Our eyes in a digital era

HOYA FACULTY

Challenges and opportunities for practitioners

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Eye for detail

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USA

Doctor Willis Clem Maples is currently in practice at Bellevue Specialty Eye Clinic in Hattiesburg, Mississippi (USA) in a practice limited to vision development and visual rehabilitation issues. In addition to his Doctor of Optometry (OD) Willis Clem Maples has a Master's in Community Health. He is a Fellow of the American Academy of Optometry and he practised privately for 12 years before being recruited to begin the vision therapy programme at the Oklahoma College of Optometry at Northeastern State University. He is a professor emeritus of this college. He has served as the president of the College of Optometrists in Vision Development (COVD) and twice served as the chair of COVD's International Examination and Certification Board. He has received the "Lifetime Achievement Award" from both the College of Optometrists in Vision Development and the Southern College of Optometry. He also lectures both in the United States and internationally.

Dr. Thomas Gosling
USA

After graduating from the Illinois College of Optometry in 1992, Dr Thomas Gosling moved to Green Bay, Wisconsin to join the largest ophthalmology clinic north of Milwaukee. During his 14-year stay in Green Bay, he was the optometrist for the Packers football team. For the past decade, Dr Gosling has worked in Denver, Colorado, where he finds his private practice the perfect environment to express the creativity behavioural optometry has to offer in a new digital world. In parallel, he acts as a Hoya technology consultant, inventor and entrepreneur. In 2011, he was named one of the Optometric Business Innovators of the Year.

Prof. Bruce Evans
United Kingdom

Professor Bruce Evans is the director of research at the Institute of Optometry in London and a visiting professor to City University London and London South Bank University. He is a fellow of the College of Optometrists and holds their higher qualifications of Diploma in Contact Lens Practice and Diploma in Orthoptics. He was awarded a fellowship of the American Academy of Optometry in 1993, fellowship of the British Contact Lens Association in 2006 and of the European Academy of Optometry in 2016. He has lectured and published extensively. His first book, Pickwell's Binocular Vision Anomalies, Third Edition, was published in 1997, with the fifth edition published in 2007. A subsequent book, Dyslexia and Vision (2001), is aimed at members of the public, teachers and eye care professionals and has been met with critical acclaim. In 2010, he co-authored Vision and Reading Difficulties for eye care professionals. He has written over 240 scientific and professional papers and given more than 250 invited lectures. His main areas of research are children's vision, dyslexia, orthoptics, contact lenses, and headaches including migraine. He has an optometric practice in Brentwood, Essex, where he specialises in children's vision, binocular vision anomalies, dyslexia and vision, and contact lenses.

Geraint Griffiths
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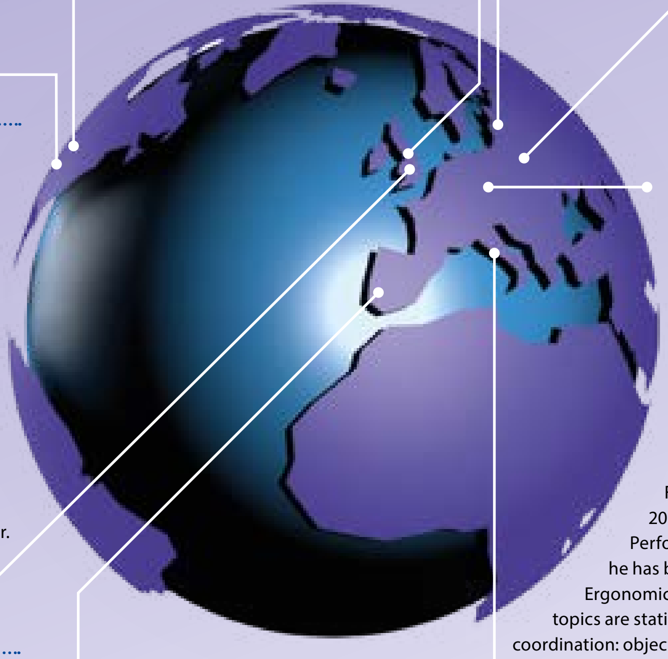
Geraint Griffiths is an independent optometrist and owner of Optical3 Opticians. He is the managing director of Sportsvision UK, chair of The Association of Sport and Schoolvision Practitioners and author of the Diplomas in Sport and Schoolvision Practice. He is an examiner for the College of Optometrists and a sportvision expert for the British Standards Institute (BSI). He believes that the understanding and management of the physiological effects of prisms in monocular and binocular vision are the key to the future of ophthalmic optics (optometry and dispensing optics) and the prevention of ocular, systemic and psychological morbidity.



Dr. Mariano González-Pérez
Spain

Doctor Mariano González-Pérez has a PhD in Optics, Optometry and Vision from the Complutense University of Madrid. He works as an assistant professor at the same university and is a practicing optometrist at Alain Afflelou Óptico in Madrid. The main outcome of his PhD was the development and validation of the first Rasch-based linear scale for measuring computer-related eye symptoms among computer workers, the Computer-Vision Symptom Scale (CVSS17). This research resulted in a publication in Investigative Ophthalmology and Visual Science, two other papers that are due to be published shortly and three more communications related to the clinical findings associated with CVSS17.

Prof. Gunta Krumina
Latvia

Professor Gunta Krumina is the head of the Department of Optometry and Vision Science at University of Latvia in Riga, director of the optometry bachelor's programme and a senior researcher-project leader. She was awarded a PhD in medical physics for her research on the correlation between stereothreshold and quality of monocular stimuli. Her main research topics are related to stereovision, visual electrophysiology and clinical optometry.
Her latest scientific work has focused on the visual screening of schoolchildren and the visual fatigue of computer users. She is currently developing a new stereotest aimed at evaluating the crossed and uncrossed disparity for local and global stereovision.

Dr. Wolfgang Jaschinski
Germany

Doctor Wolfgang Jaschinski completed his electrical engineering degree in 1976, at the Ruhr-Universität Bochum, Germany. Between 1978-1980, he worked as a research associate at the Biological Institute, Stuttgart University. Since 1980, he has been a research associate at the Leibniz Research Centre for Working Environment and Human Factors (IfADo) in Dortmund. From 1998 to 2015, he was the head of the Individual Visual Performance research group at IfADo. Since 2015, he has been the principle investigator for the Visual Ergonomics research group at IfADo. His main research topics are static and dynamic properties of binocular coordination: objective and subjective measurements of vergence eye movements; objective measurements of static and dynamic accommodation; optometric and ergonomic aspects of spectacle lenses to correct for presbyopia; visual and cognitive influences at manual interaction with visual displays.

Prof. Giancarlo Montani
Italy

Professor Giancarlo Montani, optometrist, contact lens specialist and organiser of continuing education courses in optometry in Italy, started his professional career in 1988 as professor of optics and optometry at the Institute of Optics and Optometry, Vinci, Italy. Between 1996-2001, he worked as director of the course curriculum. In 2002, he was appointed as head of the Contact Lens Division, Ophthalmology Department at Santa Chiara University Medical Centre, Pisa, Italy. Since 2005, he has taught the contact lens courses in the Optics and Optometry Department at the University of Salento, Italy.
He is the founder of the Centro di Ricerche in Contattologia at the University of Salento and a referent for Italy of the Eurolens International Survey of Contact Lens.

Alicja Brenk-Krakowska
Poland

Alicja Brenk-Krakowska is an optometrist and lecturer at the Laboratory of Vision Science and Optometry at the Adam Mickiewicz University of Poznań, Poland. After gaining two bachelor's degrees and an MSc, in 2006 she began her PhD in optometry. In 2010, she formally became a lecturer in the Laboratory of Vision Science and Optometry. As a member of the Polish Association of Optometry and Optics (PTOO), she is actively involved in the development of visual-motor techniques. She is interested in binocular instability in developmental dyslexia, the processes of prism adaptation in both children and adults with dyslexia as well as lateralisation of attention processes in dyslexics. In addition, she is involved in studies concerning the influence of prism adaptation on sensory-motor functions in normal patients with evoked left neglect. She has presented her research findings at numerous conferences in Poland and across Europe and is the author of many scientific articles. In her practice, she is actively engaged in the treatment of patients with different kinds of reading problems.

CONTENT

Olga Prenat
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INTRODUCTION

From computer vision syndrome to digital eye strain

The digital revolution has dramatically changed the way we see the world, and our eyes are literally taking the strain.
This is largely due to the fact that they are simply not made to spend long periods of time looking at screens or near tasks. The origins of computer vision syndrome and digital eye strain are multiple.
This white paper examines both causes and possible solutions to what has become a widespread phenomenon.

Eye care professionals first identified computer vision syndrome (CVS) more than 30 years ago, when computers emerged in the 1980s. CVS refers to the physical discomfort and vision-related problems experienced during and after prolonged computer use. These include eye fatigue, ocular discomfort, dry eye, blurred vision, tearing, headaches, neck pain and sensitivity to light.
With the introduction and proliferation of smartphones, tablets, e-readers, laptops and other electronic devices in the past decade, CVS has increasingly been replaced by digital eye strain (DES) to describe the symptoms associated with the use of digital displays

DIGITAL ERA

Another significant development can also be observed. Whereas computers were initially used only by adults, today millions of children regularly use digital devices at school and home, and they often perform e-multitasking.
An online survey that Hoya conducted in the United States, the United Kingdom and Hong Kong in 2017 showed that between smartphones, computers, tablets, TVs and other digital screens, most people spend an average of 8-10 hours a day looking at screens. The digital device used most – by 90% of the respondents – was a smartphone, and the most frequent combination of devices was a smartphone and laptop.[1]

The survey also found that only 22% of respondents had heard of DES. This was despite 91% of respondents seeing a correlation between at least one of the symptoms they frequently experienced and their use of digital devices. Perhaps even more surprisingly, many users of digital devices accepted their symptoms as 'unavoidable'.
This acceptance could be explained by a general lack of understanding about the role of vision as the primary sense and the finite capacity of the ocular system, which has evolved to see great distances in three dimensions, to spend hours on end looking at an object 10-50cm away.
Close distances are often combined with poorly adjusted desks and chairs that encourage bad posture and an unnatural head tilt.

Only 22% of the respondents had heard of DES

Moreover, research is only just beginning to examine the impact of blue light. High-efficiency LED bulbs, which are used almost exclusively in backlit digital screens, emit around 33% blue light compared with 4% of the incandescent bulbs of the past *(see page 50)*.
Young people are the most susceptible to blue light, and at present we do not know what the long-term effects of this will be over a lifetime of exposure *(see page 50)*. In the shorter term, what we do know is that overexposure to blue light can supress melatonin production, disrupting the natural circadian (sleep/wake) rhythms.
The disturbance of these rhythms is linked to a wide range of systemic diseases such as sleep disorders, depression, anxiety, obesity, diabetes, heart disease, stroke and cancer *(see page 42)*.

DOUBLE-EDGED SWORD

It is self-evident that society has been changed by the introduction of computers, tablets and other digital devices. This is clearly a double-edged sword. For the first time in our history, information is literally at our fingertips. Communication has been expanded and, as a result, the world has become smaller.

Yet as we embrace the various skills and tools that have become available, there are potential liabilities.
This white paper describes and reviews what is known about DES and what are suspected to be factors that should be investigated and addressed.
Bringing together research by optometrists, scientists and other vision experts, the white paper points the way to recommendations as to how eye care professionals might counteract any negative impacts.

