

Institution: University of Essex
Unit of Assessment: 4 – Psychology, Psychiatry and Neuroscience
Title of case study: Precision spectral filters in the prevention of visual discomfort
<p>1. Summary of the impact</p> <p>Essex research has investigated how coloured filters can reduce perceptual distortions experienced by those with visual stress. The results of experimentation with coloured plastic sheets overlaid on text underpin the commercial activities of three major equipment manufacturers, whose products are now used in over 60% of UK schools. Additionally, 'Intuitive Colorimeter' devices, developed at Essex, provide a robust and precise means of prescribing tinted spectacle lenses and are used by over 500 optometrists worldwide. A Society for Coloured Lens Prescribers set up by Essex and the Institute of Optometry has developed good-practice guidelines, and over 70 training events for practitioners were delivered in 12 countries between 2008 and 2013.</p>
<p>2. Underpinning research</p> <p>People show consistency with respect to the images that they judge to be uncomfortable, and this discomfort can be predicted from an image's statistical description. This applies to images ranging from photographs of everyday scenes to modern art and geometric arrays, coloured or in motion. Images are generally rated as uncomfortable to view if their characteristics depart from those that occur in natural images, such as with respect to their variation in luminance with spatial scale, variation in chromatic contrast and variation over time. Viewing of uncomfortable images can result in a large cortical haemodynamic response (Huang et al., 2011; Haigh et al., 2013), possibly reflecting an inefficiency of neuronal processing. The discomfort can be understood as homeostatic, and also as an evolutionary adaptation because images of venomous animals have statistical characteristics of uncomfortable images, and are indeed uncomfortable to view.</p> <p>For many children learning to read, text can present a significant example of an uncomfortable image. Motivated by a desire to reduce the perceptual distortions and discomfort that can accompany reading, Arnold Wilkins (Professor at Essex and Director of the Visual Perception Unit since 1997) experimented with the use of coloured sheets of plastic, to act as text overlays. In 2001 Wilkins showed that, for those experiencing visual stress, overlays could improve the speed of reading. For instance, across a sample of 12 mainstream schools it was found that 5% of children (having mean age 7 years 6 months) read more than 25% quicker when using an overlay (Wilkins et al., 2001). However, Wilkins also found that it was essential that these overlays had an appropriate, individually selected colour. It was later shown that systems of overlays that have an insufficiently large palette of colours do not benefit reading (Smith and Wilkins, 2007).</p> <p>In addition to the use of coloured overlays, Wilkins has conducted research into the use of coloured spectacle lenses, worn by readers, as another means of reducing abnormal brain activity and hence providing a treatment to visual stress. As with coloured overlays, the benefit from tinted lenses is optimal only if the colour is selected individually and with precision (Wilkins, Sihra and Nimmo-Smith, 2005). To provide a systematic and rigorous means of doing this, and in expansion of earlier research conducted whilst at Cambridge prior to 1997, Wilkins developed the Intuitive Colorimeter Mark 2 (Wilkins and Sihra, 2000) whilst at Essex. This was released in 2002 and followed in 2009 by the launch of the Mark 3 device. The colorimeter illuminates text with coloured light and permits the separate manipulation of hue (colour), saturation (strength of colour) and luminance (brightness). Observers select a colour that is optimal for clarity of vision and the shade of colour chosen then guides the provision of tinted spectacle lenses via an established protocol.</p> <p>The combination of coloured trial-lenses that match the chosen colorimeter setting is selected using a computer algorithm. This algorithm ensures that the colour chosen in the colorimeter is available when the lenses are worn under white light. The lenses provide a spectral match, which means that individuals with anomalous colour vision can use the colorimeter. The combination of coloured trial-lenses forms a prescription that enables spectacle lenses to be tinted to the precise shade using just two dyes, each with smoothly varying spectral transmission, so as to reduce metamerism.</p>

In addition to applications related to reading, Wilkins' research indicates that tinted spectacles will also be of use in a variety of neurological conditions in which the visual cortex may be hyper-excitable. Such conditions include migraine (Wilkins et al., 2002; Huang et al., 2011), autism (Ludlow, Wilkins and Heaton, 2006), photosensitive epilepsy, stroke, head injury, multiple sclerosis (Newman et al., 2007) and Tourette's Syndrome. It has also been found that, in individuals with autism, coloured filters can improve the perception of facial expression of emotion. In the case of migraine, the cortical basis of the benefit of tinted lenses has recently been demonstrated by neuroimaging. An abnormal oxygenation of the brain occurs when affected individuals observe visually stressful patterns. The oxygenation is normalised when appropriately tinted lenses are worn, but not when similarly-coloured control tints are worn (Huang et al., 2011), suggesting a value in reducing the photophobia that can accompany migraine attacks, confirmed by a preliminary double-masked study (Wilkins et al., 2002).

