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Submission 1 by Colour Vision Aviators

CAD Test

This document refutes the proposed introduction of the CAD test for the final determination of restrictions on pilots.

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 should they fail to achieve the prescribed pass mark in the CAD test.

A second submission from Colour Vision Aviators recommends an alternative testing and restriction regime.

Colour Assessment and Diagnosis (CAD) Clinical Test

The Colour Assessment and Diagnosis (CAD) clinical test was developed by City University London. The test has since been adopted by the United Kingdom Civil Aviation Authority (CAA) and is being considered by several other countries to assess whether a candidate has adequate colour perception ability to pilot aircraft.

The CAD test is a computer based test in which a candidate is required to identify the movement of a pixelated square on a pixelated background. Candidates with varying levels and forms of colour vision deficiency (CVD) will have difficulty distinguishing movement of the square at various times during the test sequence. It is the inability of a candidate to track the square against certain backgrounds that allows the diagnosis of CVD. The test is analogous to hearing tests in which the candidate is required to respond to transmitted noises of varying magnitude and frequency. An inability to hear a particular noise of certain frequency and magnitude indicates a measureable limit to one's hearing just as a loss of the target square in the CAD test indicates the limit to one's ability to perceive certain colours.

The CAD test is, in itself, not representative of any aviation task. Indeed, the test itself is no more representative of an aviation task than any other clinical test method for CVD, such as the long used pseudo isochromatic testing plates, Nagel anomaloscope, colour arrangement caps or a lantern test. All of these clinical tests, including the CAD test, have the ability to identify the presence of CVD. Some, such as colour arrangement caps and the Nagel anomaloscope also have the ability to measure the severity of CVD. None have the ability to determine how CVD will affect the ability of a candidate in their chosen career, whether that is as a pilot or any other career. The CAD clinical test is therefore, in itself, nothing more than an alternative clinical test to the many clinical tests that are already available.

Adaption of CAD test by City University London for pilot candidates

In adapting the CAD test for the assessment of pilot candidates, City University London measured the performance of candidates on the CAD test and on a PAPI simulator that was also developed by the University[1]. It was thus accepted by the UK CAA that achievement of the prescribed pass mark in the CAD test may be considered to also be representative of an ability to read the University PAPI simulator without issue. This assumption is not challenged. Most certainly, if a candidate can achieve the prescribed pass mark on the CAD test, published data indicates the candidate will also have no difficultly in reading the City University PAPI simulator.

Two aspects of the validation process are however open to challenge. Firstly, the University PAPI simulator is not representative of PAPI used in aviation. Rather the University PAPI simulator was conservative in that it eliminated secondary cues such as brightness cues that are designed into the real PAPI[2]. Secondly, the pass mark in the CAD test was adjusted so as to be conservative. A significant proportion of candidates who were able to read the City University PAPI simulator without error fall below the prescribed CAD pass mark[3]. As such the CAD test applies two levels of

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[1] UK CAA Paper 2009/04, Minimum Colour Vision Requirements for Professional Flight Crew – Part 3
[2] ibid
[3] ibid

conservatism which result in a significant proportion of CVD candidates being unnecessarily excluded. These points will be discussed in detail.

Relevance of Colour Vision to Pilots

Work, sponsored by the UK CAA, identified the precision approach path indicator (PAPI) as one of the few devices through which the conveyance of information by colour may be of importance to flight safety[4 5]. In the vast majority of cases the use of colour in aviation enhances the presentation of information but is not significant to speed or accuracy of understanding[6 7 8 9]. Warning lights are a common example. The colour of the light is irrelevant. What is important is whether the light is on or not. This point has been investigated in a number of investigations over the years. Perhaps most significant was the analysis of this topic by the Administrative Appeals Tribunal of Australia in the cases of Pape, Denison and O'Brien. Work by the UK CAA in association with the development of the CAD test similarly found a lack of circumstances in which CVD adversely affected flight safety.

Moreover, acceptance that the use of colour is haphazard and redundant in the conveyance of information is demonstrated by most regulatory authorities accepting candidates with even the most severe CVD to operate aircraft by day. If CVD candidates could not read instrumentation, radios, maps and navigation aids, all of which are common to all operations of all size aircraft, from micro lights up to heavy transports, then they would not be able to fly aircraft even by day. It is with this background that City University focused on the ability of CVD candidates to interpret PAPI signals.

