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COLOUR VISION REQUIREMENTS IN  
DIFFERENT OPERATIONAL ROLES IN  
THE ROYAL AIR FORCE

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Flying Personnel Research Committee  
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Operational Roles in the Royal Air Force**

by

**D.H. Brennan**

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39

ABSTRACT

A study into the importance of colour vision in the various operational roles of the Royal Air Force has been carried out. It is considered that good colour discrimination, although playing a valuable part in the total process of visual perception, is not of paramount importance. It would be possible by altering the present chromaticities of red and green signal colours to admit for all aircrew duties, except those of close air support, more severe grades of red green defective than at present. It is thought, however, that the small gain in recruiting would not warrant the resulting expense and disruption of present services.

The pseudo-isochromatic plates provide a simple and rapid method of detecting even minor anomalies of colour vision, and should be retained as the initial examining procedure.

With present standards, the lantern is the best 'trade test' for grading colour defectives as fit or unfit for aircrew duties. Should standards be lowered, it would be necessary to supplement the lantern with a quantitative test which should be related, if possible, to the role envisaged for the candidate.

Royal Air Force colour vision standards:

test methods;

chromaticities of signal colours.

### INTRODUCTION

The colour vision requirements and selection methods for Royal Air Force aircrew, in use today, were adopted in 1959. The present study examines whether these standards are still relevant to the operational needs of the Royal Air Force in the 1970's.

### METHODS

This report is a survey of aircrew opinion supplemented whenever possible by personal observations. The investigation was carried out mainly in RAF Strike Command, which is involved in most operational roles. Discussions and visits also took place within Air Support and Training Commands, and with centres responsible for aircrew selection.

In RAF Strike Command, discussions were held with staff officers responsible for the various roles, and visits were made at group headquarters concerned with maritime operations, air defence, and strategic bombing. The views of the Central Trials and Tactics Organisation were also obtained. Operational stations representative of each role were visited, and individual crew members gave their views on the value of colour cues in their particular role. Aircraft cockpit problems were examined and, where feasible, crews were accompanied on training sorties. Personal experience of mock emergencies was gained in the simulator.

RESULTS

Colour Requirements Common to Most Roles

Ground to Air Signals

- a. (1) Verrey Lights - red/green/white/yellow/blue
  - (2) Aldis - red/green/white
- Signalling  
    Lamp

Red and green are used in search and rescue, and in the rare event of complete loss of radio contact with ground control they would be used to indicate whether it is dangerous or safe to land. The other colours identify ground units to friendly aircraft. Verrey lights may be fired in combination, ie two reds and one green in the same cartridge, and can be difficult to see in bright hazy conditions. The Aldis lamp subtends, at a distance, a very small angle on the retina, and although very bright it can be difficult to see unless accurately aligned on the aircraft.

- b. Smoke
- (1) RAF - brown/white
- (2) Army - red/green/white/yellow/blue

Smoke is used as a marker to indicate targets, dropping zones, and friendly units.

c. Fluorescent Materials

- (1) Dayglo - orange
- (2) Fluorescein - greenish yellow dye

Dayglo is used for dinghy markings in search and rescue operations and by the Army to convey information to aircraft by varying the geometry of fabric panels. Fluorescein is used as a marker in sea survival.

Landing Aids and Air Support Markings

a. Angle of Descent Indicators:

(1) Visual Approach Slope Indicator (VASI). This is a device consisting of two sets of angled red and white lights separated on each side of the runway by 50 yards. The lights are very bright and can be seen up to 8 miles away in clear conditions. During the descent the pilot is on the correct flight path if both sets of lights look pink, or if the distant set is red and the near set white. In an emergency painted boards can be used instead of lights.

(2) Angle of Approach Indicator. This is an older device which is becoming obsolete. It uses the colours yellow, green and red. Pilots have reported confusion of the colours with other airfield lighting.

(3) Mirror Landing Devices. The Royal Navy uses a landing device whereby the pilot, when making a correct descent, aligns a circle of white light 'meatball' centrally between two horizontal datum bars of white light. Later versions of this use a yellow 'meatball' and green datum lighting.

b. Runway Lighting:

(1) The lights which indicate the lead-in path to the runway are red or white.

(2) The lights on the edge of the runway are white.

(3) The lights on the centre line of modern runways are usually green, whereas older runways may use white lights. The most modern array has alternate red and white lights.

(4) The lights on the threshold and end of the runway are transversely positioned red or green.

(5) Taxi-ways on modern airfields have green centre lighting alone or the combinations of green and blue, or blue and amber, on the taxi-way edges.

(6) Traffic lights are horizontally positioned red and green lights.

c. Airfield Identification Beacons:

(1) A flashing red beacon indicates a military airfield.