3. References to the research

- Wilkins, A.J. and N. Sihra (2000) A colorizer for use in determining an optimal ophthalmic tint. *Color Research and Application*, 26(3), 246-253. DOI:10.1002/col.1022
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- Haigh, S.M., L. Barningham, M. Berntsen, L.V. Coutts, E.S.T. Hobbs, J. Irabor, E.M. Lever, P. Tang and A.J. Wilkins (2013) Discomfort and the cortical haemodynamic response to coloured gratings. *Vision Research*, 89, 47-53. DOI:10.1016/j.visres.2013.07.003

Research funding:

- Wilkins, *Tests of a theory of visual discomfort*, MRC, Dec '97 – Sep '00, £422,560
- Wilkins, Thomson, Lightstone, *Determining the optimal colour of text interfaces by accommodating individual differences*, ESRC, Sep '03 – Sep '04, £52,162
- Wilkins, Cooper, Elwell, *Non-invasive assessment of cortical abnormality in migraine using near infrared spectroscopy*, Wellcome Trust, Jul '07 – Dec '10, £124,035

4. Details of the impact

A substantial focus of Wilkins' research on visual stress has been directed towards the understanding and development of **effective interventions to alleviate its symptoms**. His decision to conduct research in this way has been significant in generating impact. This has resulted in **commercial benefits** for equipment suppliers, as well as positive influences on **healthcare guidelines, practitioners and members of the public**. It is estimated that 5-20% of the population are affected, to varying extents, by visual stress [see corroborating source 1]. Wilkins' research has been highly influential in raising the profile not only of this condition but, importantly, of the availability and appropriateness of the various interventions that can be used to alleviate its symptoms.

Impact case study (REF3b)

Coloured Overlays: Benefits to Commercial Suppliers and Educational Users

Following Wilkins' 2001 demonstration of the available benefits of using coloured overlays for reading, their usage has been widely adopted. Overlays represent a straightforward, cheap and accessible means by which children can explore whether the use of colour could help to improve their reading. In the UK, three main bodies primarily supply coloured overlays: *Crossbow Education Ltd*, *Cerium Visual Technologies Ltd*, and *i.O.O. Sales Ltd*, all of which also operate overseas (for example, *Cerium* reports sales in five continents [2]). Smith and Wilkins' 2007 paper, which demonstrated the importance of offering a wide range of overlay colours, held significance for all three of these suppliers.

As a result of much earlier work, the range of overlays offered by i.O.O. Sales had originally been designed by Wilkins and at that time already comprised a wide selection of colours. The range offered by Cerium also offered a broad range of available colours. In letters of support both



organisations acknowledge the 2007 paper, recognising its significance in technically validating their ranges of overlays and supporting earlier decisions to offer a broad selection of colours [2] [3]. For Crossbow Education, however, this research had arguably even greater significance. Crossbow's overlay range had previously comprised just five colours. However, following (and making direct reference to) Wilkins' 2007 research, they then took the decision to expand their product range, which now includes ten colours. This is described on Crossbow's website, which states that: "In response to this [Wilkins'] research, the number of tints in the

Crossbow range was increased from five to ten" [4]. Through intelligent distribution of these colours around the CIE Uniform Chromaticity Scale diagram, this expansion meant that upwards of thirty chromaticity combinations could be obtained. In addition to underpinning this enhanced provision of overlays, a letter of support from a Crossbow Director details how Wilkins' research is also used to inform the company's written guidance material, including, for example, the manual that accompanies Crossbow's visual stress assessment pack. In both of these instances, Wilkins' research provides robust, scientific support for Crossbow's activities and has made an important contribution towards the company's continued growth and success. The letter goes on to describe how Crossbow's overlays and reading rulers are now used in **over 60% of UK schools**, and how the company's achievements have also been recognised by two BESA 'Educational Supplier of the Year' awards, in 2012 and 2013 [5]. As well as their widespread use in schools, the Crossbow Education website details how coloured overlays are also: "...used by the Police, the Ministry of Defence, the Prison Service, at a number of banks, building societies and other corporations, and at regional access centres across the country" [6].

