Institution: University of Essex		
Unit of Assessment: UoA 4		
Title of case study: Products developed to manage visual stress lead to continued worldwide commercial success and improved quality of life		
Period when the underpinning research was undertaken: 2000-2014		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Arnold Wilkins	Professor	01.12.1997 – 30.09.2014
Period when the claimed impact occurred: 01.08.2013 – 31.12.2020		
Is this case study continued from a case study submitted in 2014? Yes. See Section 4.		

1. Summary of the impact

Twenty percent of the population experience visual stress. It impedes reading and aggravates symptoms associated with cortical hyperexcitability, impairing quality of life and economic activity. Wilkins' research has identified the mechanisms of visual stress. Working with two companies, he **developed and improved products that alleviate symptoms** in those who suffer from visual stress and its consequences: Coloured page overlays (Crossbow Education) are sold across 16 countries, **yielding continued commercial benefits.** Products are now used in **70% of UK schools** improving reading in children. Business settings **benefit from research informed training courses** that help identify visual stress in employees and support them with **resources,** increasing **workplace productivity**. The **Intuitive Colorimeter** (Cerium Visual Technologies) **has been updated to an electronic version patented in 2017** and **is now used by Optometrists** [text removed for publication] to prescribe precision tinted lenses to individuals who suffer more acute symptoms. Precision tinted lenses enable Optometrists worldwide to **deliver positive outcomes to thousands of people**, widening their professional practice and improving users' quality of life.

2. Underpinning research

Visual stress refers to the perceptual distortion and discomfort that can occur on exposure to visual stimuli such as flickering lights, strongly contrasting colours and spatially repetitive patterns, such as text or supermarket shelves. It causes discomfort to one in five people in the general population and has particularly negative consequences for individuals with sensory difficulties, such as people with dyslexia, autism spectrum disorders and recurrent migraine.

Wilkins has studied the psychobiological aspects of vision and visual stress for over four decades. Since 2000, his work at Essex has characterised the visual stimulation underlying visual stress, explored the neural mechanisms involved and found new methods of treating symptoms. His research has been supported by competitive funding agencies (Wellcome Trust, ESRC, MRC) [**G1**, **G2, G3**].

A. Coloured Overlays

Wilkins examined the use of coloured plastic sheets as text overlays to reduce the perceptual distortions and discomfort that can impede reading. He showed that for those experiencing visual stress, coloured overlays improved reading speed and clarity of text. In a sample of 12 mainstream schools, 50% of children report improved clarity of text and 5% of children were shown to read at least 25% more quickly using an overlay [**R1**]. Overlays in grey did not improve reading speed, ruling out a placebo effect (e.g., increased motivation to read better/faster). Wilkins demonstrated that to achieve such effects readers required an appropriate, individually selected colour [**R2**] and that packs of overlays without a sufficiently large palette of colours do not provide a benefit [**R3**]. These findings informed the development of coloured overlay products (e.g., page and monitor overlays) and visual stress resources manufactured and sold originally by i.o.o. Sales and Cerium Visual Technologies (CVT) and subsequently Crossbow Education (CE).

B. Precision Tinted Lenses

Visual stress symptoms are related to hyper-neural activity in response to sensory stimulation, for example inappropriately firing visual neurons upon seeing text, a phenomenon particularly pronounced in those suffering from conditions associated with cortical hyperexcitability (e.g., autism spectrum disorders, migraine, epilepsy) [**R4**, **G1**]. For these affected individuals, visual stress occurs not only during reading which can be addressed with coloured page overlays, but may also occur in response to a range of daily-life stimuli, thus requiring a more *constant* use of coloured filters.

