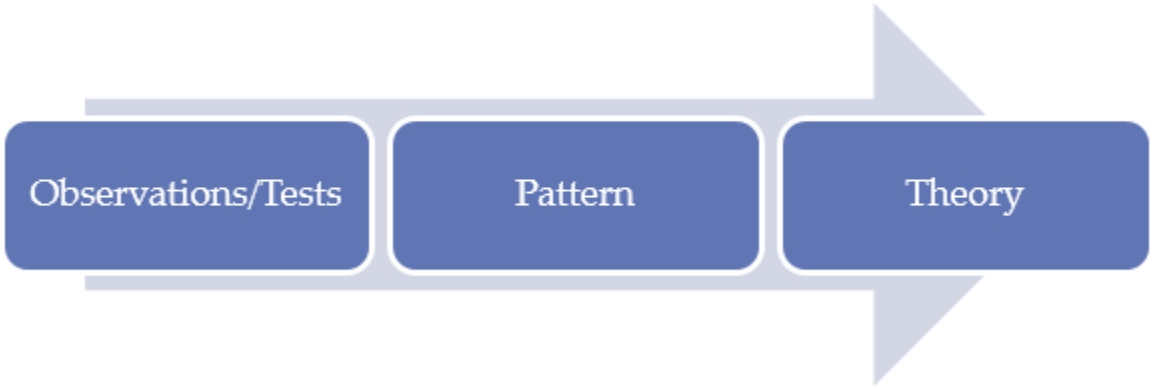


Figure 23-*Inductive Approach flow diagram* (Research-Methodology, 2019)

This research is a mixed-method approach and therefore uses both deductive and inductive approaches. It is important to understand fully the strengths and weakness of both. This table below perfectly summarises the differences between both approaches.

	Concepts associated with quantitative methods	*Concepts associated with qualitative methods*
Type of reasoning	**Deduction** Objectivity Causation	**Induction** Subjectivity Meaning
Type of question	Pre-specified Outcome-oriented	Open-ended Process-oriented
Type of analysis	Numerical estimation Statistical inference	Narrative description Constant comparison

Figure 24- *Table of comparison between Quantitative and Qualitative methods* (Research-Methodology, 2019)

METHODOLOGICAL CHOICE

Referring to the research onion, there are three different methods of choice in data collection, Mono, Mixed and Multi. (Saunders, M., Lewis, P. & Thornhill, A, 2012)

Two forms of data can be collected via these methodological choices- Quantitative and Qualitative.

Each method has different ideologies and approaches within data collection. (Punch, K, 2005)

Mono	Mixed	Multi
•Uses one data collection method (strategy) •Research chooses either a quantitative or qualitative approach •Has limitations of using one data type •Simple and time effective	•Uses one data collection method combining both types of data sets •Usually applys both quantitative and qualitative data. •Removes the limitations of using only one data type •Knowledge of both types of data required •More time consuming	•Use multiple data collection methods with each focused on collecting one type of data •Applies both quantitative and qualitative data usually individually •Data can be analysed all together or separately in relation to each collection method •Very time consuming •Mitigates all the limitations of any method

Figure 25-*Types of methodologies in research (Bryman, 2012) (Flick, U, 2011) adapted by author*

Quantitative
•Quantitative data is represented in the form of numbers providing a more statistical and factual data set •normally includes questionnaires with close ended questions, correlation and data manipulation techniques like mean, mode and median to analysis this sort of data. •Quantitative data is easier, quicker and more cost-effective to conduct, it is also easier to analyse and extract results /patterns. However, is not as in-depth and sometimes data has no meaning without explanation.
Qualitative
•Qualitative data in the form of words or text providing more of an opinionated data set •Closely associate with words, meanings and opinions, methods normally include open ended questionnaires, focus groups and interviews. •A qualitative approach allows to gain a deeper understanding than quantitative, quantitative data can be seen as looking at the surface of a question.

Figure *26-Data types in research* (Punch, K, 2005) (Bryman, A. & Bell, E, 2015) adapted by author

This research requires both quantitative and qualitative data types, to understand the opinions of aviation professionals. Mixed methods utilise both types of data mitigating the limitations and weakness of both

approaches. Using one data collection method rather than multiple, it is quicker to collect, and respondents are more likely to answer the selected strategy thus leading too more responses. Mixed methods, however, requires knowledge of both types of data, more resources to complete, and to analyse the data takes a lot of time. There are also a limited number of strategies of data collection that can accommodate both data types. It is, however, necessary to meet the aims of this research. (Saunders, M., Lewis, P. & Thornhill, A, 2012)
The multi-method could have been a good option but due to the number of resources and time it would take to conduct several different data collection methods, this was not ideal.
Therefore, a mixed-method approach was the best option achieving the aims of the research in the most time and resource-effective way whilst mitigating limitations and gaining both the data, depth of understanding needed.

STRATEGIES (PRIMARY DATA COLLECTION METHODS)

The method of data collection selected needed to be able to interpolate data using correlations, graphs and calculations to provide a deeper understanding of the answers. It also needed the ability to display the regulations to the respondents so they can understand the questions.
The survey method fits these criteria and is used to question individuals on topics, allowing them the opportunity to describe their response in more detail. (Jackson, S.L, 2011)
This table below shows the different types of survey methods with the advantages and disadvantages.

Table 4-*Table of advantages and disadvantages regarding each survey method adapted by the Author* (Denscombe, 2010)

Method	How it's used	Advantages	Disadvantages
Questionnaires	Used to gather large amounts of data in a short period	Can be used to keep responses anonymous Much cheaper than most other primary data collection methods	Difficulties getting a deeper understanding of the issue or topic The problem of 'first choice selection' and selecting something if unsure.

		Can gather large amounts of data that allow for a wide view on an issue or topic. Easy to analyse	
Interviews	Used to gather data that reflect a deeper thought process and explores the feelings and emotions of an issue.	The ability to control the direction of collecting data. Can collect specific types of data that is required, can specify in more detail.	Takes more time to arrange and conduct Costs might be incurred with arranging interviews and for interviewee travel and time costs Is harder to organise and set up – need infrastructure Potential bias from the interviewee
Documentation reviews	Used to study issues that have occurred over a longer period.	Can retrieve important and meaningful information that couldn't be achieved from other data collection methods.	Hard to access documents especially ones that haven't already been released publicly. Documentation reviews would also be difficult in this research as the aims cannot be solved via this method

Before exploring the exact method chosen, it's important to also understand the sample and sampling methods used.

SAMPLING

Many of the population's interests, knowledge and skills sets are too large to gather, especially for a topic on colour vision regulation when the required person will need some specific knowledge to understand the questions. Techniques and methods have been designed to obtain samples that can be used to represent

large populations. This is more time and cost-effective. (Proctor, T., 2003) Based on Figure 27, Table 5 defines the structure of the research sample.

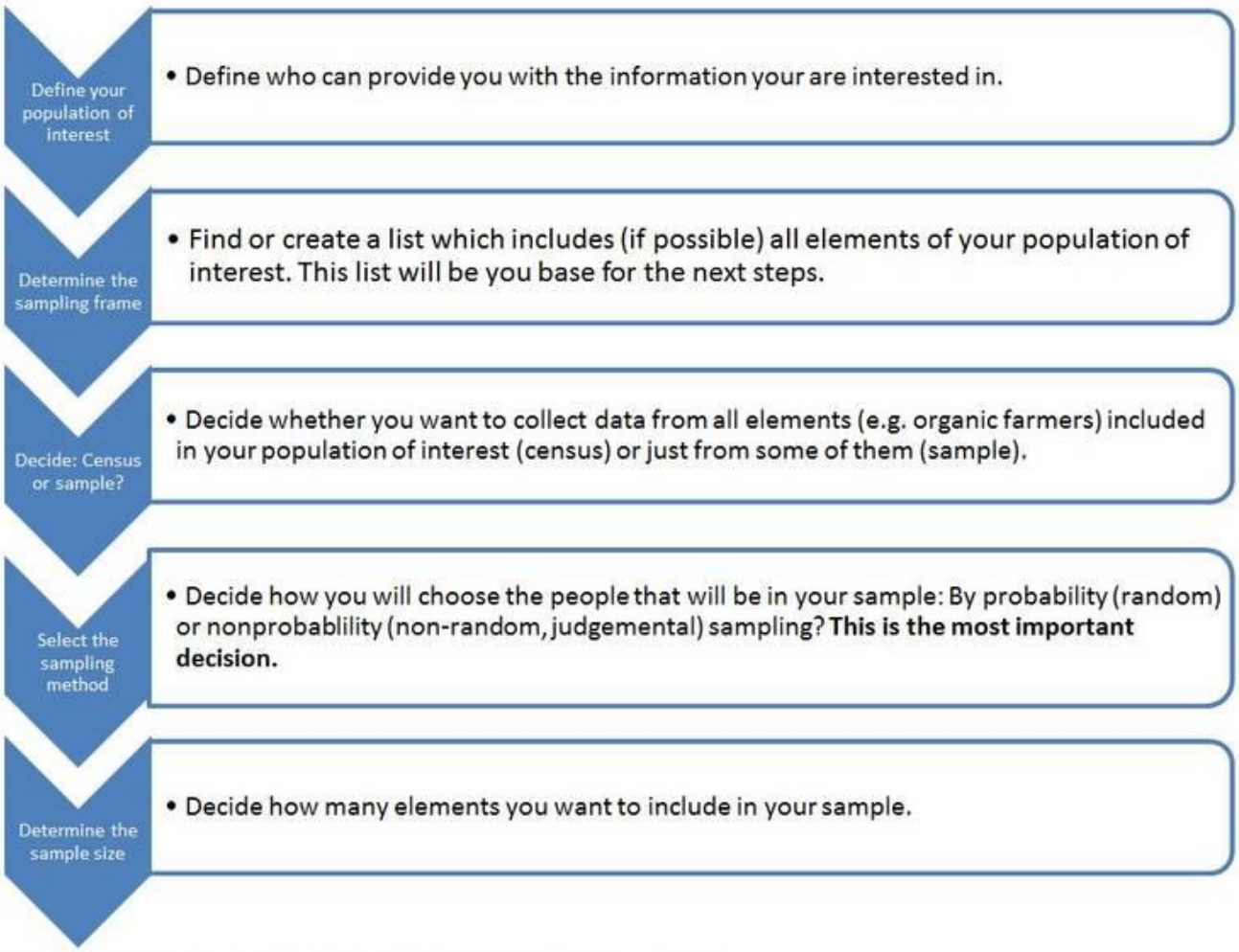


Figure 27-*Overview on the sampling process* (Malhotra et al, 2012)

Table 5 *Defining the research sample*

Target Population	The research is of interest to anyone in commercial aviation as well as people in other industries where colour vision regulation affects them professionally or recreational.
Sampling frame	This consists of anyone who currently works in the aviation industry with 3 or more years' experience, this would ensure most people could understand the regulation and questions as well as being able to identify the differences, applying their previous knowledge and experience.
Sample size	This potentially could have had a very large sample size, especially since it's allowed to be shared through the snowball method. The positives of a larger

	sample size are it gives a better chance in reducing sampling error and preventing bias. The sample size for this research was 30, this was probably because the topic is very specialist and not everyone with 3 years or more aviation experience can answer this questionnaire. It was expected that a few hundred people received the questionnaire which means the ratio of respondents that choose to do the questionnaire is quite low, again reiterating the specialism of the topic. 30 however is still a good sample size that allows a broad representation from different sectors in the aviation industry.
Distribution	Due to the specialism of the topic and the coronavirus outbreak in 2020, it was hard to get a large number of responses in a short time, however, it was important to try and get responses from all aspects of commercial and general aviation especially commercial pilots as this regulation is directly affecting them. To make sure the survey was sent to many suitable aviation professional individuals the survey was sent to several aviation groups based in the UK; APPG GA, RAeS Flight ops, Air Law, Aerospace medicine, pilots and through LinkedIn, allowing people from all over the world to answer the questionnaire.

The benefit from publishing part of my literature review in Flight Training News is that it attracted more attention to my questionnaire post that led to more responses. As seen in Appendix 11.

SAMPLING METHOD

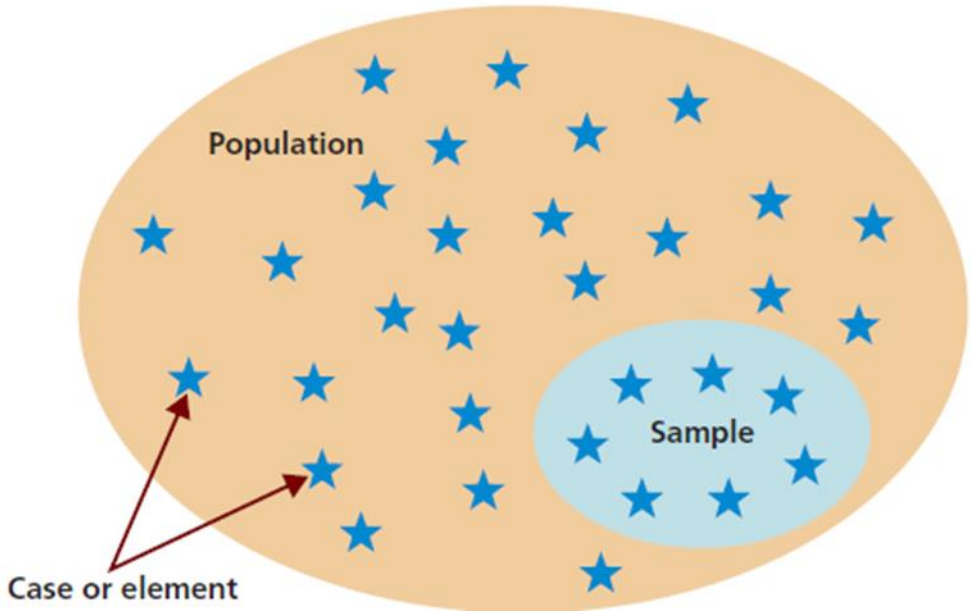


Figure 28-*Population, sample and individual cases* (Saunders et al, 2012)

The sampling method chosen was the snowball effect. The method had to be non-probability due to the specificity of the topic which ruled out the general population. A non-probability survey could be argued to be more biased as the author can then choose where the responses come from, but as can be seen that the target audience was aviation professionals, the survey was sent out to many professional aviation groups based in the UK and posted on LinkedIn that allowed for the best sample possible. The snowball effect is a volunteer method in which a sample group can grow through additional members that have been introduced from the existing sample. (Biernacki, P. and Waldorf, D, 1981) The benefit of this method is that it enables the survey to gain more responses from all aspects of aviation, and all parts of the world, however, it can also provide an over-representation of a particular group creating bias and it is tough to encourage sample members to share the survey unless they have a direct interest.

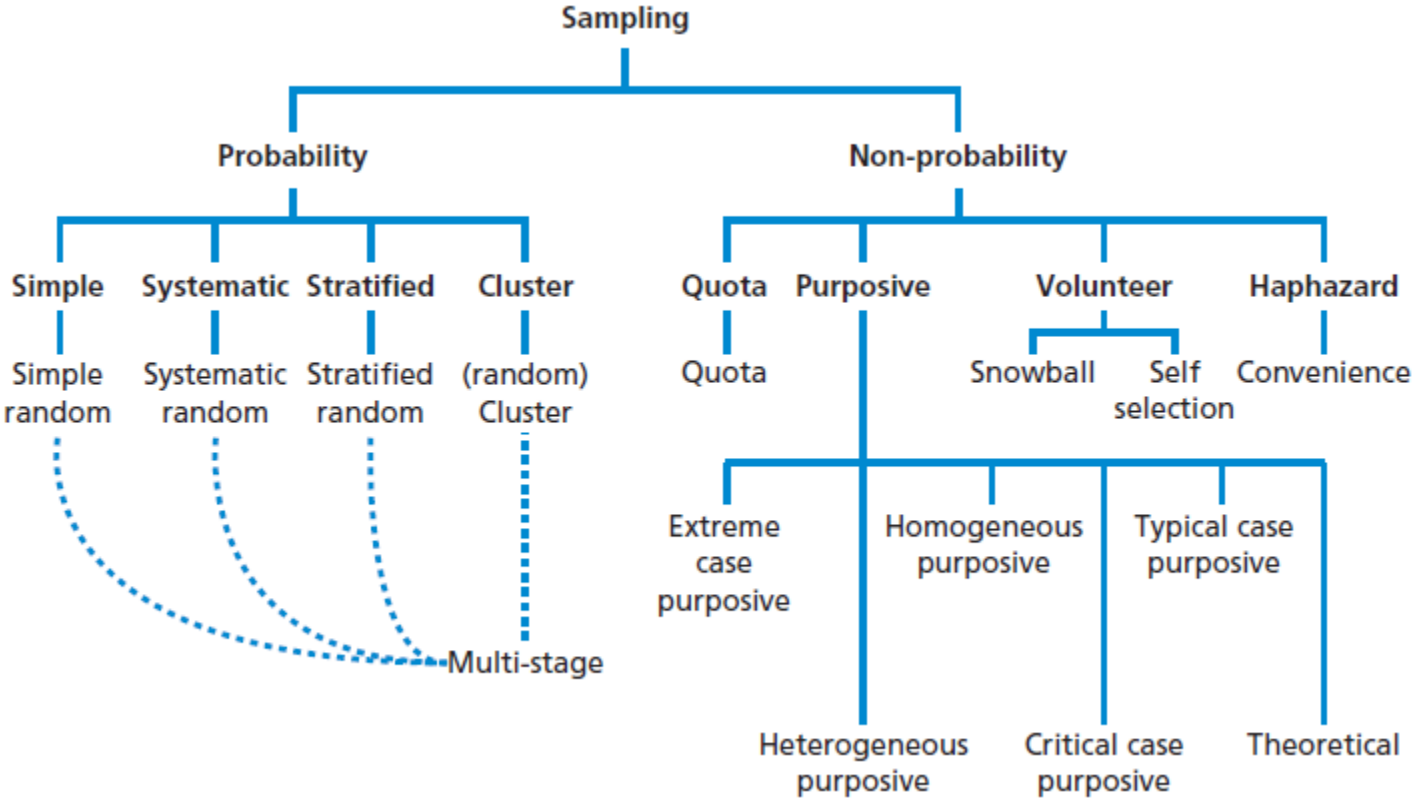


Figure 29-*Categorisation of sampling techniques* (Research-Methodology, 2019)

METHOD OF CHOICE-QUESTIONNAIRE DESIGN

Based on Table 1, an online questionnaire method was best suited for a mixed-method approach since this can be used for both quantitative and qualitative data collection. It works well with the snowball method as its easier to share. Interviews would be too difficult to organise and trying to get a wide perspective on the issue will require a lot of time and aviation professionals are likely to be very busy, however, for future research, this might be a good option to allow for further in-depth analysis. A computer questionnaire was the best choice as this could be sent out to a large number of people and is simple to create a snowball effect. It was free and easy to set up, allows respondents to see the different types of regulations in a digital format, thus coming across as more professional. Furthermore, respondents do not feel pressured to respond and being able to access it on multiple devices allows the questionnaire to be completed at a convenient place and time. The questionnaire was designed using google forms, this free online tool enables photos of regulations to be viewed, a professional look and easy viewing. It also has options to remove the ability to answer more than once and has a list of settings to change the security of the questionnaire. Another useful tool of the google forms is that it provides an overview response section. This is also a lot more sustainable than using a study-based questionnaire. (Research-Methodology, 2019)

A pilot study was conducted, more information can be found in appendix 5.

TYPES OF QUESTIONS

The mixed-method approach requires both a wide perspective but with context and in-depth answers, it is therefore important to use both open and closed-ended questions.

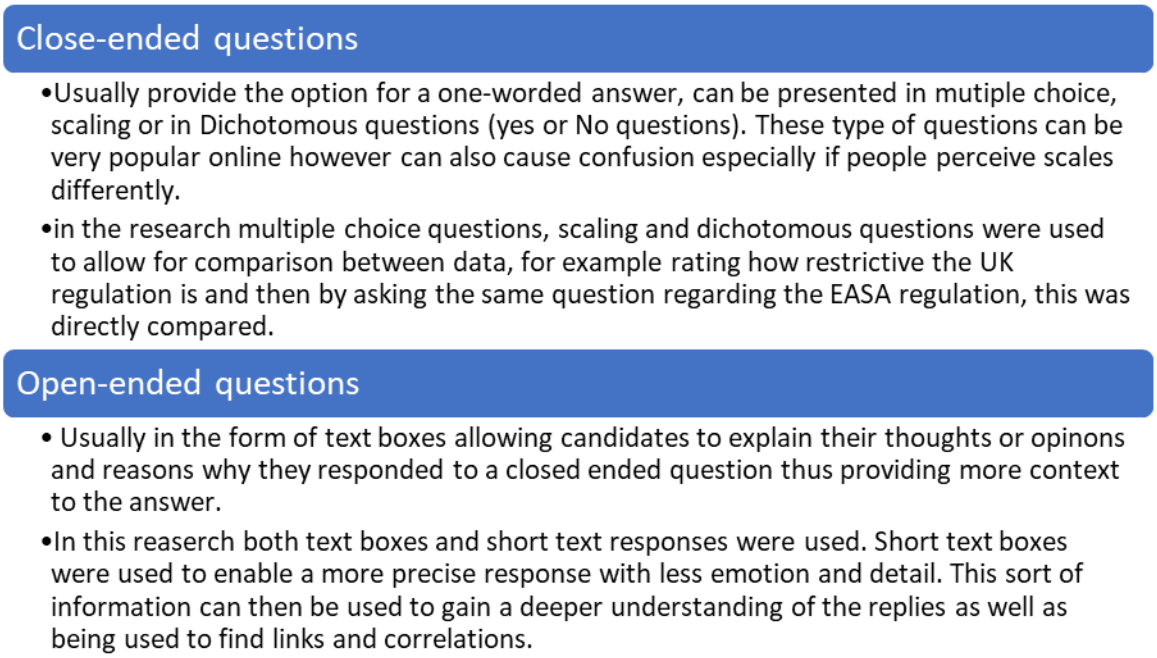


Figure 30-The differences between the close and open-ended question (Wilson, J, 2010) adapted by Author

The table below explains the reasoning for all the questions in the questionnaire and how they link to the overall aims of this research.

Table 6-*Reasoning for each question*

Question	Type	Aims	How it links to the Literature Review/Research Aims
Age	Close-ended: Dropdown menu (Quantitative)	To identify the correlations between the age of the respondents and their responses	Correlations found from the descriptions of regulations and whether the UK CAA regulation should be replaced, were analysed. Mainly connected with quantitative questions. This allowed for interesting discussions regarding the answers and the sample representation.
Gender	Close-ended: Multiple choice (Quantitative)	To identify the correlations between the gender of the respondents and their responses are given	Same as Age
What sector do you currently work in the	Close-ended: Multiple choice- with an option to enter a sector if	To identify the correlations between the sector of the respondents and their responses given	To display a variety of sectors in the sample validates the overall data further. It shows that the data represents a wide perspective of

Aviation Industry?	not on the existing list (Quantitative)	and to show the sample is a good representation of the aviation industry.	aviation professionals. It helps to also gain an understanding if particular sectors have a specific opinion when compared with the other questions.
How many years have you worked in your Sector?	Close-ended: Multiple choice/Scaling (Quantitative)	To identify the experience of the sample and how this compares to the responses given to other questions.	With a more experienced representation in the sample, this can help to strengthen the data's reliability. A strong relationship can also be provided between experience and the regulation questions. An interesting link is whether more experience determines the type of responses.
Are you aware that the UK CAA changed their colour vision regulation in 2018 to differ from EASA?	Close-ended: Dichotomous question (Quantitative)	Important to establish the samples of previous knowledge of the topic and whether the sample may have a biased opinion.	The fewer respondents unaware of the change the more likely the results would be based on information provided in the questionnaire and the experience of the respondents. If there were more respondents aware of the regulation change, this could suggest these respondents have a direct relationship to the research. It can also be demonstrated to show how well the CAA has communicated changes to regulation as in the literature review it was identified that the regulation had no transition period. (CVDPA, 2017)
Description of regulation questions: How would you describe the... regulation?	Close-ended: Multiple choice/Scaling (Quantitative)	The main section of the questionnaire used to answer whether the UK regulation is too restrictive and how all three regulations compare.	Enables the research to determine the severity of restrictiveness and aid in reasoning for the new proposed regulations format and answers. By having the questions in the same format for all the regulations this allows for comparison. The EASA regulation was also used as this was the previous format on the UK regulation and by getting opinions on this, it will provide information as to whether the regulation change was a good or bad decision and further clarify if the current regulation is too restrictive.
Explain why you choose those responses in the previous two questions?	Open-ended: Long text answer (Qualitative)	Provide context to the responses concerning the regulation restrictiveness. Can also be used to help correlate with the quantitative data to find connections and patterns.	This gives respondents a chance to provide their thoughts on each regulation, how they compare and why they choose the answers they did. For the UK regulation, in particular, themes will be explored to identify the correlation to the literature reviews,

			that states that the CAD test is where the regulation issue stems from.
If your answer was 'No' to the previous question, how many tests would you like to see?	Open-ended: Short text answer (Qualitative)	An opportunity for respondents to provide a short answer to how many tests they think is suitable and an explanation as to why	In the literature review, a common theme was that there weren't enough tests in the EASA regulation, let alone in the current UK regulation. (Defence Technology Agency, 2015) By identifying how many tests respondents would like, this could help support the decisions that were made for the proposed regulation.
Would you change anything in the EASA regulation, and if so, what would you change?	Open-ended: Short text answer (Qualitative)	An opportunity for respondents to provide a short answer as to what they think should be changed, if anything within the EASA regulation.	In the literature review, a common theme was that a practical test was needed to fix the potential problem of the current regulation. If any changes are suggested it will be interesting to see if this correlate. Examining what respondents think regarding the EASA regulation the same can be assumed the same response for the UK regulation since they are both similar.
Which regulation do you think is more suitable/aviation-related (EASA or CAA) and why?	Open-ended: Long text answer (Qualitative)	To determine exactly which regulation the sample thinks is more suitable/aviation-related.	According to the literature review, the UK regulation was the same as the EASA regulation before 2018. (caa.co.uk, 2019) If the UK regulation is deemed too restrictive it could be an option to revert to the old EASA regulation. This depends on the other feedback and responses given.
Please rate the regulations from worst to best, 1 being the worst,3 being the best	Close-ended: Scaling (Quantitative)	To allows for a direct comparison between each regulation and identify the worse and best regulation.	This will validate the other responses in the questionnaire, especially the qualitative answers.
Do you think the proposed regulation is more suitable/aviation related than both the CAA and EASA's regulations?	Close-ended: Dichotomous question (Quantitative)	To have a clear representation of how many respondents think the proposed regulation is more suitable than the CAA /EASA's regulation.	Results will be displayed on its own and then compared with the sample information that has been collected to develop useful connections.
Would you like to see the new proposed regulation (the third regulation)	Close-ended: Dichotomous question (Quantitative)	A clear and one of the most important questions in the research	The proposed regulation was developed in the literature review based on the information gathered. This question is extremely important as it achieves the 6th and final aim of the research. The

implemented to replace the current UK CAA regulation for class 1 medicals?	further qualitative questions allow for respondents to explain in-depth their thoughts about the proposed regulation.

TIME HORIZONS

There are two forms of time horizons, cross-sectional and longitudinal. This study uses a cross-sectional time horizon. Cross-sectional is used for short-term research which is related to collecting data about a population interest at a specific point in time -a snapshot. Longitudinal is more of a progressive piece of research that is constantly under review and changing, it is used more for correlation research or observations in nature. (Verywell Mind, 2019)

ETHICS

Bryman listed 10 important ethical principles to follow in all research, listed in appendix 6. (Bryman, A. & Bell, E, 2015) To ensure this research followed correct ethic protocol these actions were taken.

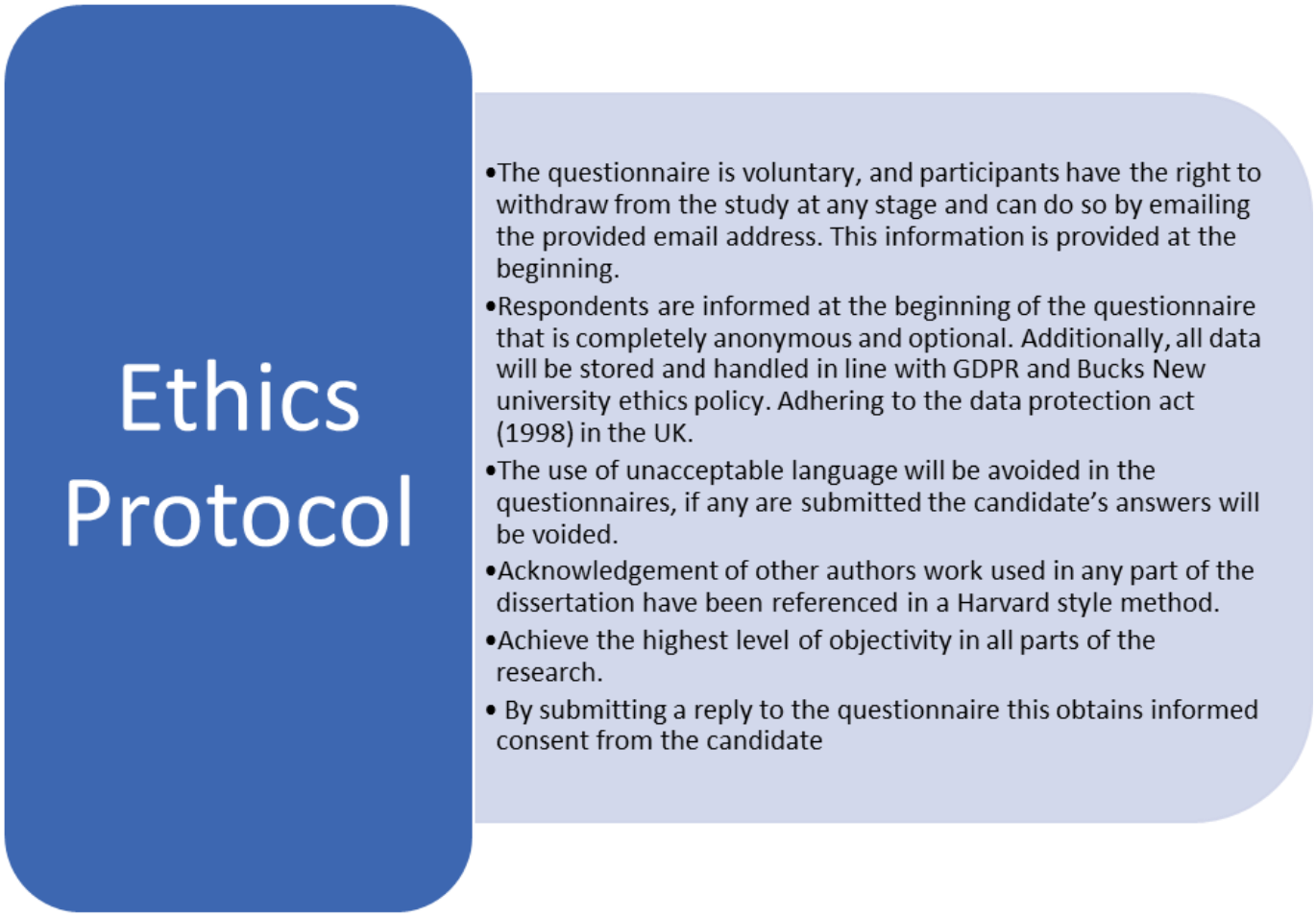


Figure 31-*Ethics protocol of the research*

The risk in this research was mitigated as no sensitive or confidential information was displayed, only information that's available to the public was displayed, however due to it being a controversial topic to some extent, to deal with any problems or sensitive matters respondents can email the author provided at the beginning of the questionnaire.

OVERVIEW OF THE RESEARCH DESIGN

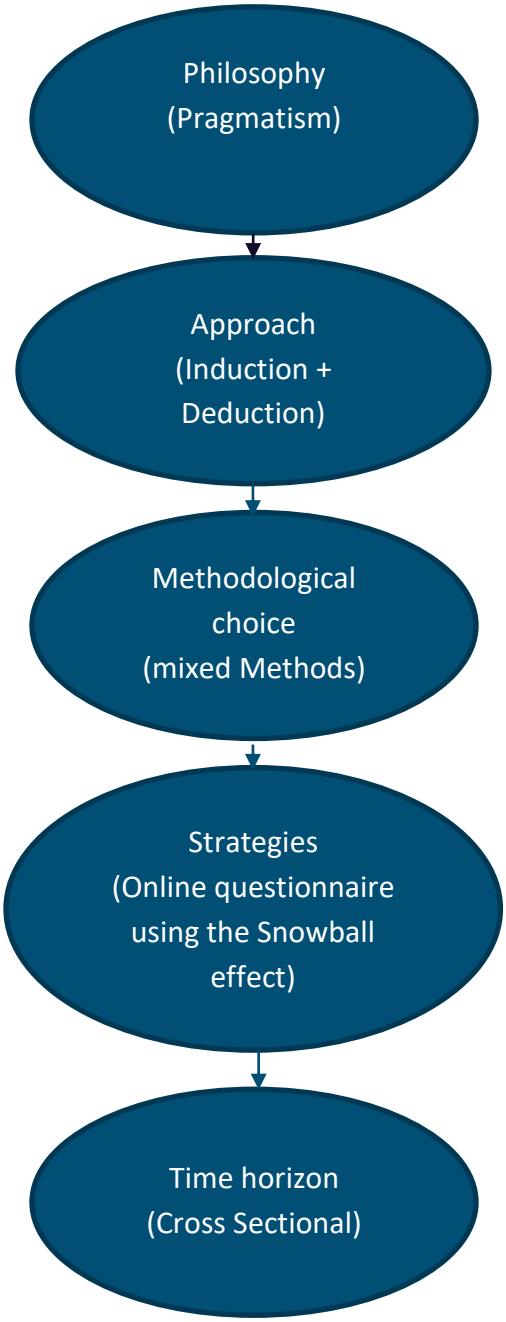


Figure 32-*Overview of research design in a flow diagram* (Author, 2020)

ANALYSIS METHOD

To analyse the quantitative data collected, Microsoft Excel was used, useful for analysing quantitative data, create graphs, applying formulas to find correlations as well as conveying the qualitative data into a quantitative form. Excel is inexpensive, provides storage of the data with encryption for protection as well as the tools to analyse the data. A disadvantage of Excel is it is an advanced program which requires knowledge of the different functions. (Robson, C, 2011)

Content Analysis was used in which all written communication is categorised and tabulated. This allows a comparison to the two data types. Qualitative data was analysed by looking at patterns to provide context to the quantitative information. By looking for a phrase or word repetitions allowed for the conversion of the qualitative into a quantitative format. (Bryman, 2011) (Research-Methodology, 2019)

With two data types it enabled finding the anomalies to be extremely simple, the data is viewed on a per response basis and if they both do not correlate it can be classed as an anomaly. The figure below shows the process of analysis.