1. E. Dobisch, N. Vlasak .Digitaler Augenstress – die neue Volkskrankheit? 01/2018, Eyebizz, p.30-33.

PAGE 6 — **If children are pacified by digital displays and television screens, they may never recover.**

PAGE 7 — **The unnecessary mental and physical effort creates an excessive energy demand in the brain**

PAGE 9 — **The visual and ocular motor balance effects of pathology can also be ameliorated by the simple expediency of a pair of spectacles.**

PAGE 15 — **To some extent, DES may simply be a modern manifestation of eye strain associated with intense use of the eyes**

PAGE 19 — **The standardised checklist will most probably play an important role**

PAGE 20 — **The optical properties of spectacle lenses, particularly with progressive lenses, are often not taken into account.**

PAGE 27 — **Only the combination of optometry and ergonomics can optimise presbyopia corrections**

PAGE 28 — **Children tend to ignore problems or might not share their symptoms with their parents for fear of being banned from using a computer.**

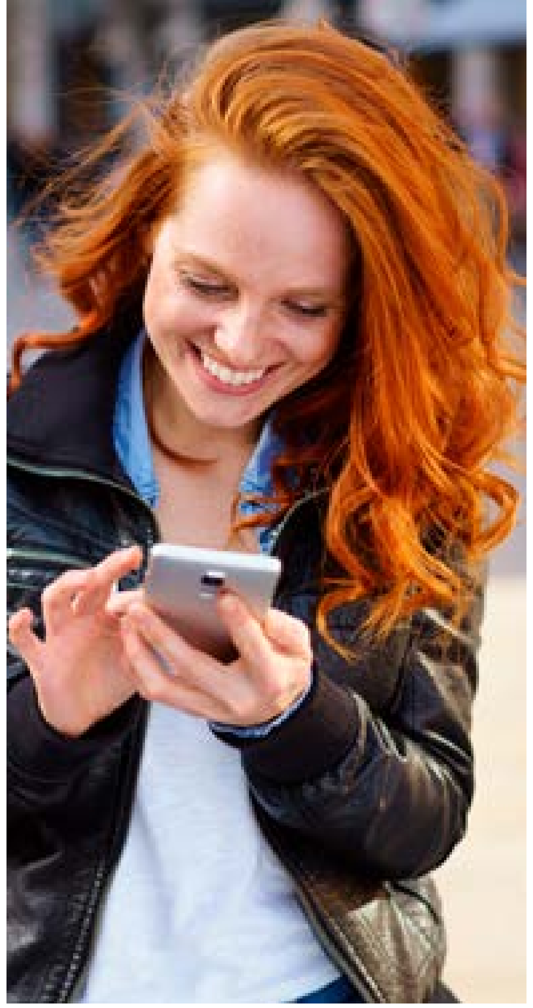
PAGE 36 — **Children with learning difficulties had significantly more visual complaints.**

PAGE 44 — **CFF presented a statistically significant decrease with the control lens, whereas no significant decreases were observed with the blue light filters.**

DIGITAL EYE STRAIN

Geraint Griffiths
Chair of The Association of Sport and Schoolvision Practitioners, UK

The new epidemic



In the summer of 1993, there were 'only' 6.25 million personal computers in the UK and no smartphones. Today, almost every person carries a smartphone, and there is little difference between a phone and a PC.

It may be part of our evolutionary success that we are able to adapt to change so quickly and call it normal. Yet visual symptoms such as fatigue, shooting pains, red eyes, headaches, distance and near vision problems and double vision are certainly not normal.[1] The difference between evolution and this information technology revolution is the perversion of the mantra that the only constant is change.

For billions of years, our vision has evolved to give us continual uninterrupted perception of the world in which we live, full of colour, form, movement and intense detail. For most of that time, we viewed the world under the continuous and even light of the sun or moon or by the incandescent light of the fire.

Since the dawn of civilisation, we have had an insatiable curiosity about our surroundings and environment. It was not enough to wonder at the beauty of nature or recognise the danger within it. We wanted to understand why and how. That quest for knowledge has accelerated exponentially since the early days of the computer and the start of the journey from the real world into cyberspace; from the real to the surreal.

THE DIGITAL AGE

To make real-world information accessible to the computer it has to be digitalised; that is, turned into a series of on and off electrical signals. When this information is accessed, it is in the form of a digital display, which has the superficial characteristics of the real world. However, this information has been corrupted, foreshortened and artificially three-dimensionalised by the process of digitalisation and display. The difference between real and cyber is the difference between a compact disc and a seat in the stalls at the Royal Philharmonic, between a television picture and a live performance of the Mouse Trap, between a game of tennis and a virtual reality mock-up. It is also the difference between the printed page and a digital computer representation.

If children are pacified by digital displays and television screens, they may never recover.[2] In old age, lack of sensory stimulation can lead to dementia.[3]

In real time and space, all the senses are integrated into a visual whole. The brain's capacity to do this allows us to see and comprehend the world around us. Neural development feeds on this intensity of sensory stimulation at every stage of our lives. When it is denied we are diminished, from the cradle to the grave.

EYE STRAIN

Digital eye strain starts with a binocular system, which has evolved to see great distances in three dimensions, suddenly required to spend all day looking at an object 10-50cm away. It is arguable that the extraocular muscles are stabilised for distance and only occasional near vision use.

Displays are fixed at perpetually close distances and becoming smaller and smaller. The characters are pixelated and unstable, with poorly defined edges, and illuminated by artificial backlight of indeterminate colour and electromagnetic wavelength.[4] These displays take no account of physiological necessity, but are ruled by the expediency of energy efficiency and persuasive addiction. They barely understand the role of vision as the primary sense and its finite capacity to manage high-intensity, non-ionizing radiation[5] and regulate our day-night cycles.[6]

EYE DOMINANCE

This is supported by new research showing that the stability of eye dominance and the relationship between the two primary visual skills of aiming and depth perception can be related directly to occupational performance .[7] The Moreton study (1996) suggests that up to 60% of the population is predisposed to reading difficulties and this is part of the human condition[8]
(see also Gunta Krumina's study of Latvian schoolchildren on page 32).

The unnecessary mental and physical effort creates an excessive energy demand in the brain

It is likely that the skill of aiming (carried out by the dominant eye) is predominant in reading, where distance is fixed for a particular visual task and individual.[9] In the office, instability in the dominant eye will affect the ability to track across a given piece of text. This can lead to all the characteristic signs of visual stress and pattern glare,[10] which impact attention, comprehension and endurance. The unnecessary mental and physical (extra- and intraocular) effort creates an excessive energy demand in the brain,[11] a craving for high-sugar foods and all the adverse effects of a yo-yoing blood sugar level that go along with it.[12]

DIAGNOSTIC ELEMENTS OF OCCUPATIONAL VISUAL PERFORMANCE

The stability of eye dominance at near depends on seven diagnostic elements of visual performance:

- **Unaided vision (measured at high and low contrast);**
- **Refraction (estimated by retinoscopy);**
- **Eye dominance;**
- **Objective muscle balance;**
- **Fixation disparity (sensory fusion) corrected using prism;[13]**
- **Colour preference and light sensitivity;[14]**
- **Accommodation facility.[15]**

And two key occupational (reading) performance indicators:

- **Rate of individual character recognition (CRST reading speed);[16]**
- **Tracking (dynamic fixation).[17]**

A deficit in any one of these will affect the interpretation of digital displays. Unstable or poorly established eye dominance makes it difficult to track from one character or word to another.

VISUAL TASK ANALYSIS (EXTERNAL DISTRACTIONS)

We have become so used to the ubiquitous digital display that we have forgotten that everything about its use is unnatural. Sitting all day at a desk[18] or, worse still, on an international flight staring at a postcard-sized lightbulb, is a physiological abomination.[19] We have forgotten that ocular physiology is dependent on the health of the cardiovascular and immune system. The digital display has far more to answer for than eye strain.

Figure 1. Ergonomics

ERGONOMICS

As far as possible, everything should be done to facilitate comfortable screen use.[20]
The office chair should allow normal spinal curvature, with a seat tilted forward to allow comfortable hand position on the keyboard and a monitor below eye level (Figure 1). Glare from external windows behind the screen will reduce the contrast. Specular reflection from behind the user will obliterate the display.[21] The distance of the screen is also critical, is ideally variable to suit the user but is always taken into account at the time of refraction and dispensing.

DISPENSING

At a time when ocular pathology is in the ascendency and the importance of visual correction and occupational optics is in decline, it is worth reflecting that vision may be the key to surviving the digital revolution. Moreover, the technology and infrastructure are already established to support our frail visual physiology.[22]

Modern lenses make this problem easier to deal with, depending on the task, including traditional office work, intense data inputting, computer-aided design, conversational terminal or customer interactive use.

An accurate refraction, including binocular balance and prism correction and correction of astigmatism to the nearest quarter of a dioptre, can stop accommodative hunting and stabilise focus and binocular vision.[23] Prism correction of up to 10 dioptres right and left is available with appropriate thinning, to stabilise eye dominance. Tints and coatings enhance transmission and contrast, prevent oil or water smearing and reduce the retinal metabolic load. Impact-resistant materials protect against ocular trauma.[24]

The visual and ocular motor balance effects of pathology can also be ameliorated by the simple expediency of a pair of spectacles.[25]

CONCLUSION

Cyberspace is seductive – it looks like a sanctuary and the fount of all knowledge, an ever-present friend – but its knowledge is finite, corrupted and without humanity; we lose ourselves in it at our peril.

This is not arguing against the use of digital displays; they are a fact of modern life and a great tool towards societal advancement. However, a better understanding of the limitations of human physiology, as well as the miracle of its development, is the key to keeping the monster in its cage, averting the possibility of the next financial crisis being caused by a pair of tired eyes in the City of London.

REFERENCES

1. Heaton, J. 1966. 'The pain in eyestrain.' American Journal of Ophthalmology 61: 104-112.
2. Paudel S., Leavy, J., Jancey, J. 2016. 'Correlates of mobile screen media use among children aged 0–8: protocol for a systematic review.' Systematic Reviews 5: 91. Winterbottom, M., Wilkins, A. 2007. 'Lighting and visual discomfort in the classroom.' Journal of Environmental Psychology 29: 63-75. Li, X., Atkins, M. 2004. 'Early childhood computer experience and cognitive and motor development.' Pediatrics 113(6): 1715-22.
3. Tsai, D., et al. 2015. 'Age-related macular degeneration and risk of degenerative dementia among the elderly in Taiwan. A population-based cohort study.' Ophthalmology 122(11): 2327-2335.
4. Snyder, H. 1979. 'The sensitivity of response measures of alphanumeric legibility to variations in dot matrix display parameters.' Human Factors 21(4): 457-471.
5. Shang, Y., et al. 2014. 'White light-emitting diodes (LEDs) at domestic lighting levels and retinal Injury in a rat model.' Environ Health Perspect 122: 269-276. Taylor, H., et al. 1992. 'The long-term effects of visible light on the eye.' Arch. Ophthalmol. 110: 99-104.
6. Hatori, M., et al. 2017. 'Global rise of potential health hazards caused by blue light-induced circadian disruption in modern aging societies.' NPJ Aging Mech Dis. 3: 9.
7. Griffiths, G. 2003. 'Eye dominance in sport – a comparative study.' Optometry Today 43: 16.
8. Moreton study. 1996. In Griffiths, G. et al. 2017. 'The comparative rate of reading speed test – Introducing a reading speed test to measure the rate of individual character recognition or tracking speed.' Pending publication. Contact www.svuk.info.
9. Griffiths, G. 2013. 'Match! Finding the best lenses of sport – the science.' Dispensing Optics.
10. Evans, B., Stevenson, S. 2008. 'The pattern glare test: a review and determination of normative values. Ophthal. Physiol. Opt. 28: 295-309.
11. Wong-Riley, M. 2010. 'Energy metabolism of the visual system.' Eye Brain 2: 99-116.
12. De Vany, A. 2011. The New Evolution Diet. London: Vermilion.
13. Mallet, R. 1964. 'The investigation of heterophoria at near and a new fixation disparity technique.' Optician 148; 3845: 573-581.
14. Griffiths, G. 2001. 'Colour preference – a comparative study.' Optometry Today 41: 20.
15. Ostberg, O. 1980. 'Accommodation and visual fatigue in display work.' Pp. 41-52 in Ergonomic aspects of visual display units, edited by Grandjean and Vigliani. London: Taylor and Francis.
16. Griffiths, G. et al. 2017. 'The comparative rate of reading speed test – Introducing a reading speed test to measure the rate of individual character recognition or tracking speed.' Contact www.svuk.info.
17. Griffiths, G. 2002. 'Eye speed, motility and athletic potential.' Optometry Today 42:12.
18. Hunting, W., et al. (1991). 'Postural and visual loads at VDT workplaces.' Ergonomics 24: 917-931.
19. O'Hagan, J., et al. 2016. 'Low-energy light bulbs, computers, tablets and the blue light hazard.' Eye 30: 230-233.
20. Jaschinski, W. 'The eyes at work: Visual ergonomics from research to application.' Leibniz Research Centre for Working Environment and Human Factors, Technical University of Dortmund, Germany.
21. Pitts, D. 1993. Pp. 151-220 in Environmental Vision. Oxford: Butterworth-Heinemann.
22. EU directive, supplement to Health and Safety at Work Act. 1993.
23. Griffiths, G., et al. 2017. 'The effect of optical and prismatic correction on the rate of individual character recognition.' Pending publication. Contact www.svuk.info.
24. Griffiths, G. 2013. 'Match! Finding the best lenses of sport – the science.' Dispensing Optics.
25. Margrain, T., et al. 2004. 'Do blue light filters confer protection against age-related macular degeneration? Prog. Retin. Eye Res. 23: 523-531.