Wilkins examined the use of coloured spectacle lenses as another means of treating the symptoms of visual stress. His research with coloured light and coloured lenses demonstrates the benefit is optimal only if the colour of the lens is selected individually and with precision [**R4**, **R5**, **G1**, **G2**]. For example, improvements in reading speed using precision tinted lenses are only achieved if there is a close match between the user's ideal colour and that used to tint the lenses. Wilkins' research identified the range and number of colours needed to provide benefits to users. It showed that at least a thousand tints are needed, and how this can be achieved through the combination of appropriately selected trial lenses. Wilkins used his research findings [**R1-R5**] to develop the Intuitive Colorimeter (IC) to enable optometrists to prescribe the optimal colour of tinted lenses rapidly and with precision. Colorimeters illuminate text with coloured light and permit the separate manipulation of hue, saturation and luminance. Observers can select a colour that is optimal for clarity of vision, which guides the provision of the 'precision tinted lenses', via a protocol established by Wilkins. Wilkins' research [**R4, R5**] also identified the importance of the precise and reliable replication of the colours established in the colorimeter in the selection of appropriate lens tints.

Wilkins' research has linked precision tinted lenses to reduced visual discomfort and associated symptoms for those experiencing migraines as precision tints help normalise enlarged cortical haemodynamic responses triggered when viewing uncomfortable images, an effect not found with other tints [**R6**, **G2**]. Precision tinted lenses were also shown to improve visual stress symptoms in children with autism spectrum disorders [**R7**].

3. References to the research (Publications and grants as listed in the REF2014 case)

The research has been funded by competitively peer-reviewed awarded research grants (ESRC, Wellcome Trust, MRC) and published in specialised international peer-reviewed journals that are highly regarded in their respective fields. The body of work has been cited 450 times (Google Scholar).

R1 Wilkins, A.J., Lewis, E., Smith, F., Rowland, E. & Tweedie, W., (2001). Coloured overlays and their benefit for reading. *Journal of Research in Reading, 24* (1), 41-64. DOI:10.1111/1467-9817.00132.x

R2 Waldie M, Wilkins A.J. (2004). How big does a coloured overlay have to be? *Ophthalmic and Physiological Optics, 24*(1), 57-60. DOI:10.1046/j.1475-1313.2003.00169.x

R3 Smith, L. & Wilkins, A.J. (2007). How many overlay colours are necessary to increase reading speed? A comparison of two systems. *Journal of Research in Reading, 30*, 332-334. DOI:10.1111/j.1467-9817.2007.00343.x

R4 Wilkins, A.J., Sihra, N. & Smith, I.N., (2005). How precise do precision tints have to be and how many are necessary? *Ophthalmic and Physiological Optics, 25* (3), 269-276. DOI:10.1111/j.1475-1313.2005.00279.x

R5 Wilkins, A.J. & Sihra, N. (2001) A colorizer for use in determining an optimal ophthalmic tint. *Color Research and Application, 26*(3), 246-253. DOI:10.1002/col.1022

R6 Huang, J., Zong, X., Wilkins A.J., Jenkins, B. Bozoki A. & Cao, Y. (2011). fMRI evidence that precision ophthalmic tints reduce cortical hyperactivation in migraine. *Cephalalgia, 31*(8), 925-936. DOI:10.1177/0333102411409076

R7 Ludlow, A. K., Wilkins, A. J., & Heaton, P. (2006). The effect of coloured overlays on reading ability in children with autism. *Journal of Autism and Developmental Disorders, 36*(4), 507-516. DOI: 10.1007/s10803-006-0090-5

Research grants

G1 2007-2010 A.J. Wilkins, & C. Cooper. Wellcome Trust. £124,036. Non-invasive assessment of cortical abnormality in migraine using near infrared spectroscopy.
G2 2003-2004 A.J. Wilkins., W.D. Thomson, A. Lightstone. ESRC. £52,162. Determining the optimal colour of text interfaces by accommodating individual differences.
G3 01/12/1997-30/09/2000 A.J. Wilkins. MRC. £422,560. Tests of a theory of visual discomfort.

4. Details of the impact

Context: Up to 20% of the population are affected, to some extent, by visual stress [**S1a**]. This is **more than 13,000,000** people in the UK alone [**S2a**]. Visual stress can prevent children from learning to read and is a major component of photophobia (light sensitivity) contributing to migraine. The economic costs of illiteracy and migraine are GBP80,000,000,000 and GBP3,420,000,000 per year in the UK alone [**S2b**].