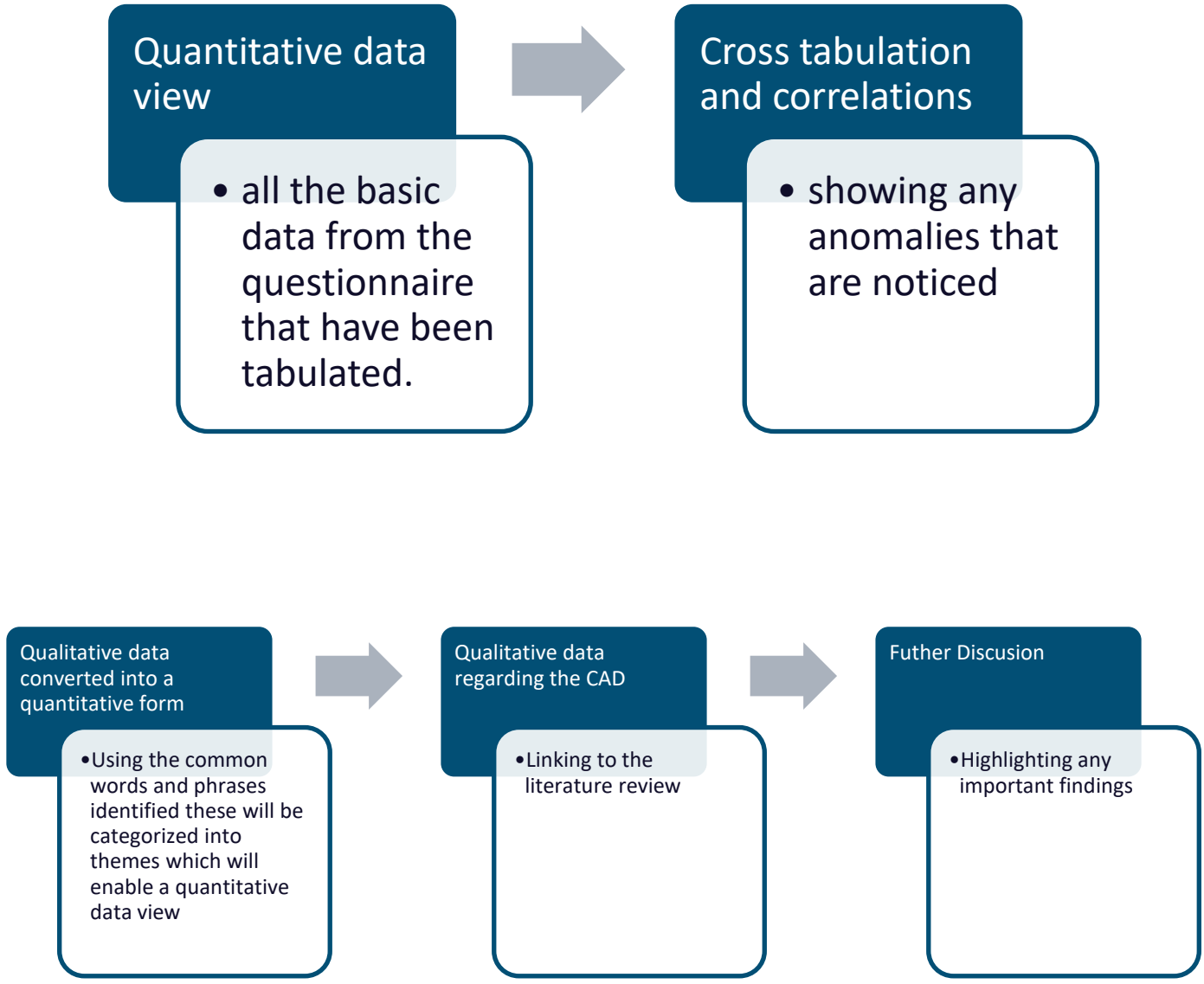


Figure 33-*Process of analysis of data*

Primary Research Findings

This primary research conducted via a questionnaire using google forms collected 30 responses and this section will provide a clear and detail presentation of the data along with the findings. This section will also explore the correlations and interpretation of the data. The questionnaire was designed to achieve the aims of this research, to find out whether the UK CAA regulation is too restrictive and if so what sort of regulation should be implemented. The proposed regulation, developed in the literature review and is made up of ICAO and EASA content, was used to gather opinions of a new regulation. All data has been interpreted via Microsoft excel with graphs to aid visual representation and give an understanding of correlations demonstrating synthesis.

RESEARCH LIMITATIONS

The research limitations derive from the sample size and the questionnaire in combination with the specificity of the topic. The sample size is a direct effect of the data collection method. The questionnaire is a method in which excels with a large sample, however, due to the specialist topic and the coronavirus outbreak in 2020, this has reduced the sample, either because they feel they're not qualified enough or they were put off by the level of detail in the questionnaire. More time permitting, a fully qualitative approach might have been more suitable. The downside is that it’s harder to conduct and will not provide a wide perspective of all industry professionals on the regulation, unlike the questionnaire. Furthermore, the data collected from the questionnaire allowed for a variety of people from around the world to respond and it can be argued 30 respondents are quite a lot concerning the topic.

The questionnaire required some level of knowledge in regulation to understand the questions, by providing more context or taking a slightly different perspective on the topic it may allow for more people to reply and increase the sample size, a huge benefit of having a questionnaire though was the ability of the responders to compare the regulations and provide feedback both in a quantitative and qualitative method.

QUANTITATIVE DATA VIEW

30 respondents in total for the Sample

Age of respondents -Totals

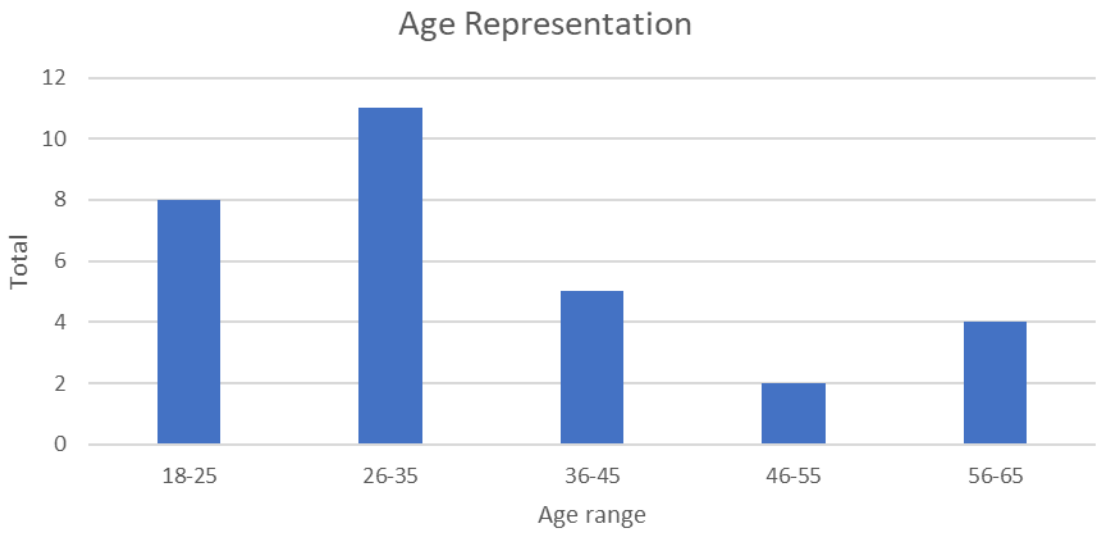


Figure 34-Questionnaire- Age Representation

The most represented age group was 26-35, with the second being the 18-25 age group.

Gender Representation -Percentage

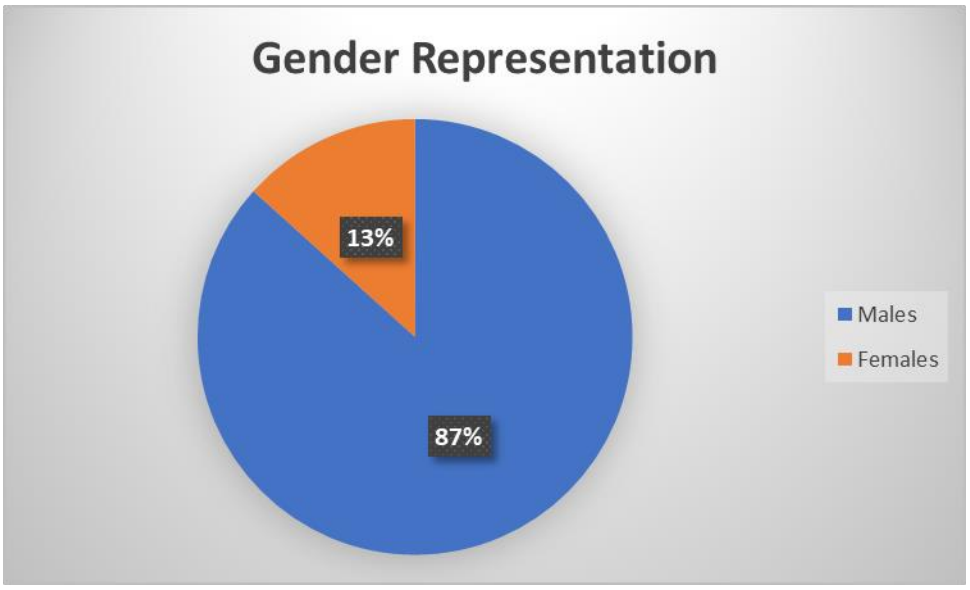


Figure 35- Questionnaire- Gender Representation

As can be seen, there were more males than females who responded, this is expected especially since there is more Males in the aviation industry, as well as Men, are more likely to have CVD with 8-10% of men being affected compared to 0.5% of women. (Aopa.org, 2020) (nhs.uk, 2020)

Sector Representation

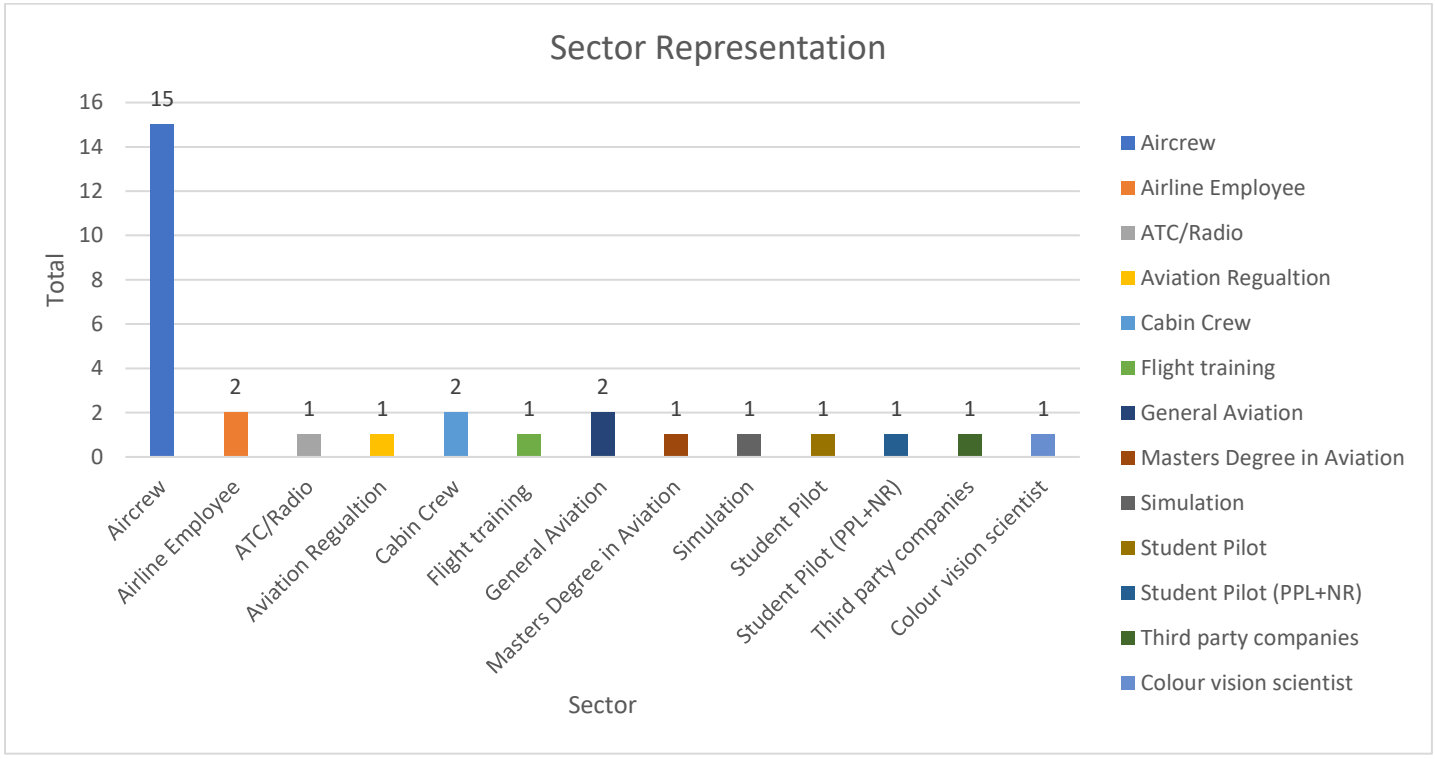


Figure 36-Questionnaire- Sector Representation

Aircrew made up over half of the respondents, however, there was good coverage of most aviation jobs. The only job that would have benefited this research that wasn't represented would be someone in aviation medicine. But it can be argued even if they were represented this would not affect the overall outcome of the research and there was representation from colour vision specialists.

Experience Representation

Figure 37-Questionnaire- Experience Representation

The experience representation shows that the largest proportionate was from respondents that have 10 or more years of aviation experience. This shows the sample had a good amount of experience and knowledge to answer the questions thereby strengthening the validity of the research outcome.

Percentage of respondents that we're aware of the change in the UK colour vision regulation in 2018

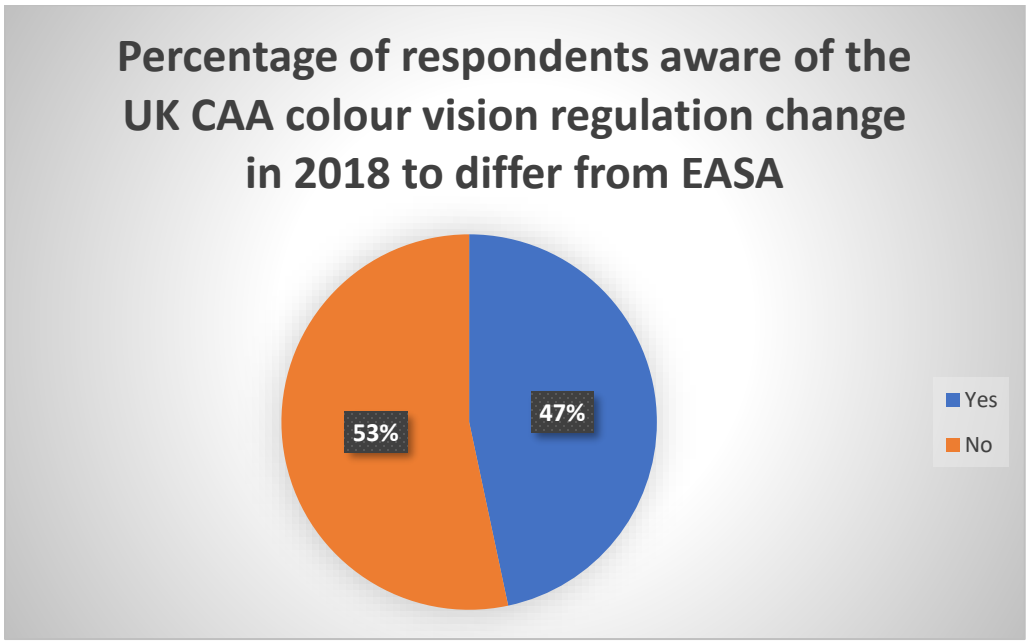


Figure 38-Questionnaire -Percentage of respondents aware of the UK colour vision regulation change in 2018

This gives a rough indicator of how much prior knowledge people have of the UK colour vision regulation and whether they have themselves been affected by it. By the number of respondents who were unaware of the UK regulation change being nearly 50%, this is a good indicator that this report is objective and unbiased. It could also demonstrate that the UK CAA communicated poorly the regulation change in 2018. This is likely since the overwhelming response is negative towards the UK CAA regulation and there was no transition period as identified in the observations made in the introduction.

EASA Regulation – How the respondents would describe the current EASA regulation

EASA Question 1: How would you describe the current EASA colour vision regulation?

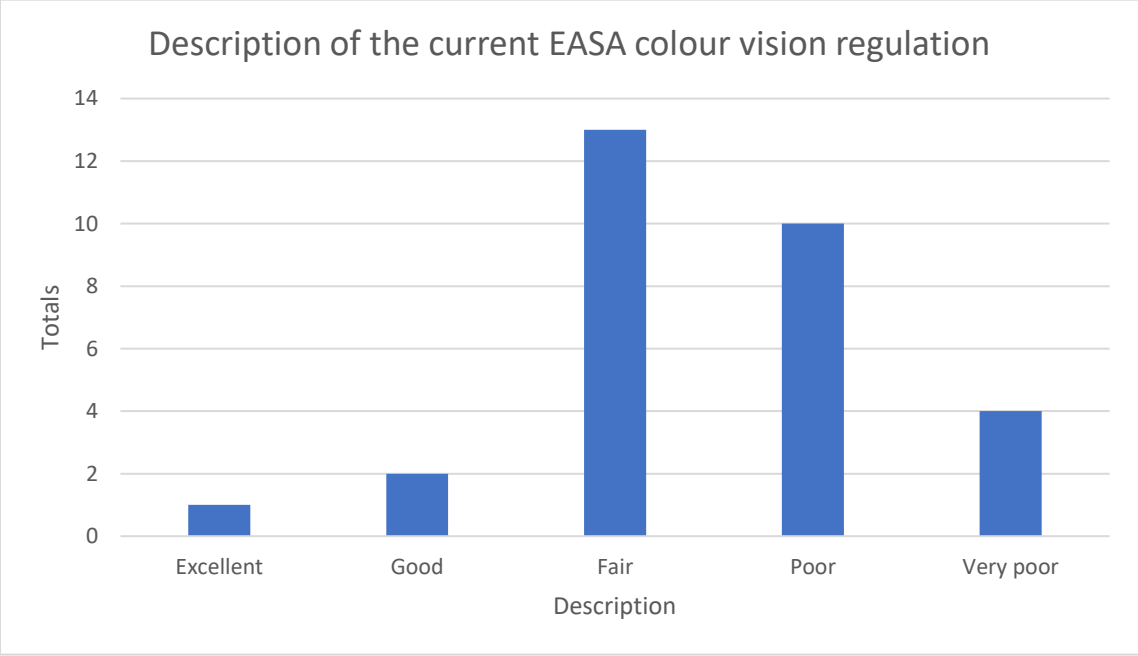


Figure 39-Questionnaire-How the respondents would describe the current EASA regulation

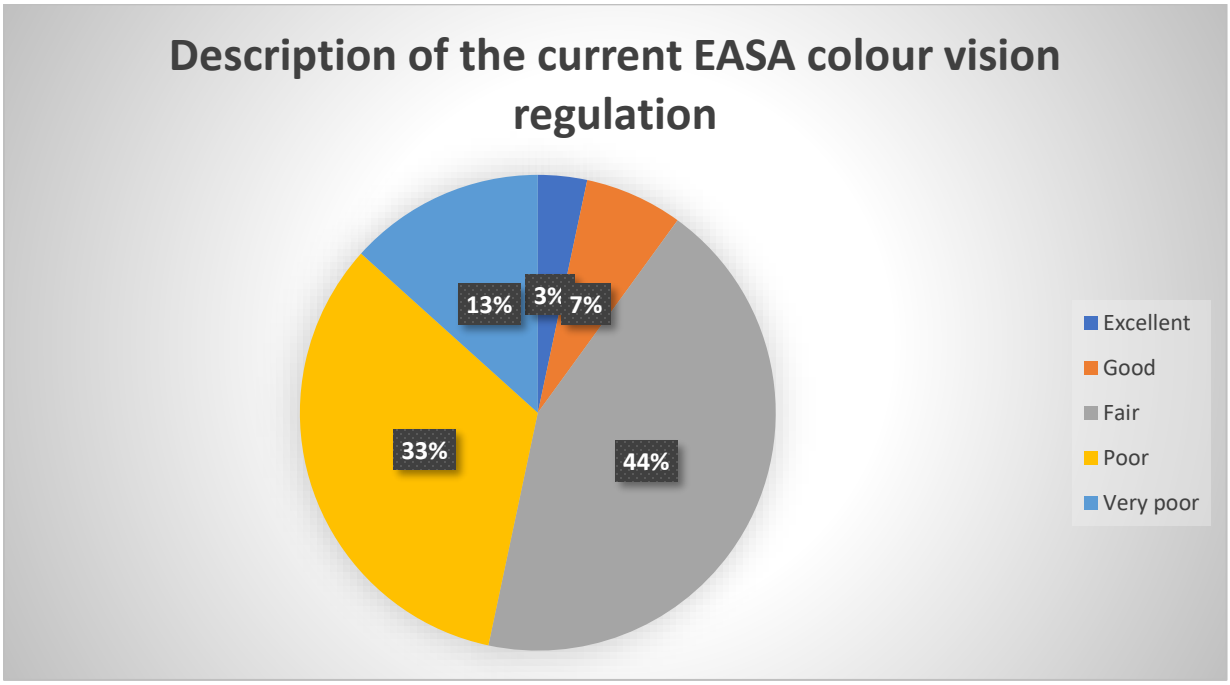


Figure 40-Questionnaire-Pie chart view of how the respondents would describe the current EASA regulation

Very few respondents said the EASA regulation was excellent or good, only 10%. 46% said that the EASA regulation was either poor or very poor however the largest result was that 44% said that this regulation was fair. With the responses regarding the EASA regulation being spilt this does not give a significant piece of evidence that the regulation is 'fair'. It can be stated that this regulation has conflicting results. This is probably due to the problems that stem from having no practical testing method but having more tests that the UK regulation.

EASA Question 2: How would you describe the current EASA colour vision regulation?

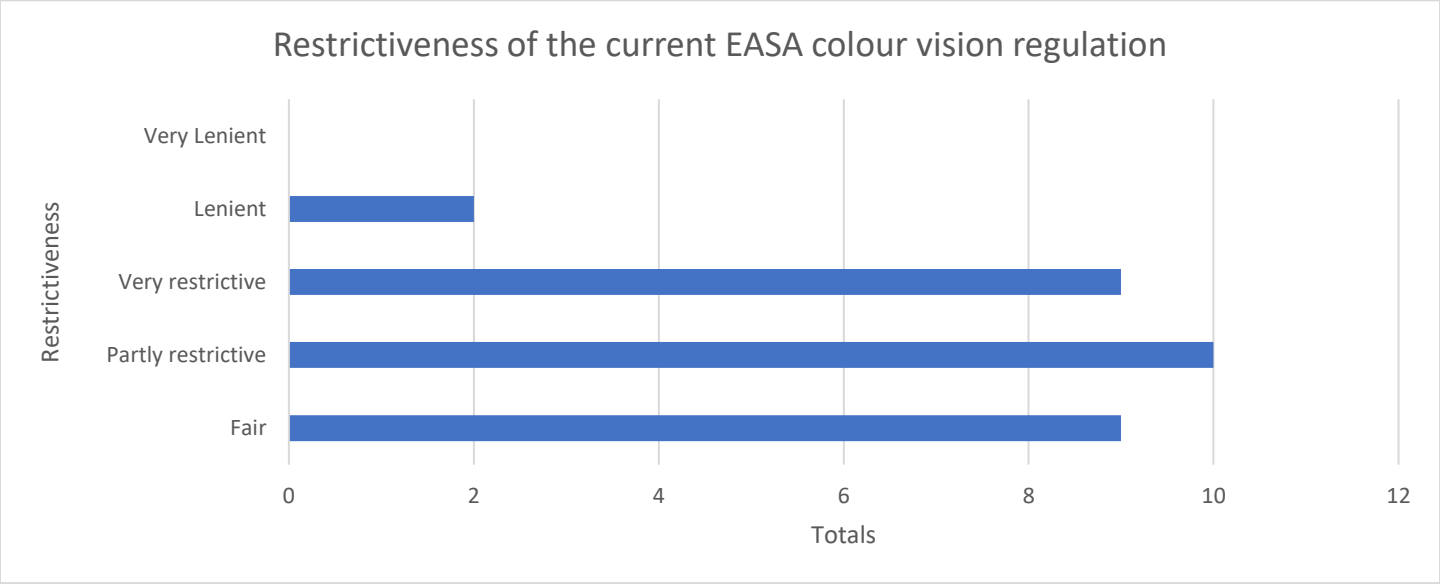


Figure 41-Questionnaire- How respondents would describe the restrictiveness of the EASA regulation

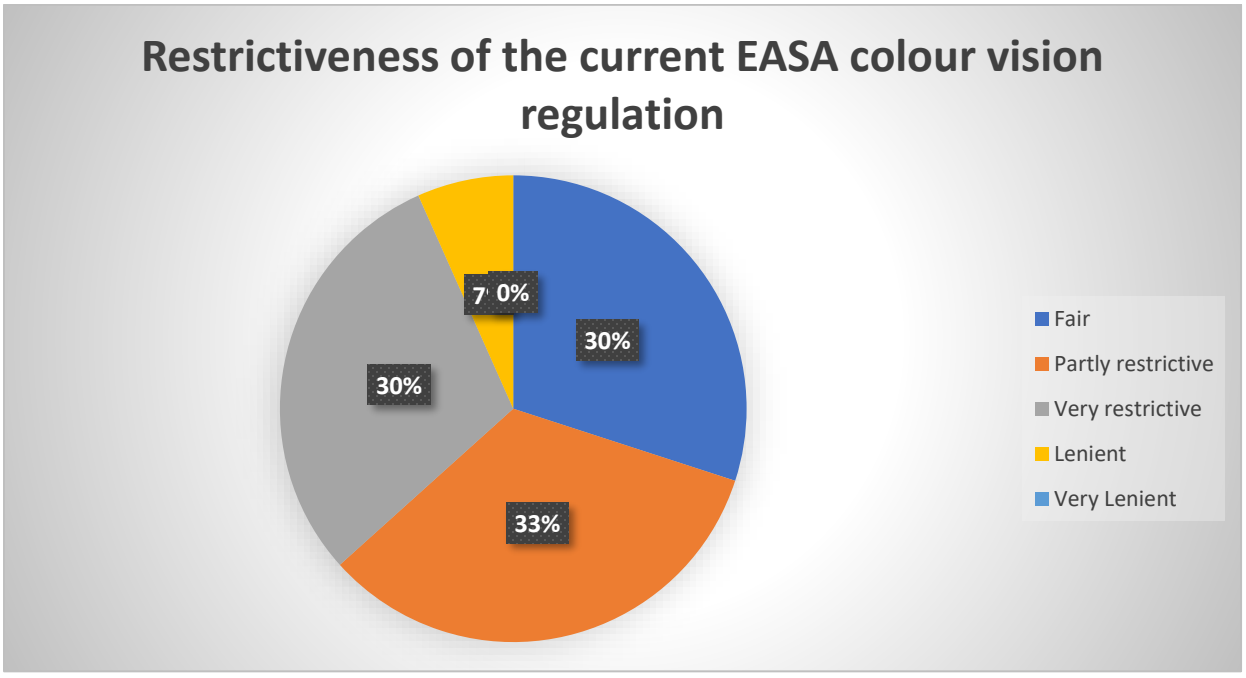


Figure 42-Questionnaire- Pie chart view of how respondents would describe the restrictiveness of the EASA regulation

This question aimed to figure out whether the regulation was too restrictive or not and compare it with the other regulations within the questionnaire. This data shows that 61% thought that the EASA regulation was either partly or very restrictive with only 30% stating that the regulation was fair. This is quite a big difference with the previous EASA question. This difference shows there is a lot of dispute as to whether this regulation is

suitable or not. However, this result is less conflicting than the previous and defiantly does show that this regulation is not deemed perfect and it may not be suitable for the UK CAA to revert to this.

CAA regulation – How the respondents describe the regulation

CAA Question 1: How would you describe the current UK CAA colour vision regulation?

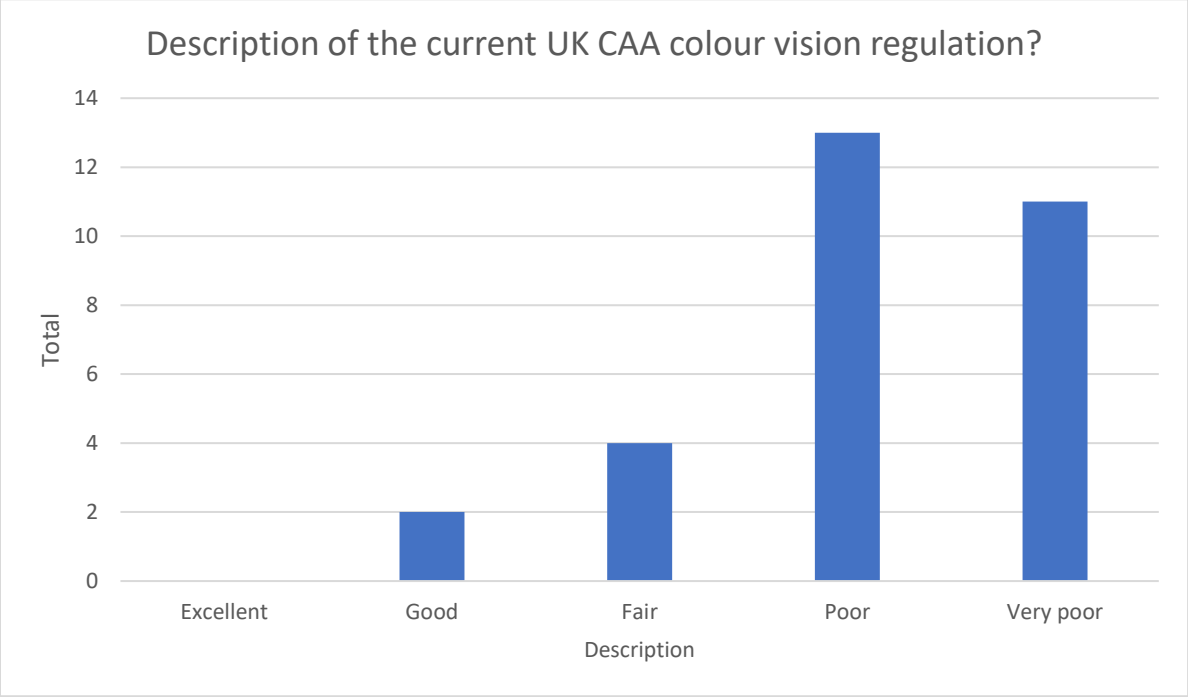


Figure 43- Questionnaire-How the respondents would describe the current CAA regulation

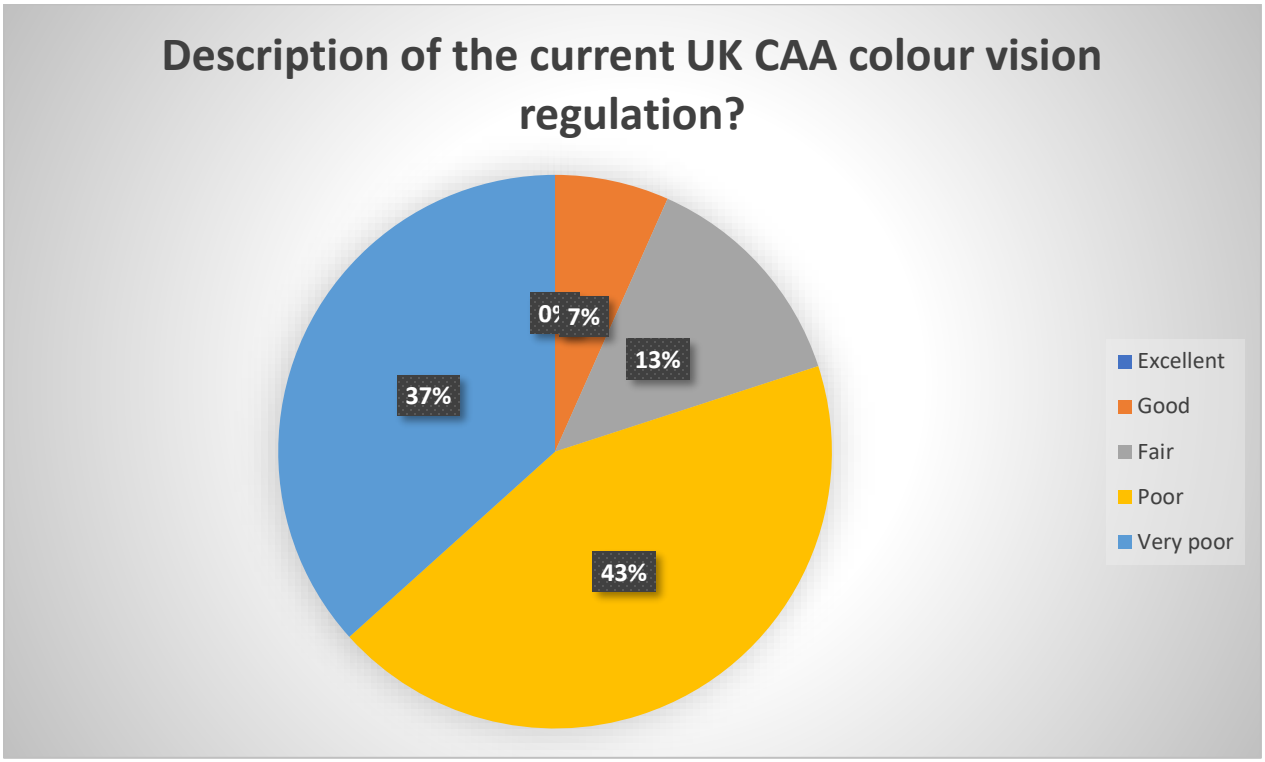


Figure 44- Questionnaire-Pie chart view of how the respondents would describe the current CAA regulation

These graphs show the descriptions selected by the respondents to describe the UK CAA regulation, 80% have either selected the UK CAA regulation as ‘very poor’ or ‘poor’ and only 13% for ‘fair’. This shows this regulation is not popular with the respondents. This was expected from the evidence supplied in the literature review regarding the UK regulation and the CAD.