Precision Approach path Indicator (PAPI) in context

To recap the operation of the PAPI, four lights are displayed to an aircraft on approach. Each is angled such that the crew will see a different combination of lights depending on the slope of their approach. If flying the nominal approach path, the crew will see two red and two white lights. If slightly higher they will see three white and one red. If still higher they will see four white. If slightly low they will see three red and one white. If very low they will see four red lights[10].

However, approach path information is not just conveyed by colour alone. Engineering specifications for PAPI require there to be a difference in brightness between the red and white signal lights. White lights are 2 – 6.5 times as bright as red lights[11 12]. The PAPI conveys approach path information using both colour and brightness with the observer, whether CVD or colour normal, able to perceive the different PAPI signals as darker red or brighter white.

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[4] UK CAA Paper 2006/04, Minimum Colour Vision Requirements for Professional Flight Crew – Part 2
[5] UK CAA Paper 2009/04, Minimum Colour Vision Requirements for Professional Flight Crew – Part 3
[6] UK CAA Paper 2009/04, Minimum Colour Vision Requirements for Professional Flight Crew – Part 2
[7] Administrative Appeals Decision 3821, Pape and the Civil Aviation Authority.
[8] Administrative Appeals Decision 5034, Denison and the Civil Aviation Authority.
[9] Administrative Appeals Decision 2014/1361, O'Brien and the Civil Aviation Safety Authority.
[10] UK CAA Paper 2009/04, Minimum Colour Vision Requirements for Professional Flight Crew – Part 3
[11] FAA AC 150– 5345-28 Precision Approach Path Indicator (PAPI) Systems
[12] UK CAA Paper 2009/04, Minimum Colour Vision Requirements for Professional Flight Crew – Part 3

Additionally, approach path information is available from the runway and approach lights[13]. Indeed many smaller airfields do not feature PAPI lights at all but instead rely on pilots interpreting their approach path by the appearance of the runway lights. This is also known to occur at major airfields on occasion during periods of PAPI maintenance.

For commercial operators, aircraft are also required to utilise approach instrumentation and the highest level of automation that is possible. Consequently, the conveyance of approach path information by colour is just one of four ways by which the crew of a commercial aircraft will ascertain their approach slope - PAPI light colour, PAPI light brightness, runway light appearance and approach instrumentation. In the case of small field operations without PAPI, colour is not used at all.

At this point, it is also worth noting that research of the PAPI system by the Australian Defence Science and Technology Organisation (DSTO) determined that the apparent colour of PAPI lights could be altered by the presence of moisture or dust on the PAPI light lens. Consequently, even a colour normal may receive incorrect information from a PAPI system if relying on colour interpretation alone. It is for this reason that warnings are presented to pilots through the Air Information Publication (AIP), indicating that the PAPI system should be used only as an aid to an approach and may provide erroneous indications[14] [15] [16].

Relevance of the City University PAPI simulator

In the case of the CAD pass mark validation by City University London, the University PAPI simulator was used. Candidates were assessed for their ability to interpret information from the simulator. Their ability to read the PAPI simulator was then related to their score in the CAD test when determining an acceptable pass mark for the CAD test.

However, the City University PAPI simulator deliberately removed the brightness difference between the red and white lights that is a design feature of real PAPI[17]. Consequently, candidates were relegated to a colour recognition test – not unlike traditional lantern tests which have already been discredited for their lack of relevance to aviation[18]. Moreover, this reliance on colour naming alone ignores the fact that a real pilot in a real commercial aircraft on approach would have four methods by which to gauge their slope – PAPI light colour, PAPI light brightness, runway light appearance and approach instrumentation.

The City University PAPI simulator, used to calibrate the CAD test, must therefore be considered overly conservative and simplistic such that it is entirely unrealistic of what is expected of a pilot when flying an approach day or night, whether guided by PAPI or not. Use of the University PAPI simulator to develop a pass mark for the

[13] FAA Report FAA-AM-79-25, Runway Shape as a Cue for Judgement of Approach Angle
[14] DSTO Systems Report 25, Hazards of Colour Coding in Visual Approach Slope Indicators, 1981.
[15] Air Information Publication Volume 4
[16] FAA Report DOT/FAA/CT-82/153, Evaluation of Precision Approach Path Indicator (PAPI).
[17] UK CAA Paper 2009/04, Minimum Colour Vision Requirements for Professional Flight Crew – Part 3
[18] ibid

CAD test and hence judge the ability of a pilot to fly must therefore be seriously questioned.