(2) A flashing green beacon indicates a civil airfield.

(3) A flashing green or white beacon indicates a civil airfield in Europe.

Air to Ground Signals

If it is necessary to indicate to a home base that an aircraft is friendly, or that contact with the tower is lost, an Aldis lamp or red flare may be used.

Air to Air

a. Anti-Collision Lights:

These are flashing red or strobe white, sometimes reinforced for daytime use with Dayglo panels, although panels can have the effect of breaking up aircraft profiles.

b. Navigation Lights:

The port side is indicated with a red light; the star-board side is indicated with a green light; whilst the tail of the aircraft has a white light. These lights

are important in that they show whether an aircraft is approaching or receding. Many pilots consider that with modern high performance aircraft it may already be too late to take avoiding action if one is close enough to have appreciated these cues.

c. National Markings and Flags:

In times of emergency it is desirable that national markings be seen as the same type of aircraft or ship may be used by hostile, neutral or friendly countries. In actual hostilities, owing to the range of modern missiles, an aircraft - if not known to be in the area and friendly - would be attacked on radar or first sighting.

d. Air to Air Refuelling:

(1) The Victor tanker has Dayglo markings and presents an array of signal lights to the recipient. The colours red, amber and green are used and are differently positioned on the centre and wing pods.

(2) A red light signals that the aircraft is approaching the tanker or must break away.

(3) An amber light shows that the recipient is line astern.

(4) A green light indicates that fuel is flowing, and an amber that the tanks are full.

(5) The sequence green, amber and back to green, conveys the information that 1,000 lbs of fuel have been given.

(6) Many pilots state that they ignore the colour of the lights, relying instead on their position.

### Aircraft Interiors

#### a. Cockpit lighting:

Many signal lights are used in the cockpit and these can be divided into three categories. Red lights indicate a hazard demanding immediate attention; amber lights indicate a lesser malfunction which if left unattended could lead to a major hazard; while blue, green or white lights confirm that a service is functioning. For example, in one aircraft a red flashing attention attracting light accompanied by a clanging bell in the headset indicates a major hazard. On looking to his left, the pilot sees the malfunction written on a panel back-lit in red. The amber cautionary light panel is on the right with the legend of the minor malfunctions also back-lit. Attention is drawn by an amber flashing light not accompanied by a clanging bell. Emergency levers, such as on the ejection seat, are painted with yellow and black bands, and some gauges have coloured segments painted in red and green.

Aircrew appear to rely to a degree on the position of lights, rather than the actual colours, to know what is amiss.

Cockpit lighting in recent aircraft is integral tungsten white, colour temperature corrected 'lunar' white, or red accompanied by floodlighting in white or red. Older aircraft may have ultra-violet and red lighting. One possible hazard noted is that owing to the difficulty in seeing instruments, pilots frequently turn up red floodlighting to maximum brilliance. This could result in some fatigue of the red receptors and difficulty with the Visual Slope Indicator (VASI).

b. Maps:

The colouring of maps is of significance in flight planning. In flight the course will be confirmed by sighting landmarks such as towns, roads, railways, hills, woods, promontories, etc. Spot heights are marked in figures, lessening the requirements for coloured contouring, while many other features of colour coding are duplicated by legends, figures or shapes.

Most navigators are able adequately to read maps in red cockpit lighting. This lends support to the value of cues, other than colour.

c. Electronics:

Repairs to electronic equipment would not be undertaken in flight. The only servicing attempted would be minor, such as changing a fuse.

## Specialised Roles

### Maritime

Search is primarily done by electronic devices. Visual sighting is by silhouette recognition which is seen before colours are appreciated, especially if a vessel is back-lit. The sea provides a grey/green and white environment in northern waters against which ship colouring of grey, white and dirty rust blends well. The red funnel markings of some trawlers, and the green decks of Royal Navy ships, are only appreciated when very close. High speed vessels provide an obvious white wake, especially when moving at right angles to the white caps.

The strike role could involve recognition of national flags or markings, but in war an unknown ship in a potentially hostile area would be attacked long before markings could be seen, probably even before the silhouette was seen.

Search and rescue; the chromatic element of this is recognition of red and green Verey lights and the recognition of Fluorescein and Dayglo.

Navigators use Decca Loran or Consol charts which have lattice lines in blue, green, brown and purple.

### Air Defence

The aircraft is radar controlled to target, and missiles are fired before the target is within visual range. In interroga-

tion there is the need to recognise profiles by night and day with confirmatory evidence of national markings in daytime.