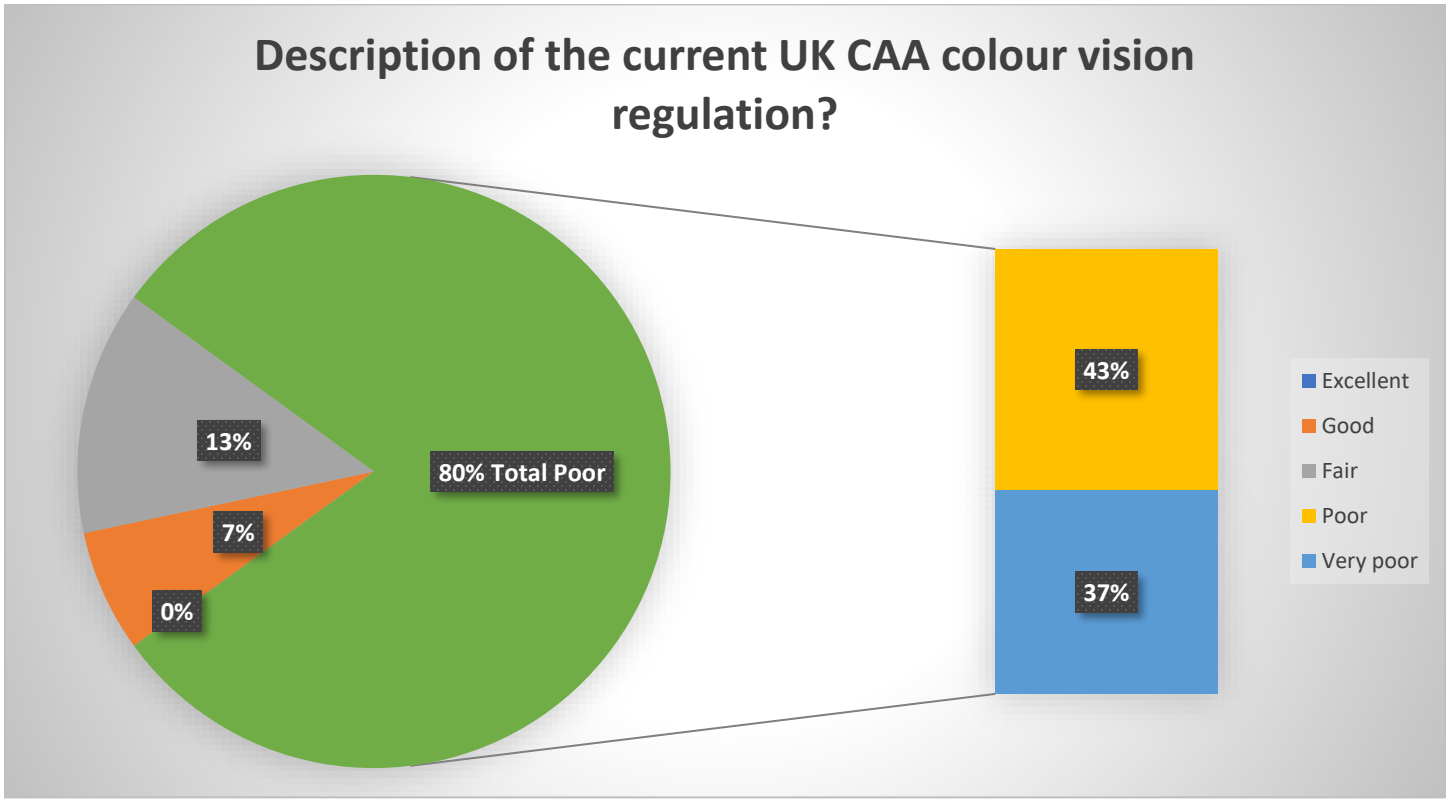


Figure 45- Questionnaire-Pie chart view of how the respondents describe the current CAA regulation combining responses of the percentage in 'Poor' and 'Very Poor', shown in green

CAA Question 2: How would you describe the current UK CAA colour vision regulation?

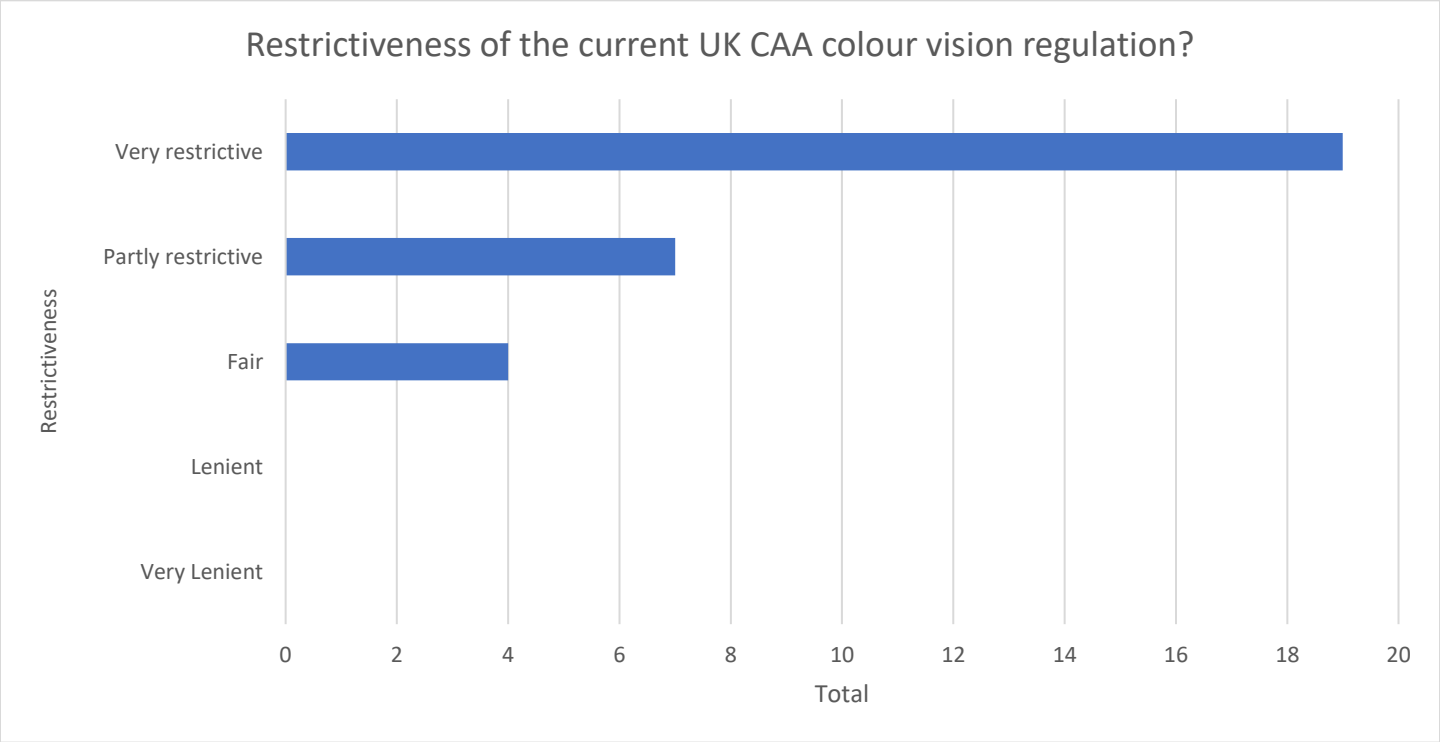


Figure 46-Questionnaire- How respondents would describe the restrictiveness of the CAA regulation

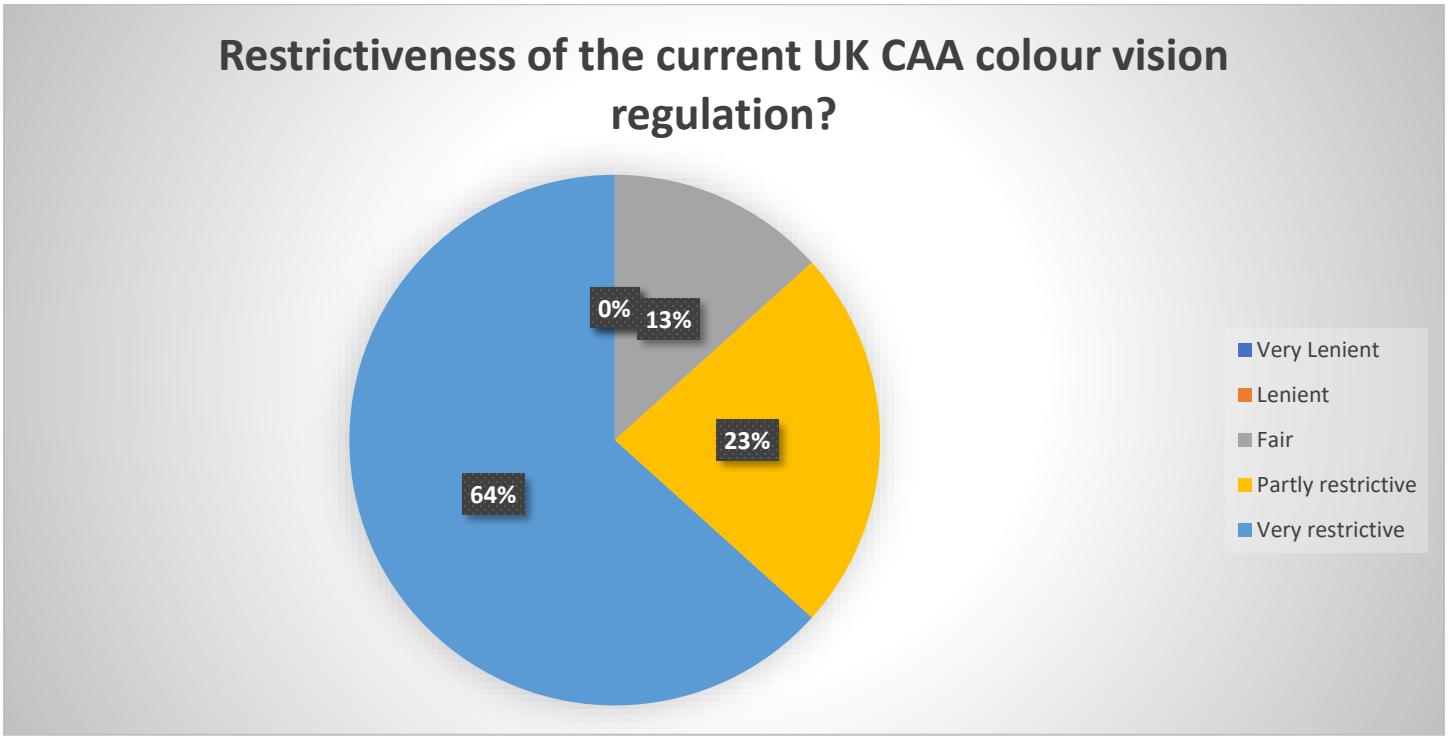


Figure 47-Questionnaire- Pie chart view of how respondents would describe the restrictiveness of the CAA regulation

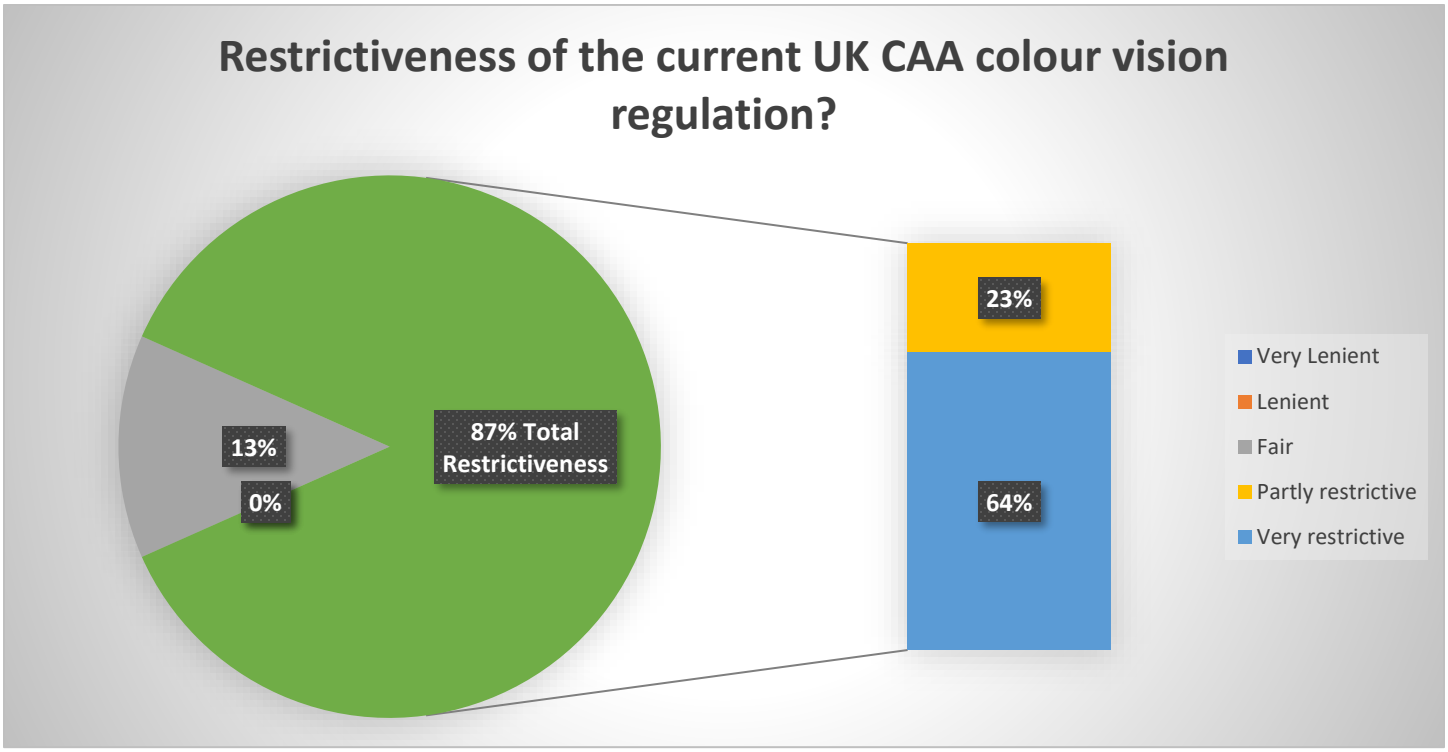


Figure 48-Questionnaire- Pie chart view of how respondents would describe the restrictiveness of the CAA regulation combining the 'Partly' and 'Very Restrictive' percentages, shown in green

These graphs show how the respondents described the UK regulation in levels of restrictiveness, from the graphs above it shows that 87% selected either 'very restrictive' or 'partly restrictive'. This clearly shows that the UK regulation is restrictive with 64% voting it was very restrictive.

This is a clear significant piece of statistical evidence to suggest that the UK regulation is too restrictive and combined with the research from the literature review provides a strong argument for the regulation to be changed.

EASA VS CAA regulation -Which is more suitable/aviation related

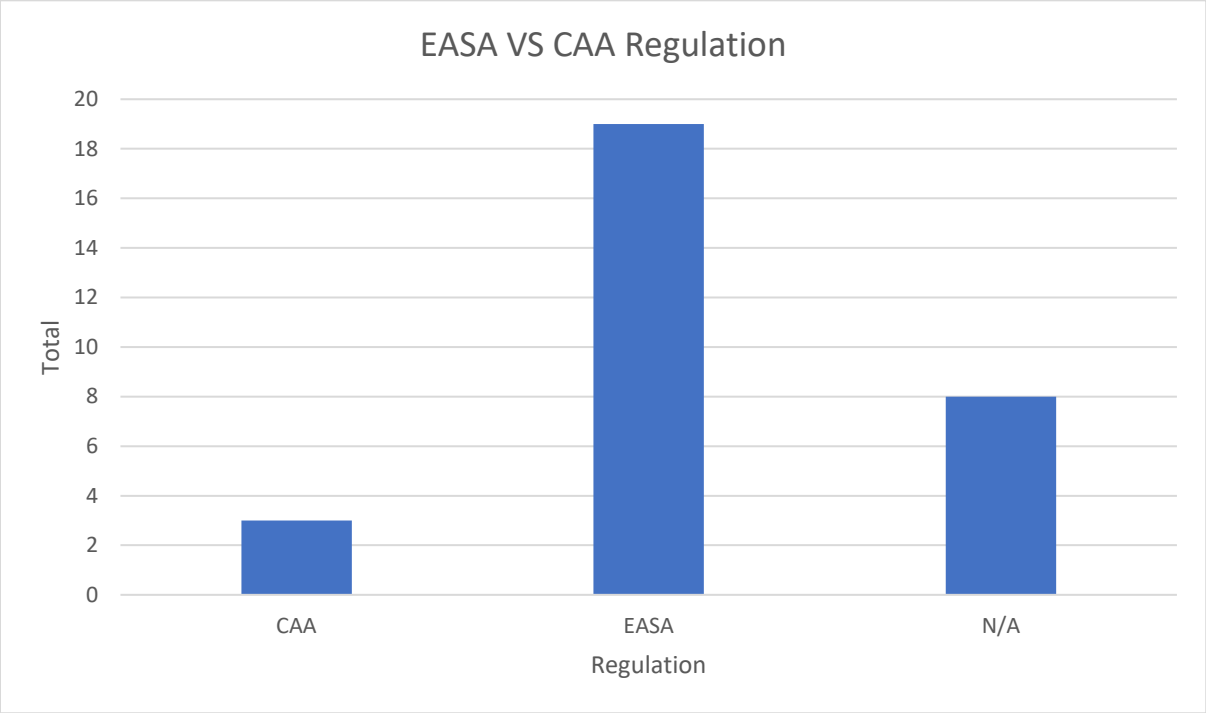


Figure 49- Questionnaire- EASA VS CAA regulation -Which is more suitable/aviation related

This graph above shows that the EASA regulation was selected over the CAA regulation as being more suitable /aviation-related. N/A represented anyone who suggested a different regulation, provided no answer or said neither. It was surprising that even N/A beat the CAA's votes. This shows even a more dislike to the CAA regulation.

Proposed Regulation

Question 1: How would you describe the proposed regulation?

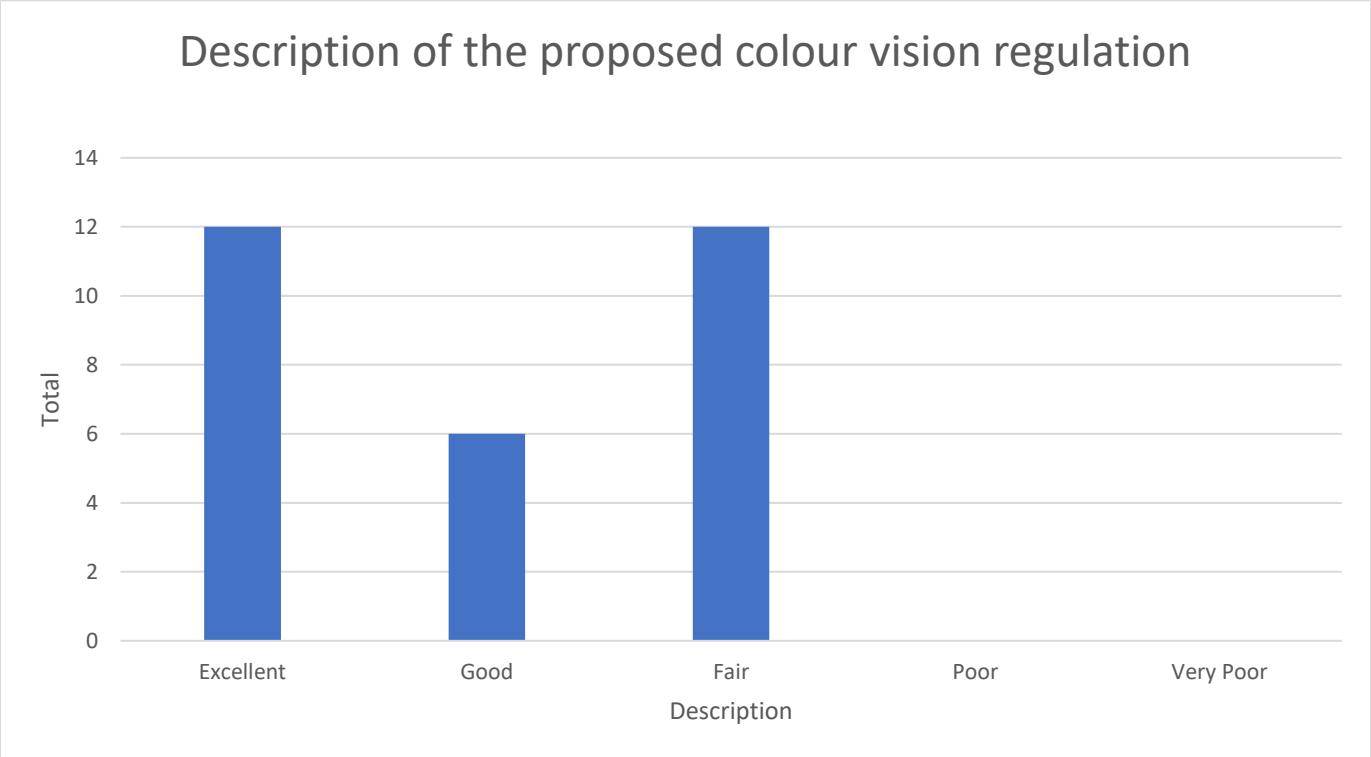


Figure 50-Questionnaire-How respondents would describe the proposed regulation

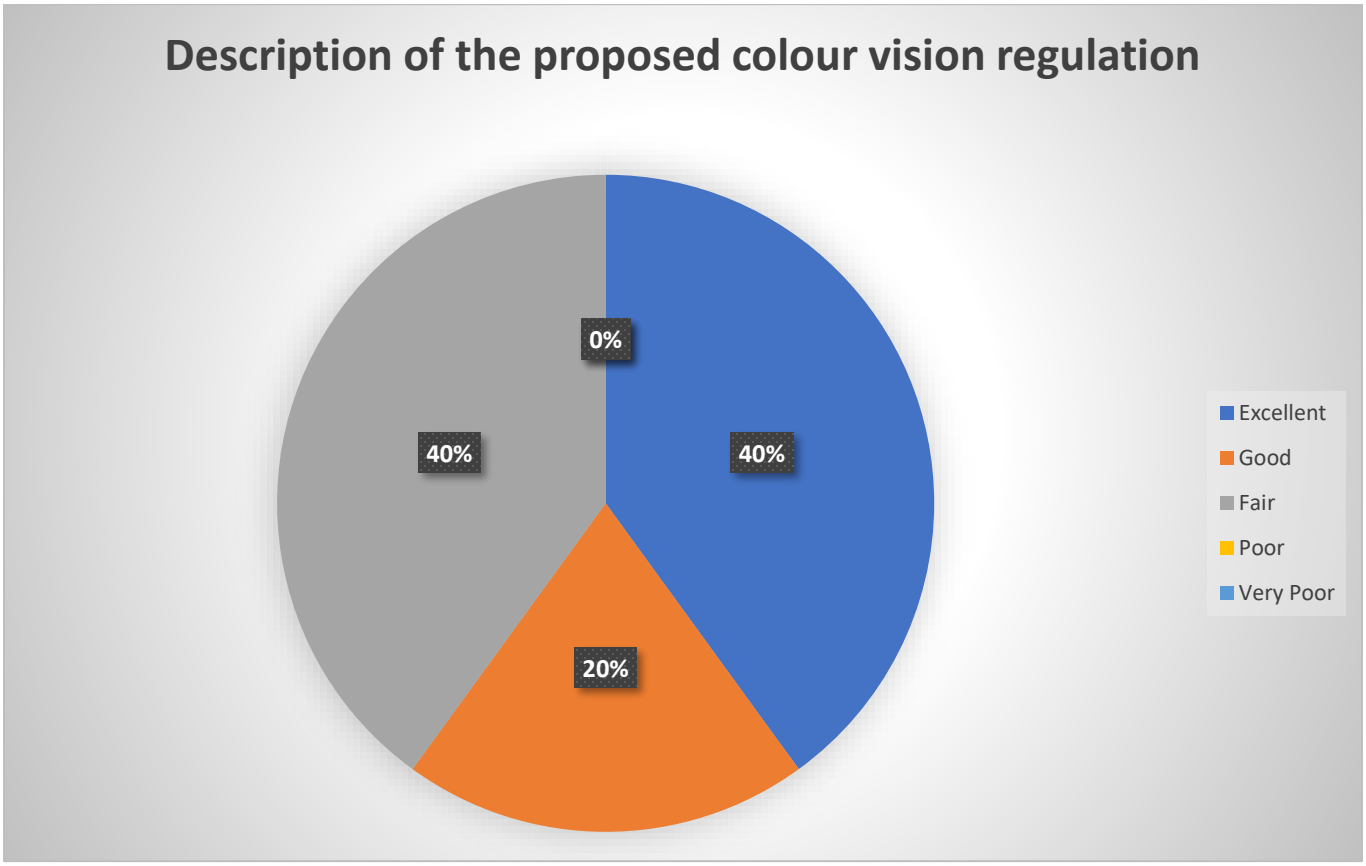


Figure 51-Questionnaire-Pie chart view of how respondents would describe the proposed regulation

100% of respondents selected for this regulation to be either ‘Fair’, ‘Good’ or ‘Excellent’, therefore no bad votes were cast for this regulation. With 60% saying the regulation was ‘good’ or ‘Excellent’. This is a positive response to the proposed regulation.

Question 2: How would you describe the proposed regulation?

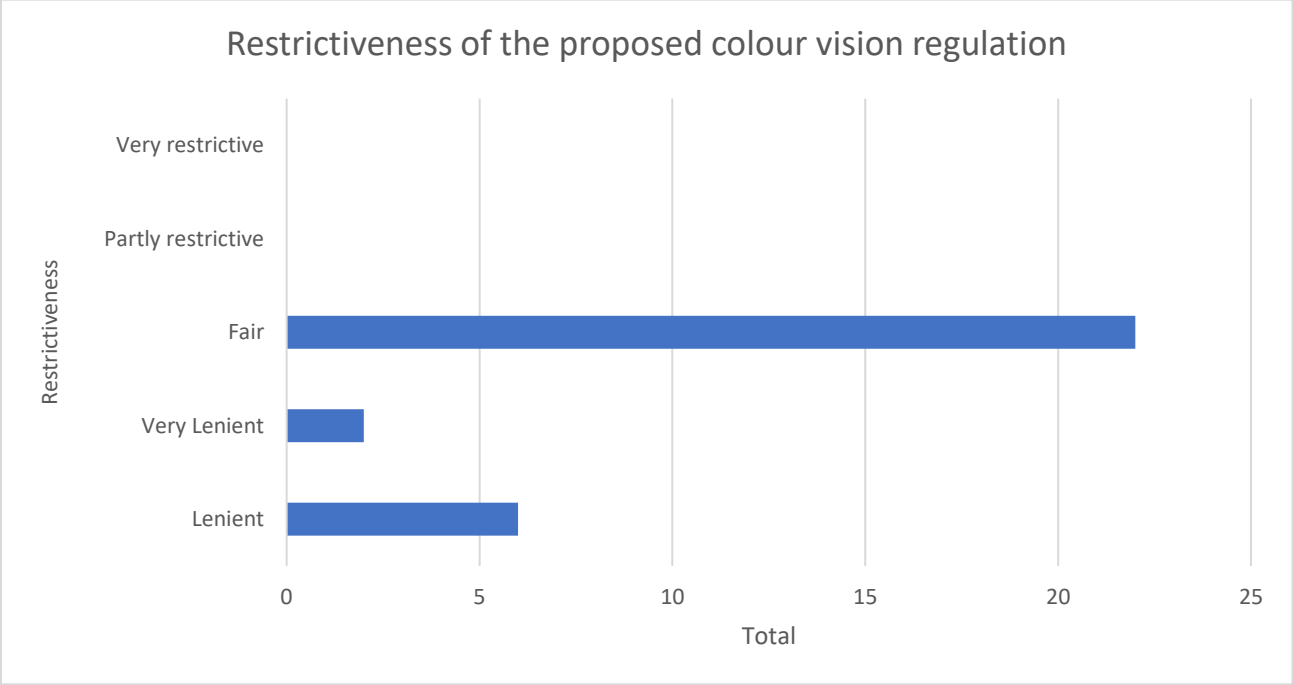


Figure 52-Questionnaire- How respondents would describe the restrictiveness of the proposed regulation

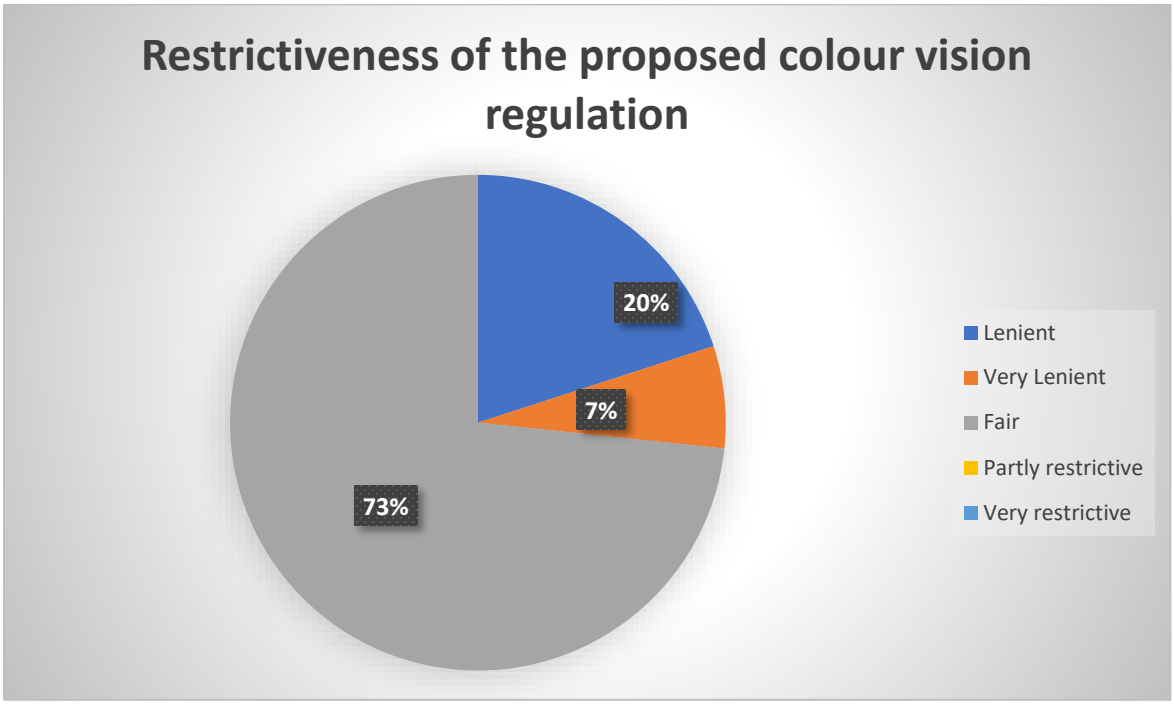


Figure 53-Questionnaire-Pie chart view of how respondents would describe the restrictiveness of the proposed regulation

The proposed test had no votes for any of the 'very restrictive' or 'partly restrictive' options. 73% said the regulation was 'fair' with 20% saying it was 'Lenient' and 7% saying 'Very Lenient'. This shows by a large majority that the proposed regulation has been selected as 'Fair'. If respondents selected very lenient it didn't correlate with the answers from the previous question as this would have come across as being poor or very poor, which there were not votes for. Thereby providing a strong argument that this type of regulation should replace the current UK CAA one.

Regulation Ratings

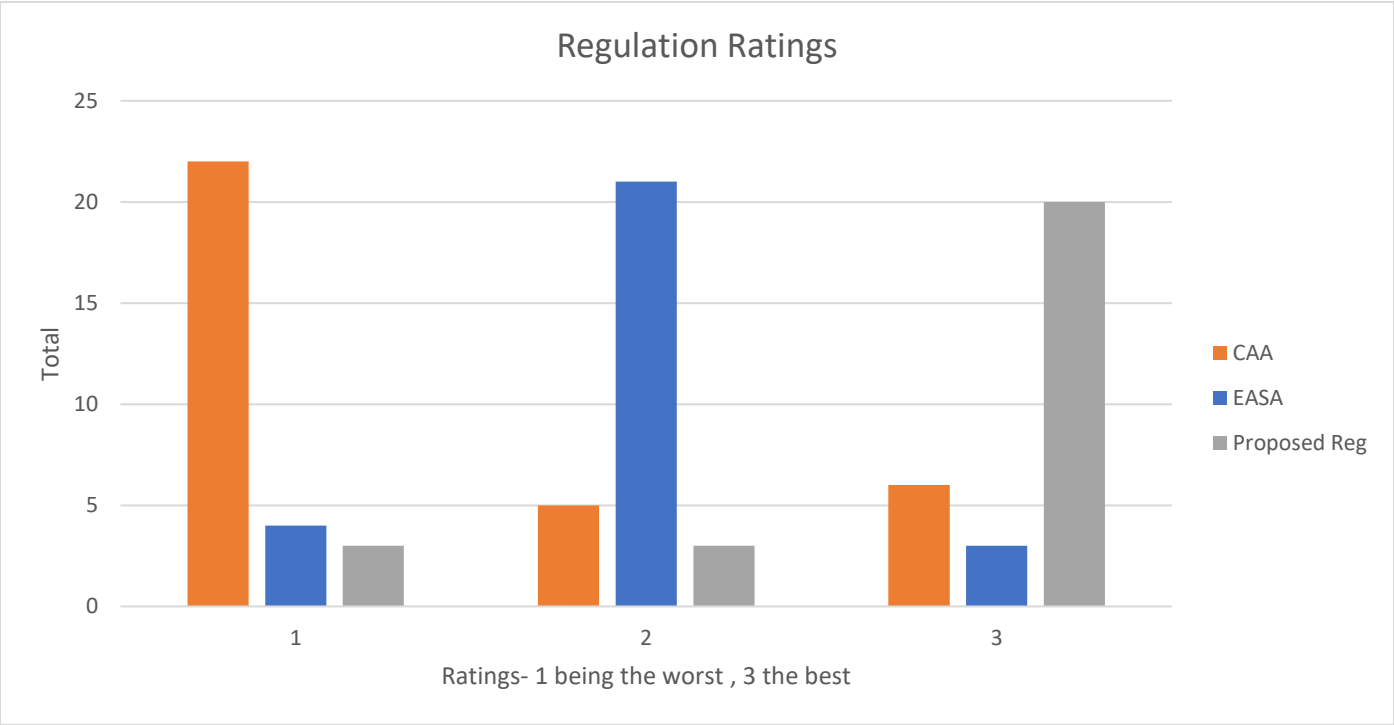
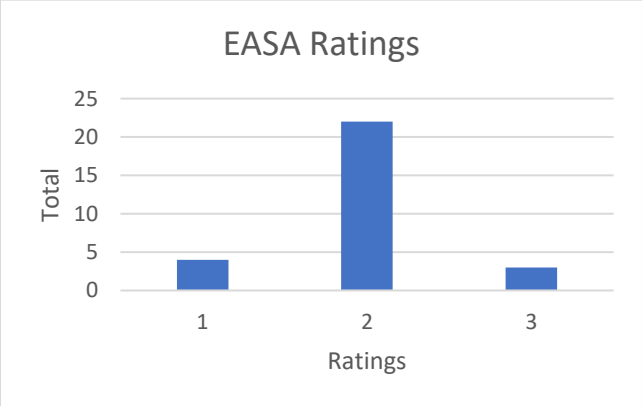
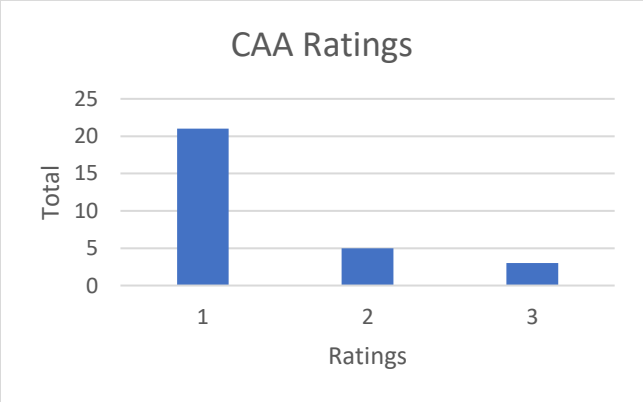


Figure 54- Questionnaire- Combined regulation ratings





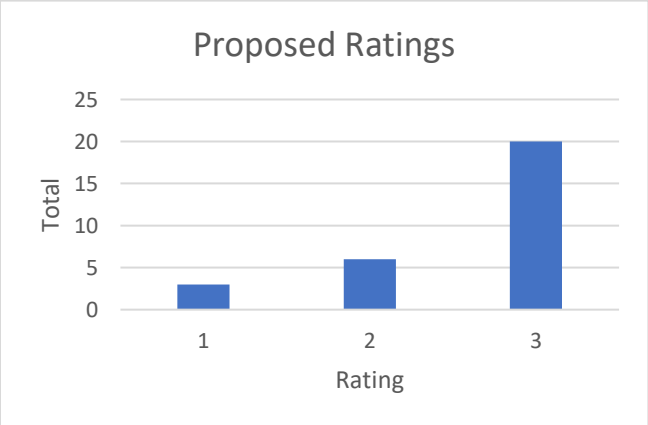


Figure 55- Questionnaire- Individual regulation ratings

The results from the ratings allow for a good perspective of the best and worse regulation and can indicate which regulation should be used. A score of 1 was the worse rated and 3 was the best. The best-rated was the proposed regulation with 20 votes, the worse regulation was the CAA with 22 votes and the EASA regulation came in the middle with 22 votes. There was some confusion with the scale meanings which was one of the limitations mentioned regarding using the scaling method. Some respondents thought 1 was the best, for example, one respondent thought the proposed regulation was much better than the CAD from their comments and other answers, however, selected it as a 1 thinking this was the best. It was clearly mentioned what the scale meant in the question, but this confusion could be down to the respondents not reading the question properly or rushing through the questionnaire. However, even with this confusion not many respondents made this error and would not affect the overall outcome of the results due to the one-sided view.