VISUAL AND OCULAR SYMPTOMS

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Computer-related visual and ocular symptoms from the CVSS17 perspective

THE RASCH-BASED SCALE

In developing the CVSS17, we had an initial bank of 277 items, which we needed to reduce. To do this, two experts assessed the formal properties of the items (such as length or clarity) and, at the same time, 17 video display terminal (VDT) workers chose the item that best represented each symptom. After that, we developed a pilot questionnaire (composed of 77 items), administered it to a sample of 636 VDT workers and performed the Rasch analysis to get the final 17 items. The CVSS17 is available online at https://www.cvss17.com in English, Italian and Spanish.

The CVSS17 gives a measure ranging from 17 to 53 points, there are five different levels in this score range and our studies showed that the population mean is 30,73 and the median is 30.
Based on Rasch analysis results, we can consider that subjects scoring over 35 deserve special attention.

The Computer-Vision Symptom Scale (CVSS17) is a patient-reported outcomes (PRO) instrument developed using the Rasch model, a mathematical model that involves two parameters:

1. **The respondent's amount of the variable assessed by the PRO instrument, symptoms level in our case.**
2. **The item difficulty.**

These two values are defined on the same scale and both determine the probability of a subject answering any response option of any item. Rasch analysis offers several advantages in the development of symptom scales, such as:

- **Allows the generalization of the results across different samples and different items,**
- **Takes into account that response options may not be psychologically equally spaced,**
- **Helps in unidimensionality testing,**
- **Produces an ordered set of items,**
- **Identifies poorly functioning items as well as unexpected responses.**

SCORES

CVSS17 scores have shown a significant association with:

- **visual discomfort scale (VDS) scores,**
- **the ocular surface disease index (OSDI),**
- **refractive status,**
- **the amplitude of accommodation.**

We found in our research that the best optometric measure for predicting symptoms is the difference between the theoretical amplitude (Hofstetter) and the registered amplitude of accommodation.

Computer-Vision Symptom Scale

CVSS17 QUESTIONNAIRE

PLEASE COMPLETE BOTH SIDES OF THIS FORM

Study Id:

Age:

Gender:

How many hours **a day** do you normally use the computer **at** work?

How many hours **a week** do you normally use the computer **at** work?

How many hours **a day** do you normally use the computer **outside** work?

THE QUESTIONS THAT FOLLOW ASK ABOUT HOW YOU FELT OVER THE PAST FOUR WEEKS WHILE AT WORK.*:

**If you normally wear glasses or contact lenses during most working hours, please describe how you felt while wearing this correction.*

While working on the computer for a while *(please circle the appropriate response)*:

A2. **Did the letters on the screen become blurry?**
1. Never 2. Very Little 3. Little 4. Moderate amount 5. Much 6. Very Much

A4. **Did your eyes become tired?**
1. Never 2. Almost Never 3. Seldom 4. Occasionally 5. Frequently 6. Almost Always 7. Always

A9. **Did your eyes hurt?**
1. Never 2. Rarely 3. Frequently 4. Constantly

A20. **Did you have to blink more than usual?**
1. Never 2. Rarely 3. Frequently 4. Constantly

A21. **Did your eyes burn?**
1. Never 2. Rarely 3. Frequently 4. Constantly

A22. **Did you have to strain to see well?**
1. Not at all 2. Very little 3. A Little 4. A moderate amount 5. Much 6. Very Much

A28. **Did you feel like you were crossing your eyes?**
1. Never 2. Rarely 3. Frequently 4. Constantly

A30. **Did the letters appear double?**
1. Not at all 2. Very little 3. A Little 4. A moderate amount 5. Much 6. Very Much

PLEASE CONTINUE OVERLEAF >

VISUAL AND OCULAR SYMPTOMS

While working on the computer for a while *(please circle the appropriate response)*:

A32. **Did your eyes sting?**
1. Never 2. Rarely 3. Frequently 4. Constantly

A17. **After working on the computer for a while did your eyes become heavy?**
1. Never 2. Rarely 3. Frequently 4. Constantly

A33. **After working on the computer for a while did lights bother you?**
1. Never 2. Almost never 3. A few times 4. Several times 5. Often 6. Very often

OVER THE PAST FOUR WEEKS WHILE AT WORK, PLEASE INDICATE TO WHAT EXTENT YOU HAVE EXPERIENCED ANY OF THE FOLLOWING:

	1. Non	2. Very Little	3. Little	4. Moderate amount	5. Much	6. Very Much
B7. **Watery eyes**						
B8. **Eye redness**						

TO FINISH, PLEASE INDICATE TO WHAT EXTENT YOU AGREE OR DISAGREE EACH ONE OF THE FOLLOWING STATEMENTS*:

**If you normally wear glasses or contact lenses during most of your working hours, answer as if you were wearing them*

C16. **At the end of my working day, my eyes feel heavy**
1. Strongly Disagree 2. Slightly Disagree 3. Slightly Agree 4. Strongly Agree

C21. **After working at the computer, I have to strain to see well**
1. Strongly Disagree 2. Slightly Disagree 3. Slightly Agree 4. Strongly Agree

C23. **While I'm working on the computer, my eyes become dry**
1. Strongly Disagree 2. Slightly Disagree 3. Slightly Agree 4. Strongly Agree

C24. **After some time at the computer, lights bother me**
1. Strongly Disagree 2. Slightly Disagree 3. Slightly Agree 4. Strongly Agree

THANK YOU FOR YOUR ASSISTANCE

SINGLE CONSENSUS-BASED DEFINITION

To develop a single consensus-based definition of the Computer vision syndrome (CVS), we had to identify the symptoms that define the problem or, at least, the type of symptoms. In generating the CVSS17 content, we developed an item bank composed by 77 items that evaluated 26 different symptoms.

As we conducted Rasch analysis and Rasch model guarantees that selected items are measuring the same latent variable, we can consider the symptoms assessed by the CVSS17 as a representative sample of the total present in the CVS. Based on the CVSS17 factor analysis results, there are two main components in computer-related symptoms:

- **the internal symptom factor (ISF, related to accommodation and refractive status)**
- **the external symptom factor (ESF, related to dry eye).**

In this scatter plot, each bubble represents an item, which is ordered according to its ESF loading (on the horizontal axis), and its ISF loading (on the vertical axis).

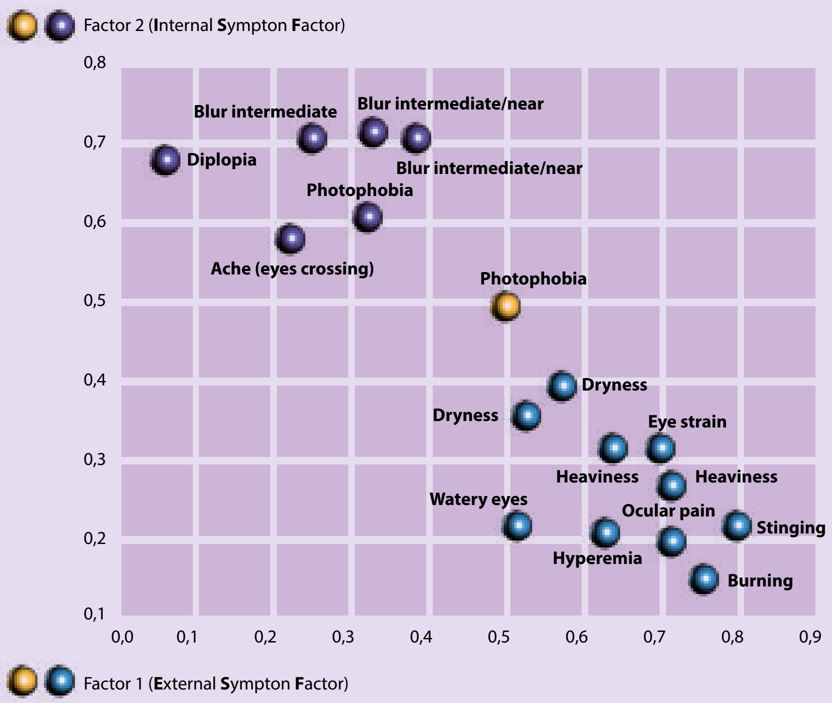


Figure 1.
Plot of the loading factors for Factor 1 (External symptom factor, horizontal axis) against Factor 2 (Internal symptom factor, vertical axis) for the CVSS17 items. Each item's name has been replaced by the symptom assessed by the item.

CONCLUSION

CVSS17 is the most valid and reliable instrument for assessing CVS among VDT workers, and the set of symptoms it assessed is a representative sample of CVS. In addition, CVS is composed of two main factors: one related to dry eye and the other linked to visual function and dry eye; amplitude of accommodation and ocular refraction appear as the main sources of symptoms.

COMPUTER VISION SYNDROME

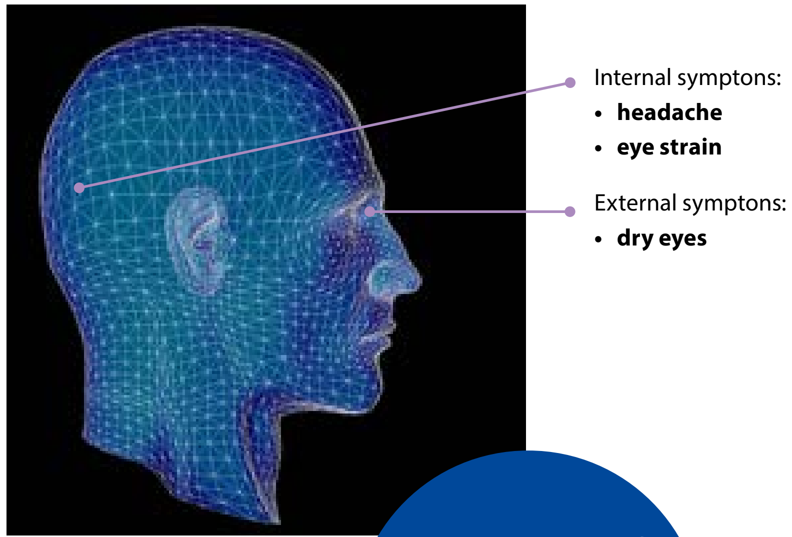
New problem or rediscovery of old problems?

Prof. Bruce Evans
Institute of Optometry, UK

Digital eye strain *(DES, also known as computer vision syndrome)* **is essentially a diagnosis of exclusion.**
Some of the symptoms that are often attributed to DES, such as headaches, could have pathological causes, and the eye care practitioner must exclude these before making a diagnosis of DES. For example, head pain in sub-acute angle-closure glaucoma can occur at any time[1] and, for a patient who spends a great deal of time using computers, could be blamed on computer use.