#### Low Level Strike

Strike against enemy targets is likely always to be at low level. The aircraft would fly to just outside enemy radar, and then descend to operating height and make a high speed approach to target. Collision avoidance radar is fitted, but visual watch is also kept as a safeguard, and in order to check the low level navigation by sighting roads, bridges, railways etc. In operations opaque screens would cover all windows and no one would look outside at all to avoid danger of flash blindness and retinal burns.

The maps preferred are topographical tactical charts which are relatively uncluttered.

#### Transport and Armed Reconnaissance

In the present survey no colour problems were discovered peculiar to this role.

#### Close Air Support to Ground Troops

This role includes the use of fixed wing, rotary wing and VTOL aircraft. These are radio controlled, or rely on Verey, smoke, Aldis or Dayglo panel geometry. Aircrew would have the need to recognise military formations, vehicles, tanks

and terrain features. It is in this role of close air support that the greatest need for good colour discrimination exists.

Camouflage markings are chosen to confuse the normal trichromat. The colour defective in this respect may, therefore, be at an advantage.

#### DISCUSSION

The approach used in this survey was to interview aircrew as to the importance of colour in their various roles, and to supplement this wherever possible by personal experience. It is realised that this approach has disadvantages as it is difficult for the colour normal to envisage the problems faced by the colour defective. Also it is appreciated that answers to questions may vary according to how the questions are phrased. Nevertheless, this was the most practical approach, and a remarkable consistency of views was obtained from officers of differing seniority engaged in widely differing tasks. The initial reaction of most officers was to regard a high degree of hue discrimination as essential. Many were surprised, however, on analysing this view, at how little they really relied on colour as a paramount cue.

Visual perception is dependent on a great variety of different visual cues supplemented cortically by experience and intelligence. Much of the visual information may be duplicated by different cues, and it is this redundancy of information which gives an individual confidence in what he sees. If colour vision standards were lowered one of these cues would be removed and, therefore, the colour defective would

be at some disadvantage, however small, with the colour normal.

The incidence of colour defectives in the British male population is approximately 8%, and of these about half could be passed as fit for aircrew duties using the present test methods. Should colour entry standards be lowered in order to gain more recruits for aircrew duties, it would be necessary to change coloured signal standards internationally. It may be considered that this is not justified when the small gain in recruiting is weighed against the expense and the possible decrement in performance.

The present test methods of screening with the pseudo-isochromatic charts, followed by grading defectives with the lantern, are suitable for present standards. If standards were lowered it would be necessary to assess the defective's deficiency quantitatively and, if possible, relate this to the minimum requirements necessary for the safe and efficient execution of his role.

#### ACKNOWLEDGEMENT

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#### REFERENCE

WALRAVEN P L (1966). The fluctuation theory of colour discrimination. In Studies in Perception. The Institute for Perception RWO/TNO, National Defence Research Organisation Soesterberg, The Netherlands.

ANNEX 1TYPES OF COLOUR DEFECTIVE

Some degree of colour anomaly occurs with a mean frequency of approximately 1 in 12 in the British male population.

Colour vision is a function of the cones and therefore of photopic (day) vision. The rods, which cannot discriminate between colours, are responsible for scotopic (night) vision. The rods are maximally sensitive to shorter wave lengths in the blue-green region of the spectrum, peaking at about 500 nm. They are relatively insensitive to longer wavelengths at the red end of the spectrum.

According to the generally accepted Young-Helmholtz theory of colour vision, there are three classes of cone present maximally at the macula, in the ratio of 1 : 10 : 10 . These cones have absorption peaks at about 440 nm (blue), 540 nm (green), 580 nm (red). A combination of these three primary colours in the correct proportions is seen as white light, and by varying the proportions and saturation any other colour can be matched. According to the work of Walraven, information from the three types of cone is analysed into three channels. A brightness channel which is the summation of brightness information from each cone, and two chromatic channels, a Red-Green and a Yellow (red + green)-Blue channel. It might, therefore, be more accurate to use the term double dichromats rather than normal trichromats.

Colour defectives are generally sub-divided into three main groups.

1. **MONOCHROMATS:** Complete absence of colour sensation.
  - a. Rod - frequency 1 in 30,000. Associated with poor day visual acuity.
  - b. Cone - frequency 1 in 100,000,000. Associated with good day and night visual acuity.
  
2. **DICHROMATS:** Require only two primaries to match all colours.
  - a. Protanopes: 1 in 100. Lack red cones, therefore suffer a loss of brightness as well as absence of red sensation. This gives rise to red/green confusion.
  - b. Deuteranopes: 1 in 100. Do not possess separate red and green cones but a single cone presumably containing both red and green pigments. There is no loss of brightness, but red/green confusion.
  - c. Tritanopes: 1 in 13-65,000. Very rare, lack blue cones. The normal individual is tritanopic if the field of vision is small enough as the fovea centralis does not contain blue cones.
  