Is the proposed regulation more suitable /aviation related than both the UK CAA and EASA's regulations?

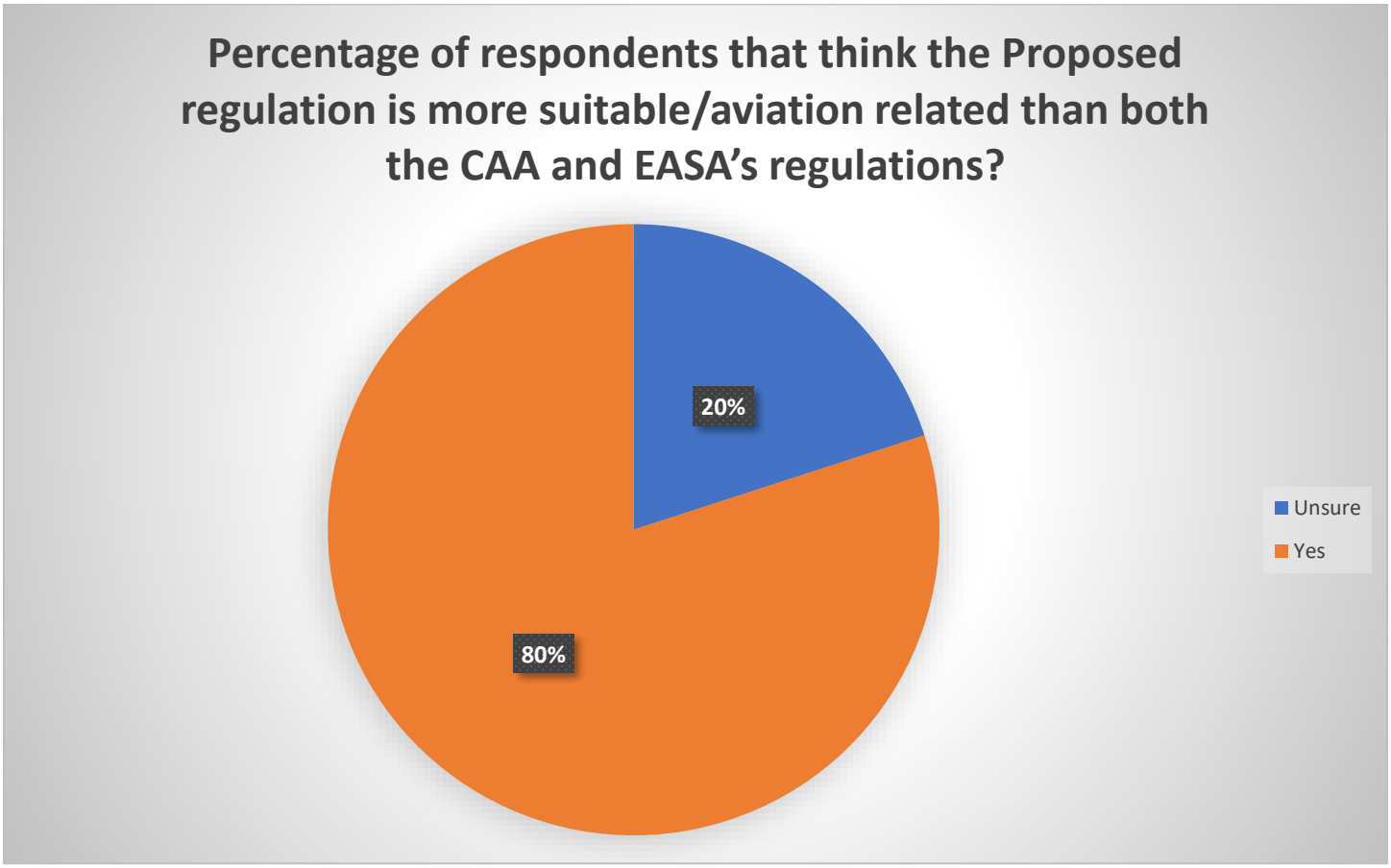


Figure 56-Questionnaire - Pie chart view of whether the proposed regulation is more suitable/aviation related than both the CAA and EASA regulation

This graph shows that 80% of respondents thought that the proposed regulation was more suitable /aviation related than both the other regulations and this answer correlates well with the rest of the research results. 20 % said they were unsure, which could be down to many reasons for example not enough knowledge or the question was too vague. However, it is important to note no one said no to this question which is extremely positive towards the proposed regulation.

Final question: Would respondents like to see the proposed regulation implemented to replace the current UK CAA regulation or class 1 medicals.

Based on the aims of this research, this question importance grows depending on the outcome of whether the UK CAA regulation is too restrictive. Clearly from the evidence provided both from the literature review and the primary data collected it can be concluded that the UK CAA regulation is indeed too restrictive. This

question, therefore, is extremely important as this provides aviation professional opinions on another type of regulation that could replace the current UK CAA method.

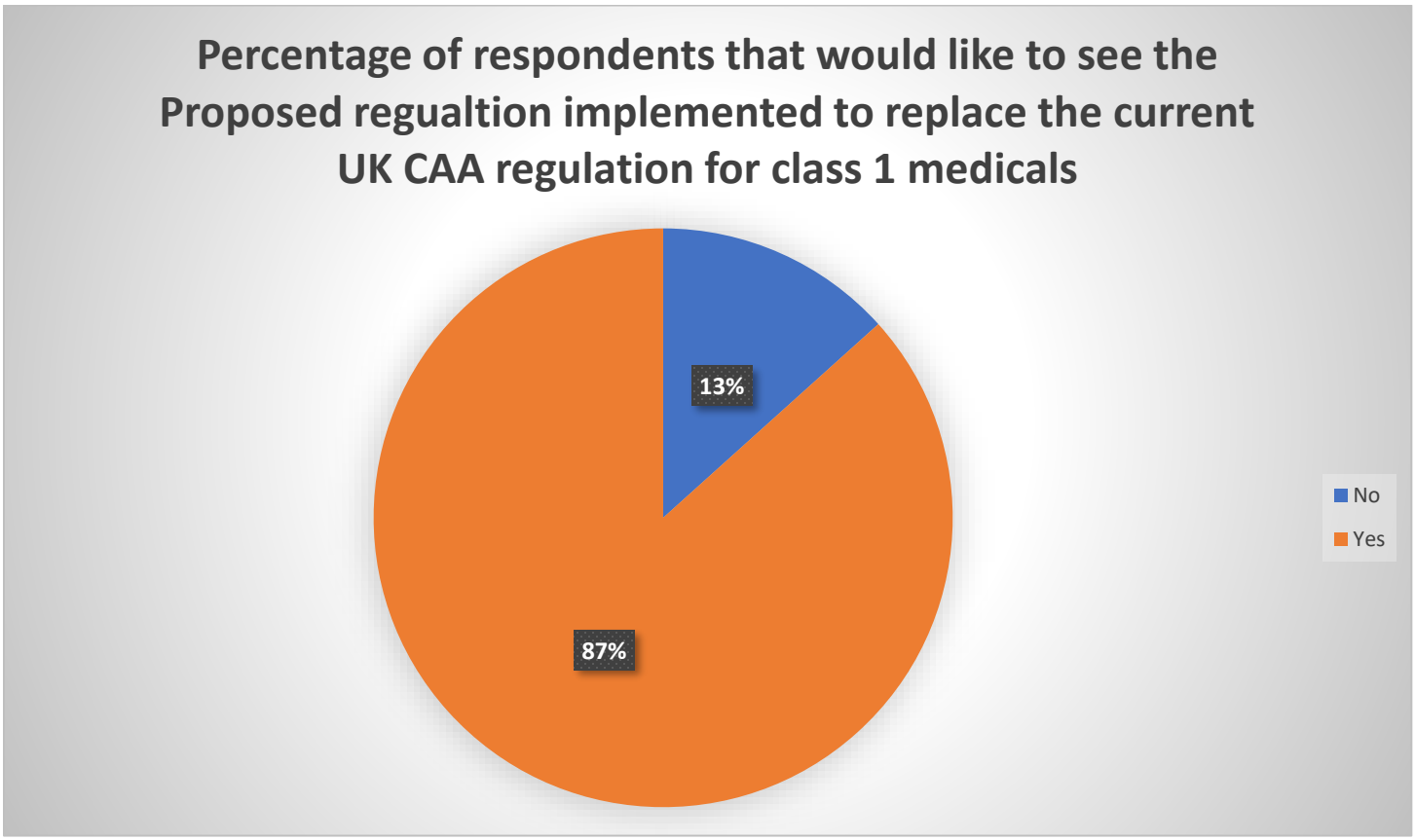


Figure 57-Questionnaire- Pie chart view- would respondents like to see the proposed regulations implemented to replace the current UK CAA regulation

As can be seen from the figure above, 87% said 'Yes' to replace the UK regulation with the proposed regulation. In correlation with figure 58 above, not all respondents who said 'unsure' also said 'No' to the proposed regulation.

It's important to gather context to some of the questions as well as understanding anomalies for example why the percentages for the last two questions weren't the same which was expected.

Cross tabulation methods are very useful for identifying correlations, linking this with the qualitative data will provide more context to the answers provided.

CROSS TABULATION AND CORRELATIONS RESPONDENTS

Age of respondents compared to the level of each regulation's restrictiveness

The graphs show there was a correlation that the age group 56-65 mostly selected fair for all three regulations and selected differently to the other age groups. This age group might be unaware of the development in aircraft technologies and a lack of use in colour within flying an aircraft in the modern era according to the literature review. Or this group could have more experience than any of the other age categories and therefore their responses are more reliable. However, many respondents with 10 + years' experience come from other age categories which seem to correlate with each other. It is likely the initial reasoning, as the correlation suggests that most age groups with various experience vote the same.

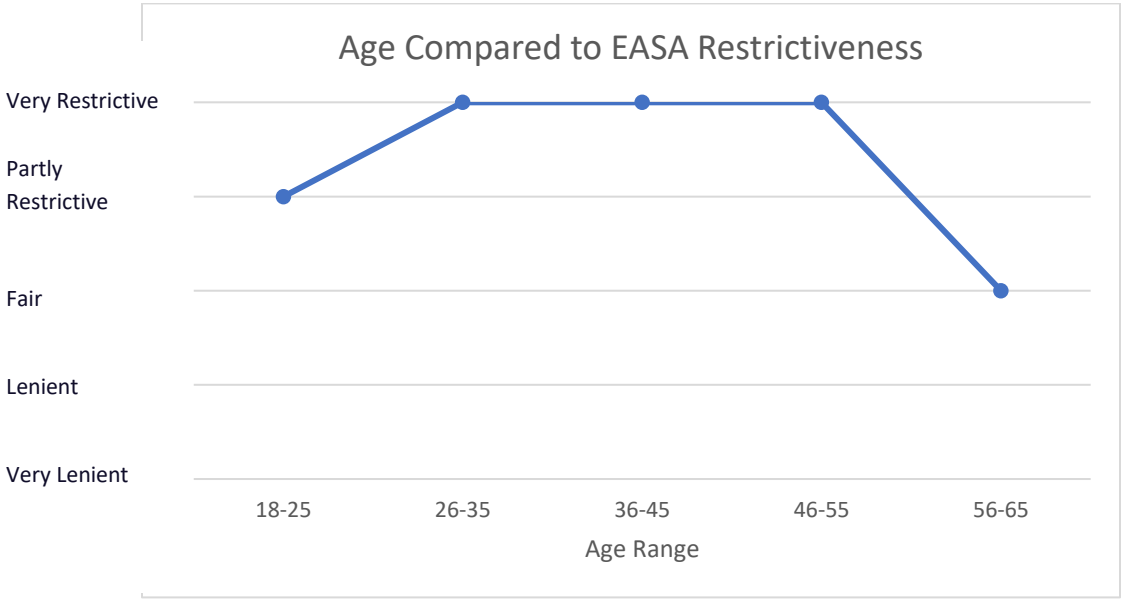


Figure 58-Cross Tabulation- Age of respondents compared to EASA's level of restrictiveness

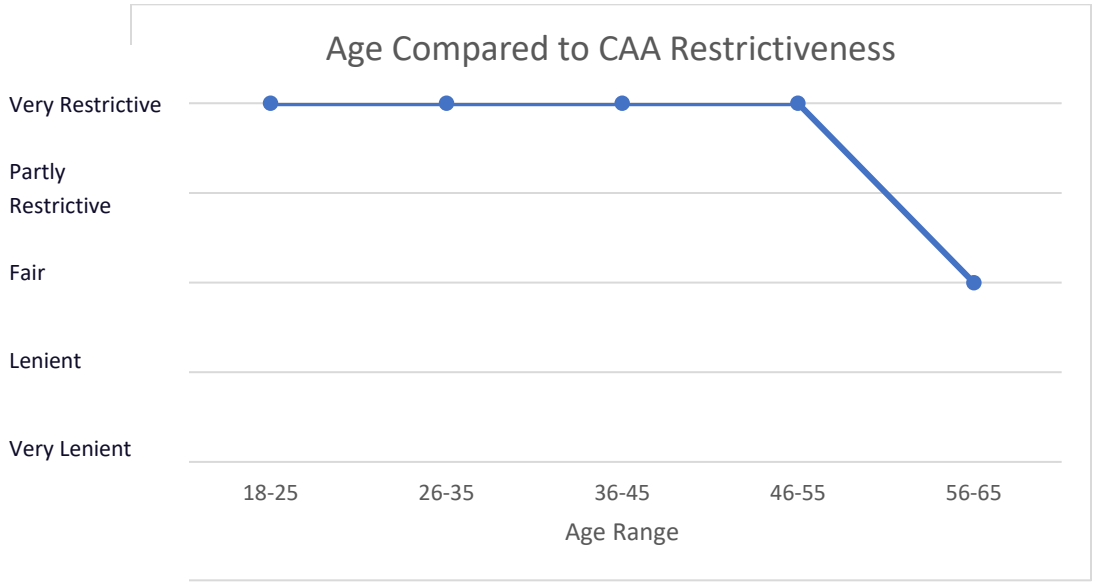


Figure 59-Cross Tabulation- Age of respondents compared to CAA's level of restrictiveness

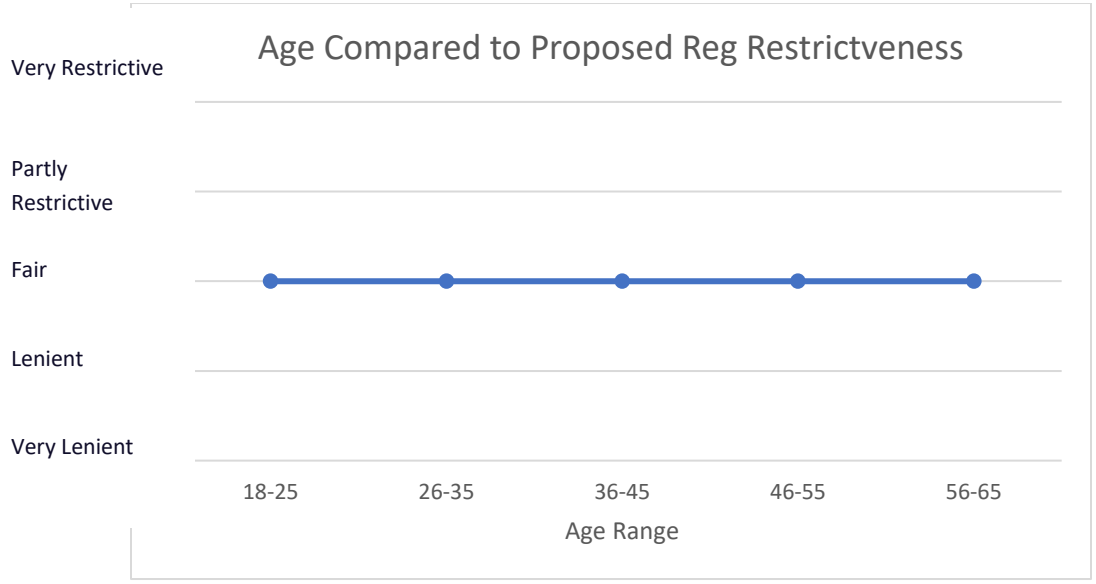


Figure 60-Cross Tabulation- Age of respondents compared to the Proposed reg level of restrictiveness

Comparison of answers given to the 'replacing the UK regulation with proposed regulation 'question and the Sector

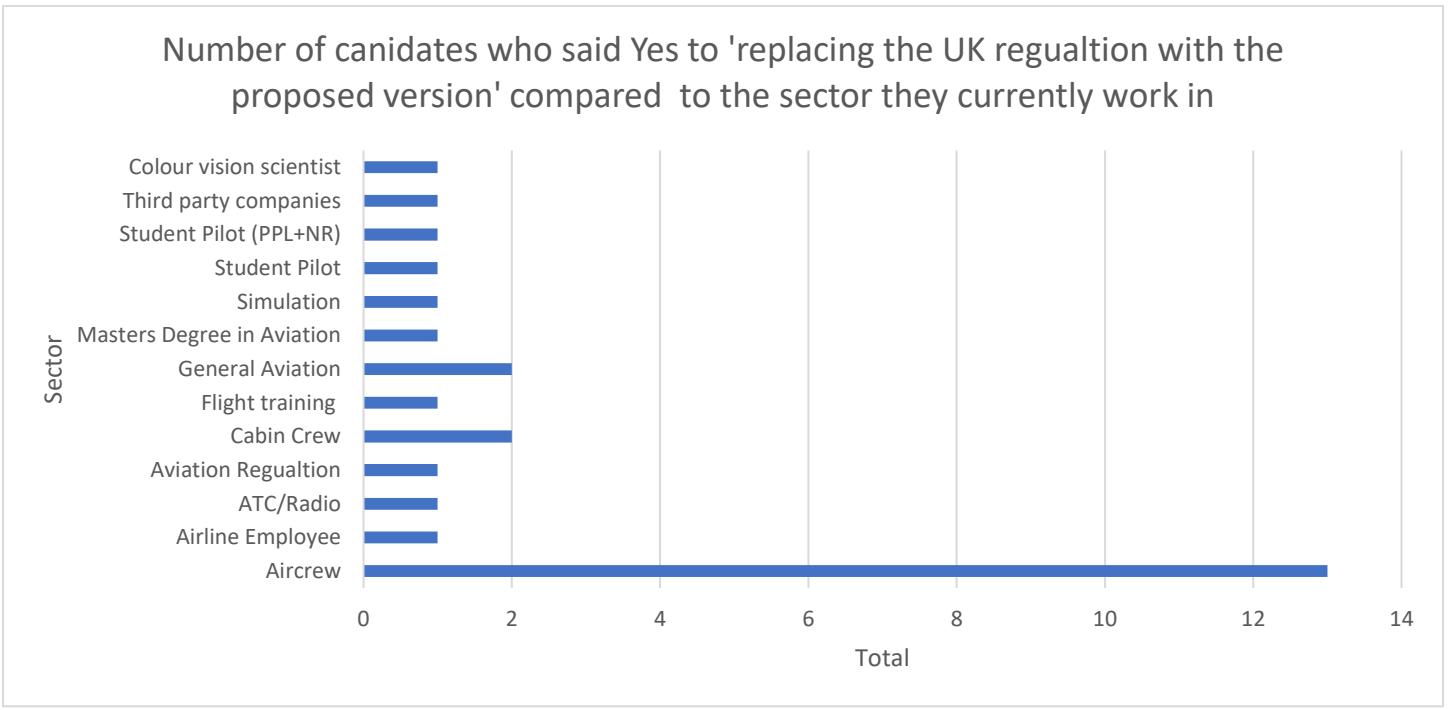


Figure 61-Cross Tabulation-Comparison of answers given to the ‘replacing the UK regulation with proposed regulation ‘question and the Sector

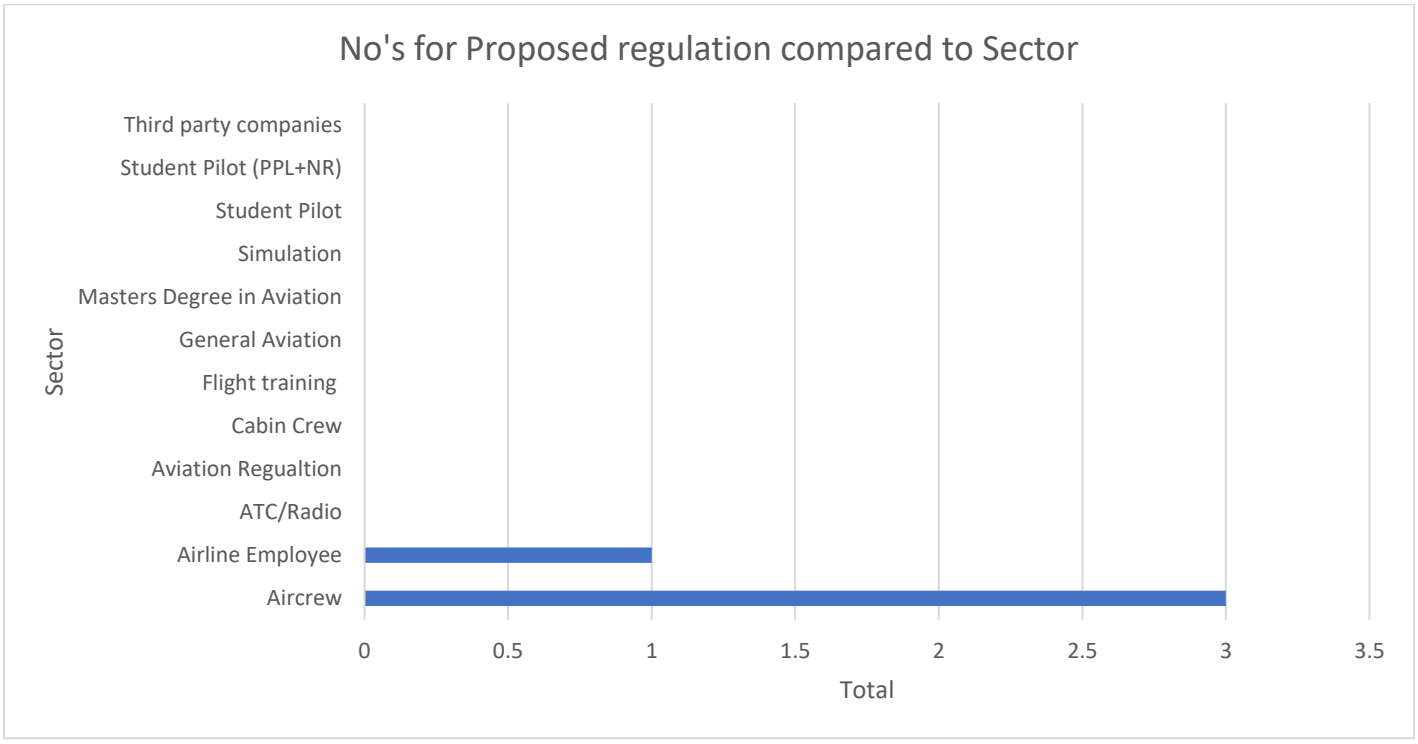


Figure 62-Cross Tabulation-Comparison of answers given to the 'replacing the UK regulation with proposed regulation 'question and the Sector

When comparing both the graphs, this shows that the majority of sectors said 'Yes' and 13 out of 16 aircrew also said 'Yes'. It is interesting to see what sectors said 'No', which was Aircrew and Airline Employees. However, this correlation suffers from the small sample size to understand the thoughts of each sector a larger sample is needed with a larger representation in each.

The restrictiveness of the proposed regulation compared to whether it was accepted as a suitable replacement for the UK.

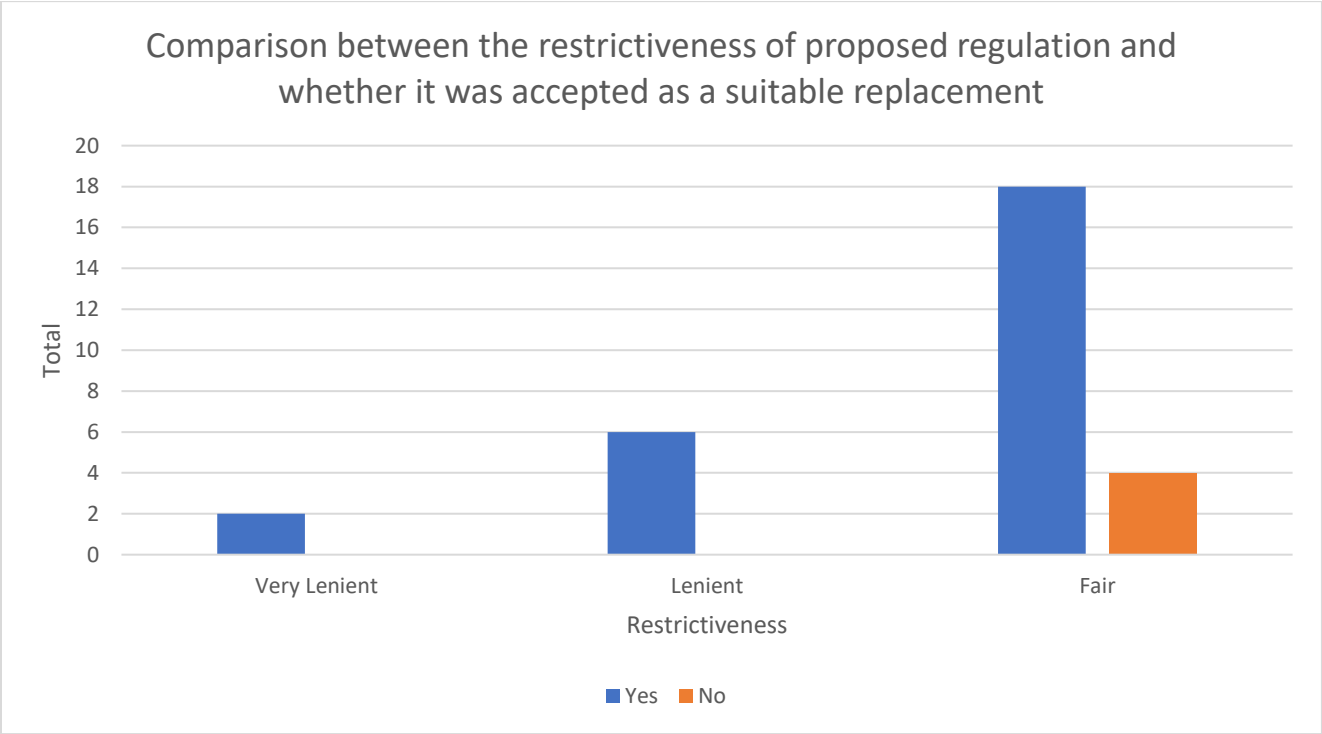


Figure 63-Cross Tabulation The restrictiveness of the proposed regulation compared to whether it was accepted as a suitable replacement for the UK.

This comparison is very interesting, it shows that 4 respondents who thought the regulation was fair said they didn't think it was a suitable replacement. It also shows that the respondents who thought the regulation was either 'Lenient or 'Very Lenient' said the regulation was a suitable replacement. A further look into the

individual responses and the qualitative data is provided below, to identify whether this is an error or there is a reason behind this.

Table looking at the anomalies on votes stating that the proposed regulation was fair but would not choose it to replace the UK regulation.

Table 7-Table on anomalies stating that the proposed regulation was fair but would not choose it to replace the UK regulation

Qualitative theme	EASA Explanation	CAA or EASA and why	Any further comments regarding this regulation?	A proposed regulation to replace UK regulation?
Not enough knowledge	Once again. I do not feel qualified enough to make a judgement. Are there other tests available?	They both seem suitable enough to me, if I had to choose, I'd probably go with the CAA regulation, because it seems to give the AME more discretion.		No
Not enough knowledge	It APPEARS to be more restrictive and I answer this on the basis that, from experience, the CAA usually is, often unreasonable/unnecessarily so. Stay with EASA. Going back to CAA autonomy would be a BIG mistake.	EASA. See above.		No
Not enough knowledge	G	CAA	It is not that clear exactly what Change is proposed.	No

Not enough knowledge	Looks suitable	I have no opinion your either Colour blind or not	No

By theming the qualitative information, it can be seen the 4 respondents who selected 'No' for the proposed regulation to replace the current CAA regulation, do not have enough knowledge about this specific topic and the regulation involved. The respondents are going by personal experience to answer the question or by first impressions of the regulation. Furthermore, these respondents when voting for the best and worse regulation scored all three as a 2, this should not have been allowed however this doesn't affect the results based on respondents with no knowledge of the testing and then just randomly selecting an answer. It does, however, confirm that these respondents didn't have enough knowledge to answer the questionnaire effectively.

The suitability of the proposed regulation compared to replacing the UK regulation with the proposed regulation

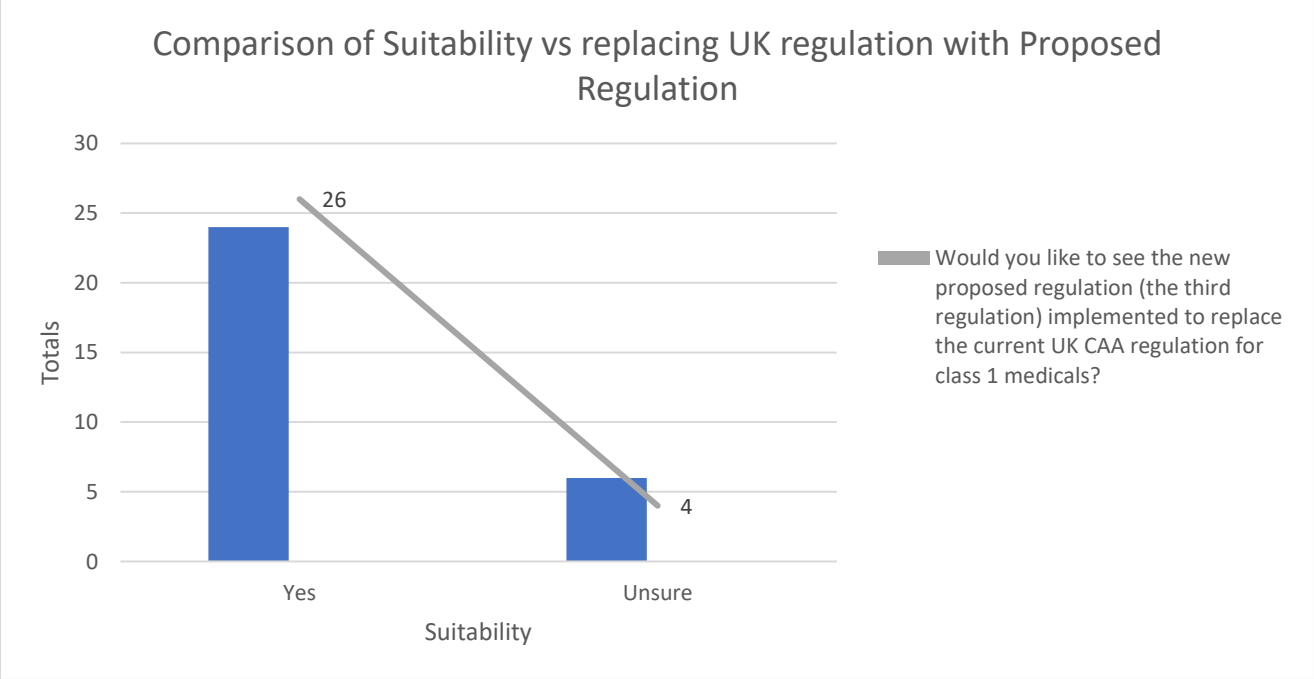


Figure 64-Cross Tabulation - The suitability of the proposed regulation compared to replacing the UK regulation with the proposed regulation

Figure 61 shows in grey the number of respondents that said Yes or No to 'replacing the UK regulation with the proposed regulation' in comparison to the blue columns, that show 'the answers to whether the proposed regulation is more suitable/aviation related than the other regulations'.

The correlation in this cross-tabulation is almost identical. According to the trend If a respondent has said that the proposed regulation is more suitable/aviation related than the other regulations, then they also vote for the proposed regulation to replace the current UK regulation. Except for four respondents. These respondents have said they would like to see the proposed regulation replacement but haven't selected that it's more suitable and aviation-related than the other test. This is further examined below.