Continuation Statement
The REF2014 case demonstrated that the research described in Section 2 achieved impact by providing **two innovative solutions to alleviate visual stress** and its consequences: coloured overlays and precision tinted spectacle lenses designed with an intuitive colorimeter. **Since August 2013** there has **been continued commercial success** of the coloured overlays, **a wider uptake of products in schools and additional uptake in businesses**. An **improved, electronic version of the IC** has been **developed, patented, and successfully launched** in 2018. The new version allows for **quicker and more accurate** testing helping optometrists to reach individuals who previously could not easily endure a longer examination. The new design is easier to use enabling CVT to **expand their clientele**.

A1. Crossbow Education (CE) benefit from continued commercial success from sales of coloured overlays and visual stress resources
CE is the UK brand leader for its award winning visual stress range [**S1b**,**c, S3**], distributed across 16 countries in Africa, Asia, Australasia, Europe, North America and the Middle East via CE, Amazon, and educational/business suppliers [**S4**]. Wilkins' research [**R1-3**] '*provided the scientific foundation of our visual stress support products and services'* notes CE CEO [**S3**, **S1d**]. Wilkins' research [**R3**] was used to **optimise the design of CE's overlay ranges**, expanding from 5 colours to 10 [**S1d**]. CE's CEO states *'Wilkins' 2007 demonstration that a wide range of colours is required to improve the reading speed of many individuals remains fundamental to our approach'* [**S3**] adding '*our **visual stress assessment pack is based on Prof Wilkins research** into coloured overlays and their effects on reading speed'* [**R1-3**, **S3**]. He further acknowledges the **key contribution the research made towards CE's continued growth and success** '***Since 2013** we have distributed 181,748 coloured overlay packs, 269,784 reading ruler packs and 5,678 overlay assessment packs'* concluding *'We could not have achieved all this without the work conducted at the University of Essex'* [**S3**]**.**

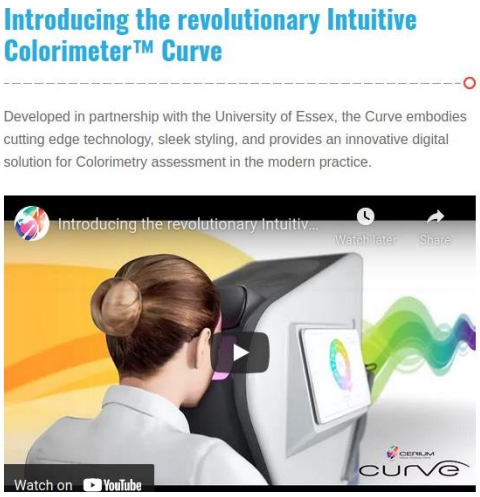
A2. Coloured overlays win 2014 SEN award, increase reach in schools and improve reading in children with visual stress continuing to transform lives worldwide
The sale and use of CE's overlays to support reading is widespread [**S4**]. They are currently **used in 70% of UK schools**, up from 60% in 2013 [**S3**] and part of the visual stress product collection that was awarded the **SEN Resource of the Year award** in **2014** [**S1b**]. With 8,890,000 pupils in UK schools in 2020 [**S2c**], the overlays are accessible to over 6,223,000 children and **significantly improve reading** in around 5% of children [**R1**], **benefiting over 311,150 children** in the UK alone. People with dyslexia particularly benefit and CE's coloured reading rulers are **endorsed by the British Dyslexia Association** [**S1e**]. The CEO of CE states '*We continue to receive countless testimonials relating how lives have been transformed by the improvements users of these products experience*' [**S3**]. Parents and teachers worldwide attest to the benefits: *'His [student] fluency has vastly improved since using this color ruler and overlay, going from rarely reading to voluntarily picking up books.'* Teacher, USA. *'My child now uses the coloured reading rulers at home and school and, not only have we all seen significant progress in his reading ability, he now*

actually enjoys reading' Parent, Australia. '*I am a specialist teacher assessor for dyslexia and use them all the time for my pupils. The reading rulers are amazing for children with Irlen Syndrome who do not want to wear glasses.'* Teacher, UK [**S5**].