DES is typically defined as a combination of eye and vision problems associated with the use of digital devices (e.g., computers, tablets, smart phones). Classifications of DES have been provided by several authors, for example Gowrisankaran and Sheedy (2015), who classified the symptoms into internal and external symptoms.[2]
This followed an earlier paper by Sheedy and colleagues (2003), who carried out a factor analysis of asthenopia, discovering that asthenopic symptoms fall into external (e.g. irritation from dry eye) and internal (e.g. ache, strain and headache from accommodative/binocular stress).[3]

It is interesting that this seminal work had nothing to do with digital devices, and yet the classification appears to apply to DES. To some extent, DES may simply be a modern manifestation of eye strain associated with intense use of the eyes. Interestingly, for some patients modern computerised devices can reduce asthenopic symptoms that, in years gone by, might have resulted from less suitable and less adaptable working environments.

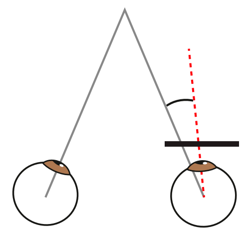


About 50 years ago, Duke-Elder (1970) advised that concentrated visual tasks require light that is adequate but not excessive, brightness contrast and colour contrast should not be excessive, and flicker should be avoided.[4] This advice from the pre-computer age would, if applied today, be likely to prevent a great many cases of DES. Nonetheless, there are some specific challenges associated with computer use, and these are now discussed.

To some extent, DES may simply be a modern manifestation of eye strain associated with intense use of the eyes

BINOCULAR AND ACCOMMODATIVE CHALLENGES

At some workstations the positioning of the computer monitor is fixed, and for patients with incomitant deviations the monitor may be in the wrong position.[5] This could trigger symptoms (e.g. blur, diplopia, asthenopia) or, in extreme cases, cause decompensation of an incomitant deviation.
For this reason, it is important for the optometrist to check ocular motility and, if an incomitant deviation or A- or V-syndrome is present, advise the patient on appropriate workstation positioning.



Heterophoria.

HETEROPHORIA

Another binocular vision anomaly that can cause problems is decompensated heterophoria.
For such patients, prolonged vision at an inappropriate viewing distance can cause the heterophoria to decompensate, with associated symptoms. Combining test results can be helpful to diagnose decompensated heterophoria or binocular instability *(Table 1)*, and the condition can be corrected with refractive correction/modification, prisms or eye exercises.
Accommodative anomalies[5] can also cause symptoms in some patients who use digital devices (e.g. smartphones) at a close viewing distance. For such patients, a modern lens that provides accommodative support may be helpful *(e.g. Hoya Nulux Active or Sync III)*.

SIGN OR SYMPTOM

Table 1.
An algorithm that can help with the diagnosis of decompensated heterophoria.[5]

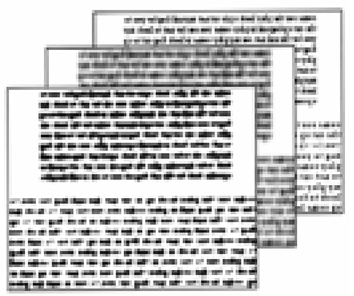
One or more of the symptons of decompensated heterophoria	+3
Cover test: heterphoria detected	+1
Cover test: absence of rapid and smooth recovery *(+1 if quality of recovery 'border-line")*	+2
Aligning prism (Mallett): *1Δ+ for under 40 years or 2Δ+ for 40 years and over*	+2
Aligning prism (Mallett): *<1Δ but unstable*	+1
Foveal suppression (Mallett): *>3', or diplopia during foveal suppression test*	+2

If score < 4 : diagnose normal
> 5 : treat
4 - 5 : continue down table

Sheard's criterion: failed	+2
Percival's criterion: failed	+1
Dissociated heterophoria unstable so that result is over range 3Δ *(i.e. phoria +2Δ)*	+1
Fusional amplitude *(divergent break point + convergent break point)* **<20Δ**	+1

If total score < 6 : diagnose normal
> 5 : treat

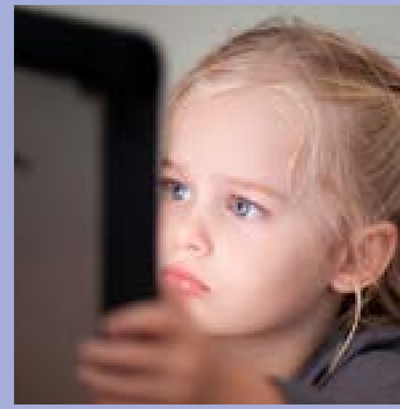
Figure 1.
Text that has been spatially filtered to show the striped pattern it forms. Image reproduced with kind permission of Professor Arnold Wilkins, who modified after Wilkins (1993).[7]



SPECIFIC PROBLEMS WITH DISPLAYS

Visual stress, also known as pattern-related visual stress or Meares-Irlen syndrome, is a controversial condition that has attracted considerable interest.[6] The condition primarily affects young people and seems to be particularly problematic in those with migraine, epilepsy, autism or dyslexia. Visual stress is believed to result from a hyperexcitability of the visual cortex, which in susceptible individuals can be overstimulated by striped patterns, including text *(Figure 1)*.
This can lead to eye strain and headache, and cause text to appear blurred and unstable with prolonged reading. There are some features of digital displays that may exacerbate the symptoms of visual stress: high contrast between text and background, strong colour contrasts, flicker and brightness.

However, there are also some respects in which digital devices lend themselves to the management of visual stress. For example, the condition can be alleviated by coloured filters, and the current iOS operating system for iPad and iPhone devices allows the software to apply an electronic coloured filter of the user's choice.
Modern LCD displays are backlit by LEDs, and often the brightness of these LEDs is controlled by making them flicker. There is a very large variation between different displays, with some flickering at a rate as slow as 60Hz, which can cause symptoms for many people prone to visual stress.
Digital devices that provide a 3-D stimulus are becoming commonplace, especially for computer games that children and young adults can view for long periods. 3-D displays can cause symptoms for several reasons: flicker, dissociation of convergence and accommodation,[8] and from motion sickness (vection).[9]



One group that may be particularly affected by digital devices are children. They appear to be more prone to visual stress[10] and often work in classrooms that have suboptimal design.[11]

CONCLUSION

Like any tool, computers can be used to good or bad effect.
Any concentrated visual task can cause asthenopic symptoms, and the usual causes of asthenopia should be searched for in symptomatic patients. There are some features of computer displays that may make them particularly likely to cause symptoms, and eye care practitioners should advise on workstation positioning and the need to avoid strong contrasts (including colour contrasts) and flicker.

REFERENCES

1. Lewis, J. F., S. Subacute angle-closure glaucoma as a cause of headache in the presence of a white eye. Headache 38, 684-686 (1998).
2 Gowrisankaran, S. & Sheedy, J. E. Computer vision syndrome: A review. Work 52, 303-314, doi:10.3233/WOR-152162 (2015).
3 Sheedy, J., Hayes, J. & Engle, J. Is all asthenopia the same? Optom. Vis. Sci 81, 732-739 (2003).
4 Duke-Elder, S. & Abrams, D. in System of Ophthalmology.Volume V.Ophthalmic Optics and Refraction Ch. 15, 559-578 (Henry Kimpton, 1970).
5 Evans, B. J. W. Pickwell's Binocular Vision Anomalies. 5th edn, (Elsevier, 2007).
6 Evans, B. J. W., Allen, P.M. A systematic review of controlled trials on visual stress using Intuitive Overlays or the Intuitive Colorimeter. Journal of Optometry 9, 205-218 (2016).
7 Wilkins, A. in Visual Process in Reading and Reading Disabilities (eds D.M. Willows, R.S. Kruk, & E. Corcos) Ch. 20, 435-456 (Lawrence Erlbaum Associates, 1993).
8 Lambooij, M., Fortuin, M., Ijsselsteijn, W., Evans, B. & Heynderickx, I. Measuring visual fatigue and visual discomfort associated with 3-D displays. Journal of the Society for Information Display 18, 931-943 (2010).
9 Howarth, P. A. Potential hazards of viewing 3-D stereoscopic television, cinema and computer games: a review. Ophthalmic Physiol Opt 31, 111-122, doi:10.1111/j.1475-1313.2011.00822.x [doi] (2011).
10 Evans, B. J. W. & Stevenson, S. J. The Pattern Glare Test: a review and determination of normative values. Ophthal. Physiol. Opt 28, 295-309 (2008).
11 Winterbottom, M. & Wilkins, A. Lighting and visual discomfort in the classroom. J. Environ. Psychology 29, 63-75 (2007).

CHECKLIST

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USA

Quality of life checklist:
Documenting clinical success

Health care has two major goals:

- **the protection of life** *(mortality factor)*
- **improvement in the quality of life** *(morbidity factor)*

My profession, optometry, has been dedicated primarily to solving the morbidity factors of society, commonly termed 'quality of life' (QOL).

QUALITY OF LIFE

It is universally accepted that QOL is important. Less universally accepted is how to measure QOL. Recently, standardised instruments have been developed that have been scientifically shown to have good test-retest agreement and validity.

These QOL checklists are used to document issues concerning patient symptoms and to measure improvement after intervention with a clinical regimen of treatment.

Three of these checklists are

- **the Convergence Insufficiency Symptom Survey (CISS),**
- **the College of Optometrists in Vision Development Quality of Life Checklist (COVD-QOL)**
- **the Conlon Survey.**

The latter is not often used in everyday optometric practice.

My background is primarily as a clinician specialising in vision rehabilitation. It is important to me that I can document to myself and to the patient that the visual treatments I offer are indeed efficacious.
The College of Optometrists in Vision Development (COVD), the board certifying body for optometrists who specialise in vision rehabilitation, developed a 30-item checklist in an attempt to document these QOL changes.

However, they had not performed any study to investigate if the instrument was reliable. I took it upon myself to perform such a study. I showed that if subjects completed the checklist on two different occasions, separated by enough time for them not to remember their previous answers, they would complete the checklist the same; evidence of test-retest reliability.

Two of my graduate students then compared the COVD-QOL symptoms between diagnosed and medically controlled attention deficit subjects (no change in amphetamine dose in over one year) to normal subjects. The attention deficit subjects reported about twice the visual symptoms of the normal group. Another of my graduate students later compared the COVD-QOL to academic performance and found an inverse relationship between the symptoms and academic performance; the higher the symptoms, the lower the academic scores.

The higher the symptoms, the lower the academic scores.

IN-OFFICE VISION THERAPY

In a prospective, multi-centre study, I compared the symptoms before and after treatment by board certified optometrists. The treatment was individually prescribed and included spectacles as deemed appropriate by the clinician, ergonomic changes and in-office vision therapy. After 20 hours of therapy or the completion of the therapy, whichever came first, the symptoms were compared. Each of the 30 symptoms was found to be statistically significantly improved after treatment.

30 symptoms was found to be statistically significantly improved after treatment.

Other studies by different clinicians have been undertaken using the COVD-QOL as the main outcome. Each of these published papers has reported relationships and changes with therapy on various subject samples, including socially at-risk adolescents, children with convergence and accommodative problems, academic performance and attention deficit.

CONCLUSION

It is clear that more research is needed in the area of instruments to document QOL factors in this changing society.
The flood of electronic instruments (computers, mobile telephones, electronic games, screen-generated viewing devices and so on) will most probably cause some different and increased visual symptoms.
These must be documented and therapies developed to counteract the myriad of symptoms that will likely be experienced. The standardised checklist will most probably play an important role in this scenario.

The standardised checklist will most probably play an important role

OPTIMISING PRESBYOPIA CORRECTIONS

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Leibniz Research Centre for Working Environment and Human Factors, Dortmund, Germany

An integrated optometric-ergonomic approach: Optimising presbyopia corrections for the computer workstation

Optometry offers a large range of spectacles glasses that can provide clear vision at work. These include single vision lenses (for near, intermediate and far vision) and progressive lenses, either for general purposes or vision at a computer monitor and within the office (near, intermediate and far vision up to 4-5 meters).