Qualitative data in correlation to suitability vs replacing UK reg with Proposed Regulation

This table below identifies some of the important responses made by the four respondents that don't follow the trend correlation of the suitability vs replacing UK regulation with the proposed regulation graph.

Table 8-Cross tabulation - Qualitative data in correlation to suitability vs replacing UK regulation with Proposed Regulation

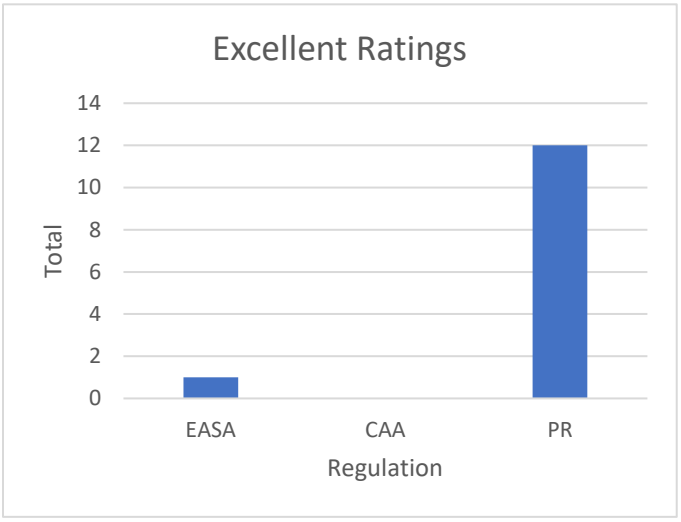
Would you change anything in the EASA regulation?	Describe the current UK CAA colour vision regulation? 2	Explanations	EASA or CAA and why?	Describe the proposed colour vision regulation? 3	more suitable/aviation related than both the CAA and EASA's regulations?	Proposed regulation implemented to replace the current UK CAA regulation?
Not enough knowledge on my part except for the information in the presentation you gave.	Fair	There are options for additional selections instead of just 15.	CAA	Lenient	Unsure	Yes
Think it should consider the latest technology to determine suitability/capability.	Partly restrictive	G	CAA	Fair	Yes	No
No	Partly restrictive	Seems to add an additional layer of testing above and beyond that	EASA seems to take the more sensible approach that balances safety and commerciality	Lenient	Unsure	Yes

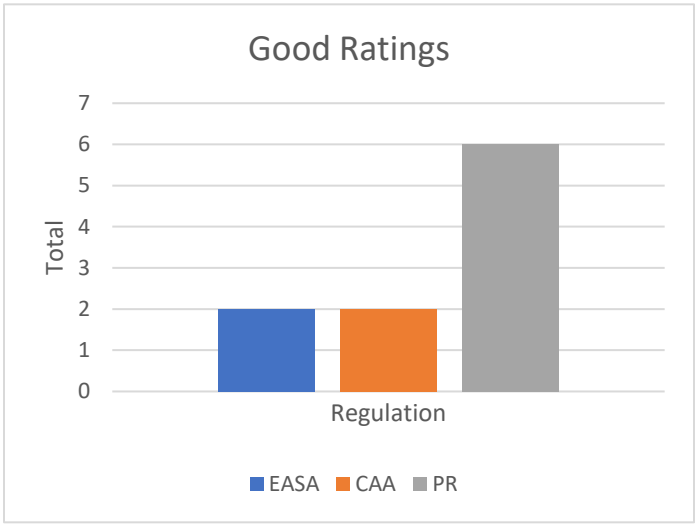
		required by EASA				
N/A	Very restrictive	UK Applicants don't have as many alternative options available to them.	EASA	Lenient	Unsure	Yes

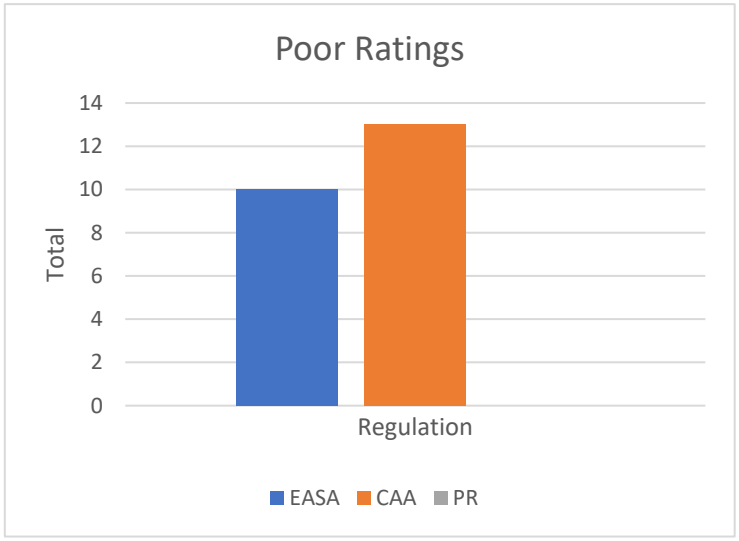
This graph shows the respondents who selected ‘unsure’ for the suitability and selected ‘Yes’ for the replacement seems to all have the theme of not having as much knowledge that other respondents have and hence put unsure on suitability. However, this does not mean these answers are not useful as it shows that even respondents with little or no knowledge of this regulation still think the proposed regulation should replace the UK regulation as they see the UK CAA as restrictive just by comparing the pieces of regulations provided in the questionnaire without any prior knowledge.

One respondent in Table 3 said ‘no’ to the replacement of the regulation but has selected ‘Yes’ to the suitability question seems to be an error in the data, as when both qualitative and quantitative data from the rest of the respondent's answers are examined, they support the view that this respondent is for the proposed regulation and negative towards the others, and hence it would be expected to put ‘Yes’ for the proposed regulation replacement. This has not affected the overall research outcome due to there being such a one-sided outcome.

Comparison between the ratings between all 3 types of regulations







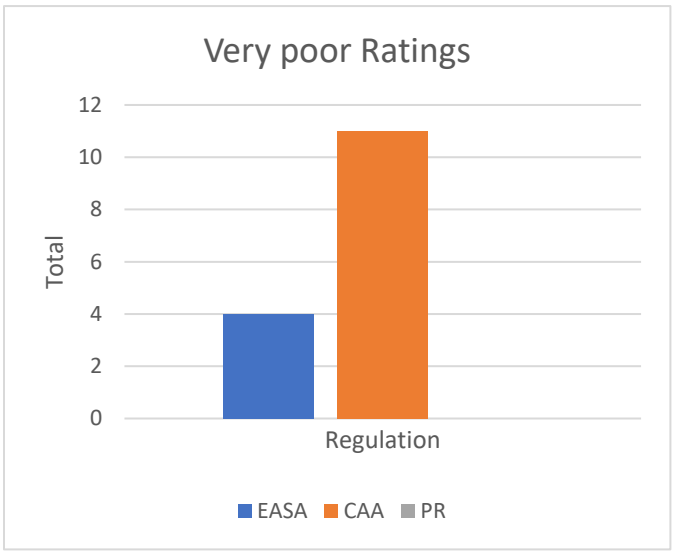


Figure 65 -Cross-tabulation -Comparison between the ratings between all 3 types of regulations

These 4 graphs show the comparison between the ratings of all 3 types of regulations, it's interesting to note that the UK is the only regulation with no 'excellent' votes and the proposed regulation is the only regulation with no 'Very Poor' votes. This again clearly highlights the support for the proposed regulation and the negative feedback regarding the UK CAA regulation.

Comparison between the respondents that agree with the proposed regulation replacement for UK class 1

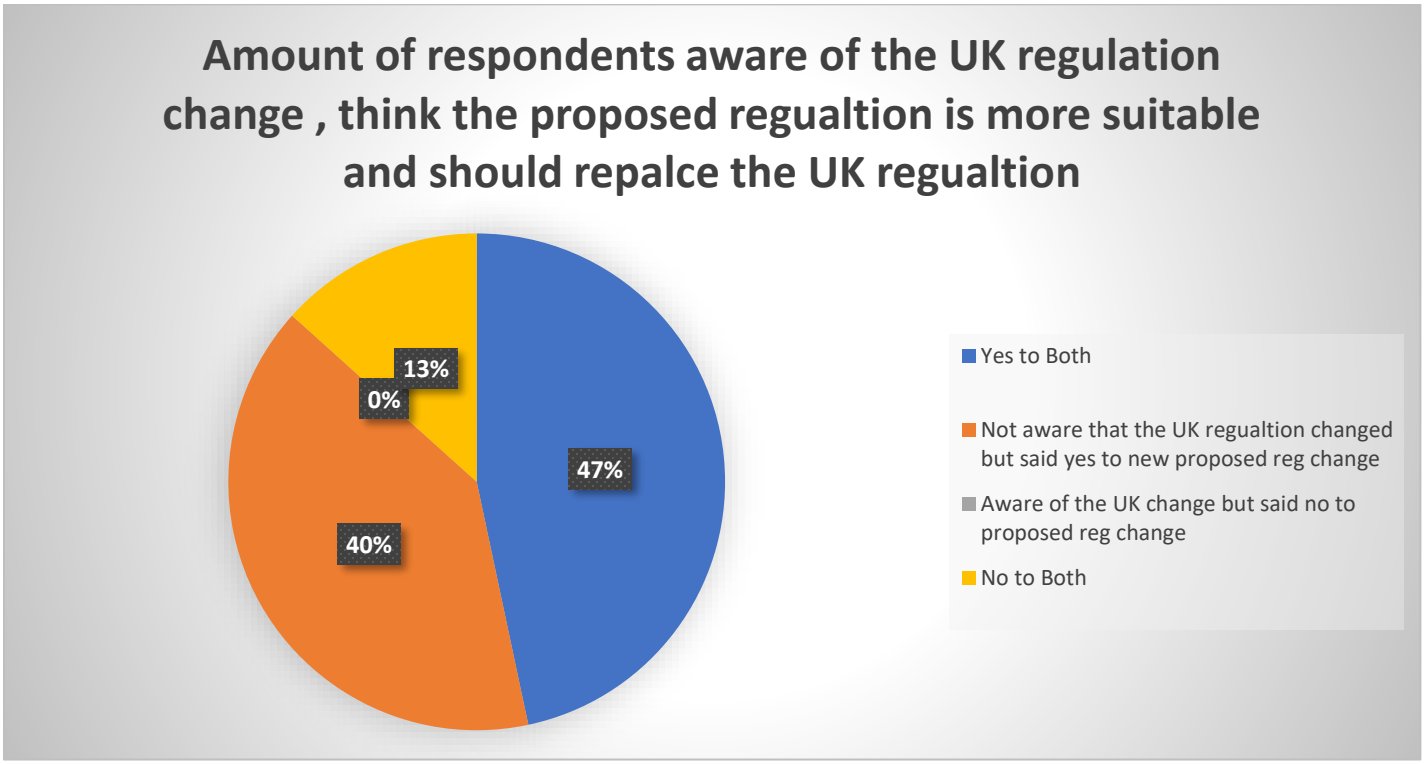


Figure 66- Cross tabulation-A comparison between the respondents that agree with the proposed regulation replacement for UK class 1

From the pie chart above this shows that 47% of respondents said 'yes' to both, however also 40% had no idea about the regulation change and said 'yes' to the new proposed regulation. This further validates the data as it shows that the data is from respondent's decisions based on their knowledge of aviation regulation, experience and the information provided in the questionnaire, therefore not biased with a pre-existing connection to the topic.

Respondents experience in comparison to the restrictiveness of the regulation options

These graphs below show in theory that the more years of experience the sample has, the more reliable and accurate the responses will be to the questions about the regulations. However, what must be taken into account is that not all experience groups are represented equally. This can unfairly represent some groups especially when comparisons are made, therefore the comparisons are limited somewhat for this section.

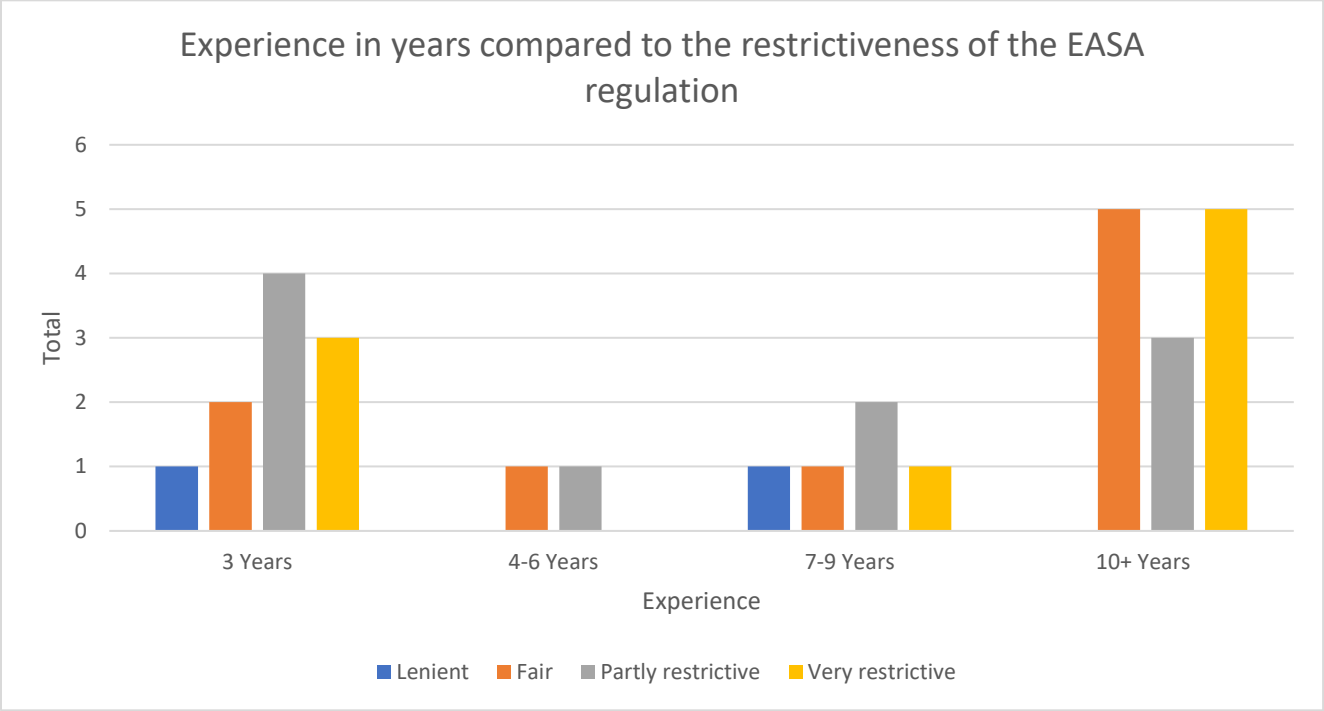


Figure 67-Cross tabulation- Respondents experience in comparison to the restrictiveness of the EASA regulation

This graph shows that respondents with 10+ years' experience selected the EASA regulation as either 'Fair' or 'Very Restrictive'. The respondents with 3 years' experience selected the most for 'partly restrictive' and the second-highest for 'Very Restrictive'.

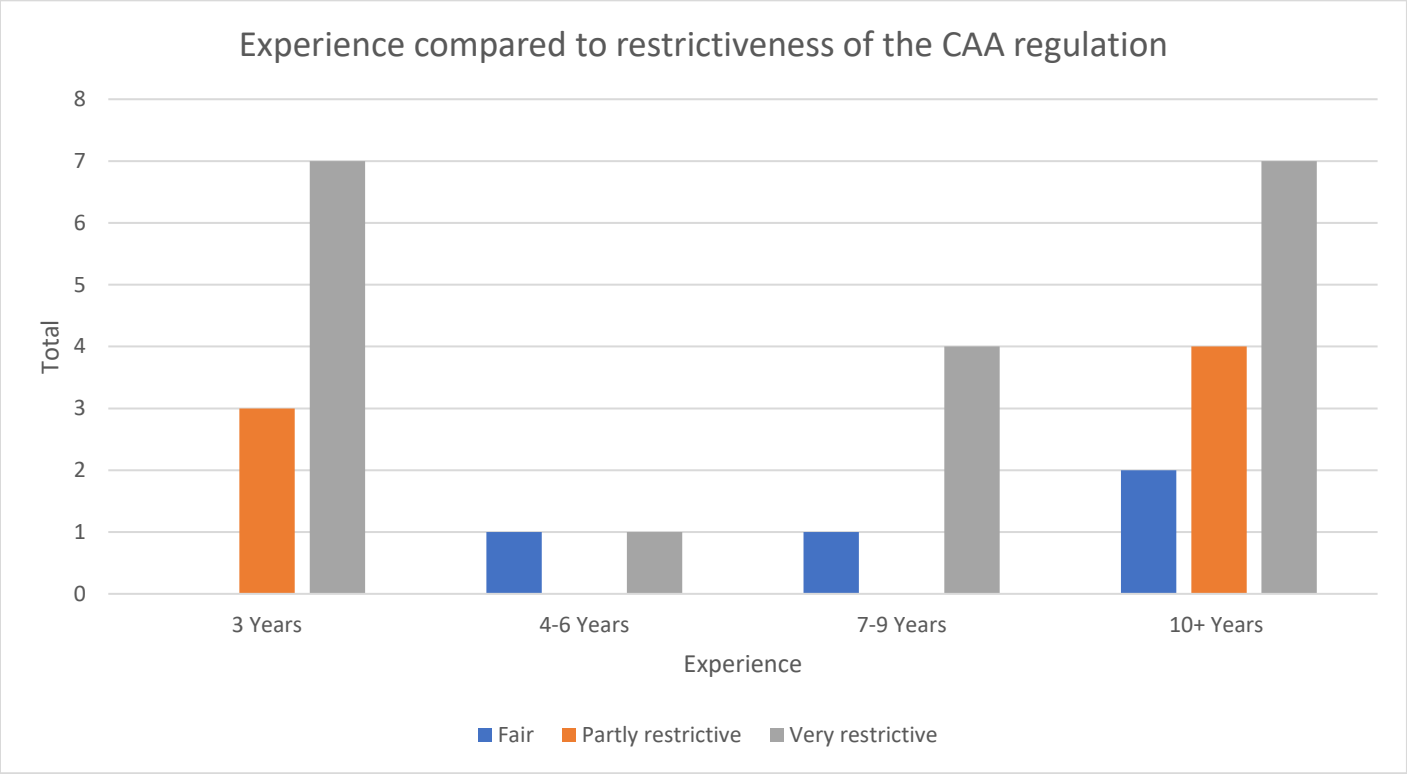


Figure 68-Cross tabulation- Respondents experience in comparison to the restrictiveness of the CAA regulation

An interesting finding from the graph above was that both the respondents with 3 and 10 years + experience selected the highest for 'Very Restrictive' which is a good sign in two ways. One is that the sample restriction of 3 years aviation experience was indeed a good decision as it shows that these respondents had a good amount of knowledge to answer the questions. Also, the results show a very similar correlation between the two largest groups represented in experience, 3 and 10+ years. This means that the amount of experience from 3 to 10+ years didn't affect the answers provide as they followed a very similar correlation.

There is also a strong finding from this graph, that respondents with 10 + years' experience - 85% said the CAA was restrictive with nearly 50% saying it was very restrictive. This reiterates the UK CAA is too restrictive. As mentioned in the literature review the problems with CAA regulation stems from the CAD test, later on, it is explored as to whether the primary data collected correlates to the literature regarding the CAD test.

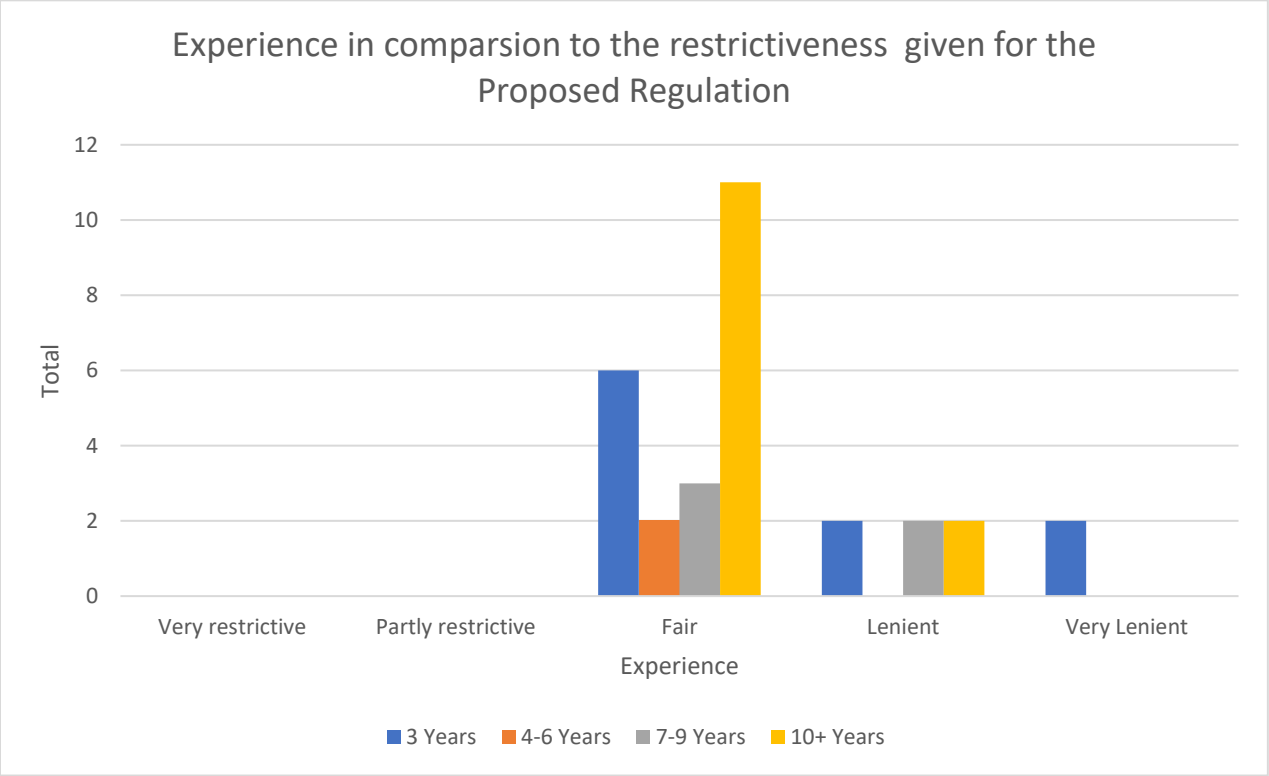


Figure 69- Cross-tabulation- Respondents experience in comparison to the restrictiveness of the proposed regulation

This graph shows nearly all respondents selected that the proposed regulation was 'fair' and that respondents with 10+ years also selected for this highly. This shows that the proposed regulation has been quite accurately selected as 'Fair' and is statistically significant.

Is the EASA or CAA regulation more suitable/aviation related compared to the level of experience a respondent has?

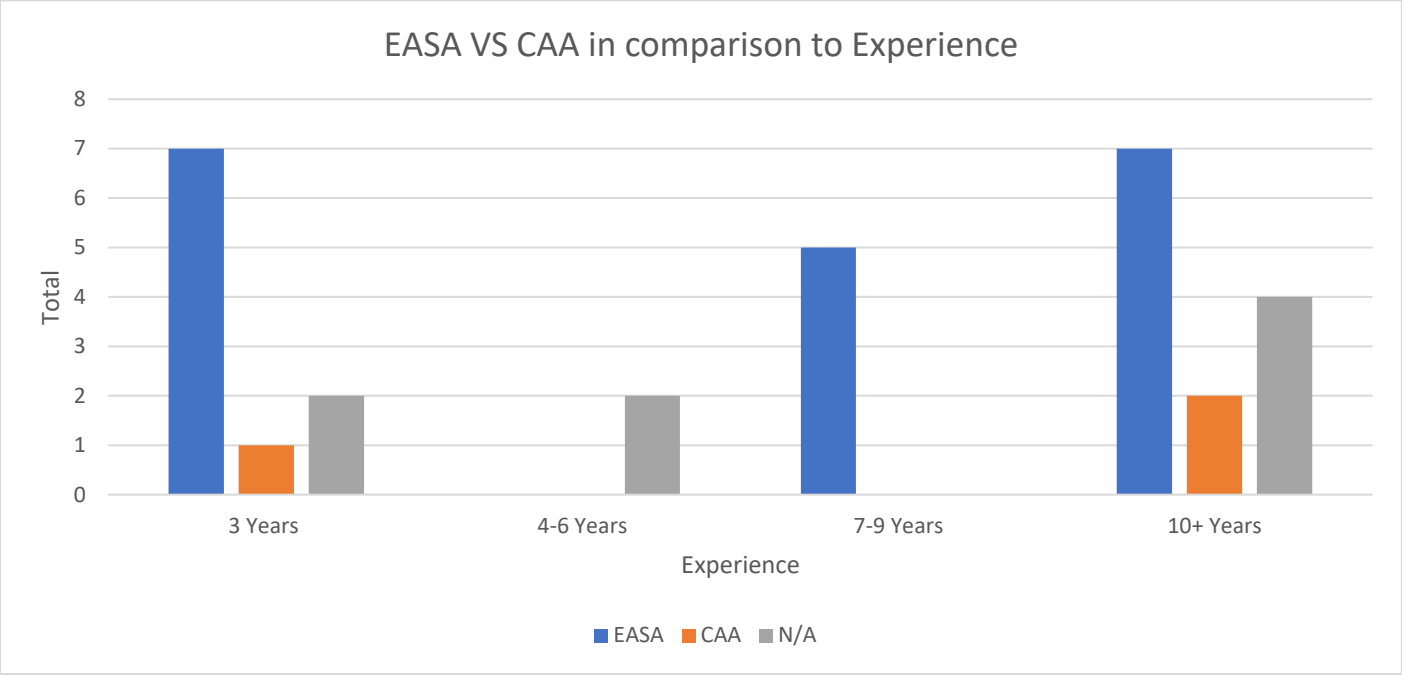


Figure 70-Cross tabulation- Is the EASA or CAA regulation more suitable/aviation related compared to the level of experience a respondent has

In Figure 72, EASA is the most popular vote however across all year groups the second-highest vote was for N/A which shows that the CAA regulation is overwhelmingly disliked by all experience groups especially the 10 + years. If the 10+ years group had more respondents that liked the CAA regulation even though the EASA regulation across all groups was still the highest selected, this could provide contradiction that the respondents with more experienced would have a better idea and that the CAA may perhaps be better than the EASA regulation, but this is not the case as all the data correlates and shows regardless of experience all age groups dislike the CAA regulation.

Comparison between experience and whether a respondent wants the proposed regulation as a replacement to the current UK CAA regulation

It's important to establish the connection between the experience and the final question, arguable the most important -whether a respondent wants a replacement to the UK regulation. From the early graphs, it has now been identified that regardless of experience this has no or little effect on the response outcome. It could be determined however that if more 10+ years selected against the proposed regulations replacement, that due

to the level of these respondent's experience, they know better and thus provides an argument against the replacement. However, as expected this was not the case.

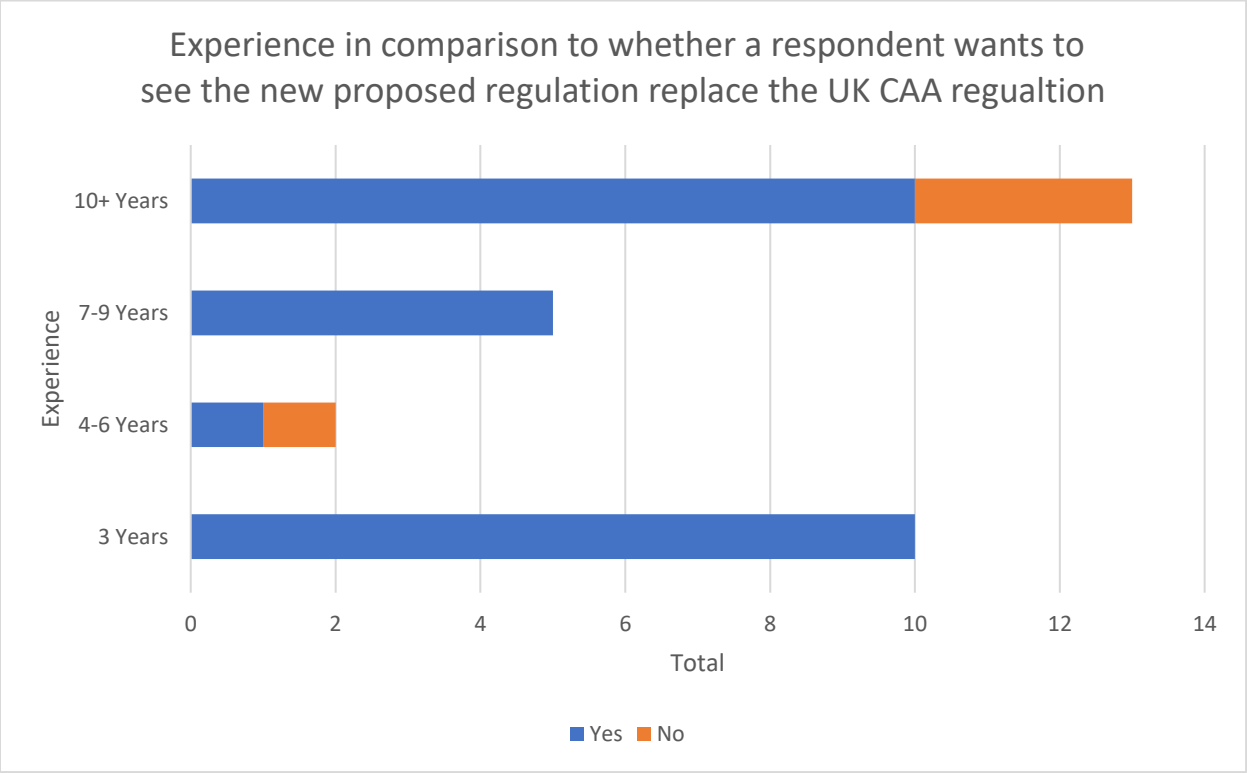


Figure 71-Cross tabulation- Comparison between experience and whether a respondent wants the proposed regulation as a replacement to the current UK CAA regulation

This graph above shows that 3 respondents from the 10+ group said 'No' to replacing the regulation and that 1 respondent which is half of the respondents in the 4-6 group said the same. This does not affect the overall outcome of results, most respondents even with high levels of experience selected for the replacement of regulation. 77% of 10+ years selected 'Yes' as shown in the pie chart below.

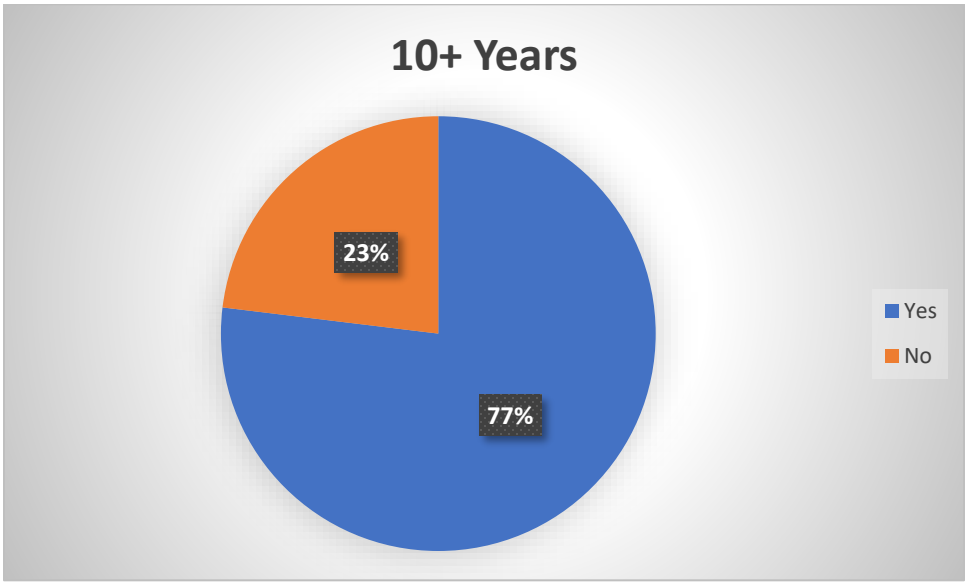


Figure 72- Cross-tabulation- Comparison between respondents with 10+ years' experience and whether a respondent wants the proposed regulation as a replacement to the current UK CAA regulation

QUALITATIVE DATA

The analysis of data from the text boxes in the questionnaire have led to identifying common themes. These themes will be synthesised to add context to the research, as well as being compared with the literature review to establish an outcome.

Regulation description responses

These questions were used to provide context to the multiple-choice questions regarding each regulation. 3 themes were identified from most of the comments that were related to the reasoning for the descriptions regarding all 3 regulations.