A3. Coloured overlays and newly launched CPD courses now extend the reach to employers and employees in UK business settings

CE's corporate arm, Visual Stress Solutions (VSS) provides overlays, visual stress resources and continuing professional development (CPD) courses to enable employers to identify and support employees with visual stress, a barrier to workplace productivity [**S6a**]. By making 'reasonable adjustments' to improve employees' visual stress symptoms employers can ensure Equality Act compliance [**S6b**]. CE's CEO testifies that in **2018 they added CPD courses** to their offering which are **'*based on Prof Wilkins' research*** *at the University of Essex*' [**R1-3**]. Since 2018, it has already enabled **over 400 representatives from organisations** including the NHS, Police, Fire Service, Prison Service, MOD, Santander, RAC, and Western Power to '***identify visual stress*** *in the workplace and* ***make the most effective treatment recommendation*** *using our Visual Stress Assessment Pack*' states CE's CEO [**S3**], adding, '*The* ***huge difference this makes to individuals' work and home life*** *is evidenced by the positive feedback we receive from those undertaking our courses'* [**S3**]. The Head of Equality & Well-being, Fire Service, comments: '*I now have the skills to take back to my workplace to be able to carry out Visual Stress assessments with confidence. Since the training I have carried out a number of assessments, the most recent assessment resulted in an increased reading speed of 23%'* [**S6c**]**.** Employees using overlays say '*At last! I can read my emails', 'I can read a lot quicker*' [**S6c**]. The CEO concludes '***Working with Prof Wilkins*** *and applying the research undertaken at Essex, enabled Crossbow VSS* ***to help 1000s of people*** *in the workplace by alleviating visual stress through simple affordable methods and technologies*' [**S3**].

B1. Cerium Visual Technologies improve the IC and benefit from increased commercial success through widespread use of the IC to prescribe precision tinted lenses



Wilkins' research [**R4-6**] has underpinned the continuing development of the Mark 2, 3 and 4 versions of the IC [**S7a-d**, **S8**, **P1**] released in 2002, 2009, and 2018 respectively, manufactured and sold by CVT. The MD of CVT states that the company '*was founded on, and continues to grow around, the insights from research conducted by Professor Wilkins'*. Through a KTP with Essex in 2014 led by Wilkins [**S9**], **CVT improved the IC** [**S7b**]. An **international patent** was filed for the **Mark 4, known as the Curve, in 2016** [**P1**], following a 2014 UK application. The advanced IC enabled reduced manufacturing costs and by simplifying and semi-automating the process of selecting the appropriate tint, facilitated a more streamlined assessment process [**S8**]. During the KTP Wilkins applied the insights from his underpinning research in visual stress and its treatment with colour [**R4-R6**]. On the development of the Curve the CVT MD states '***Wilkins' research*** *at Essex [**R4, R5**] on the use of the Colorimeter* ***provided a scientific basis*** *for best practice in treating visual stress through colour, which was utilised in the [KTP] project*' adding '*During the KTP Wilkins worked closely with the Associate to* ***apply Essex expertise in visual stress and its treatment with colour to develop the new Colorimeter***' [**S8**].

The IC is in widespread use worldwide [**S10a**]. The MD states: '***ICs have been sold and are in use across North America, Europe, Australia, Asia, Africa, and the Middle East*** [text removed for publication] [**S8**]. The Curve's digital design necessitates less practitioner training to prescribe lenses, enabling high street chains such as Specsavers to use it, **widening CVT's customer base** [**S10b**]. [text removed for publication] The Curve was shortlisted for the **Association of Optometrists product of the year** (2019) [**S7e**].