The physical laws of optics describe the relation between the refraction of the lens (in terms of dioptres) and the range of clear vision in space (in terms of distance from the eye).

This relation represents a challenge in presbyopia, when the amplitude of accommodation is reduced. Theoretically – and optimally – the refractive lens power with the remaining accommodation should correspond to the viewing distances of the visual targets at the workstation.

However, in most cases the eye care professional does not know these dimensions precisely and can only refer to typical, average conditions such as a viewing distance of about 75cm and a gaze inclination of about 15 degrees. This may be successful for many users but not for those operating in other conditions.

A better solution would be to evaluate the individual workstation conditions.

TOWARDS AN OPTIMIZED PROCEDURE

The procedures described so far have the limitation that the ergonomic conditions at the workstation are taken as given and are assumed to be favourable. However, ergonomists know from practical experience that workstations are often not equipped optimally and not approved by an ergonomist or occupational physician. If these conditions are maintained and not improved, they represent a suboptimal starting point for the subsequent choice of spectacles in presbyopia. Even if an ergonomic expert has adjusted the workstation, the optical properties of spectacle lenses, particularly with progressive lenses, are often not taken into account.

The optical properties of spectacle lenses, particularly with progressive lenses, are often not taken into account.

This situation requires optimising both spectacles and workstation conditions in a way that also takes into account the requirements of the visual task. This approach is outlined here with the steps involved:

- **body posture at the desk,**
- **physiological and optical functions**

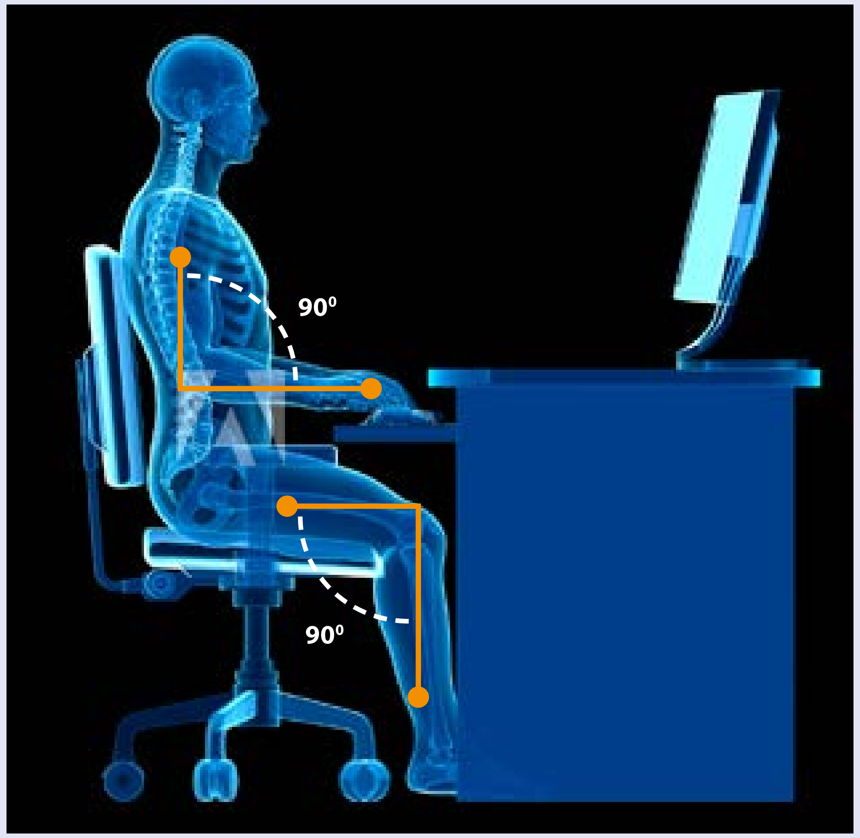
- **comfortable head inclination**
- **comfortable eye inclination**
- **presbyopia correction.**

All these factors depend on the individual

BODY POSTURE

The conventional body posture during computer use at work is sitting at a desk. To reduce musculoskeletal strain in the long run, the office furniture should be adjusted to the individual anthropometric values of the user: as a rule of thumb, the user should have an angle of about 90 degrees at the knees and at the elbow when seated and with the arms positioned to use a keyboard.

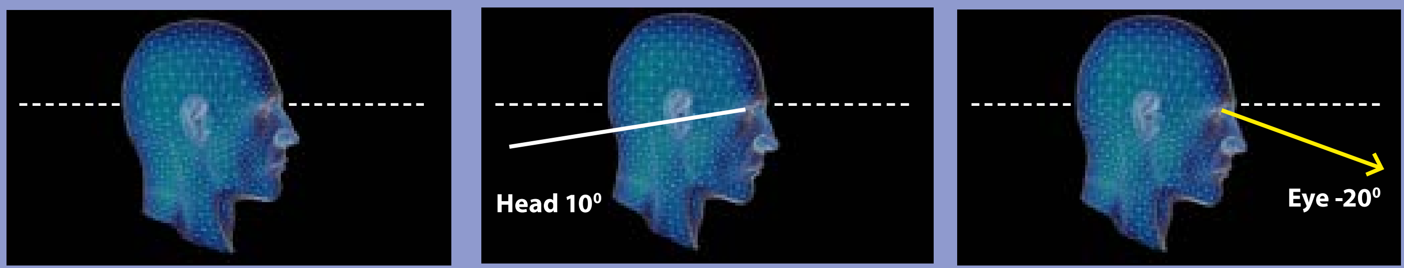
Yet even such a generally favourable posture should not be maintained over many hours, since any static posture will lead to problems in the long run. Therefore, the body posture should be changed from time to time and the patient may even consider working standing up at an adjustable desk.



COMFORTABLE HEAD INCLINATION

Users of general purpose progressives at a conventional, rather high monitor position often incline their head too high, which results in neck strain. Smartphones are used with a head inclination that is too low, also risking neck strain. But what is an acceptable intermediate range?
Research measured the subjectively experienced neck strain and the physiological neck muscle activity as a function of head inclination, specified by the line from the ear to the eye. If this line is directed about 10 degrees upwards, the head is in a comfortable position, averaged across subjects.
Since the ears are typically lower than the eyes, a 10-degree upward inclination of the ear-eye line does not mean an upward inclined head but a comfortable position. [1,7]

In *Figure 1*, the green part of the arc illustrates the average head inclination of minimal neck strain; the red parts of the arc indicate increased strain. Most importantly, individuals differ in their comfortable head inclination within a range of about ±10 degrees, indicated by the yellow parts of the arc.



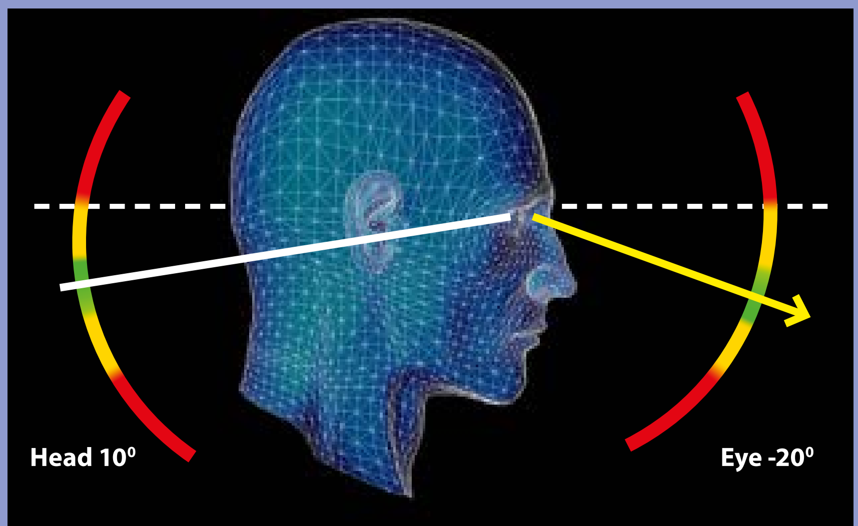
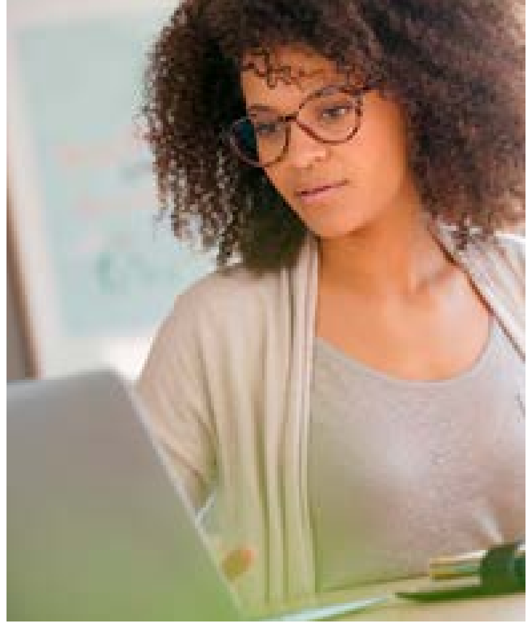


Figure 1.
Illustration of neck strain depending on head inclination and gaze inclination.
High and low inclinations result in increased strain (indicated by the red arcs).
The minimum strain occurs at an individual intermediate position (indicated by the green arcs).
The yellow arcs illustrate the inter-individual ranges.

COMFORTABLE GAZE INCLINATION

The head inclination is directly visible and seen as uncomfortable in extreme cases. But the inclination of the eye within the head is also important but generally overlooked, since it is not easily visible and mostly not noticed introspectively, i.e. the user does not consider his/her own internal state or feeling of comfort with respect to eye inclination. Studies measured the comfortable eye inclination relative to the head, which resulted in an average comfortable gaze inclination relative to horizontal of about 20 degrees downward. [1,6]

In *Figure 1*, the green and red parts of the arc illustrate the gaze inclination of minimal and increased eye strain in the average case, respectively. Again, a range of individual differences in comfortable gaze inclination of ±10 degrees should be taken into account, indicated by the yellow parts of the arc.

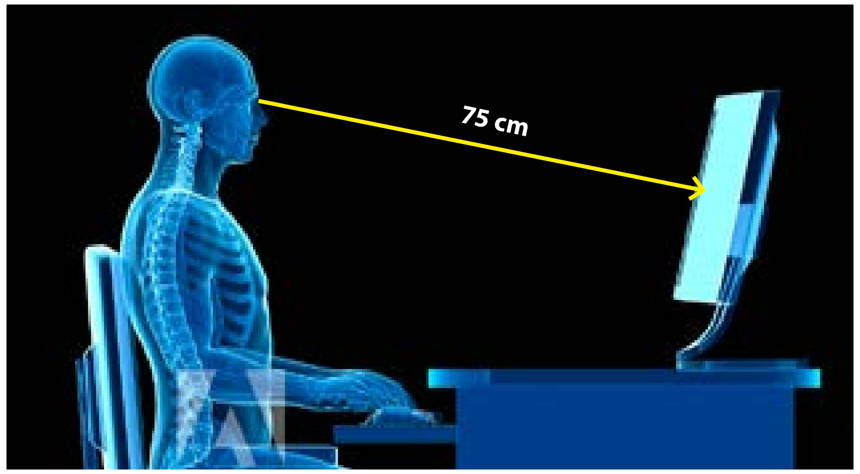


SIMPLE PROCEDURE TO DETERMINE INDIVIDUAL COMFORTABLE GAZE INCLINATION

Studies have identified a range of individually comfortable gaze inclinations from about -10 to -30 degrees, with an average at about -20 degrees (relative to horizontal). If the eye care professional wishes to estimate the individual values, the following simple procedure may be applied [6,7]:

- **The person to be tested is seated comfortably in front of his/her desk.**
- **Both the chair and the desk should be adjusted ergonomically in height.**

At a typical viewing distance of about 75 cm, a vertical scale is placed up to eye level; the scale shows numbers in steps of 1cm with zero at desk height.



The person is requested to raise and lower their head to uncomfortably high and low positions and then to adopt the most comfortable head inclination.