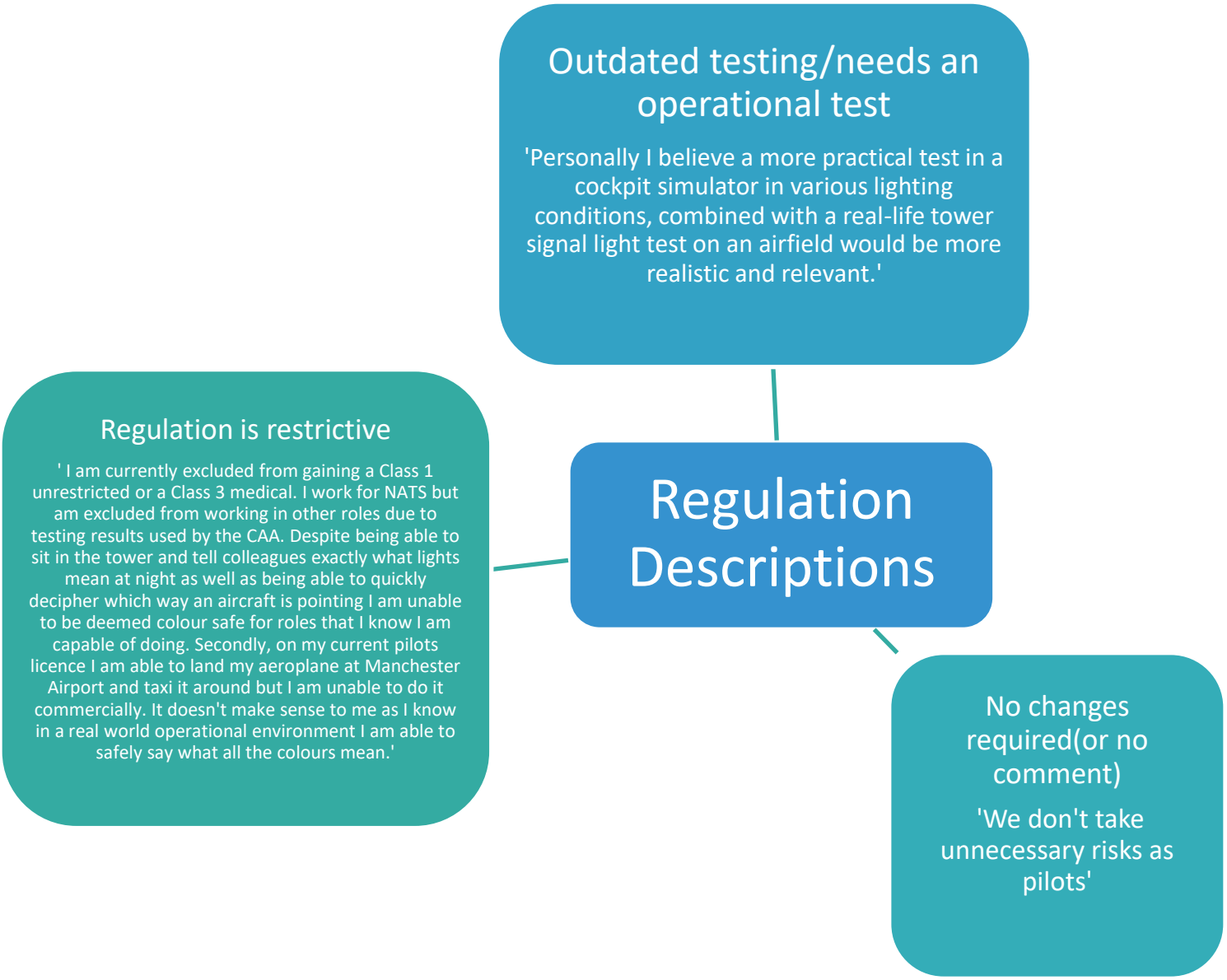


Figure 73-Qualitative Data-Themes relating to the regulation description

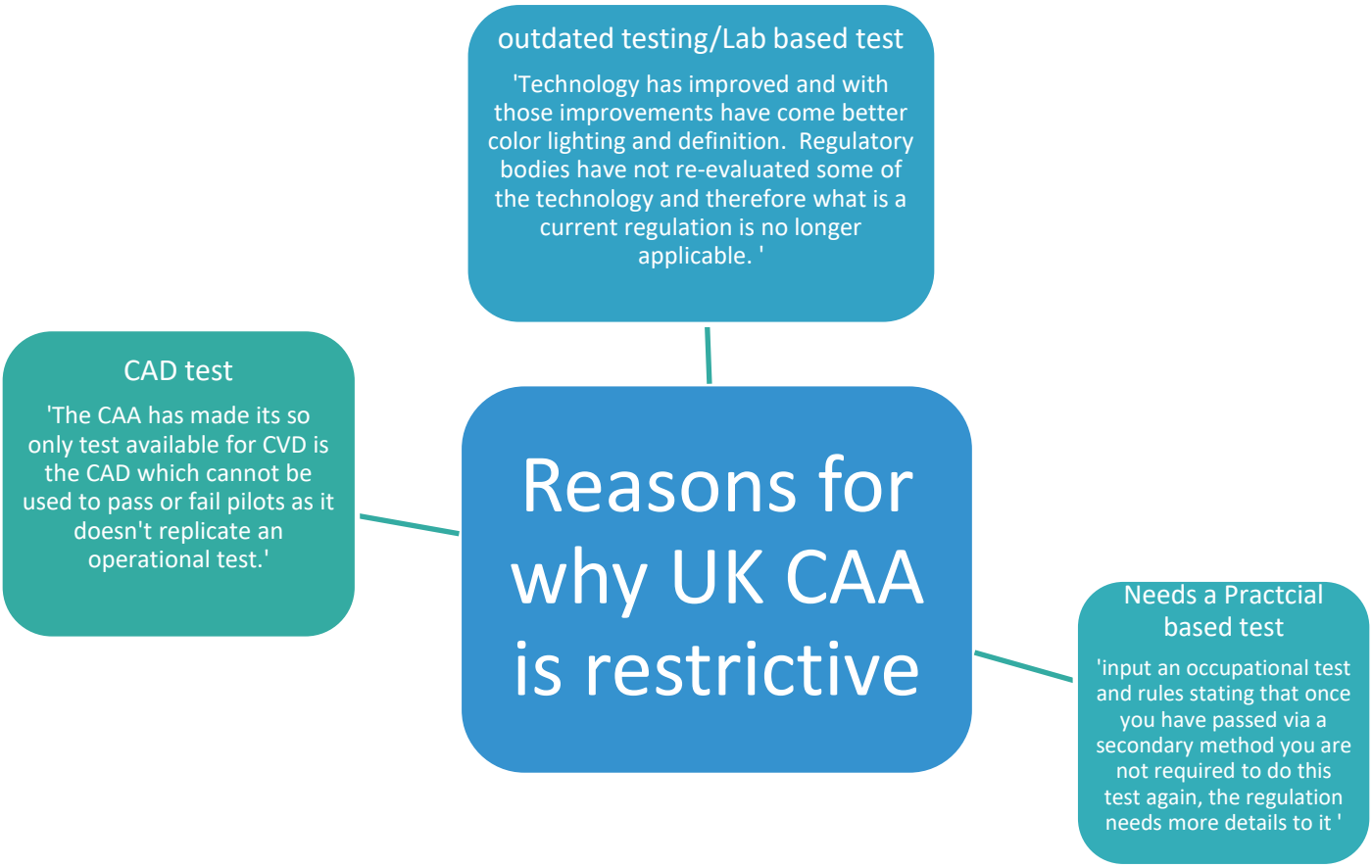


Figure 74-Qualitative Data-Themes relating to the reasons why the UK CAA is restrictive

CAD test exact reasons- all link together

When examining the response to the UK regulation it was expected that responses would include the CAD test, as this is the only CVD testing option and thus goes hand in hand.

Common themes were identified that related to the CAD test, these 5 themes all negative regarding the CAD and all link with each other have been represented in a cycle chart below. There were no positive comments towards the CAD or UK regulation even though there were 4 respondents that thought the regulation was fair. This supports the argument that these respondents had not enough knowledge.

All 5 of these themes were mentioned in the literature reviews by the CVDPA and the DTA report. This study has identified that the CAD test is not a good test according to both literature and opinions from aviation professionals, thus the UK CAA regulation is over-restrictive by using this as their sole CVD test method.

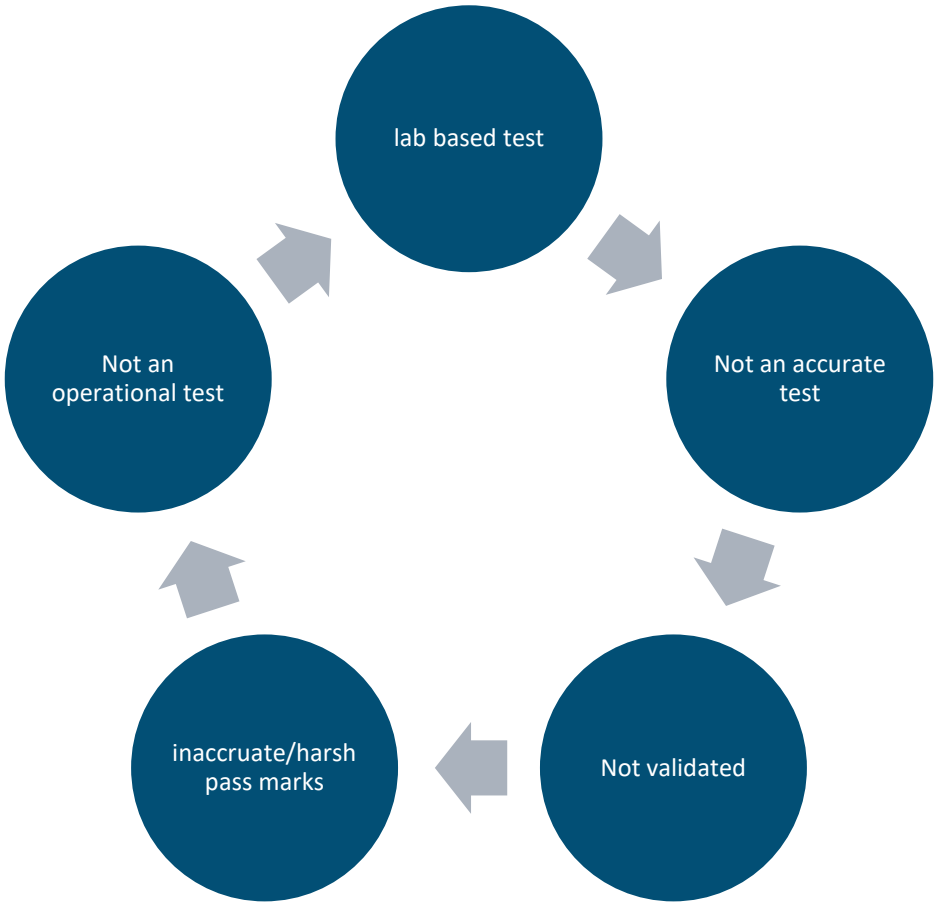


Figure 75-Qualitative Data-Themes from comments linked to the CAD

Practical test comments-link to literature review

The literature review indicated one method in which the current UK regulation could be improved, by the addition of a practical colour vision assessment, similar to the OCVA that New Zealand implement. This was reiterated in the many comments collected. To further support the decisions made for the proposed regulation and its format. An analysis of the selected arguments for and against the practical test is ideal in this case.

A very important supporting comment that stood out was from a Male respondent with 10+ years' experience as a Pilot in the age category 36-45. They said regarding the current regulation

'There is no provision for operational testing. As an Australian CVD pilot with protanopia, I have enjoyed a 20-year career here with over 8000 hours experience (despite failing every clinical CVD test including the CAD). I have been involved in check & training roles, airline management roles & am currently flying the A320 after spending 8 years flying Dash 8's. I have passed every single flight test and simulator check on

first attempt with high grades. The UK/EASA should look at the recent New Zealand and Australian examples which recognise the value in proper operational testing.'

This statement supports that the lab-based test do not demonstrate whether a respondent can safely fly an aircraft and that only a practical based colour vision assessment can determine this. The respondent also reiterates that the OCVA is a good option in which the UK and EASA should implement.

Further comments from other respondents also support this theme:

'need an occupational test, all easa tests are currently lab-based and the pass marks are more restrictive especially for the Ishihara than other ICAO states'

'input an occupational test and rules stating that once you have passed via a secondary method you are not required to do this test again; the regulation needs more details to it'

'Personally, I believe a more practical test in a cockpit simulator in various lighting conditions, combined with a real-life tower signal light test on an airfield would be more realistic and relevant.'

'Their tests are more lab-based than practical.'

The comments below are against the change or don't think there are any necessary changes, they have the theme that the EASA regulation, not the CAA regulation, has a suitable number of testing options and hence lab-based tests are sufficient, scientific tests that provide a good level of safety.

'EASA regulation is in place from years and years, with a good balance of safety and also CVD entrance in the cockpits'

'Multi-layered colour testing. Failing the first test is not an instant rejection.'

'Provides a suitable number of testing options.'

'Seems like the EASA regulation gives multiple opportunities for the respondent to pass.'

'No, because it is based on scientific principle and provides pilots with a suitable number of opportunities to demonstrate their colour capability. Therefore, EASA's regulation is objective, too harsh and nor too fair.'

Important comments -colour vision specialist

A colour vision specialist with over 10 years + experience answered the survey, his comments provide a very scientific and reliable piece of evidence that helps give strong support to the main arguments in this research.

'Somewhat arbitrary pass-fail cut-offs for the additional tests.

'Needs the development of a functional test that includes critical tasks.'

'As above, needs the development of a functional test that includes critical tasks.'

'Reduced choice of secondary tests is worse. Nagel anomaloscope is a reliable test. CAD test is a self-certified test promoted by City University that requires calibrated equipment. Independent verification of the test and cut-offs is needed.'

'EASA. Lantern testing is well-established, but the equipment is becoming unavailable.'

'New functional tests are needed.'

It is important to note that many of the colour vision specialists comments relate to the outcome of the literature review; that the UK regulation needs a functional practical element that tests the critical tasks that a pilot faces, the current regulation pass marks are too restrictive and the CAD test as the sole CVD test is 'worse' thus the UK CAA is more restrictive.

It is also interesting that the respondent mentions the EASA lantern test is 'well-established', in the literature review it was shown that the lantern test had high specificity and sensitivity scores. (Bailey, K. and Carter, T, 2016). The equipment is becoming more unavailable, this is probably due to the age of these tests.

Also mentioned is that the anomaloscope is a reliable test, all these comments are completely the opposite to the CAA's reasoning for the regulation decision. (caa.co.uk, 2019) This leads to the observation that the UK CAA reasoning, listed in Appendix 4, has no references and is unknown where the information derives from. This in combination with the comments from the colour specialist really

Lastly and even more importantly this specialist states the 'CAD test is a self-certified test promoted by City University that requires calibrated equipment. Independent verification of the test and cut-offs is needed.' This reiterates the evidence found in the literature review from the DTA and CVDPA report and the comments from other respondents, this strengthens the evidence that the CAD is a flawed test and thus the UK regulation is over-restrictive.

QUALITATIVE DATA INTO QUANTITATIVE

It is important to also examine the qualitative data by correlating the themes to get the context concerning the answers. Cross tabulating this with the quantitative gives then a good understanding of any anomalies, some that have already been previously explored and it also helps to further strengthen the data.

Reasons for the EASA regulation answers

The percentages don't add up to 100 due to respondents saying more than one of the options

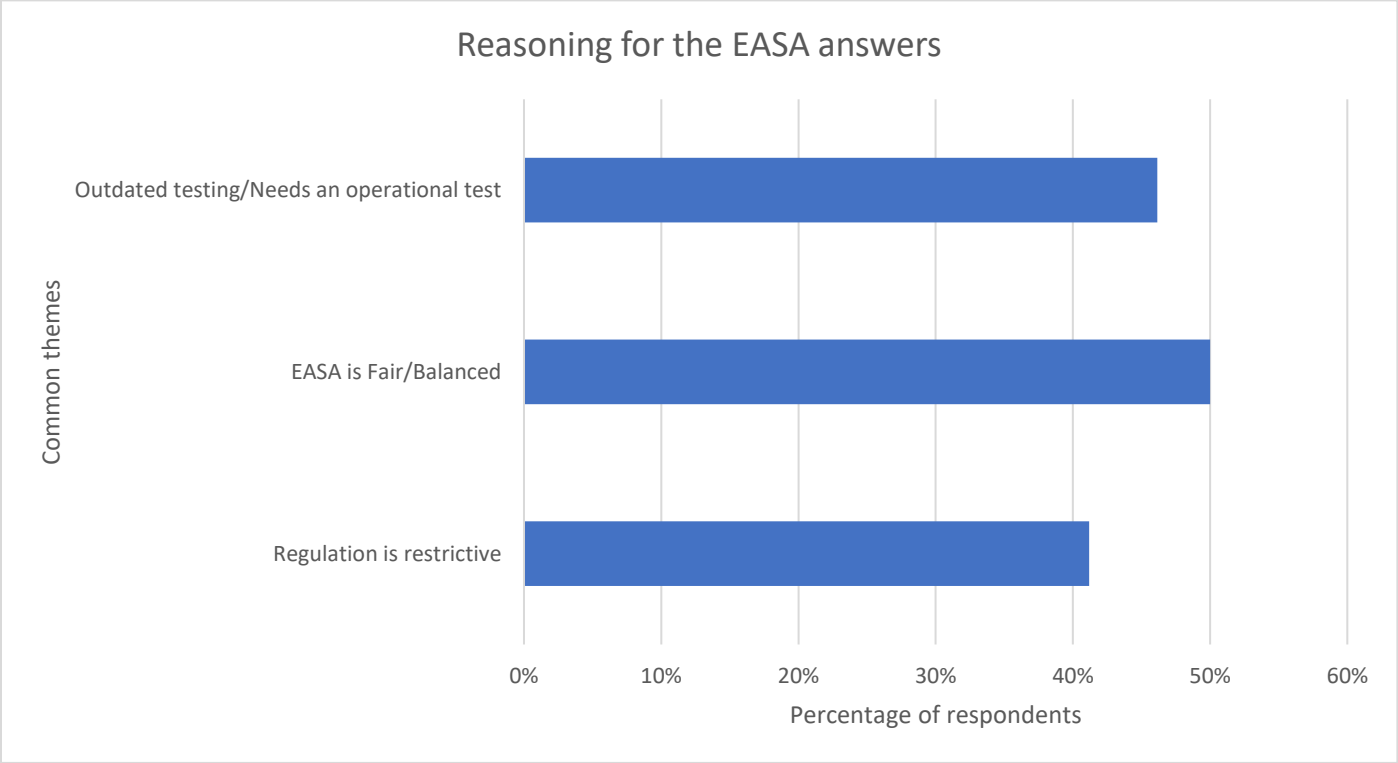


Figure 76- Qualitative data- Reasons for the EASA regulation answers

It can be seen in the graph above that 46% of respondents said that the EASA regulation has outdated testing or needs an operational test. The highest selected category was that EASA is fair and balanced however this isn't by much at 50%. 41% said that the regulation was restrictive. Furthermore, what is interesting to understand is if a respondent selected that the EASA regulation has outdated testing or needs an operational test they would also be likely to say that the regulation is restrictive as well. So, it can be argued the percentage if added together would be larger than the 'Fair' option.

Comparison between experience and reasoning for the answers to the EASA regulation

These 3 graphs below show that nearly all but 1 respondent from the 10+ experience group selected either that the regulation is restrictive or that it needs an operational test. Another interesting point to note, the 3 years group was the highest voting group for the 'Fair' option. This could be down to a lack of knowledge or experience in understanding the colour vision regulation, also a lot of others in the same year group selected for the other two options. This was also a small number of individuals and this is replicated in the other age groups, therefore there isn't much further information that can be drawn from this other than as before, a good sample restriction was in place that ensured, regardless of experience the response is likely to be the fit the trend.

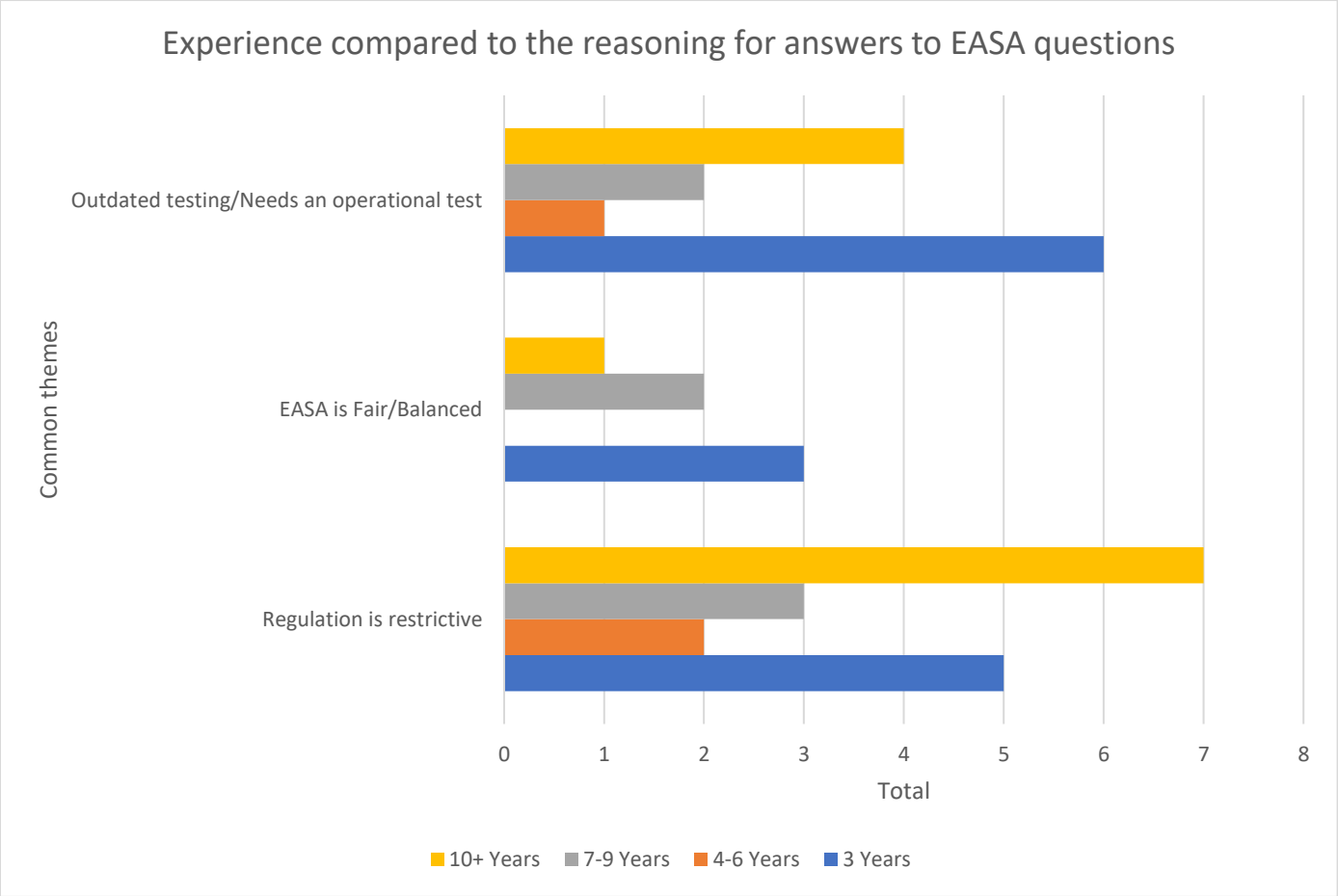
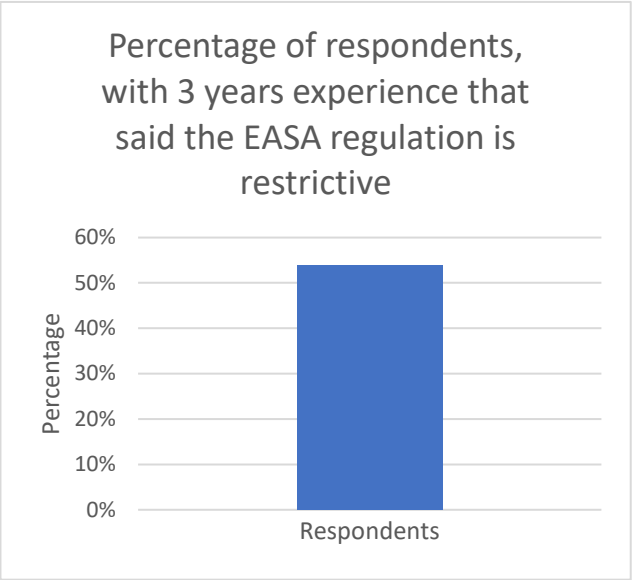


Figure 77- Qualitative data- Comparison between experience and reasoning for the answers to the EASA regulation



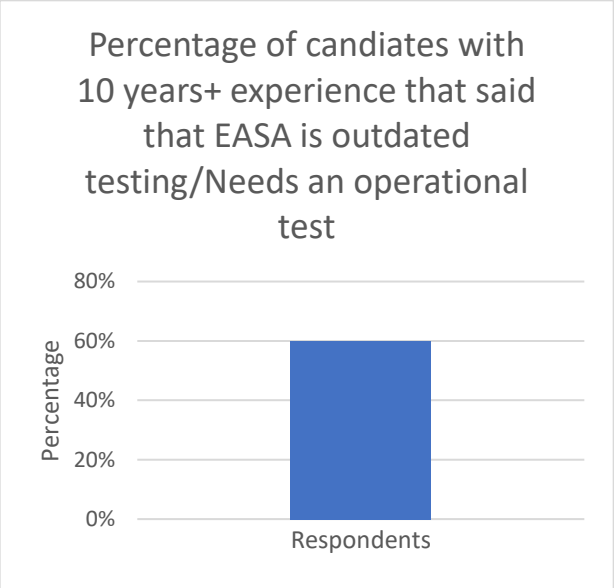


Figure 78- Qualitative data- Percentages of respondents with 3- and 10-years' experience and reasoning for the answers to the EASA regulation

Suggestions for what respondents would change in the EASA regulation

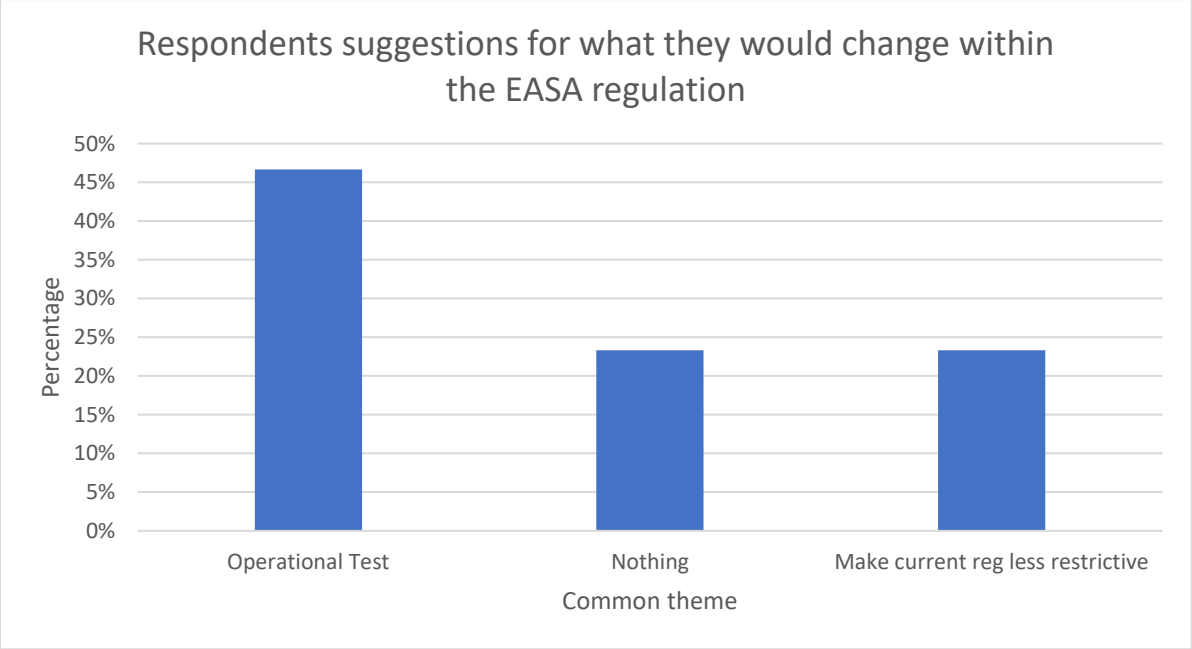


Figure 79 -Qualitative data -Suggestions for what respondents would change in the EASA regulation

The most suggested theme was that an operational test in which should be implemented into the EASA regulation, the other themes were equal in responses. However, by adding an operational test it indirectly makes the regulation less restrictive. 45% is a considerable amount of responses.

Reasons for the CAA answers

All three themes do not add up to 100% as respondents can state multiple options.

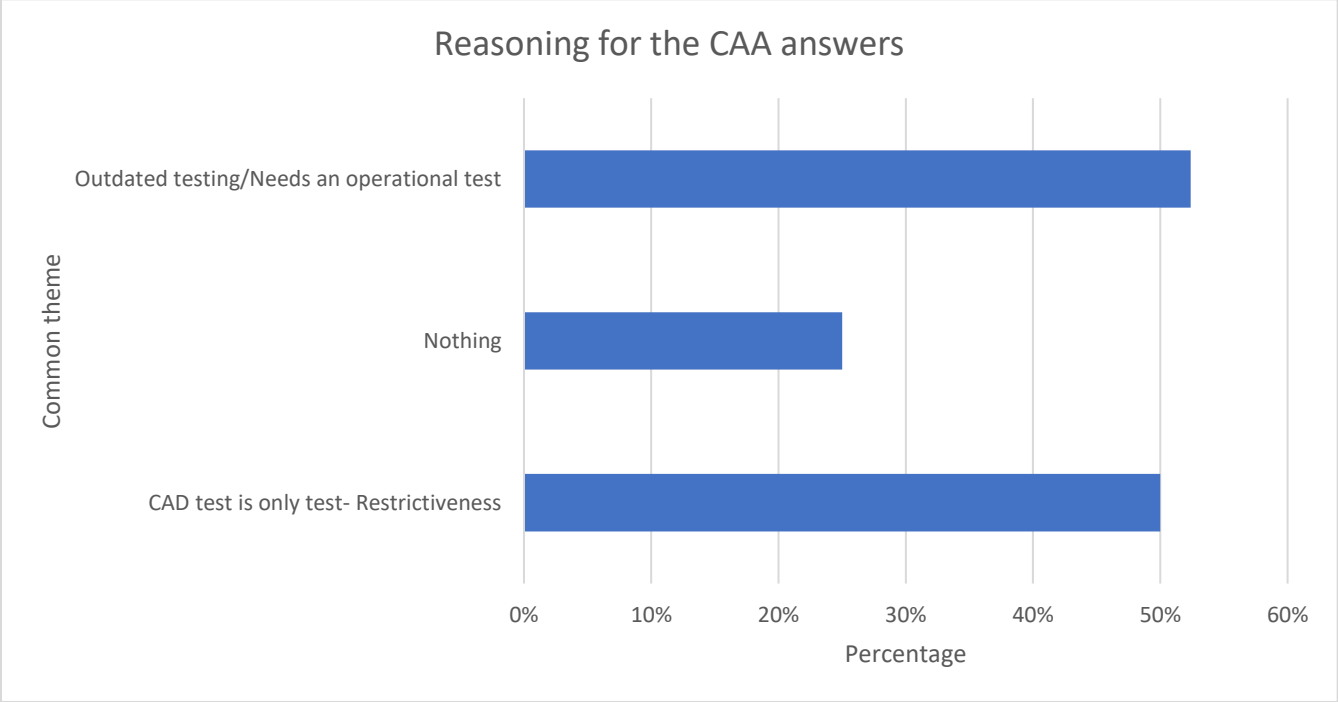


Figure 80- Qualitative data- Reasons for the CAA answers

It can be seen from the graph above that a large percentage of respondents want an operational test implemented into the UK regulation and that they also think by having the CAD as the only testing option for CVD, this regulation is too restrictive.

Comparison between experience and the reasoning for the answers to the CAA regulation

These graphs below show the overwhelming responses that the UK CAA regulation needs an operational test and by having the CAD as the only testing options this is too restrictive.

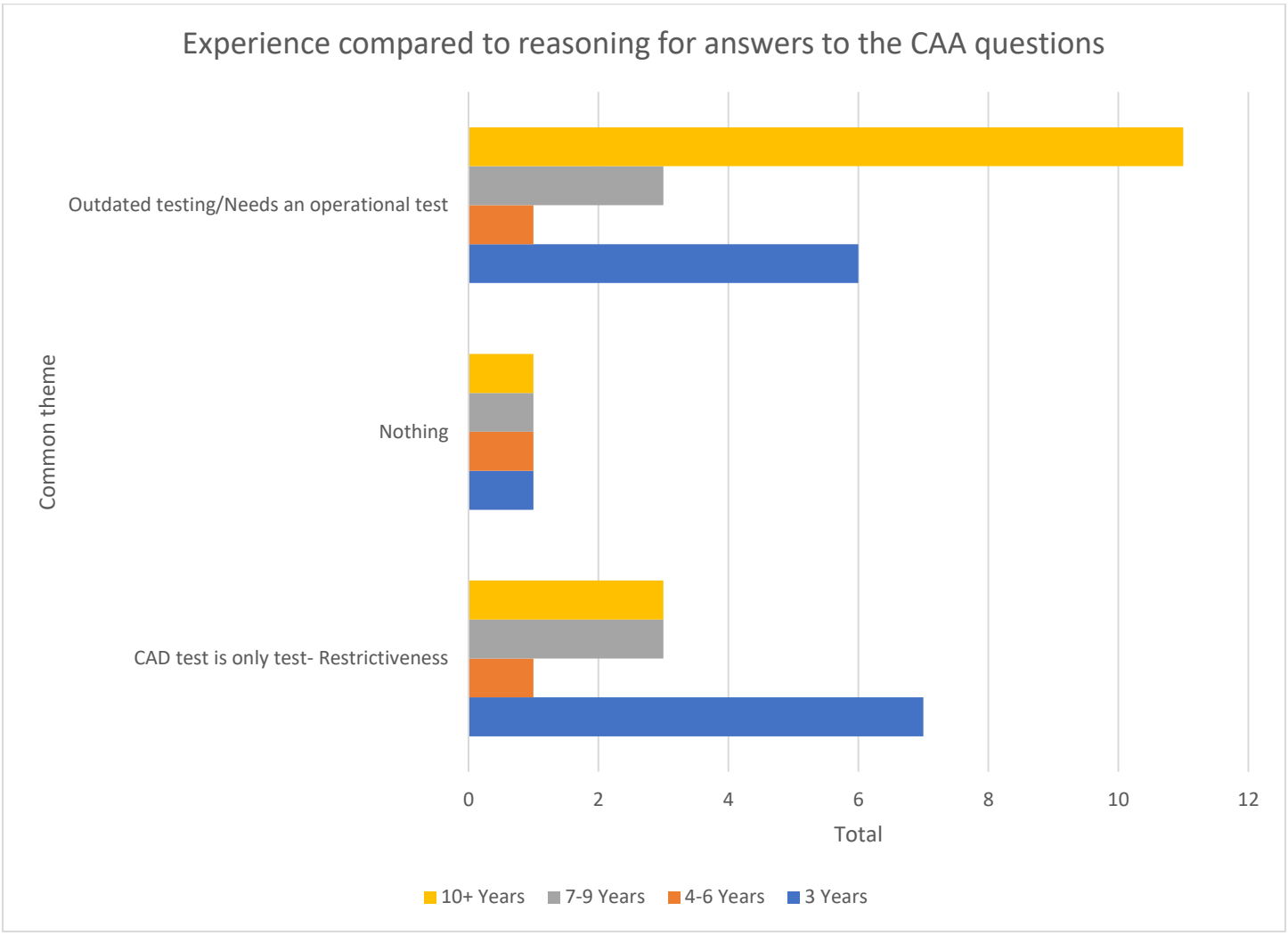
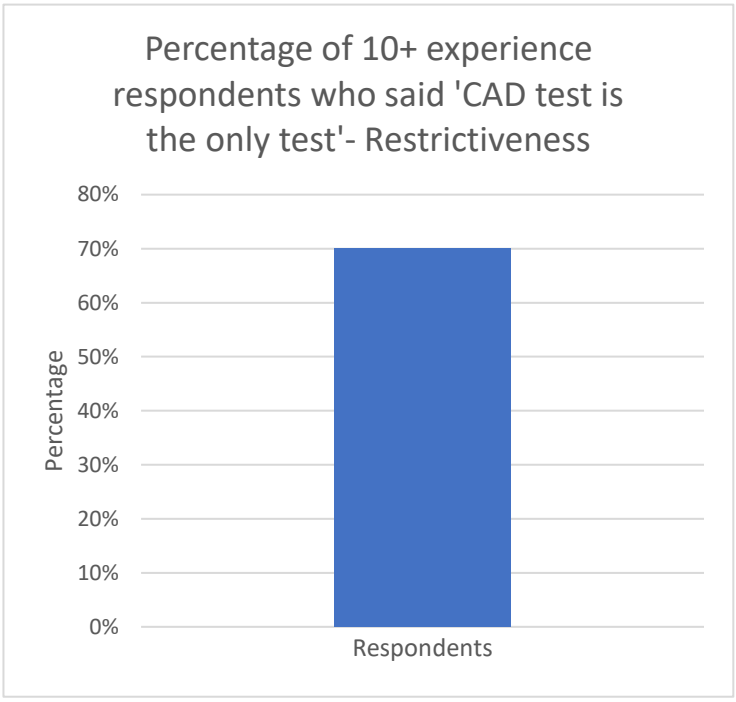


Figure 81-Qualitative data- Comparison between experience and the reasoning for the answers to the CAA regulation

As can be seen from these two graphs below the most experienced group, 10+ years, 70% said that the UK regulation is too restrictive, and the CAD test is the only test option. 85% said the CAA regulation was outdated and needs an operational test.