Although not documented or referenced, it is occasionally argued by clinical staff that the elimination of brightness differences between the red and white lights of the PAPI may simulate what may be expected in conditions of low visibility. However, in such conditions pilots do not rely on PAPI. As already mentioned, it is required of New Zealand commercial operators to use the highest level of automation possible during an approach. In operations where visibility is significantly degraded the PAPI is entirely superfluous and indeed may not be observed at all by the pilot flying an instrument approach. In the case of visual approaches, conditions of poor visibility will preclude operations in total due to legal minima applying. The suggestion that brightness differences between lights may be negated by environmental conditions is therefore irrelevant. In the case of the work by City University London to develop CAD pass marks, no explanation is provided for eliminating brightness cues in the University PAPI simulator.

Federal Aviation Authority (FAA) PAPI Simulator

When examining the effects of changing from incandescent lights to light emitting diodes (LED) in the PAPI, the FAA developed their own PAPI simulator for use in clinical trials. The FAA PAPI simulator was intended to be realistic of a fielded PAPI and did not totally eliminate brightness differences between the various lights, although it did reduce the brightness difference such that the white light was only 20% brighter than the red light in order to be conservative. Candidates with normal colour vision as well as various forms and severity of CVD were asked to identify signals on the FAA PAPI simulator. In that study, there was no difference in performance between candidates with normal colour vision and those with CVD when using incandescent lights. The move to LED technology saw protan, deutan and tritan CVD candidates achieve perfect scores in the PAPI test[19].

Given CVD applicants performed as well as colour normal candidates in the FAA PAPI test, one must seriously question the prescribed CAD test pass marks. Indeed, one must seriously question the grounds for any restriction against CVD pilots given their ability to read the FAA PAPI simulator without issue.

Adjustment of pass mark by City University in the CAD test

In determining a pass mark for pilot applicants on the CAD test, the value of 12 standard normal units (12 SN) was selected for protan candidates and a value of six standard normal units (6 SN) was selected for deutan candidates. These values however were not based on the score required to pass the already conservative City University PAPI simulator. In the case of protan candidates, 67.5% of candidates passed the University PAPI simulator, however the CAD pass score only allowed 50% of candidates to pass. In the case of deutan candidates, 44% passed the University PAPI simulator but only 38% achieved the required CAD pass mark[20]. It can be seen that the CAD pass marks were overly conservative when compared to

[19] FAA Report DOT/FAA/AM-14/6, Usability of Light Emitting Diodes in Precision Approach Path Indicator Systems by Individuals with Marginal Color Vision
[20] UK CAA Paper 2009/04, Minimum Colour Vision Requirements for Professional Flight Crew – Part 3

the already conservative City University PAPI simulator (which, as discussed, eliminated brightness cues, reducing the PAPI simulator to a colour naming test).

In considering the effect of using a modified white light in the PAPI simulator to better represent the future use of LED lighting, the discrepancy was even greater with still more CVD candidates passing the University PAPI simulator[21].

City University states that it considered those candidates who passed the University PAPI simulator but who did not meet the prescribed pass mark for the CAD test would have difficulty in other aspects of piloting aircraft[22]. Presumably this refers to the use of instrumentation, maps and navigation aids. This suggestion appears to ignore the already mentioned body of work by the University which identified the PAPI as the most significant task involving colour in aviation. Moreover, it appears to ignore the fact that colour vision deficient pilots already fly using the same instrumentation, maps and aids by day and in some jurisdictions by night. The self-contradiction in deliberately raising the pass mark beyond that required for the University PAPI simulator is clear.

Conclusions

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 such as the Farnsworth D15 colour arrangement test and the Nagel anomaloscope. Both systems are already available in New Zealand, with the colour arrangement test being accessible for minimal cost at local optometrists.

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 New Zealand population. The business case for change must therefore be questioned.

The relevance of the CAD test to ascertaining whether a candidate 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 pass mark is without foundation. City University contradict their own work in suggesting those candidates 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. 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

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[21] ibid

[22] UK CAA Paper 2009/04, Minimum Colour Vision Requirements for Professional Flight Crew – Part 3

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 candidates. 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 candidate'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 reasonable basis for concluding that the candidate's CVD status is not of aeromedical significance.