Both for initial assessments and in subsequent long-term use, coloured overlays have proven to offer a cost-effective, accessible and easily administered measure to prevent schoolchildren



suffering from symptoms of visual stress. In many cases, following initial use of coloured overlays, a logical next step can be to explore the use of precision tinted lenses as a long-term solution. Whilst representing greater administrative effort and cost, the use of coloured lenses can offer a number of benefits. The primary advantages are that the colour can be selected more precisely, giving greater relief of symptoms, and that the glasses are suitable in supporting writing as well as reading at a distance, e.g. from the classroom board. Canadian-based 'Opticalm' is an example of an overseas

organisation which both undertakes assessments and also provides access to interventions – including overlays and tinted lenses – with the aim of alleviating the symptoms of visual stress. The majority of the studies listed on Opticalm's website reference research undertaken by Wilkins (a total of 17 references) [7].

Colorimetry in CPD and Professional Practice

Wilkins' Mark 2 and Mark 3 Colorimeters (those versions of the device which are now most commonly in use), along with the coloured lenses he designed, are manufactured by Cerium Visual Technologies. These instruments have been sold and are in use in international territories worldwide, including the US, Canada, Europe, Australia, Hong Kong, South Africa and Singapore. All optometry schools in the UK also now have colorimeters. In 2011, more than **10,000 pairs of precision tinted lenses were prescribed by over 500 optometrists worldwide, using colorimeters**. This illustrates the widespread use that the device is experiencing. In the UK alone, the Institute of Optometry report colorimeter-based assessment in over 1000 cases of children with specific learning difficulties. The Institute has also set up a visual stress clinic, specifically for colorimetry [2].

Finally, the insight and outputs of Wilkins' research have been used to directly underpin a diverse programme of **training and support for practitioners** over the past five years. For example, the Society for Coloured Lens Prescribers (SCLP, which was established in 2007 jointly by the University of Essex and the Institute of Optometry), has provided over 70 courses, lectures and training events for eye care practitioners between April 2008 and July 2013. These were delivered in 12 different countries and represented over 290 hours of continued professional development for practitioners. Many of these events have drawn directly on Wilkins' Essex-based research, and an online record shows that Wilkins has spoken at 16 of these meetings [8]. In 2009 Wilkins' research was also cited by guidelines from the College of Optometrists, with respect to using colour-based interventions in the treatment of patients with specific learning difficulties and visual stress [9]. It should also be noted that Wilkins' work has also been widely cited in the media. On the radio and in the written press, a University report indicates that, globally, more than 80 features between January 2009 and February 2013 have referenced Wilkins' research [10]. In 2011 Wilkins' work also featured in the BBC television documentary *Don't Call Me Stupid* [11].

5. Sources to corroborate the impact [All sources saved on file with HEI, available on request]

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[2] General Manager, Cerium Visual Technologies Ltd

[3] Operations Manager, i.O.O. Sales Ltd

[4] Crossbow Education Ltd. *Coloured Overlays, Dyslexia and Irlen Syndrome* [online] Available at: http://www.crossboweducation.com/coloured_overlays,%20Dyslexia%20and%20Irlen%20Syndrome.htm [Accessed 3 July 2013]

[5] Director, Crossbow Education Ltd

[6] Crossbow Education Ltd, *Dyslexia and Visual Stress Workplace Solutions* [online] Available at: http://www.crossboweducation.com/dyslexia_and_visual_stress_work.htm [Accessed 7 October 2013]

[7] Opticalm, 2013. *Research* [online] Available at: <http://www.opticalm.ca/Research.html> [Accessed 7 October 2013]

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[9] The College of Optometrists, 2009. *Examining Patients with Specific Learning Difficulties or Visual Discomfort* [pdf] Available at: <http://www.college-optometrists.org/download.cfm/docid/FC637F98-DB94-4EA5-80D7CC6961C9E885> [Accessed 14 June 2013]

[10] University of Essex Communications and External Relations, 2013. *Press Report, Wilkins*

[11] Kara Tointon: *Don't call me Stupid*, 2011. [TV programme] BBC, BBC Three, 18 August 2011 04.20