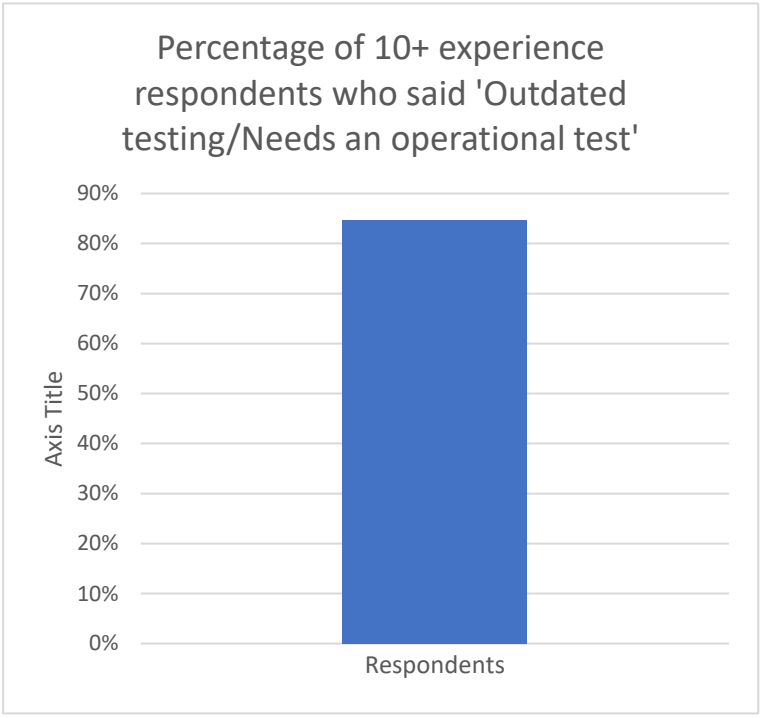


Figure 82- Qualitative Data-Percentage of respondents with 10+ years' experience responding to the CAA regulation

Comparison of experience and responses for the EASA vs CAA question

These combined column graphs are very useful in seeing what percentage of each year group selected either EASA, CAA or Neither. The largest percentage of votes for the CAA test was by the 10+ year group, however, this is still a very small number by looking at the direct data. Therefore, this is not a reliable statement. The EASA option is very balanced between the three most represented experience groups. It is also interesting that the 4-6-year group selected 'Neither' as the option. However, this was also the smallest represented group with only 2 respondents. Therefore, this comparison should not be taken too strongly.

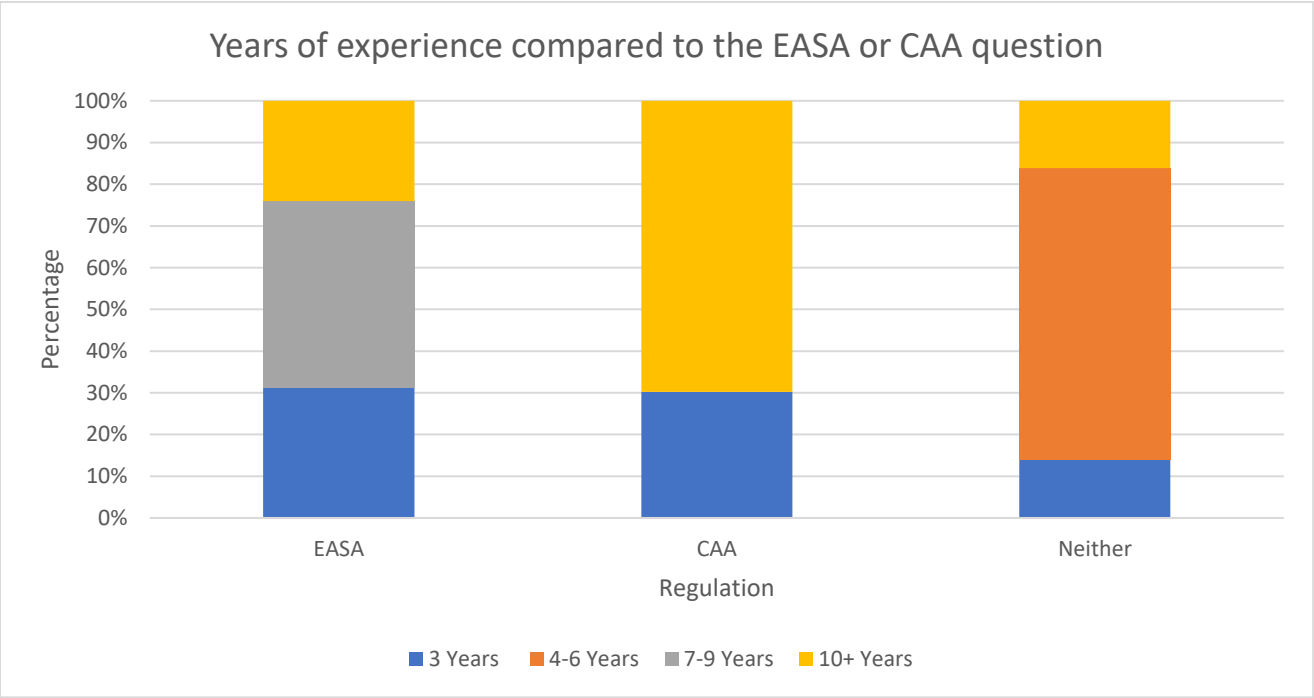


Figure 83 Qualitative Data- Comparison of experience and responses for the EASA vs CAA question

DATA REGARDING THE CAD TEST

The UK CAA use two tests in their regulation to asses class 1 pilots however as mentioned in the literature review only one test allows CVDs to pass and that's the CAD test. (Cvdpa.com, 2019) From the data shown in this research, the UK regulation and hence the CAD test have been selected very negatively. It is important to understand why this is the case. Comments have identified 5 common themes in figure 77. By looking at opinions directly related to the CAD, 3 themes appeared regularly out of the 5 identified. 13 comments said the CAD test was restrictive, 7 comments said that the CAD does not simulate an operational test and 5 comments mentioned that the test was inaccurate. In fact, 63% of respondents when explaining their thoughts about the UK regulation negatively mentioned the CAD test. The CAD test was not mentioned in the questionnaire as part of any questions, it is interesting to see that respondents have singled out this test from the two options in the UK regulation as being a major problem.

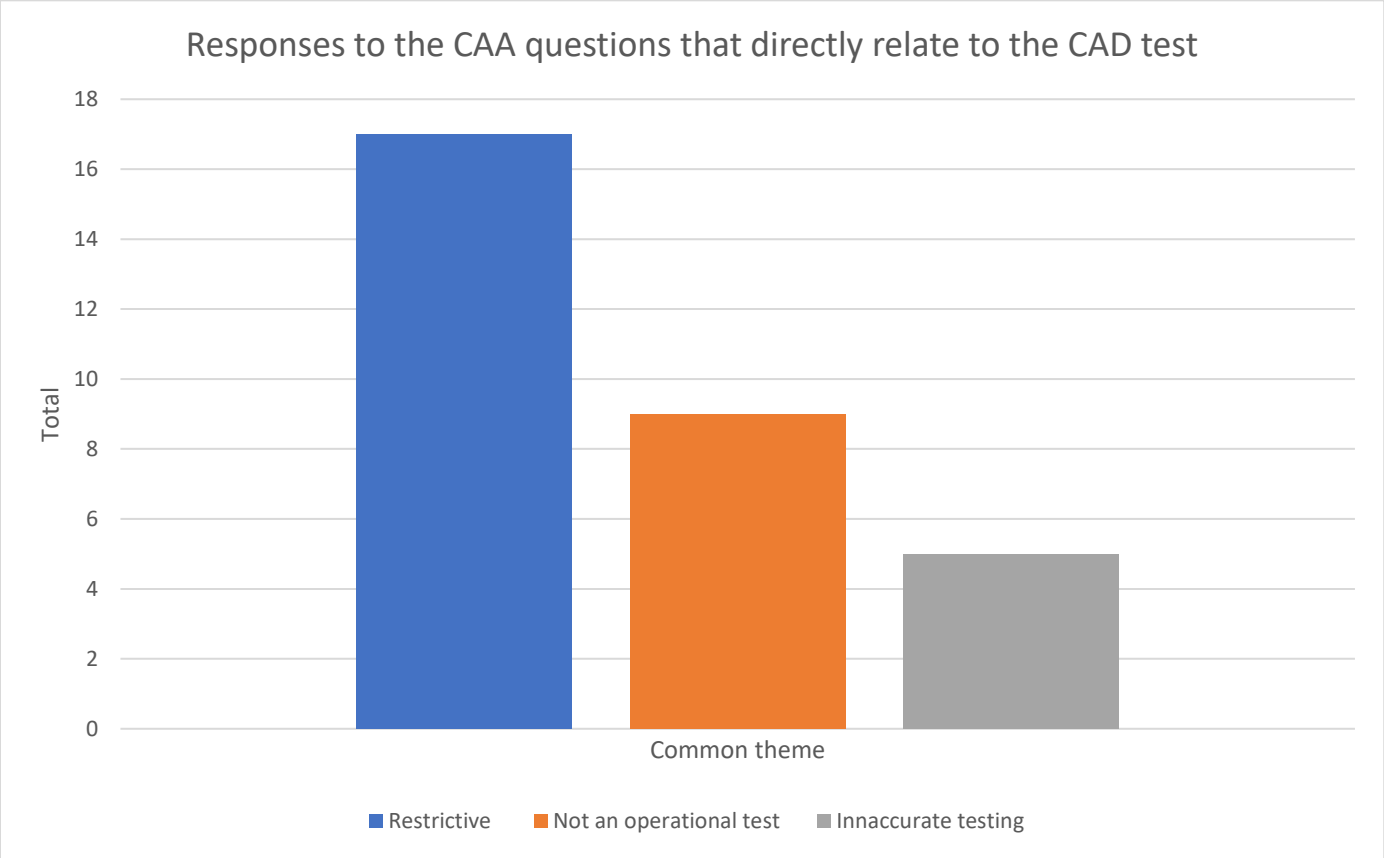


Figure 84-Qualitative data regarding the CAD test-Responses to the CAA questions that directly relate to the CAD test

Correlation between the negative responses with CAD test and the UK CAA regulation

To show the correlation of the number of respondents that dislike the CAD test compared to how many respondents dislike the UK CAA regulation the correlation is very interesting to examine. 19 respondents mentioned the CAD, all of which were negative. The correlation is very strong, and the CAD responses make up a large amount of the negative responses for the UK CAA regulation.

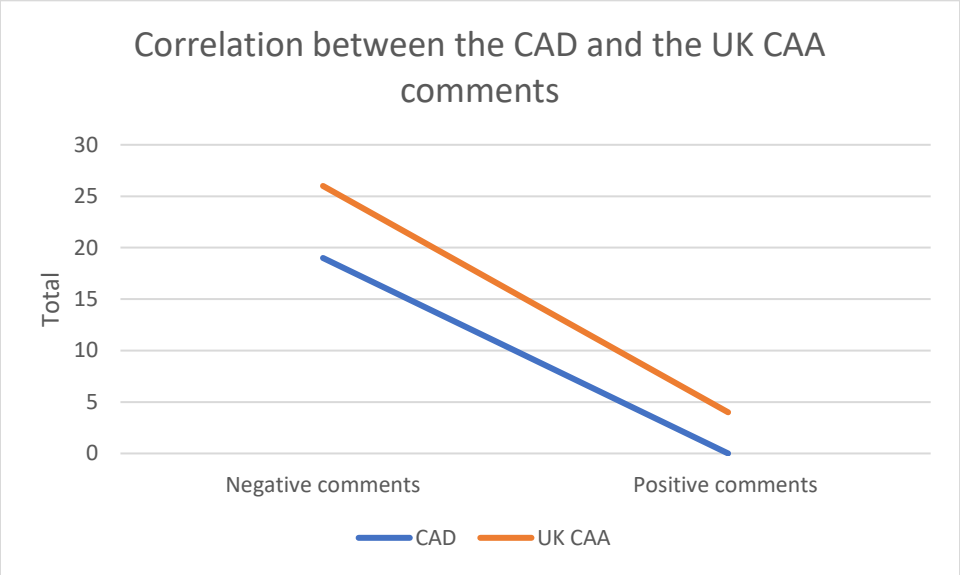


Figure 85--Qualitative data regarding the CAD test- Correlation between the negative responses with CAD test and the UK CAA regulation

FURTHER DISCUSSION

The methodology shows there was a rigorous and structured research approach. Using the research onion in synthesis with the research aims, this enabled the data collated to fully answer the research questions while also exploring patterns, trends and correlations.

The data above provided several statistically significant conclusions to the research which are reliable and impartial. The anomalous identified had little or no effect on the overall outcome of the research as the responses were very one-sided for the most part. The only limitations as mentioned was the sample size that affected some of the comparisons, for example, Age and Experience compared to other questions. However, correlations suggested that these even with a larger sample would maintain a very similar outcome.

The reliability of the data can be validated the fact that a sample size of 30, is big enough to demonstrate an overall opinion from a wide number of sectors within the aviation industry. Furthermore, with the questionnaire restriction to respondents with 3 or more years of aviation experience, ensured that the questionnaire is filled out effectively and limits the possibility of random answers to questions because respondents don't know. The research also shows that the research has a breadth of experience from all sectors in aviation. Lastly, by examining the colour specialists' responses in combinations with the rest of the

data and the literature review, it has been found that these all correlate and thus the data provide is very reliable.

The impartialness was shown by the percentage that wasn't aware of the UK regulation change in 2018- 47%,40% still selected for the proposed regulation replacement with only 7% voting against. These statistics show the weighted results of just the respondents with no prior knowledge of the UK regulation. This correlates with the overall data and thus provides good evidence that due to the trend matching; the data is both reliable and impartial. The questionnaire was sent out to well established RAeS groups with specialists in the field. It was also posted on LinkedIn using the popularity of the published article as a way to promote the questionnaire. This could be seen to collate respondents with a pre-existing relationship to the topic or had biases towards the research article, however from the data shown regarding the percentage that weren't aware and still selected for the proposed regulation change. This was nearly 50% of respondents. Due to this trend, biases would not likely affect the overall outcome.

Conclusion

There was much debate as to whether the CAA regulation is suitable in assessing commercial pilots colour vision. Arguments state that the regulation has been used for many years, is scientifically proven and it prevents any possible risk. The counter-argument shows there aren't enough testing options and they are all lab-based tests, the literature review and the comments in the research state that lab-based tests does not determine whether a respondent can safely fly an aircraft, thus there should be a practical testing element similar to the testing New Zealand, Australia or the FAA have implemented. The main reason for asking questions about the EASA regulation was to see if the UK CAA could ever go back to this format if it was deemed too restrictive, however with the conflicting results in this particular question, this study cannot conclude that this would or wouldn't be a suitable option.

The results regarding the UK regulation were examined and in combination with the literature review, it was established that regardless of experience, the CAD test and the CAA regulation, are too restrictive. The responses and comments towards the CAA regulation were overwhelmingly negative, linking to the themes that there are many problems with the CAD test, one test is too restrictive, it not an operational test, has inaccurate pass marks and the regulation is moving backwards against the direction of the UK's goals to be the best country in the world for aviation. The relevance of this regulation and the CAD test must be seriously questioned in their usefulness to determine whether a respondent can safely perform their duties as a pilot. Even more shocking was that it has been identified from both the literature review and the colour vision specialist that the CAD had never been independently reviewed, the test is based on inaccurate PAPIs and thus the test and pass marks are inaccurate in which they are failing many pilots on. Trials in the FAA showed that PAPI cannot be confused by respondents with a colour defect, thus leading to the fact colour vision testing might not be required at all. (CAA, 2006) CASA's CMO statement in Appendix 3 highlights the now lack of importance with colour vision in the aviation industry.

Prodigiously respondents' results suggested the implementation of an operational test, this linked with the recommendations from the literature review and thus was implemented into the proposed regulation prior to the questionnaire. Evaluation of the questionnaire came back with positive results, 87% would want the UK current regulation replaced with the proposed regulation, it also discovered that respondents which said 'No' were even unsure or didn't understand the differences enough between the regulations. If more information

was provided, this could have potentially increased the overall result further. The few anomalies found in this research had very little effect on the overall outcome. It would be interesting in future research to do a multi-method approach, obtaining quantitative data in an interview format from specialists with a wealth of knowledge in this area to see if this correlates with the quantitative data.

If the UK CAA continue to use this regulation the irregulates identified will increasingly become worse. The current Brexit situation means that the UK CAA will become its own independent state of authority creating its own laws and regulations. (CAA, 2020) This is seen as the perfect opportunity for the UK CAA to implement the highly recommended proposed regulation suggested from this study. To create these changes, this research will be forwarded to the DFT and the UK CAA in the aim to move towards creating a crucial change in the UK colour vision regulation for commercial pilots.

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Appendices

APPENDIX 1- QUESTIONNAIRE

Questionnaire on the UK CAA Colour Vision Regulation for Commercial Pilots

Please only fill in this questionnaire if you have over 3 years experience working in the aviation sector. The questionnaire should take roughly 5 minutes to complete and is completely anonymous and optional . All respondents who participate in this reaserch will be kept confidential. Additionally, all data will be stored and handled in line with GDPR and Bucks New university ethics policy. If you'd like to withdraw at anytime please email jpenning1212@gmail.com
Thank you for your contribution towards an important aviation project!

*Required

Age *

Choose

Gender *

- Male
- Female
- Prefer not to say
- Other:

What sector do you currently work in the Aviation Industry? *

- ◯ Aircrew
- ◯ Engineering
- ◯ Aeromedicine
- ◯ ATC/Radio
- ◯ Cabin Crew
- ◯ Aviation Regualtion
- ◯ Airport Employee
- ◯ Airline Employee
- ◯ Aviation Operations
- ◯ Third party companies
- ◯ General Aviation
- ◯ Military
- ◯ Other: _____

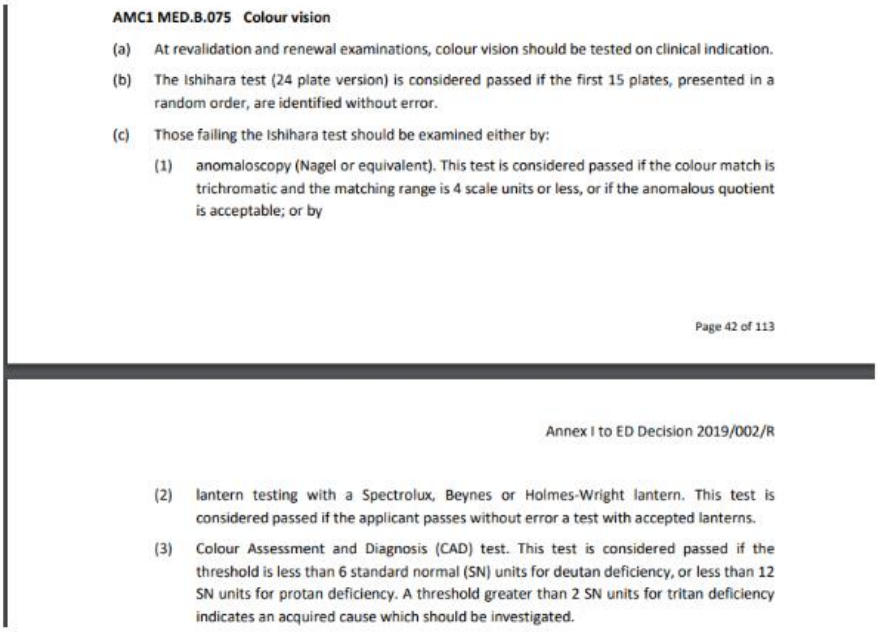
How many years have you worked in your Sector? *

Choose ▾

Are you aware that the UK CAA changed their colour vision regulation in 2018 to differ from EASA? *

- ◯ Yes
- ◯ No

Please examine the current EASA colour vision regulation(no longer in use by the UK CAA)



AMC1 MED.B.075 Colour vision

(a) At revalidation and renewal examinations, colour vision should be tested on clinical indication.

(b) The Ishihara test (24 plate version) is considered passed if the first 15 plates, presented in a random order, are identified without error.

(c) Those failing the Ishihara test should be examined either by:

(1) anomaloscopy (Nagel or equivalent). This test is considered passed if the colour match is trichromatic and the matching range is 4 scale units or less, or if the anomalous quotient is acceptable; or by

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(2) lantern testing with a Spectrolux, Beynes or Holmes-Wright lantern. This test is considered passed if the applicant passes without error a test with accepted lanterns.

(3) Colour Assessment and Diagnosis (CAD) test. This test is considered passed if the threshold is less than 6 standard normal (SN) units for deutan deficiency, or less than 12 SN units for protan deficiency. A threshold greater than 2 SN units for tritan deficiency indicates an acquired cause which should be investigated.

How would you describe the current EASA colour vision regulation? *

	Very poor	Poor	Fair	Good	Excellent
The EASA regulation is	○	○	○	○	○

How would you describe the current EASA colour vision regulation? *

	Very restrictive	Partly restrictive	Fair	Lenieant	Very Lenieant
The EASA regulation is	○	○	○	○	○

Explain why you choose those responses in the previous two questions? *

Your answer

Do you think the EASA regulation provides a suitable number of testing options for candidates ? *

- ◯ Yes
- ◯ No

If your answer was 'No' to the previous question , how many tests would you like to see ?

Your answer

Would you change anything in the EASA regulation, and if so what would you change ?

Your answer

Now please examine the current UK CAA colour vision regulation (Please note the differences under section C in the testing options and pass marks)

Implementing Rules	Acceptable Means of Compliance	UK CAA GM
MED.B.075 Colour vision	UK Alternative AMC to MED B.075 Colour vision (Class 1 and 2)	
(a) Applicants shall be required to demonstrate the ability to perceive readily the colours that are necessary for the safe performance of duties.	(a) At revalidation colour vision should be tested on clinical indication.	
(b) Examination • Applicants shall pass the Ishihara test for the initial issue of a medical certificate. 2) Applicants who fail to pass in the Ishihara test shall undergo further colour perception testing to establish whether they are colour safe.	(b) The Ishihara test (24 plate version) is considered passed if the first 15 plates, presented in a random order, are identified without error.	The Ishihara test is to be conducted as per manufacturer's instructions: test distance 75cm with plane of plates at right angles to line of vision under daylight or daylight simulated light (usually colour temperature around 6500K) allowing 3 seconds per plate for response. The plates should be presented to the applicant in a random order. Ishihara plates should be updated periodically or if showing any signs of fading.
(c) In the case of Class 1 medical certificates, applicants shall have normal perception of colours or be colour safe. Applicants who fail further colour perception testing shall be assessed as unfit. Applicants for a Class 1 medical certificate shall be referred to the licensing authority.	(c) Those failing the Ishihara test should be examined by: (1) Anomaloscopy (Nagel or equivalent). This test is considered passed if the colour match shows normal trichromacy, i.e. a matching midpoint of 38-42 scale units and the matching range is 4 scale units or less; or by (2) Colour Assessment and Diagnosis (CAD) Test. This is considered passed if the threshold is less than 6 SU for deutan deficiency, or less than 12 SU for protan deficiency. A threshold greater than 2SU for tritan deficiency indicates an acquired cause which should be investigated.	The Alternative Means of Compliance submitted by the UK CAA can be accessed below this table. The UK CAA does not accept lantern testing as evidence of being colour safe. Anomaloscopy (Nagel or equivalent) may be considered provided the full protocol used for testing is enclosed with the result. This test is only considered passed if the colour match shows normal trichromacy, i.e. a matching midpoint of 38-42 scale units and the matching range is 4 scale units or less. Tests that have not been performed in the UK must have been conducted by an Aeromedical Centre in another Competent Authority. Applicants failing the Anomaloscope test may undergo the CAD test. All applicants in the UK for advanced colour vision testing should be tested using the CAD test conducted under CAA protocols (available on request). The CAD test will only pass as colour safe, those individuals who perform as well as individuals with colour vision in the normal range on the most difficult aviation colour vision tasks.

How would you describe the current UK CAA colour vision regulation? *

	Very poor	Poor	Fair	Good	Excellent
The CAA regulation is	○	○	○	○	○

How would you describe the current UK CAA colour vision regulation? *

	Very restrictive	Partly restrictive	Fair	Lenieant	Very Lenieant
The CAA regulation is	○	○	○	○	○

Explain why you choose those responses in the previous two questions? *

Your answer

Which regulation do you think is more suitable/aviation related (EASA or CAA) and why ? *

Your answer

Please examine the final regulation(this is a proposed colour vision regulation based on the EASA, New Zealand ,Australia and ICAO approach)

A new proposed Class 1 Colour Vision regulation for the UK CAA

MED.B.075 Colour Vision

Screening test

Ishihara test (24 plate version) is considered passed if the first 15 plates, presented in a random order, are identified with a maximum of one error.

This test is then required for each renewal unless a candidate has passed via one of the secondary testing method or practical tests.

If a candidate has failed the Ishihara, they are then required to pass one of the secondary testing methods for an issue of a class 1, a candidate may sit multiple tests and is only required to pass one method.

Secondary tests

(1) Anomaloscopy (Nagel or equivalent). This test is considered passed if the colour match is trichromatic and the matching range is 4 scale units or less, or if the anomalous quotient is acceptable: or by

(2) lantern testing with a Spectrolux, Beynes or Holmes-Wright lantern. This test is considered passed if the applicant passes without error a test with accepted lanterns. Any other type of Lantern test result should be sent to the relevant aviation authority for review: or by

(3) Colour Assessment and Diagnosis (CAD) test. This test is considered passed if the threshold is less than 6 standard normal (SN) units for deutan deficiency, or less than 12 SN units for protan deficiency. A threshold greater than 2 SN units for tritan deficiency indicates an acquired cause which should be investigated: or by

(4) Farnsworth D15. This test is considered pass if there are no errors

A candidate that has passed one of the secondary tests is considered as colour safe and can be issued with a class 1 medical certificate , they do not have to resit this test in their career , a medical notice should be put on record they have passed via one of these tests.

If a candidate is not able to pass any of the secondary tests, then they are able to sit an Operational colour vision assessment (OCVA).

OCVA:

This consists of a ground and flight assessment, in which the candidate must demonstrate the ability to read and interpret charts, instrumentation, displays, aeronautical lighting, and terrain and conditions.

The assessment is carried out initially by day and may be repeated at night for those candidates wishing to remove the night limitation. As this is a flight assessment, it is desirable that applicants have some experience in piloting aircraft.

Advice on when the assessment should be undertaken should best be made in consultation with an A or B Cat flight instructor, with the final decision on timing to be made by the candidate. Prior to the commencement of an assessment the applicant must produce evidence of their identity. The applicant may choose to undertake the assessment in the day time only or during the day time and night time. The day OCVA must be completed before the night assessment.

Part 2

the candidate. Prior to the commencement of an assessment the applicant must produce evidence of their identity. The applicant may choose to undertake the assessment in the day time only or during the day time and night time. The day OCVA must be completed before the night assessment.

If the applicant passes the day time component of the OCVA, they will be permitted to undertake air operations with passengers (if appropriately licenced) and will have restrictions on their medical certificate reduced to – 'Not valid for flight in the vicinity of a controlled aerodrome unless the aircraft is in radio contact with aerodrome control.' 'Not valid for night flying.' If the applicant passes both the day and night time component of the OCVA, they will be permitted to undertake air operations with passengers and to fly at night (if appropriately licenced and rated) and will have restrictions on their medical certificate reduced to – 'Not valid for flight in the vicinity of a controlled aerodrome unless the aircraft is in radio contact with aerodrome control.'

(Operational Colour Vision Assessment - Guidance for Candidates Page 3 of 6 Civil Aviation Authority of New Zealand)

How would you describe the proposed colour vision regulation? *

	Very poor	Poor	Fair	Good	Excellent
This regulation is	○	○	○	○	○

How would you describe the proposed colour vision regulation? *

	Very restrictive	Partly restrictive	Fair	Lenieant	Very Lenieant
This regulation is	○	○	○	○	○

Do you think this regulation is more suitable/aviation related than both the CAA and EASAs regulations? *

- ○ Yes
- ○ No
- ○ Unsure

Please rate the regulations from worst to best , 1 being the worst ,3 being the best *

	1	2	3
EASA	○	○	○
UK CAA	○	○	○
Proposed Regulation (ICAO)	○	○	○

Any further comments regarding this regulation?

Your answer

Would you like to see the new proposed regulation (the third regulation) implemented to replace the current UK CAA regulation for class 1 medicals? *

- ○ Yes
- ○ No

Submit

APPENDIX 2-QUANTITATIVE DATA

Age	Gender	What sector do you currently work in the Aviation Industry?	How many years have you worked in your Sector?	Are you aware that the UK CAA changed their colour vision regulation in 2018 to differ from EASA?	How would you describe the current EASA colour vision regulation?
18-25	Male	Student Pilot	3 years	Yes	Good
18-25	Male	Student Pilot (PPL+NR)	3 years	Yes	Fair
18-25	Male	Aircrew	3 years	Yes	Poor
36-45	Male	Aircrew	10+ years	No	Fair
26-35	Male	Cabin Crew	7-9 years	Yes	Fair
26-35	Male	Aircrew	10+ years	No	Poor
46-55	Female	General Aviation	4-6 years	Yes	Poor
56-65	Male	Airline Employee	10+ years	No	Fair
56-65	Male	Colour vision scientist	10+ years	Yes	Fair
56-65	Male	Aircrew	10+ years	No	Fair
26-35	Male	Aircrew	10+ years	Yes	Very poor
56-65	Male	Third party companies	10+ years	Yes	Poor
46-55	Male	Aircrew	10+ years	No	Poor
36-45	Male	Masters Degree in Aviation	10+ years	Yes	Poor
26-35	Male	ATC/Radio	7-9 years	No	Poor
26-35	Male	Aircrew	10+ years	No	Fair
36-45	Male	Aircrew	10+ years	Yes	Very poor
26-35	Male	Flight training	3 years	Yes	Poor

26-35	Female	Airline Employee	3 years	Yes	Poor
36-45	Male	Aircrew	10+ years	No	Very poor
18-25	Male	Cabin Crew	3 years	No	Fair
36-45	Male	Aircrew	10+ years	No	Fair
18-25	Male	Aircrew	4-6 years	No	Fair
26-35	Male	Aircrew	3 years	No	Fair
26-35	Male	Aircrew	7-9 years	No	Fair
18-25	Female	Aircrew	3 years	Yes	Poor
26-35	Male	Aircrew	7-9 years	No	Fair
18-25	Female	General Aviation	3 years	No	Very poor
26-35	Male	Simulation	7-9 years	No	Good
18-25	Male	Aviation Regulation	3 years	Yes	Fair

How would you describe the current EASA colour vision regulation? 2	Do you think the EASA regulation provides a suitable number of testing options for respondents?	How would you describe the current UK CAA colour vision regulation?	How would you describe the current UK CAA colour vision regulation? 4	How would you describe the proposed colour vision regulation?
Partly restrictive	Yes	Poor	Very restrictive	Excellent
Partly restrictive	Yes	Very poor	Very restrictive	Excellent
Partly restrictive	No	Very poor	Very restrictive	Excellent
Fair	Yes	Poor	Very restrictive	Excellent
Partly restrictive	No	Very poor	Very restrictive	Excellent
Partly restrictive	No	Poor	Partly restrictive	Good
Partly restrictive	No	Very poor	Very restrictive	Fair
Fair	Yes	Fair	Fair	Fair
Fair	No	Fair	Fair	Fair
Fair	Yes	Poor	Partly restrictive	Fair
Very restrictive	No	Very poor	Very restrictive	Fair

Partly restrictive	No	Good	Fair	Good
Very restrictive	No	Poor	Very restrictive	Fair
Very restrictive	Yes	Very poor	Very restrictive	Fair
Very restrictive	No	Poor	Very restrictive	Excellent
Fair	No	Poor	Partly restrictive	Good
Very restrictive	No	Very poor	Very restrictive	Excellent
Very restrictive	No	Very poor	Very restrictive	Excellent
Very restrictive	No	Very poor	Very restrictive	Excellent
Very restrictive	No	Very poor	Very restrictive	Fair
Fair	No	Fair	Very restrictive	Good
Partly restrictive	Yes	Fair	Partly restrictive	Fair
Fair	Yes	Fair	Fair	Fair
Fair	Yes	Poor	Partly restrictive	Good
Partly restrictive	Yes	Good	Fair	Fair
Very restrictive	No	Very poor	Very restrictive	Good
Fair	Yes	Poor	Very restrictive	Fair
Partly restrictive	No	Poor	Partly restrictive	Fair
Lenient	Yes	Poor	Very restrictive	Excellent
Lenient	Yes	Poor	Partly restrictive	Excellent

How would you describe the proposed colour vision regulation? 5	Do you think this regulation is more suitable/aviation related than both the CAA and EASA's regulations?	Please rate the regulations from worst to best, 1 being the worst,3 being the best [EASA]	Please rate the regulations from worst to best, 1 being the worst,3 being the best [UK CAA]	Please rate the regulations from worst to best, 1 being the worst,3 being the best [Proposed Regulation (ICAO)]	Would you like to see the new proposed regulation (the third regulation) implemented to replace the current UK CAA regulation for class 1 medicals?
Lenient	Yes				Yes
Fair	Yes	2	1	3	Yes
Fair	Yes	2	1	3	Yes
Fair	Yes	2	1	3	Yes
Fair	Yes	2	1	3	Yes
Lenient	Yes	2	1	3	Yes
Fair	Yes	2	1	3	Yes
Fair	Unsure	2	2	2	No
Fair	Unsure	2	1	2	Yes

Fair	Unsure	2	3	2	No
Fair	Yes	2	1	3	Yes
Lenient	Unsure	3	2	1	Yes
Fair	Yes	2	3	1	Yes
Fair	Yes	2	3	1	Yes
Fair	Yes	2	1	3	Yes
Fair	Yes	2	1	3	Yes
Fair	Yes	1	1	3	Yes
Very Lenient	Yes	2	1	3	Yes
Fair	Yes	1	1	3	Yes
Fair	Yes	1	1	3	Yes
Very Lenient	Yes	1	2	3	Yes
Fair	Yes	2	2	2	No
Fair	Unsure	2	2	2	No
Lenient	Unsure	3	1	2	Yes
Fair	Yes	2	1	3	Yes
Fair	Yes	2	1	3	Yes
Lenient	Unsure	3	1	2	Yes
Fair	Yes	2	1	3	Yes
Lenient	Yes	2	1	3	Yes
Fair	Yes	2	1	3	Yes

APPENDIX 3- EXPERT OPINIONS FROM LITERATURE

CEO and Director of Aviation Safety Shane Carmody comments:

A solution has been found to a somewhat thorny and long-running issue that is important to a group of pilots. The issue is colour vision deficiency and the way CASA manages safety related assessments as part of the medical certification process. Colour vision deficiency affects about 400 Australian pilots and a three-stage testing process has been in place for some time, with a pass at any stage allowing an unrestricted medical to be issued. Where all three tests are failed then a medical certificate can be issued subject to conditions.