Recommended screening process

The following three tier screening process is recommended.

Primary screening. During their initial medical assessment candidates shall be examined as proposed by the GD using Ishihara Pseudo isochromatic plate tests. Should a candidate pass this screening they will be issued their medical certification without restriction. Should they fail they will be referred for secondary screening. Failure at this stage will result in conditions:

- Not valid for air operations carrying passengers.
- Not valid for night flight.
- Not valid for flight under IFR.
- Not valid in the vicinity of a controlled aerodrome unless in radio contact with ATC.

Secondary screening. All secondary screening methods used by ICAO nations shall be accepted for secondary screening. This includes the Farnsworth, Holmes Wright and Giles Archer lanterns, Farnsworth D15 test, CAD test and signal gun test. Should a candidate pass secondary screening they will be issued their medical certification without restriction. Failure at this stage will result in conditions:

- Not valid for air operations carrying passengers.
- Not valid for night flight.
- Not valid for flight under IFR.
- Not valid in the vicinity of a controlled aerodrome unless in radio contact with ATC.

Practical flight test. Candidates who fail primary and secondary screening tests may demonstrate their ability to safely operate during the applicable PPL, CPL, IFR or ATPL practical flight tests. Upon successful completion of any one of these flight tests restrictions will be reduced to:

- Not valid in the vicinity of a controlled aerodrome unless in radio contact with ATC.
- In the case of ATPL holders, valid for ATPL privileges only as or with a co-pilot.

Obviously, the removal of all other restrictions from the individuals medical does not imply that they have all ratings and licences. For example, they will still be required to satisfactorily pass a night rating before flying at night or an IFR flight test before flying in IMC.

About the author

Ryan Brookes is the Director of Applied Vehicle Systems (AVS) research for the Defence Technology Agency, New Zealand Defence Force. Ryan joined DTA as a Research Leader in March 2008, following a 15-year career with the Royal New Zealand Air Force (RNZAF). He was appointed to the role of Group Director, Applied Vehicle Systems in January 2013 to lead a team of approximately 20 scientists and engineers.

Ryan has a BE(Hons) in aeronautical engineering from the University of New South Wales (Australia), and a MSc in aerospace vehicle design from Cranfield University (UK). Ryan is a CVD pilot, holding a commercial pilot license and is a qualified flying instructor.

Ryan is familiar with numerous clinical CVD tests from first-hand experience as well as the demands of piloting aircraft both by day and night. Ryan has researched the topic of CVD in pilots for the last six years.

The report has been reviewed and endorsed by:

- Phillip Maguire, ATPL holder and Airline Pilot
- John O'Brien, Dash 8 Captain and Instrument Rating Flight Examiner, Australia. John is also a CVD pilot.
- Dr. Arthur Pape, Designated Aviation Medical Examiner and founder of Colour Vision Defective Pilots Association of Australia. Arthur is also a CVD pilot and holder of a multi-engine instrument rating.
- Mr Tim Woods, founder of Colour Vision Aviators, New Zealand.

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References

Air Information Publication Volume 4.

Administrative Appeals Decision 3821, Pape and the Civil Aviation Authority.

Administrative Appeals Decision 5034, Denison and the Civil Aviation Authority.

Administrative Appeals Decision 2014/1361, O'Brien and the Civil Aviation Safety Authority.

DSTO Systems Report 25, Hazards of Colour Coding in Visual Approach Slope Indicators, 1981.

FAA AC 150– 5345-28, Precision Approach Path Indicator (PAPI) Systems.

FAA Report DOT/FAA/AM-14/6, Usability of Light Emitting Diodes in Precision Approach Path Indicator Systems by Individuals with Marginal Color Vision

FAA Report FAA-AM-79-25, Runway Shape as a Cue for Judgement of Approach Angle.

FAA Report DOT/FAA/CT-82/153, Evaluation of Precision Approach Path Indicator (PAPI).

UK CAA Paper 2006/04, Minimum Colour Vision Requirements for Professional Flight Crew – Part 1

UK CAA Paper 2006/04, Minimum Colour Vision Requirements for Professional Flight Crew – Part 2

UK CAA Paper 2009/04, Minimum Colour Vision Requirements for Professional Flight Crew – Part 3