B2. Optometrists across the world use the Curve to prescribe precision tinted lenses to more diverse customer base Wilkins' body of research [**R4 - R6**] was foundational for the Colorimeter **patent** [**P1**]. The latest version of the IC, the Curve, allows for quick, less straining, individual prescriptions. The CVT MD testifies *'The IC enables [practices] to offer patients something unique**, diversifying their practice, and opening up new patient referral streams**.'* and adds '*the **Curve's new automated design, allows for quicker testing, enabling individuals such as those with neurological conditions (e.g., autism, migraine), who can benefit from precision tinted lenses** [**R6-7**] but would previously have experienced discomfort during the longer examination, to be prescribed lenses*' [**S8**]. Wilkins research [**R4-7**] underpins the Society for Coloured Lens Prescribers (SCLP) training programme for eye care practitioners supporting them to use the IC in practice [**S8**]. **Since 2013, an additional 78 lectures/training events were run across 14 countries,** including France, Germany, Hungary, Israel, Korea and Spain. This represents over 180 hours of CPD for practitioners [**S11**].

Optometrists in the UK, Australia, and the USA confirm that the IC offers a valuable addition to their services [**S12a**] which could not have been achieved without the underpinning body of Essex research leading to the IC development: '*Colorimetry provides an additional tool in helping solve patient problems which cannot be resolved by simple prescriptions alone*' Optometrist UK. *'The ability to prescribe precision tinted lenses has added another dimension to my optometry practice. I have been able to help patients with difficulty reading text and migraine sufferers. For the first time Australian Optometrists have the opportunity to prescribe with precision to patients who suffer from Visual Stress'.* Optometrist, Australia. '*The Intuitive Colorimeter has been a valuable addition to our practice […] the Colorimeter is another powerful tool in the rehabilitation or functional optometrists' arsenal*.' Optometrist, USA. The *C*linical Editor, Optometry Today found the IC '*invaluable for prescribing precision tints to manage the adverse effects of visual stress in a range of neurological conditions'* adding that it *'allowed me to develop a niche area of clinical interest.*'

B3. Individuals worldwide benefit from precision tinted lenses. User testimonials support Essex findings [**R4-7**] that **lenses improve visual stress symptoms and quality of life**, including for those with **autism spectrum disorders** or **experiencing migraine**: '*The glasses help him deal with visual stress from epilepsy and autism. He feels calmer at school and fluorescent lights and bright days don't bother him*.' Parent, Canada. Users confirm Essex research that tinted lenses improve reading abilities [**R1**]: '*It is not an exaggeration to say that visual stress treatment has totally transformed my reading abilities and also significantly reduced the frequency and severity of my migraine*.' Patient, UK. [**S12b**]. CVT's MD concludes '*Wilkins research and the collaboration between CVT and the University of Essex has enabled the development of an instrument [IC] that continues to improve symptoms of visual stress in patients with reading difficulties and a range of complex neurological conditions, improving their quality of life'* [**S8**].

5. Sources to corroborate the impact

S1a-e Crossbow Education Webpages. Accessed Dec. 2020
S2a-c Data sources outlining UK population (Office for National Statistics), economic costs of illiteracy and migraine (Migraine Trust), number of UK schools and pupils (Dept. for Education)
S3 Testimonial, CEO, Crossbow Education/Crossbow Visual Stress Solutions. Dated Jan. 2021
S4 Worldwide sale of Crossbow overlay and visual stress resources. Accessed Dec. 2020
S5 Worldwide customer testimonials for Crossbow Education's overlay products. Accessed Dec. 2020
S6a-c Crossbow Visual Stress Solutions Webpages. Accessed Dec. 2020.
S7a-e Cerium Visual Technologies Webpages Accessed Dec. 2020.
S8 Testimonial, Managing Director, Cerium Visual Technologies. Dated Nov. 2020.
S9 KTP CVT/Essex Details. Accessed Feb. 2021.
S10a Worldwide use of Intuitive Colorimeter **b.** UK Chains using IC. Accessed Dec. 2020.
S11 SCLP CPD training. Accessed Feb. 2021
S12a IC Practitioner Testimonials **S12b** IC Patient Testimonials. Accessed Dec. 2020.
P1 Patent: Wilkins, A. (2017). Visual Stress Assessment Device. Publication number: WO2017/072496; Application number: PCT/GB2016/053301.