Research in recent years has shown relying on diagnostic tests alone may be unnecessarily limiting when considering the impact of colour vision deficiency on aviation safety. Advances in technology, operating techniques and human factors training can now mitigate many of the safety risks of colour vision deficiency. Technology to assist pilots has developed significantly and the impact of colour vision deficiency on aviation safety should take these changes into account. These factors have been recognised overseas, most recently in

New Zealand where a new approach to colour vision deficiency came into effect in May 2019, which includes an operational colour vision assessment. This assessment comprises a ground-based assessment and an in-flight assessment which looks at a pilot's ability to interpret visual information. A separate assessment is done for day flying and night flying.

We have decided to adopt this approach to colour vision deficiency assessment and in the short term we will recognise the New Zealand operational colour vision assessment as an alternative to Australia's current third level of testing. Work is already well underway on the development of an Australian operational test for colour vision deficiency by mid-2020. Any Australian pilots who wish to use the New Zealand assessment can do so now, although it will require travel to that country. CASA has carefully examined all relevant safety issues and believes this new approach offers a practical alternative assessment for colour vision deficient pilots. We have listened to the views of pilots and made judgements based on research and evidence.

Best wishes

Shane Carmody

(Civil Aviation Safety Authority, 2020)

Expert opinion of Professor Boris Crassini

Professor Boris Crassini is a retired professor of psychology of Deakin University, Australia. His areas of academic research were human visual perception and infant development of perception. He has appeared as an expert witness in several cases concerning colour vision and its relevance in the workplace. This has included the aviation industry. Professor Crassini states:

"Defective colour vision is a real phenomenon as reflected in, for example, the impaired ability of people with defective colour vision to name and discriminate emitted or reflected light of particular wavelengths. If asked to perform a task the performance of which depends critically on the ability to name and discriminate emitted or reflected light of particular wavelengths, people with defective colour vision will exhibit impaired performance compared with the performance of people with normal colour vision. I am unaware of any evidence that shows that the safe performance of piloting an aircraft depends critically on the ability to name and discriminate emitted or reflected light of particular wavelengths. Therefore, it follows logically that people with defective colour vision are able to pilot aircraft safely."

(Research and Technology Organization, 2001).

Expert opinion of Associate Professor Geoffrey Stuart Associate Professor Geoffrey Stuart of the Accident Research Centre of Monash University

works in the area of visual perception and, referring to CVD piloting experience in Australia, states: "The demonstrated ability of CVD pilots to use aircraft systems is highly relevant, and has convinced the

Administrative Appeals Tribunal that pilots of demonstrable ability do not represent a risk to aviation safety when appropriate conditions are imposed."
(O'Brien and Civil Aviation Safety Authority, 2015)

Expert opinion of Professor Barry Cole

A review of the literature found no definitive material to indicate that normal colour vision is required for aircrew in modern aviation. Professor Barry Cole, a retired optometrist from Melbourne University appears to have been the most prolific author of papers advocating the exclusion of individuals with CVD from aviation. Indeed, Professor Cole authored papers advocating the exclusion of CVD individuals from all forms of transport, citing the risk of confusing colour signals or missing signals altogether. The work of Professor Cole is however generally focused on clinical test methods and simulation by clinical test methods and is discussed later in this report. His work was examined by the Administrative Appeals Tribunal of Australia when considering the Commonwealth funded test case of 1989. Ultimately that review concluded a relaxation of conditions on CVD pilots, as already discussed.
(Stuart, G, 2015)

Comments from (Colour Vision Aviators, 2013)

The CAD test is undoubtedly a useful tool for identifying and numerically quantifying the colour vision ability of individuals. However, it does not appear to add significantly from pre-existing methods.
It is unclear why City University London promoted the CAD test for the assessment of pilot applicants as opposed to validating a pre-existing test against the simulated PAPI. Granted the CAD test is an independent and repeatable clinical test which is nicely packaged within a computer system. That said, it is expensive and not readily accessible to most of the UK. The business case for change must therefore be questioned.

The relevance of the CAD test to ascertaining whether a respondent is able to safely operate an aircraft must be seriously questioned. The pass mark assigned for the CAD test appears to have been arbitrarily raised beyond that required to read the City University PAPI simulator. The change in the pass mark is without foundation. City University contradicts their own work in suggesting those respondents who pass the University PAPI simulator but who cannot achieve the prescribed pass mark for the CAD test will be unable to adequately complete other tasks required of a pilot. The documentation clearly indicates that PAPI interpretation was viewed as the single most difficult task involving colour interpretation for a pilot.
The City University PAPI simulator itself, used to indicate an acceptable level of performance, is flawed in that it reduced the PAPI interpretation to a simple colour naming test by eliminating other cues such a light brightness, which is a design feature of real PAPI.
Trials by the FAA with their own PAPI simulator, which did not eliminate brightness (although it did reduce brightness difference below what may be expected with a fielded PAPI system), demonstrated that all groups of CVD individuals were able to correctly identify PAPI signals just as well as colour normal individuals.

Consequently, it is the view of this author that the use of the CAD test, like other clinical tests, is untenable for the final selection of unrestricted pilot respondents. Moreover, based on a review of the literature combined with the body of empirical evidence built by CVD pilots operating in many nations, including New Zealand and Australia, there is no basis to restrict the privileges of CVD pilots.
A practical demonstration of competence should thus be permitted for CVD pilots during the applicable practical flight test. This practical flight test should not be reduced to a colour naming activity but rather be an impartial assessment of the respondent's ability to safely operate the aircraft through all normal and emergency scenarios in keeping with existing practical flight test standards. Satisfactory performance in the flight test can be considered a reasonable basis for concluding that the respondent's CVD status is not of aeromedical significance'. (Colour Vision Aviators, 2013)

APPENDIX 4- UK CAA'S REASONING FOR THE REGULATION CHANGE

There is a wide diversity of colour testing methods employed and standards used for the assessment of flight crew minimum colour vision requirements throughout the world, including amongst European States.
Ishihara (IH) tests
Colour vision requirements and assessment of 'colour safety' based on Ishihara (IH) tests have the following problems:

1. Inconsistent application of the manufacturers' instructions / CIE protocols for the conduct of the tests by the test operator/institution.

2. Variation in the lighting conditions used to view the test plates (illuminant spectral power distribution and illuminance level).

3. Use of different test plate editions that are by no means identical, and the current availability of very inexpensive 'Ishihara' test plates sets on the web that may not be genuine.

4. The possible use of other cues such as the recognition of vertically and/or horizontally arranged dot patterns, or the learning of the order of plates when the presentation sequence is not randomised.

5. A large proportion of normal trichromats fail the IH plates (various editions) when the protocol requires zero errors for a Pass.

6. A large proportion of applicants with congenital colour deficiency (some with severe loss of RG colour vision) that pass with 3 or fewer errors on the 38 plates edition. There is little or no correlation between the applicant's severity of colour vision loss and the number of failed IH test plates.

7. When more than three errors are allowed as a pass, some applicants with congenital colour deficiency that pass can have severe loss of colour vision. For example, having a pass standard (e.g. for LAPL) that requires fewer plates to be correctly identified (LAPL 9 of the 15 plates) allows applicants with severe colour deficiency to pass.

Lantern Tests

Colour vision requirements and assessment of 'colour safety' based on lantern tests have the following problems.

1. Inconsistent application of the manufacturers' instructions for the conduct of the tests by the test operator/institution.

2. Maintenance and calibration is usually not carried out. Old lanterns are difficult to service and many types are no longer manufactured.

3. Applicants can learn the order of the lights presented and use other cues to correctly name the lights, particularly if the starting point and order of presentation are not varied.

4. The variability in outcome on repeated lantern test protocols is high which results in many false positives and negatives.

5. Lanterns do not diagnose or quantify either the type or the severity of colour vision loss.

6. A significant proportion of deutan subjects (in particular) pass lantern tests based on red, green and white lights without guaranteeing minimum colour deficiency.

7. Different organisations/states performing the tests and interpreting the results have different definitions of what constitutes a pass.

8. Many lanterns were not specifically designed for aviation purposes, so the colour of the lights used and the intensity do not necessarily represent a proper representation of the coloured signals/ lights used in aviation.

Anomaloscope Tests

Colour vision requirements and assessment of 'colour safety' based on anomaloscope tests (i.e., dichromatic, RG colour matching tests) have the following problems.

1. Inconsistent application of the manufacturers' instructions for the conduct of the tests by the test operator/institution.

2. Calibration and proper maintenance cannot be demonstrated, and 'normal' match parameters are usually needed when the light source is replaced, etc.

3. There can be substantial differences in testing between anomaloscope type and models, such as the use of white, interstimulus adapting fields.

4. Although anomaloscopes (which employ a dichromatic Rayleigh match) distinguish between the type of RG colour deficiency (e.g., protan- vs deutan-like deficiency) the severity of colour vision loss and whether the applicant is 'colour safe' cannot be demonstrated.

5. Different organisations/states performing the tests and interpreting the results have different definitions of what constitutes a pass. This particularly relates to interpretation of the matching midpoint and the size of the matching range. Applicants with a 'normal' matching mid-point as tested might have a large range, and those with a very abnormal midpoint might have a small matching range, often well within the mean matching range measured in normal trichromats.

6. Some subjects exhibit 'extreme' anomalous matches that spread over the midpoint measured in normal trichromats. These subjects cannot therefore be diagnosed as either deutan- or protan-like.

7. A small proportion of subjects exhibit normal Rayleigh matches, but demonstrate significant loss of RG chromatic sensitivity in other tests. The opposite is also the case when subjects with heavily abnormal anomaloscope midpoints exhibit completely normal RG chromatic sensitivity.

8. Anomaloscopes were designed for clinical diagnostic reasons and not specifically designed for use in aviation to determine whether an individual is colour safe of not. They can determine whether subjects are normal trichromats with a normal matching mid-point and normal matching range.

The Colour Assessment and Diagnosis (CAD) Test

The Colour Assessment and Diagnosis (CAD) Test provides an accurate and reproducible assessment of an applicant's class of colour vision and severity of RG and YB colour vison loss. The latter can be used to set Pass / Fail limits that do not discriminate against applicants with mild to moderate RG colour deficiency who have been shown to carry out the safety-critical, colour related tasks as well as normal trichromats.

The CAD test cannot be learnt and there are no cues the applicant could use to pass it. The results reflect only the RG and the YB sensitivity of the eye. The results are expressed in Standard Normal CAD units (i.e., RG = 1.0 and YB = 1.0) which represent the median RG and YB colour signal strengths for young, healthy normal trichromats. A threshold of 6 units means that the applicant requires 6 times greater colour signal strength than the standard CAD observer.

Upper limits that describe the binocular and the monocular performance of normal trichromats as a function of age (~ 8 to 85 yrs of age) are incorporated in the test. These are used to screen reliably for normal trichromatic colour vision and also make it possible to detect the presence of retinal or / and systemic diseases that affect vision. The CAD test can also detect acquired deficiencies, even when acquired loss is present in applicants with congenital RG colour deficiency. (caa.co.uk, 2020)

APPENDIX 5- A PILOT STUDY

A pilot study was undertaken which 5 respondents answered, the idea of this was to see whether the questionnaire met the aims of the research, was easy to understand and could be answered by the target audience. More detail about the pilot study in appendix… Questions asked:

1. Do you think the questionnaire is easy to follow and easy to read?
2. Do you think aviation experts will be able to answer this questionnaire with no previous knowledge of colour vision?
3. Do you think it's suitable for the target audience?

All respondents said that the questionnaire was easy to follow and flowed well. 2 out of the 5 said that the regulation might be a little confusing for someone with no previous colour vision knowledge but said they should be able to tell that one is more restrictive than the other by the number of testing options available. All respondents said that it was suitable for the target audience. The only suggestion was to include another regulation from Australia or New Zealand before the prosed regulation, however, this suggestion was not implemented due to the fact the questionnaire would be too long, however, the title given to the proposed regulation states that it uses parts of the New Zealand regulation.

There was also an option to do the proposed regulation in a separate questionnaire if the responses from the first two regulations, the EASA and CAA, came back to be negative, e.g it was restrictive, and that a proposed regulation was needed , however, due to the limited time it was decided that both will be in the same questionnaire and if the response to the EASA and CAA regulation was positive, not much attention would be then given to the proposed regulation data, also it would then hopefully correlate with the responses.

APPENDIX 6- ETHICS PROTOCOL

1. Research participants should not be subjected to harm in any ways whatsoever.
2. Respect for the dignity of research participants should be prioritised.
3. Full consent should be obtained from the participants prior to the study.
4. The protection of the privacy of research participants must be ensured.
5. Adequate level of confidentiality of the research data should be ensured.
6. Anonymity of individuals and organisations participating in the research must be ensured.
7. Any deception or exaggeration about the aims and objectives of the research must be avoided.

8. Affiliations in any forms, sources of funding, as well as any possible conflicts of interests must be declared.
9. Any type of communication in relation to the research should be done with honesty and transparency.
10. Any type of misleading information, as well as representation of primary data findings in a biased way must be avoided. (Bryman, A. & Bell, E, 2015)

APPENDIX 7- ANOMALOSCOPE TEST PROCEDURE

The respondents need to match the two half fields in both colour and brightness by changing the red/green mixture at the top disk and the brightness of the yellow field at the bottom disk using the two knobs located on the side of the machine. The matches are recorded on a scale and put into a graph. The score is shown in two items, the range of matches and the mid-point. The range of results can be from 1-72. Normal trichromats achieving a match average consistent to a mid-scale range of settings 40 to 50, with 45 being the normal midpoint. When the results are outside the normal midpoint the extent of the range will be used to determine the type of colour deficiency and its severity. (Ncbi.nlm.nih.gov., 1981)

APPENDIX 8- LANTERN TEST PROCEDURE

Lantern Test

a. The test is usually performed by Service Ophthalmologists or other approved persons. The lantern is regarded as a form of trade test displaying pairs of vertically arranged lights in a combination of red, green and white. These are viewed at a distance of 6m (20 feet) either by direct vision or mirror reversal, in light surroundings or in total darkness as laid down in current instructions. The respondent may wear spectacles if he/she wishes and maybe 'dark adapted' if necessary. The colour pairs may be changed by rotating the colour setting flange at the rear of the lantern, the colour pairs present being indicated by the code number visible in windows on each side and at the rear of the lantern. The code numbers represent: Code 1 2 3 4 5 6 7 8 9 R2 G2 W G2 R1 R1 W G1 G1 Colour W R1 W R2 R2 G1 G2 R2 G2

The intensity of the lights presented may be varied by the filter change lever at the rear of the lantern, the setting being: DEM for demonstration only.

HIGH BRIGHTNESS

LOW BRIGHTNESS

b. In order to reduce errors the examination method and instruction to the examinee are to be followed exactly in each case:

(1) The examinee is to be seated with the lantern apertures at eye level.

(2) Connect the lantern to 230/240-volt supply and switch on with the rotary switch at the rear of the lantern. No warming-up period is necessary.

(3) Turn the filter lever to DEM and the colour setting flange to Code 1.
(4) Say to examinee "This is a test to find out whether you can readily recognise the colours of red, green or white. Name both colours calling the one on top first. The top colour you see now is red".
(5) Turn the colour flange to Code 2. Say to examinee "The top colour you see now is green".
(6) Turn the colour flange to Code 3. Say to examinee "The top colour you see now is white".
(7) Turn the filter change lever to HIGH or LOW BRIGHTNESS as appropriate. Turn the colour flange to Code 4, 6, 8 or 2 (ie any red, green combination). Say to examinee: "Start now, naming first the top then the bottom colour. Do not use any words other than red or green or white. You will be given 5 seconds to name the colours". If the examinee uses any colour name other than red, green or white he/ she is to be reminded that only these words are to be used. No other comments are to be made by the examiner.
(8) Show each colour pair to the examinee in consecutive order. Each response must be given within 5 seconds.
c. The lantern is not to be opened except for routine annual servicing; at which time the lamp is to be changed.
(UK Gov, 2013)

APPENDIX 9 –DFT COMMUNICATION

[redacted] Wed, 15 Jan, 14:52

to me

Hi Jordan,

I hope this email finds you well, and apologies for the delay in responding. As you know from the email from our Secretary of State, we have been looking into the issues you have raised in your paper. I will provide you with an update as soon as we can, but I didn't want to delay any further before formally inviting you to visit our offices and do some shadowing as I believe you discussed with [redacted]

Would you be able to suggest some dates when you will be free to come into the department? It would be helpful if you could suggest a few in order to maximise the availability of people you may wish to meet. We can also discuss your report then.

In terms of the day itself, my team will put together an itinerary, but it would be helpful if you could let me know if there are any particular areas of aviation policy you would like to cover (beyond those raised in your report, which I'll take as read!) or any other ideas you have about what you'd like to get out of the day.

Best wishes,

[redacted]

Department for Transport [redacted]

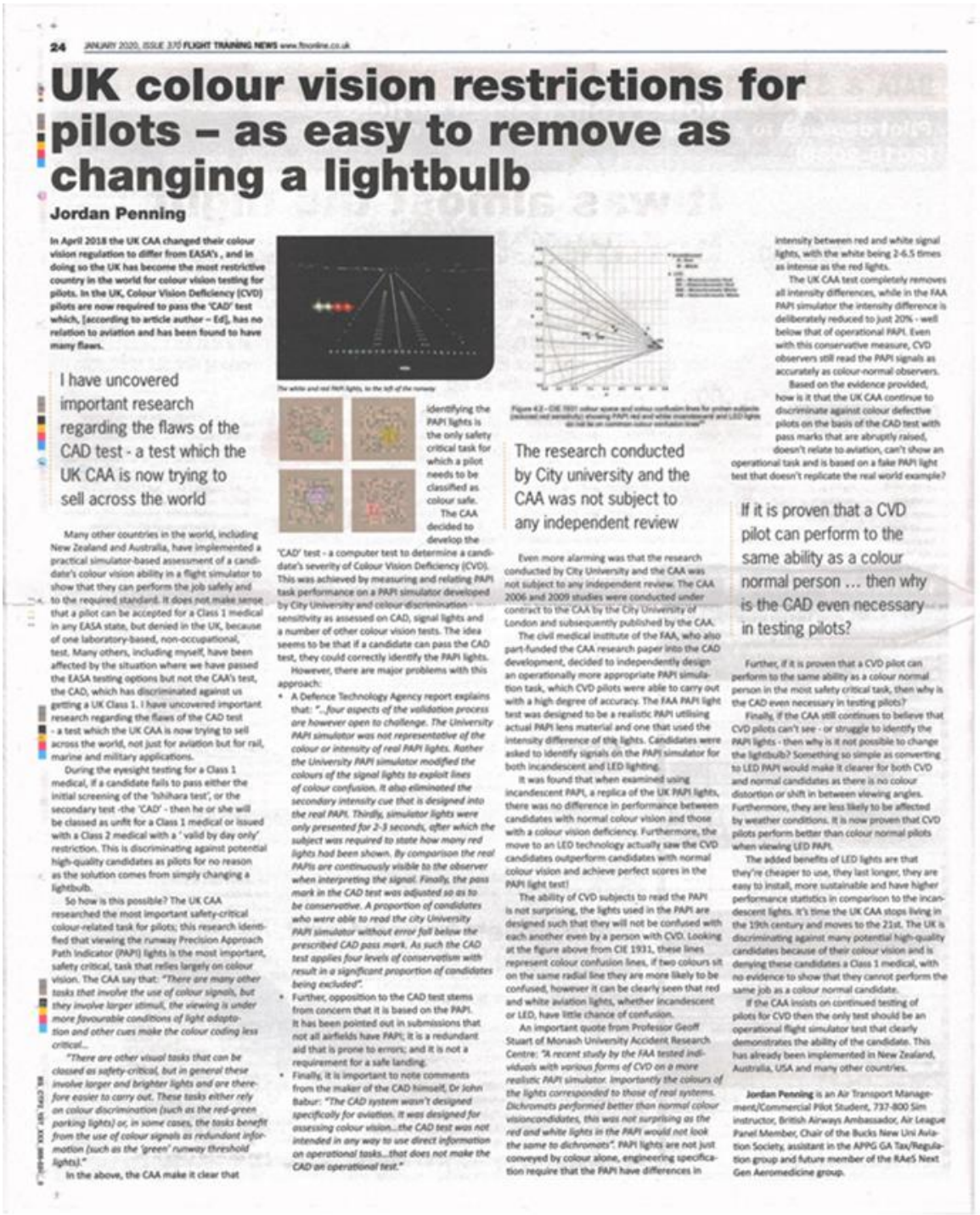
Head of Domestic Aviation Safety, Aviation Strategy and Consumers
1/25, Great Minster House
33 Horseferry Road, London, SW1P 4DR
[redacted]

Follow us on twitter @transportgovuk
Post to: Great Minster Hse, 33 Horseferry Rd, London, SW1P 4DR

APPENDIX 10- THE LEVEL OF RESTRICTIVENESS IN THE LISTED REGULATIONS

The United States, Canada, New Zealand and Australia are jurisdictions that allow greater leniency to pilots with CVD. In the United States, CVD pilots can operate without limitation based on lenient pass marks in various Pseudo Isochromatic Plate tests or on the basis of demonstrated competency. For example, in the FAA regulation, the pass mark for the Ishihara is 6 errors or less in comparison to the UK CAA regulation which is 0 errors. In Canada, CVD pilots may operate without limitation based on the Farnsworth D15 test. Finally, all these authorities use a "real world" test.' (Caa.govt.nz, 2015) (Defence Research and Development Canada, 2017)

APPENDIX 11- FLIGHT TRAINING NEWS PUBLICATION AND PROMOTION OF QUESTIONNAIRE



24 JANUARY 2020, ISSUE 370 FLIGHT TRAINING NEWS www.ftnonline.co.uk

UK colour vision restrictions for pilots – as easy to remove as changing a lightbulb

Jordan Penning

In April 2018 the UK CAA changed their colour vision regulation to differ from EASA's , and in doing so the UK has become the most restrictive country in the world for colour vision testing for pilots. In the UK, Colour Vision Deficiency (CVD) pilots are now required to pass the 'CAD' test which, [according to article author – Ed], has no relation to aviation and has been found to have many flaws.

I have uncovered important research regarding the flaws of the CAD test - a test which the UK CAA is now trying to sell across the world

Many other countries in the world, including New Zealand and Australia, have implemented a practical simulator-based assessment of a candidate's colour vision ability in a flight simulator to show that they can perform the job safely and to the required standard. It does not make sense that a pilot can be accepted for a Class 1 medical in any EASA state, but denied in the UK, because of one laboratory-based, non-occupational, test. Many others, including myself, have been affected by the situation where we have passed the EASA testing options but not the CAA's test, the CAD, which has discriminated against us getting a UK Class 1. I have uncovered important research regarding the flaws of the CAD test - a test which the UK CAA is now trying to sell across the world, not just for aviation but for rail, marine and military applications.

During the eyesight testing for a Class 1 medical, if a candidate fails to pass either the initial screening of the 'Ishihara test', or the secondary test -the 'CAD' - then he or she will be classed as unfit for a Class 1 medical or issued with a Class 2 medical with a ' valid by day only' restriction. This is discriminating against potential high-quality candidates as pilots for no reason as the solution comes from simply changing a lightbulb.

So how is this possible? The UK CAA researched the most important safety-critical colour-related task for pilots; this research identified that viewing the runway Precision Approach Path Indicator (PAPI) lights is the most important, safety critical, task that relies largely on colour vision. The CAA say that: *"There are many other tasks that involve the use of colour signals, but they involve larger stimuli, the viewing is under more favourable conditions of light adaptation and other cues make the colour coding less critical...*

"There are other visual tasks that can be classed as safety-critical, but in general these involve larger and brighter lights and are therefore easier to carry out. These tasks either rely on colour discrimination (such as the red-green parking lights) or, in some cases, the tasks benefit from the use of colour signals as redundant information (such as the 'green' runway threshold lights)."

In the above, the CAA make it clear that identifying the PAPI lights is the only safety critical task for which a pilot needs to be classified as colour safe.

The CAA decided to develop the 'CAD' test - a computer test to determine a candidate's severity of Colour Vision Deficiency (CVD). This was achieved by measuring and relating PAPI task performance on a PAPI simulator developed by City University and colour discrimination - sensitivity as assessed on CAD, signal lights and a number of other colour vision tests. The idea seems to be that if a candidate can pass the CAD test, they could correctly identify the PAPI lights.

However, there are major problems with this approach:

- A Defence Technology Agency report explains that: *"...four aspects of the validation process are however open to challenge. The University PAPI simulator was not representative of the colour or intensity of real PAPI lights. Rather the University PAPI simulator modified the colours of the signal lights to exploit lines of colour confusion. It also eliminated the secondary intensity cue that is designed into the real PAPI. Thirdly, simulator lights were only presented for 2-3 seconds, after which the subject was required to state how many red lights had been shown. By comparison the real PAPIs are continuously visible to the observer when interpreting the signal. Finally, the pass mark in the CAD test was adjusted so as to be conservative. A proportion of candidates who were able to read the city University PAPI simulator without error fall below the prescribed CAD pass mark. As such the CAD test applies four levels of conservatism with result in a significant proportion of candidates being excluded".*
- Further, opposition to the CAD test stems from concern that it is based on the PAPI. It has been pointed out in submissions that not all airfields have PAPI; it is a redundant aid that is prone to errors; and it is not a requirement for a safe landing.
- Finally, it is important to note comments from the maker of the CAD himself, Dr John Babur: *"The CAD system wasn't designed specifically for aviation. It was designed for assessing colour vision...the CAD test was not intended in any way to use direct information on operational tasks...that does not make the CAD an operational test."*

The research conducted by City university and the CAA was not subject to any independent review

Even more alarming was that the research conducted by City University and the CAA was not subject to any independent review. The CAA 2006 and 2009 studies were conducted under contract to the CAA by the City University of London and subsequently published by the CAA.

The civil medical institute of the FAA, who also part-funded the CAA research paper into the CAD development, decided to independently design an operationally more appropriate PAPI simulation task, which CVD pilots were able to carry out with a high degree of accuracy. The FAA PAPI light test was designed to be a realistic PAPI utilising actual PAPI lens material and one that used the intensity difference of the lights. Candidates were asked to identify signals on the PAPI simulator for both incandescent and LED lighting.

It was found that when examined using incandescent PAPI, a replica of the UK PAPI lights, there was no difference in performance between candidates with normal colour vision and those with a colour vision deficiency. Furthermore, the move to an LED technology actually saw the CVD candidates outperform candidates with normal colour vision and achieve perfect scores in the PAPI light test!

The ability of CVD subjects to read the PAPI is not surprising, the lights used in the PAPI are designed such that they will not be confused with each another even by a person with CVD. Looking at the figure above from CIE 1931, these lines represent colour confusion lines, if two colours sit on the same radial line they are more likely to be confused, however it can be clearly seen that red and white aviation lights, whether incandescent or LED, have little chance of confusion.

An important quote from Professor Geoff Stuart of Monash University Accident Research Centre: *"A recent study by the FAA tested individuals with various forms of CVD on a more realistic PAPI simulator. Importantly the colours of the lights corresponded to those of real systems. Dichromats performed better than normal colour visioncandidates, this was not surprising as the red and white lights in the PAPI would not look the same to dichromats".* PAPI lights are not just conveyed by colour alone, engineering specification require that the PAPI have differences in intensity between red and white signal lights, with the white being 2-6.5 times as intense as the red lights.

The UK CAA test completely removes all intensity differences, while in the FAA PAPI simulator the intensity difference is deliberately reduced to just 20% - well below that of operational PAPI. Even with this conservative measure, CVD observers still read the PAPI signals as accurately as colour-normal observers.

Based on the evidence provided, how is it that the UK CAA continue to discriminate against colour defective pilots on the basis of the CAD test with pass marks that are abruptly raised, doesn't relate to aviation, can't show an operational task and is based on a fake PAPI light test that doesn't replicate the real world example?

If it is proven that a CVD pilot can perform to the same ability as a colour normal person ... then why is the CAD even necessary in testing pilots?

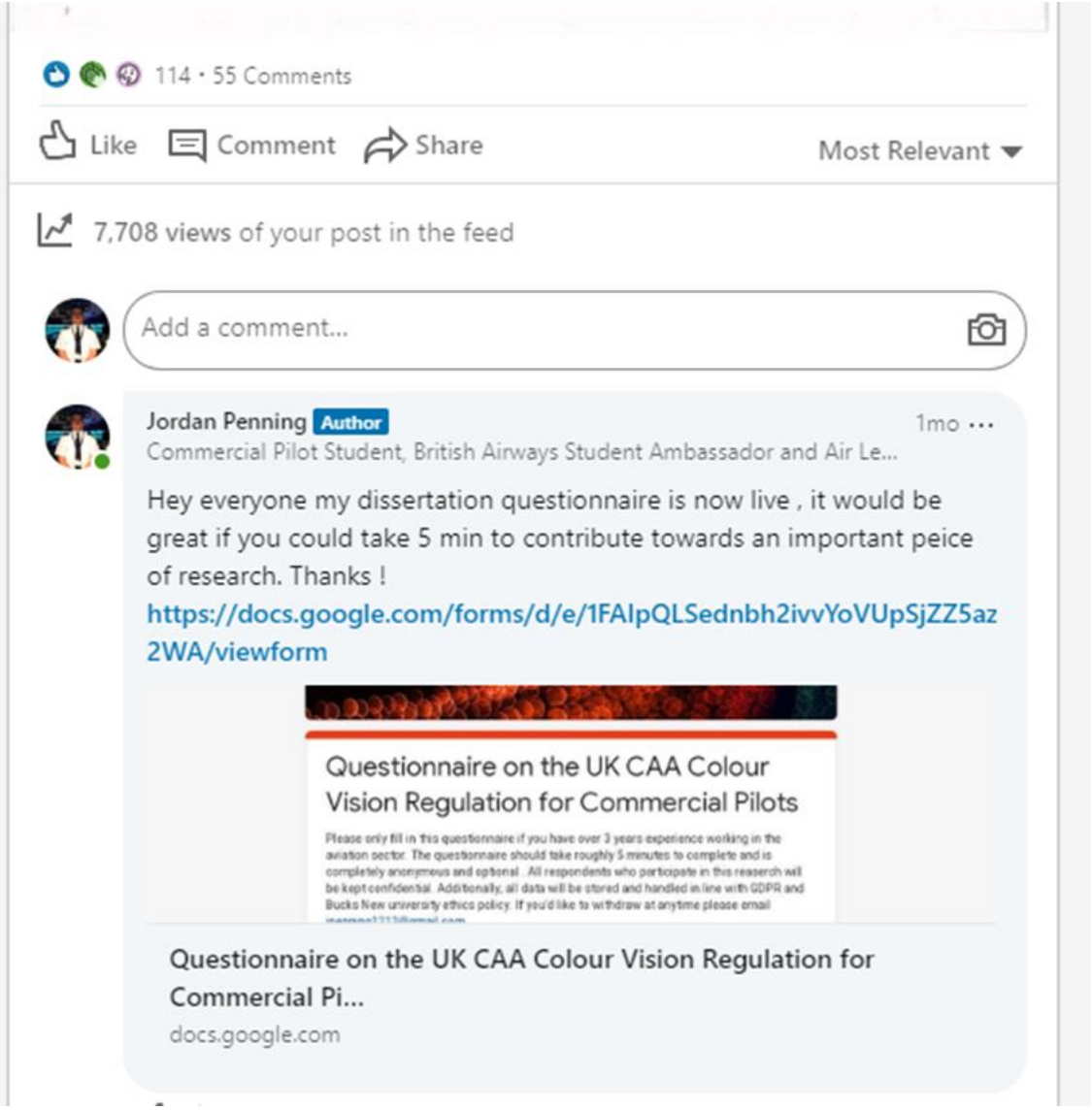
Further, if it is proven that a CVD pilot can perform to the same ability as a colour normal person in the most safety critical task, then why is the CAD even necessary in testing pilots?

Finally, if the CAA still continues to believe that CVD pilots can't see - or struggle to identify the PAPI lights - then why is it not possible to change the lightbulb? Something so simple as converting to LED PAPI would make it clearer for both CVD and normal candidates as there is no colour distortion or shift in between viewing angles. Furthermore, they are less likely to be affected by weather conditions. It is now proven that CVD pilots perform better than colour normal pilots when viewing LED PAPI.

The added benefits of LED lights are that they're cheaper to use, they last longer, they are easy to install, more sustainable and have higher performance statistics in comparison to the incandescent lights. It's time the UK CAA stops living in the 19th century and moves to the 21st. The UK is discriminating against many potential high-quality candidates because of their colour vision and is denying these candidates a Class 1 medical, with no evidence to show that they cannot perform the same job as a colour normal candidate.

If the CAA insists on continued testing of pilots for CVD then the only test should be an operational flight simulator test that clearly demonstrates the ability of the candidate. This has already been implemented in New Zealand, Australia, USA and many other countries.

Jordan Penning is an Air Transport Management/Commercial Pilot Student, 737-800 Sim instructor, British Airways Ambassador, Air League Panel Member, Chair of the Bucks New Uni Aviation Society, assistant in the APPG GA Tax/Regulation group and future member of the RAeS Next Gen Aeromedicine group.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Jordan Penning
Author
1mo
Commercial Pilot Student, British Airways Student Ambassador and Air Le...
Hey everyone my dissertation questionnaire is now live , it would be great if you could take 5 min to contribute towards an important peice of research. Thanks !
https://docs.google.com/forms/d/e/1FAIpQLSednbh2ivvYoVUpSjZZ5az2WA/viewform
Questionnaire on the UK CAA Colour Vision Regulation for Commercial Pilots
Please only fill in this questionnaire if you have over 3 years experience working in the aviation sector. The questionnaire should take roughly 5 minutes to complete and is completely anonymous and optional . All respondents who participate in this reasearch will be kept confidential. Additionally, all data will be stored and handled in line with GDPR and Bucks New university ethics policy. If you'd like to withdraw at anytime please email
Questionnaire on the UK CAA Colour Vision Regulation for Commercial Pi...
docs.google.com