This should be done with closed eyes, so that surrounding objects do not influence the result.

The resulting comfortable head position should then be maintained.

The person inclines their eyeballs upwards and downwards to experience uncomfortable conditions and then to adopt the most comfortable eye inclination relative to the head.

Once this position of head and eyes is adopted, the person opens their eyes and will perceive one of the numbers on the vertical scale. The position of this resulting target number is an estimation of the person's comfortable gaze inclination. Research has shown reliable individual differences in this comfortable gaze inclination [6,7,9].

A single comfortable posture is not meant to be adopted for long periods of time.

This procedure serves the purpose of making individuals experience neck and eye strain in order to find a comfortable posture at work. However, a single – even if comfortable – posture is not meant to be adopted for long periods of time. Rather, dynamic variation around these comfortable head and eye positions is advisable.

FINDING THE OPTIMAL VERTICAL POSITION OF COMPUTER MONITORS

Non-presbyopic subjects are able to see clearly wherever the monitor is positioned relative to the eyes. Still, visual and musculoskeletal strain may arise if the monitor position does not correspond to the individual physiological conditions. Concerning the vertical monitor position, the comfortable gaze inclination may be estimated using the procedure described before. In order to take into account the viewing distance to the monitor as well (which is important for the vergence load), the following procedure can be applied: the subject experiences significantly different monitor positions (high and low, far and near) and – based on these experiences – adjusts his/her monitor to the most comfortable position. These individual monitor positions can differ considerably among non-presbyopic subjects.[2, 3]

In presbyopic subjects, the type of spectacles to support accommodation represents a specific limitation of the monitor position with respect to clear vision. Therefore, the choice between lens types (office lenses, general purpose progressives or computer vision progressive lens) should first be made, depending on the tasks to be carried out and the preferences of the user.

The presbyopia correction determines the individual vertical zone of clear vision, depending on the profile of the addition power within the lens, the remaining accommodative power and the wearer's comfortable head and gaze inclination.

Figure 2.
Three examples of near vision spectacles.

The 'optometric diagrams' (left graphs) illustrate the accommodative power in terms of near and far points (in dioptres) as a function of eye inclination (in degrees). The same data are replotted (in centimetres, relative to the eye position) into 'workplace diagrams' (right graphs).

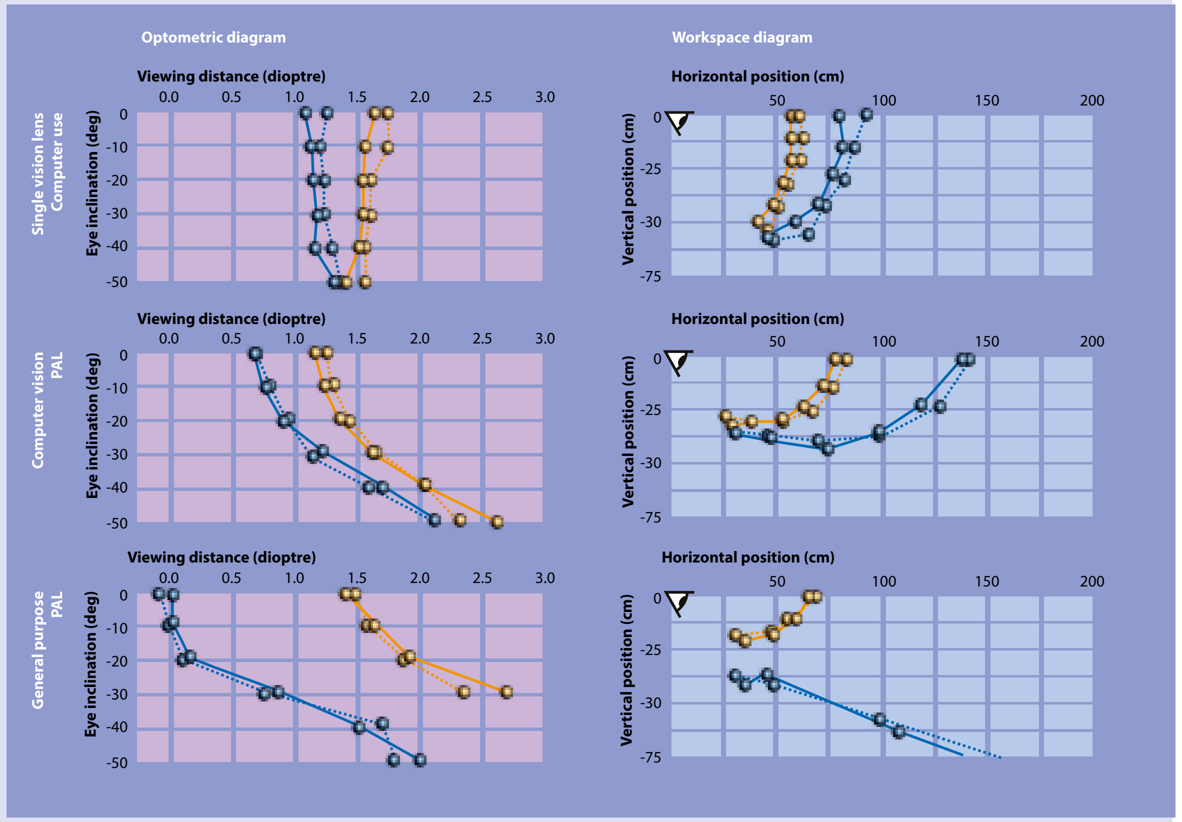
The single vision lens for computer use has an addition power of 1.25 dioptre at all angles of eye inclination (see left graph) and provides clear vision at viewing distances between 60-80cm (see right graph);

The computer vision PAL has a lens design to provide clear vision in the range of 80-145cm at horizontal gaze (see right graph).

The general purpose PAL provides clear vision from 70cm to infinity at horizontal gaze (see right graph).

The pair of two data points refer to repeated measurements.

Far points
Near points



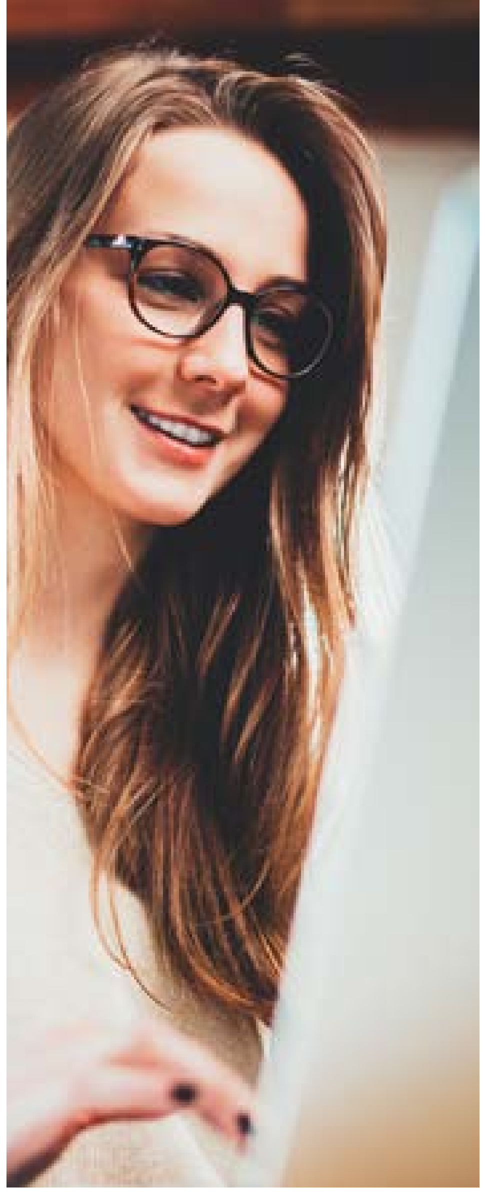


Figure 2 shows examples of these three types of lenses.[5] The curves in the left graphs show the accommodative power as near and far points (in dioptres) as a function of the angle of eye inclination (in degrees), referred to as 'optometric diagrams'.

In the right graphs, the same data are replotted (in centimetres, relative to the eye position) into 'workplace diagrams', which illustrate the vertical zones of clear vision relative to the eyes in a way that the user can directly experience (in contrast to the dioptric values). The monitor should be placed between the far and near point curves. Obviously, such diagrams will differ between individuals.

As a guideline for the average case, *Figure 3a* shows the mean value of the near point curve of 59 wearers of general purpose progressives and adopting their individual comfortable head inclination.

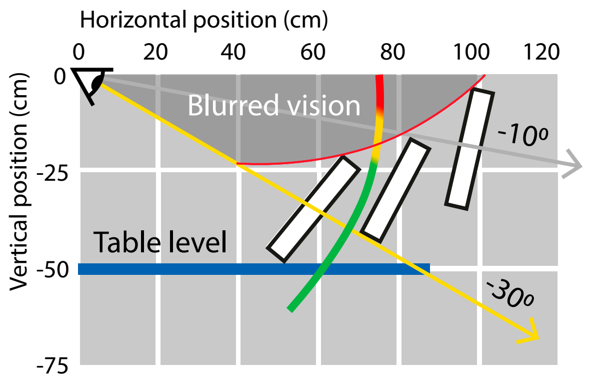
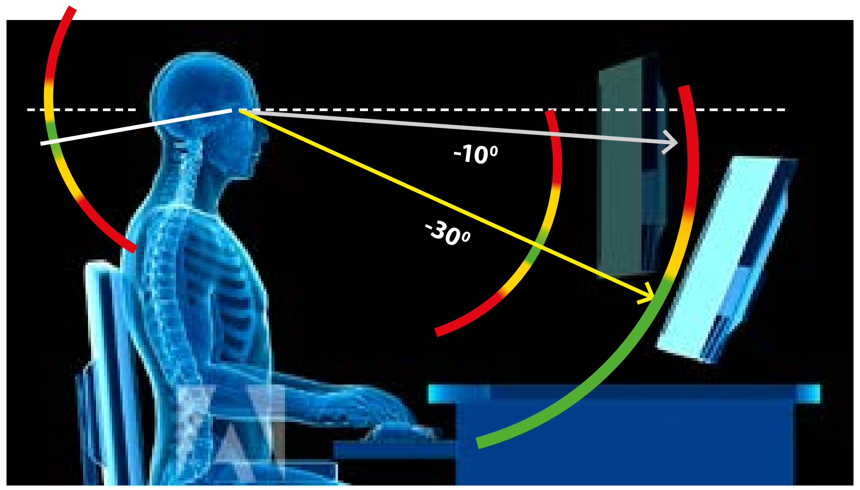


Figure 3a.
The average near point curve of 59 wearers of general purpose progressive lenses relative to eye position is plotted as a red line.
In the range of clear vision below this curve, three possible monitor positions are shown.
The resulting arc illustrates vision as a function of the gaze angle (red = blurred vision, green = clear vision).



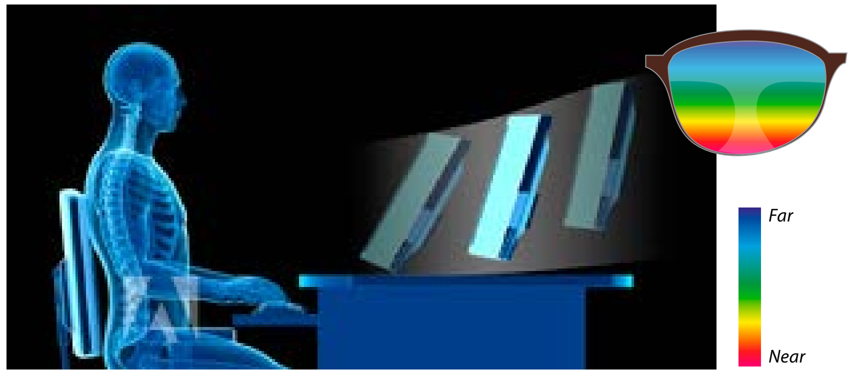
It can be seen that for clear vision, the upper edge of the monitor should be about 15cm below eye level at a conventional viewing distance of 75 cm. Note that lower monitor positions require tilting the monitor backwards, so that the viewing direction is perpendicular to the screen surface. Technically, a rather low monitor position may require a very flexible mechanical monitor support arm.

