

Lessons in Adversity: Adapting Methods for Assessments of Colour Perception

Nicola Hill, Kamila Radwanska & Siddharth Shyamsundar

BAE Systems, UK

SUMMARY

This paper outlines the practical challenges the authors faced while testing colour perception in helmet mounted displays in a first-of-its-kind flight testing in high ambient light. This paper outlines issues that may hamper future human factors studies and offers potential mitigations, serving as a stepping stone for future assessments. A brief review of the study's results is also presented.

KEYWORDS

Helmet Mounted Displays, Colour Perception, Human Performance

Introduction

Helmet Mounted Displays (HMDs) are Augmented Reality (AR) devices used by fast-jet pilots which overlay virtual information onto the outside world view. Virtual symbology and imagery showing flight parameters and sensor information are displayed on a see-through visor. As the modern military fighter jet advances, so do the functional requirements of the HMD. At present, most existing HMDs use monochrome green as the sole display colour. However, the use of a single colour has limitations, including reduced situational awareness in complex tasks (Wickens, et al., 1995) and increased cognitive load (Melzer, et al., 1997). As HMDs move to displaying more information around navigation, targeting, sensor feeds and aircraft health monitoring, the use of colour could help manage the presentation of information better, and in turn reduce human error and workload (Foote & Hoffmann, 2018). However, this is not without complications. Foremost amongst these is the problem of additive colour mixing, whereby light from the sun may change the way certain colours are perceived. Environmental conditions like cloud cover and colour may also impact accurate colour perception. While this has been researched to some degree, most studies have been restricted to laboratory conditions. An assessment was therefore proposed to determine what colours were seen as being 'true to colour' and readable when displayed within the context of a cockpit in real world high ambient light conditions. A series of alphanumeric characters and symbols were presented to participants in different colours, with readability and colour discrimination being assessed using a questionnaire.

The Challenge of Testing

Given the authors' access to general aviation assets and specialised military aviation helmets like the BAES Striker II®, the study initially proposed the use of the Striker II helmet in a twin seat Diamond DA-42 aircraft. The Striker II is capable of displaying data in colour, and the DA-42 serves as a reliable, economically viable testing platform. However, right from planning, this study uncovered several previously unreported issues which have been briefly mentioned below:

- The cockpit size of the DA-42 imposed restrictions on potential participants' anthropometric range due to the helmet interacting with the ceiling of the canopy

- Modern day fast-jet helmets contain a liner that is bespoke to each pilot. Pilots' heads are laser scanned to ensure accurate fit. Unfortunately, given the cost and time required for this, the authors had to use the default liner for all participants, which adversely impacted visibility of the presented symbology
- A general aviation aircraft doesn't possess the power connectors required for a fast-jet helmet. Despite pan-business conversations and efforts, a solution to power the Striker II within the DA42 was deemed unfeasible

As a result, the research team pivoted to using the Microsoft HoloLens 2® AR device. However, early shakedown of this method also ran into problems. These are summarised below:

- For the HoloLens 2 to accurately track head movement, it assumes that the individual is stationary relative to the Earth. Since our assessments were being conducted in a moving, flying DA-42, this interfered with the HoloLens 2's tracking and inertial systems, making the device unusable in flight
- Due to the time of the year (November), the researchers had a very limited window during which they could conduct testing. The DA-42 is only able to fly particular flight regimes with restricted angles of attack, so not all illumination conditions could be tested
- Due to the lack of a bubble canopy like of most fast-jets, conditions like sun-rear, where sunlight enters from the back of the aircraft canopy could not be tested
- The high instrument panel on the DA-42 reduced the amount of light entering the cockpit, limiting the lux level the participant was exposed to

Adapting to a Limited Assessment

With limited options on the table, the only viable option left to the authors was to run the assessment on the ground. Participants were taken to a designated open area and asked to relay the colours and symbology they viewed on the HoloLens 2 when high ambient conditions were encountered.

The results indicated that, whilst assessing in outdoor conditions with high ambient light, white was recognised with the most accuracy, which supports previous research (Moffitt & Browne, 2018). Cyan was a close second at 65% accuracy, then green at 50%. Blue performed poorly and no symbology could be recognised with a lux reading above 5260lx, making this colour unusable. Magenta also performed poorly in high ambient light.

Recommendations

Optimal outcomes should have been obtained from this research if a representative cockpit environment and HMD had been procured. With that in mind, the following learnings may be used through an assessment phase, from design to results, to ensure a rigorous assessment:

- Using a real-world HMD (or at the very least, a solution with matching capability to a real-world HMD)
- Acquiring the use of an aircraft with a cockpit that replicates the light effects of a bubble canopy
- Assessing by means of flight testing different levels of high ambient light and cloud conditions

Whilst taking the assessment of colour perception in high ambient light out of the laboratory and into the outdoors, this study aimed to pioneer on-field assessments of colour perception in outdoor high ambient environments. Instead, we discovered a series of first-of-class challenges that we hope the human factors community can learn from when attempting such assessments.

References

- Foote, B., & Hoffmann, R. (2018). *Colour and impact to HMD design*. Bellingham, WA: The International Society for Optics and Photonics (SPIE).
- Melzer, J.E., & Moffitt, K. (1997). *Head-Mounted Displays: Designing for the User*.
- Moffitt, K., & Browne, M. P. (2019). Visibility of color symbology in head-up and head-mounted displays in daylight environments. *Optical Engineering*, 58(5), 051809.
- Wickens, C.D., & Carswell, C.M. (1995). "The proximity compatibility principle: Its psychological foundation and relevance to display design." *Human Factors*, 37(3), 473–494.