3. **ABNORMALOUS TRICHROMATS**
  - a. Protanomalous: 1 in 100. Require more red stimulation for a match than normal.
  - b. Deuteranomalous: 1 in 20. Require more green stimulation for a match than the normal.

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  - a. Protanomalous: 1 in 100. Require more red stimulation for a match than normal.
  - b. Deuteranomalous: 1 in 20. Require more green stimulation for a match than the normal.

c. Tritanomalous: Rare, but suggested to be 1 in 4,000. Require more blue stimulation for a match than normal.

As can be seen from the above approximate figures, it is only with red green defectives we need be concerned.

As by far the majority of flying personnel are normal trichromats, it is important that any changes or additions to colour cues made for the minority should not confuse the majority.

ANNEX II

REQUIREMENT FOR COLOUR DISCRIMINATION

It is important to reject the misleading term 'Colour Blindness' and instead substitute the more descriptive phrase 'Colour Defective'. A noteworthy point is that even in the colour normal, one spectral wavelength does not always elicit the same colour response. This can be due to the effects of simultaneous and successive contrast, and with increasing age the deposition of yellow pigment in the lens.

It will also be of value to know how the various types of colour defective 'see' different colours.

As will be appreciated the signal colours of red and green both in lights and flares could be made more obvious to the protanope and deuteranope by making the red more orange and the green more blue. To make confusion even less likely, further cues could be added such as a bar across a green light, but not on a red; or in flares by using a 2 star red and a one star green. (International standardisation would be required). The lattice lines on Decca, Lorax or Condol charts could have an added shape coding.

Should the red signal colour be made more orange it would be necessary to abandon yellow light signals as these could be confused with the new red standard. It would also be necessary to ensure that white light is of a high colour temperature, as discrimination between a dim white light and the new red signal colour could be difficult.

If the green signal colour were made more blue it would be necessary to increase the power of the illuminating source. This would be necessary as the new filter would have a greater absorption factor, and in order to maintain visibility at its present level power consumption would have to be increased two or three times.

Yellow is not a vital signal colour in aviation, and the power of illuminating sources can be increased, but it is considered that the return in recruiting would not justify the international effort and cost involved.

ANNEX III

COLOUR TEST METHODS

1. PSEUDO-ISOCROMATIC CHARTS

The best known of these are the Ishihara and H.K.R. plates. The Ishihara plates do not test for tritan defects but are of great value as a rapid screen for large numbers in eliminating all but minor degrees of red/green anomaly. In their use, light of the correct colour temperature is essential as is avoidance of oblique lighting which, due to differing degrees of ink gloss, could lead to spurious results. When inks begin to fade the plates must be replaced.

2. LANTERN TESTS

These are popular as 'trade tests' with the armed forces, merchant marine and transport ministries of many nations, as they provide a practical test of a man's ability to recognise signal colours at different distances according to the angle subtended on the macula by the aperture used. The lantern tests are simple to use, and most examinees accept the justice of relating this test to their job. The Ministry of Defence, in collaboration with the Department of Trade and Industry and the Civil Aviation Authority is at present sponsoring the development of a new lantern. This lantern should obviate the disadvantage of older lanterns in terms of colour temperature, cleanliness of small apertures and spectral characteristics of the filters.

3. FARNSWORTH MUNSELL 100 HUE TEST

This is a good, if laborious, test which involved grading of unsaturated colour caps in their natural order. It can be operated by unskilled people and gives the degree of colour deficiency in a quantitative form.

4. LOVIBOND COLOUR VISION TESTER

This is a prototype machine which has not yet been fully evaluated. The candidate is required to match a central neutral grey light to a peripheral circle of randomised colours containing only one similar grey. The brightness of the colours is under the control of the candidate and the degree of saturation can be varied continuously by the examiner.

5. ANOMALOSCOPE

This is the most scientifically valuable instrument for colour vision testing, particularly in the anomalous trichromat. There are many versions but all consist basically in presenting the candidate with a split field which he is required to match a selected colour in one half of the field by a mixture of two or more spectrally pure colours in the other half, the mixture used being read quantitatively. Unfortunately it is expensive, bulky and requires skilled operators.

6. ROYAL AIR FORCE TEST METHODS

A candidate is screened with the Ishihara plates. If entirely correct he is graded colour normal and is passed fit for all roles. Should he fail the Ishihara test he must correctly name the signal colours red/green/white at all sizes of aperture on either the Martin or Giles Archer lantern and he is then graded colour abnormal but safe for aircrew duties.