Figure 3b.
Combination of three strain functions that refer to the head inclination, eye inclination and clear vision with general purpose progressive lenses, in the average case (red = blurred vision, green = clear vision).

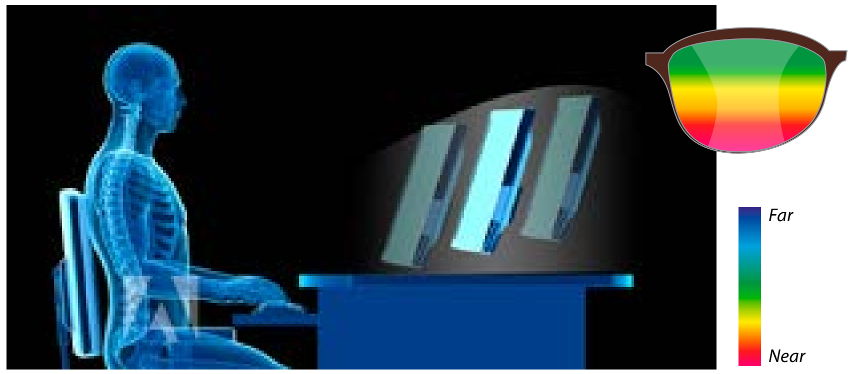
HORIZONTAL FIELD OF VIEW

The situation is different with computer vision progressives in which the horizontal field of view is wider, so that the complete width of a monitor may be seen clearly. *Figure 4* compares the vertical zones of clear vision of general purpose progressives and computer vision progressives.[4]
It can be concluded that clear vision with computer vision progressives is possible with a higher monitor position; this can be reached with most conventional mechanical stands of monitors.

Figure 4.
Different aspects of general purpose progressives versus computer vision progressives.



Recommended monitor position for General Purpose Progressive Addition Lens
Narrow horizontal zone of clear vision.
Horizontal head movements required.



Typical high monitor positions for for Computer vision Progressive Addition Lens
Wider horizontal zone of clear vision.
Full monitor clear without head movements.

THE CHOICE OF SPECTACLES

The choice between different spectacles: a matter of optometric and ergonomic consultation.
To make the choice between types of presbyopia-correcting spectacles, the eye care practitioner should consider different occupational requirements and individual preferences based on the answers to the following questions:

- **Is the user predominantly viewing the monitor for long periods of time or are computer tasks frequently interrupted by other tasks such as text reading, manual tasks or meetings?**
- **Are most visual tasks carried out at the desk, within an office of a few square metres or is clear far vision also required in a large office or outside?**
- **How large is the horizontal field of view? Which type of monitor is used: a single screen of a smaller or larger size, or multiple screens covering a large part of the visual field?**
- **Is the user willing to change spectacles depending on the situation?**

OPTIMISING PRESBYOPIA CORRECTIONS

CONCLUSION

Only the combination of optometry and ergonomics can optimise presbyopia corrections for the computer workstation.
Studies in offices have shown the advantages of this approach: vision at the monitor can be improved and neck strain can be reduced.[8, 9]
For practical applications of this combined approach, a web-based consultation tool can be found online.[10]

Only the combination of optometry and ergonomics can optimise presbyopia corrections

REFERENCES

1 Jaschinski W, Luttmann A, Jäger M: Effect of Head Inclination on Neck Muscular Activity, Tracking Performance and Subjective Neck Strain: Visual and Biomechanical Conditions for Designing the Computer Workstation p. 223-238 In: Springer-Verlag Berlin Heidelberg 2016, In: B. Deml et al. (eds.), Advances in Ergonomic Design of Systems, Products and Processes

2 Jaschinski, W, Heuer, H and Kylian, H: A procedure to determine the individually comfortable position of visual displays relative to the eyes. Ergonomics, 42, No. 4, 535-549 (1999)

3 Jaschinski, W, Heuer, H and Kylian, H: Preferred position of visual displays relative to the eyes: a field study of visual strain and individual differences. Ergonomics, 41, No. 7, 1034-1049 (1998)

4 Jaschinski W, König M, Lobisch, Reiffen C (2017) Better seeing and working at the computer. Website http://ergonomic-vision.ifado.

5 König M, Haensel C, Jaschinski W: How to place the computer monitor: measurements of vertical zones of clear vision with presbyopic corrections. Clin Exp Optom 98: 244-253 (2015)

6 Masseida J, Perske F, Jaschinski W: Messmethoden und Eigenschaften der physiologisch günstigen Blickneigung. Z Arbeitswiss 67: 221-231 (2013)

7 Masseida J, Philipp J-J, Wicher C, Jaschinski W: Verschiedene Kenngrößen für die physiologisch günstige Kopfneigung. Z Arbeitswiss 67: 207-219 (2013)

8 Meinert M, König M, Jaschinski W: Web-based office ergonomics intervention on work-related complaints: a field study. Ergonomics 56: 1658-1668 (2013)

9 Weidling P, Jaschinski W: The vertical monitor position for presbyopic computer users with progressive lenses: how to reach clear vision and comfortable head posture. Ergonomics 58 (11): 1813-1829 (2015)

10 http://ergonomic-vision.ifado.de/en/.

CHILDREN'S VISION

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Does computer vision syndrome really affect children? The impact of computer and digital device use on children's vision.

Computers and mobile devices with screens were initially used only by adults, but today millions of children regularly use computers at school and home, both for education and entertainment. Even young children are surrounded by television, computers and modern technologies. They often perform e-multitasking as well.

Although the visual impact of computer use has been widely studied in adults, only a few studies have investigated its influence on children. In recent years, there has been a significant increase in the use of mobile devices such as smartphones and tablets among young children. Touch-screen devices easily attract children's attention and children become proficient users even after brief exposure. When they start crawling or toddling, e-devices become a perfect visual lure.[1]

Moreover, parents often uses e-devices to pacify their offspring. Another study showed that 10% of parents give their children access to smartphones or tablets when they, the parents, are absorbed with household chores.[2]
Young children also mirror their parents' behaviour and finally become a part of the mobile screen media world.

SYMPTOMS

Kozeis (2009) suggests that many visual symptoms experienced by children using e-devices may be similar or even the same as those experienced by adults.[3] These symptoms occur because the visual demands related to such tasks surpass the child's visual abilities, which does not allow them to perform the tasks comfortably. However, certain individual aspects that occur in children using e-devices may lead to increased susceptibility to digital eye strain, also known as computer vision syndrome (CVS), as compared to adults.

Children tend to ignore problems or might not share their symptoms with their parents for fear of being banned from using a computer.

Children usually adapt easily to poorer working conditions and overlook somatic complaints. In addition, children have limited self-awareness and they find it easier to adapt to a given situation.
Firstly, they tend to ignore problems or might not share their symptoms with their parents for fear of being banned from using a computer. Secondly, children who do experience problems tend to avoid the activities they find difficult. However, since **e-devices are so attractive to children, they will not use as many avoidance techniques as they might employ for other activities,** e.g. reading, unless their symptoms become severe.

POTENTIAL PROBLEMS

Khalaj et al. (2015) showed that the most prevalent eye-related problem reported by adolescent computer users is eye strain and the least prevalent is dry eye.[4] Children and adolescents might often report blurred distance vision but not dry eyes.[7]

In our preliminary studies[5] to examine the prevalence of symptoms in children, we asked 79 Polish parents and guardians (54 with children aged 4 or above and 25 with adolescent children) to complete a questionnaire on the use of e-devices with screens. In the group with a mean age of 9.1+/-3.7 years we found that all children used at least one e-device, and most of them spent time watching TV (86%), using laptops (76%) or smartphones (75%) *(Figure 1)*.

A game console was the least frequently used e-device. Additionally, the children spent around an hour a day in front of TV screens and a similar amount of time with smartphones. On average, they spent approximately 3.5 hours using some e-device and in certain instances they were multi-tasking *(Figure 2)*.

Moreover, we observed that the older the children, the more time they spent using e-devices (r=0.535, p=0.000). In the case of smartphones, quite a strong positive correlation was found between the duration of use and the child's age, i.e. the older the child the more time he/she spent using a smartphone (r=0.594, p=0.000). Daily use of TV appeared similar in all age groups (r=-0.036, p=0.750) *(Figure 3)*.

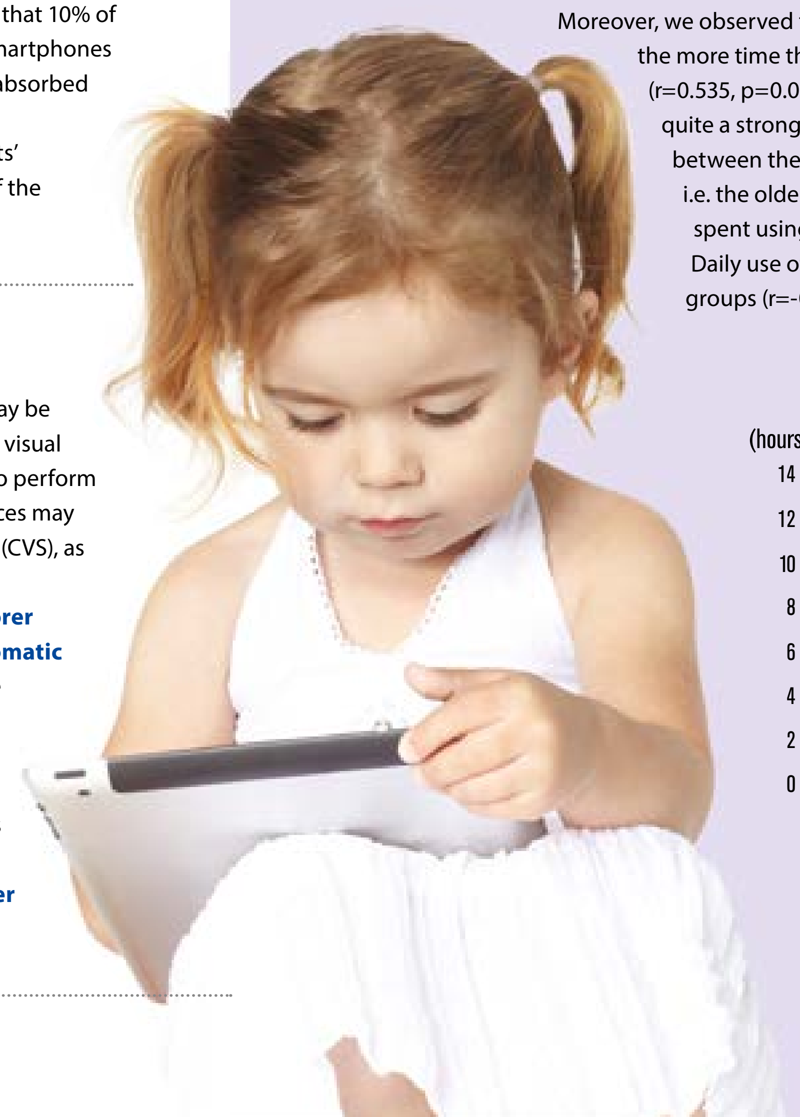


Figure 1
The use of e-devices by children.

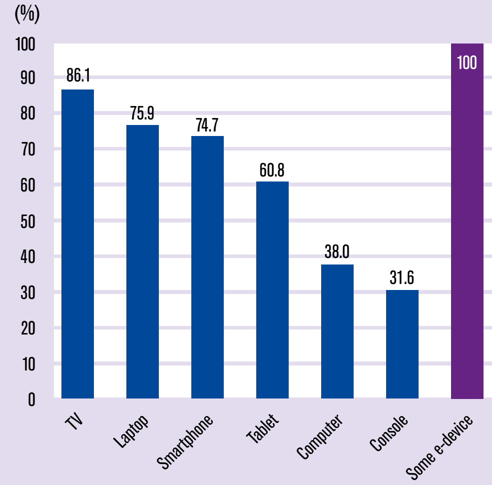


Figure 2
Daily e-device usage by children in minutes per day.[5]

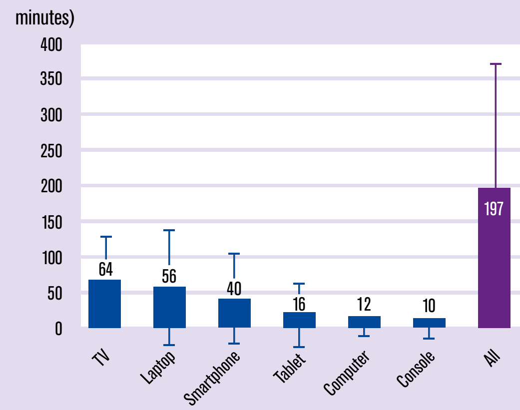


Figure 3
Daily device usage and child's age.[5]

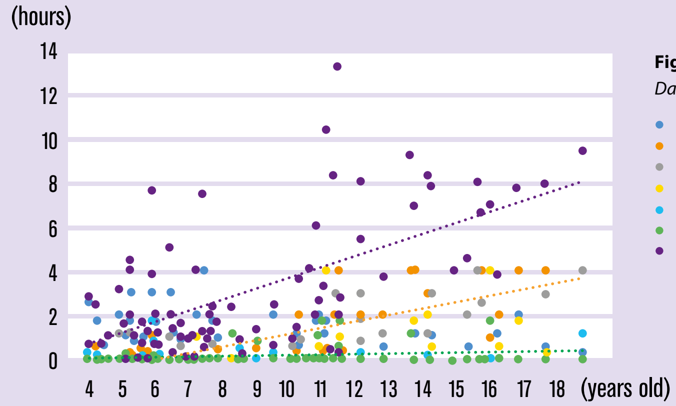
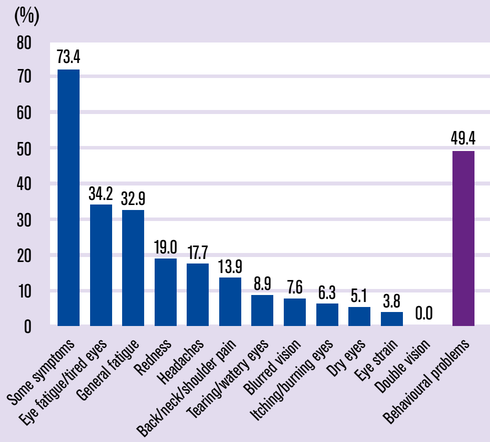


Figure 4
Occurrence of symptoms in children using e-devices.[5]



In terms of complaints related to the use of e-devices, more than 73% of children experienced some eye problems, usually tired eyes (35%) and general fatigue. The least commonly reported problems were dry eyes (5%) and eye strain (4%). None of the children reported double vision.
However, the most prevalent symptoms following the use of e-devices were certain behavioural changes (e.g. hyperactivity, problems falling asleep).
The behavioural changes affected nearly 50% of children *(Figure 4)*.

POTENTIAL CAUSES OF CVS IN CHILDREN

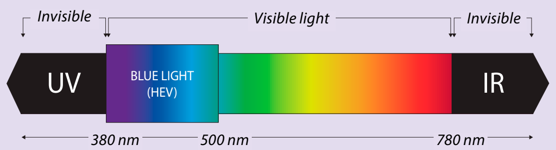
Close working distance can increase the demand for accommodation and vergence.

While ocular causes (uncorrected refractive error, inappropriate oculomotor response and dry eye) have been cited as contributing to the symptoms associated with computer use, there is little objective data showing how these parameters influence computer work in adults and hardly any data for children.
Close working distance can increase the demand for accommodation and vergence.
Mobile devices, particularly tablets and smartphones, have relatively small screens and display small fonts, which might influence the working distance. While research results remain inconclusive[6], lengthy near work with a screen seems to lead to the occurrence of myopia and/or its progression. When we look at the accommodative vergence system, there is some clinical evidence that excessive smartphone use might even lead to acute acquired comitant esotropia (AACE) in adolescents.[8]

As refractive errors and accommodative vergence causes of CVS are under debate, another possible cause is dry eye. Dry eye in computer users may result from a decreased frequency of blinking and an increased rate of tear evaporation. Some studies suggest that dry eye rarely affects children.[9] However, **the prevalence of dry eye in children may be underestimated as the condition is often overlooked and ocular irritation might be attributed to other causes including allergies.** Moreover, children find it hard to self-report dry eye.[7] There is some evidence of an increased risk of dry eye disease (DED) in children following the use of smartphones.[10] Conversely, outdoor activity appears to be a protective factor against paediatric DED.[10]

Computer work, however, is related to more risk factors. Another potential cause of ocular problems affecting children and related to excessive use of digital screens is overexposure of the eyes to blue light or high-energy visible light (HEV). While HEV light is unavoidable, overexposure to blue light could damage the retinal cells, which might increase the risk of macular degeneration later in life.

HEV - High Energy Visible light
UV - Ultraviolet light
IR - Infrared light



At the same time, blue light is also beneficial as it helps the human body to establish a natural circadian (sleep/wake) rhythm and supports cognitive functions such as alertness, memory and control of emotions. Moreover, it may help to control myopia progression. *Foulds et al. (2013)* reported that blue light had a suppressive effect on myopia.[11] Recently, *Torii et al. (2017)* found a minor effect of blue light (470nm) and a significant effect of violet light (360-400nm).[12]

CONCLUSION

In summary, the use of computers and other e-devices has positive, detrimental and also unknown consequences on children's vision.
It is important to realize how children should use e-devices in order to find a balance between protecting their vision and allowing them to develop in the digital world. A study showed that children who used computers performed better in terms of school readiness and cognitive development than their peers not exposed to computers.[13]

Thus, we need to consider how much time children should spend using e-devices and what e-devices are appropriate for each age group, especially since the currently used standards appear to be obsolete and children spend more time than recommended in front of digital screens.

REFERENCES

1 Cristia A, Seidl A. Parental Reports on Touch Screen Use in Early Childhood. PLoS One. 2015, 10(6).
2 Paudel S, Leavy J, Jancey J. Correlates of mobile screen media use among children aged 0–8: protocol for a systematic review, Systematic Reviews. 2016, 5: 91.
3 Kozeis N. Impact of computer use on children's vision. Hippokratia. 2009, 13(4): 230-1.
4 Khalaj M., Ebrahimi M., Shojai P., Bagherzadeh R., Sadeghi T., & Ghalenoei M., Computer Vision Syndrome in Eleven to Eighteen-Year-Old Students in Qazvin, Biotechnology and Health Sciences. 2015, 2(3): e28234.
5 Brenk-Krakowska A, Jankowska M. Wpływ urządzeń elektronicznych na widzenie u dzieci – możliwe dolegliwości i ich potencjalne przyczyny (Impact of digital devices on children vision – symptoms and potential causes. Article in Polish, Optyka. 2017, 4(47): 36-42.
6 Zadnik K., et al. Collaborative Longitudinal Evaluation of Ethnicity and Refractive Error (CLEERE) Study Group. Prediction of Juvenile-Onset Myopia, JAMA Ophthalmol. 2015, 133(6): 683-9.
7 Hu L, Yan Z, Ye T, Lu F, Xu P, Chen H. Differences in children and adolescents' ability of reporting two CVS-related visual problems. Ergonomics. 2013; 56(10): 1546-57.
8 Lee HS, Park SW, Heo H. Acute acquired comitant esotropia related to excessive Smartphone use, BMC Ophthalmol. 2016; 16: 37.
9 Alves M, Dias AC, Rocha EM. Dry eye in childhood: epidemiological and clinical aspects. Ocul Surf. 2008; 6(1): 44-51.
10 Moon JH, Kim KW, Moon NJ. Smartphone use is a risk factor for pediatric dry eye disease according to region and age: a case control study. BMC Ophthalmol. 2016 Oct 28;16(1):188.
11 Foulds WS, Barathi VA, Luu CD, Progressive myopia or hyperopia can be induced in chicks and reversed by manipulation of the chromaticity of ambient light. Invest Ophthalmol Vis Sci. 2013 Dec 9;54(13): 8004-12.
12 Torii H, Kurihara T, Seko Y, Negishi K, Ohnuma K, Inaba T, Kawashima M, Jiang X, Kondo S, Miyauchi M, Miwa Y, Katada Y, Mori K, Kato K, Tsubota K, Goto H, Oda M, Hatori M, Tsubota K. Violet Light Exposure Can Be a Preventive Strategy Against Myopia Progression. EBioMedicine. 2017 Feb; 15: 210-219.
13 Li X, Atkins MS. Early childhood computer experience and cognitive and motor development. Pediatrics. 2004 Jun;113(6):1715-22.

A SURVEY OF NEAR VISUAL FUNCTION

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In Latvian schoolchildren with and without learning difficulties.

Over the course of their education, children's visual systems experience multiple stress factors, including reading, writing, using computers and interactive boards.

PURPOSE

The first sign of near-vision fatigue is an unbalanced accommodation and vergence system [1-8] Significant refractive errors, strabismus and amblyopia are detectable and usually corrected before school (up to six years of age). Accommodative and vergence problems are detectable only at a later age.[9-13]
The purpose of our research was to study near-vision problems in schoolchildren and to evaluate their possible relationship with learning difficulties.

METHOD

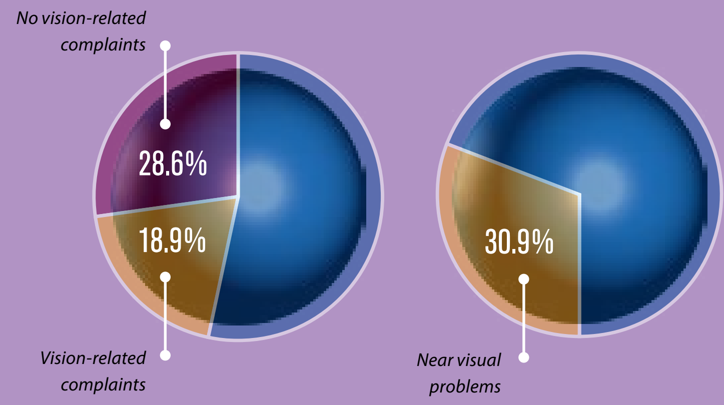
Accommodative and vergence problems are detectable only at a later age.

In Latvia, no official guidelines exist for vision examination in schoolchildren. Therefore, we developed a screening model incorporating tests for visual acuity at a distance of 3m, hyperopia (using +2.50 D for children aged 7-10 years and +1.50 D for children aged 11-18 years), accommo-dation, suppression and stereovision, heterophoria, near point of convergence, vergence facility and colour vision (87% sensitivity, 77% specificity). We evaluated the screening results of 10,861 schoolchildren (aged 7-18 years; 51% girls; 30 schools) examined between 2011 and 2013. Of those, 10,648 children attended standard schools and 213 children attended schools for children with learning difficulties.

RESULTS AND ANALYSIS

The analysis showed that 47.5% of the children in standard schools failed the screening:

18.9% had vision-related complaints
28.6% had no vision-related complaints



The largest group of children (30.9%) may experience problems with near visual tasks because they failed near vision skill tests.

Both vision-related complaints *(Figure 1A)* and visual acuity at distance *(Figure 1B)* were dependent on the age of the patients, increasing significantly up to the age of 12-13 years.
Statistical analysis demonstrated that children with learning difficulties have more visual complaints (~28%).

Dusek et al. (2010) demonstrated that children with reading and writing difficulties were more likely to complain of burning or stinging eyes, tiredness after reading, eye strain when looking at a near object, blurred vision at near and at distance. In our study, we could not find the statistical difference in visual acuity between the two groups, contrary to Dusek et al. In our study, 22% of children had decreased visual acuity at distance and only 1.6% had decreased visu-al acuity at near.

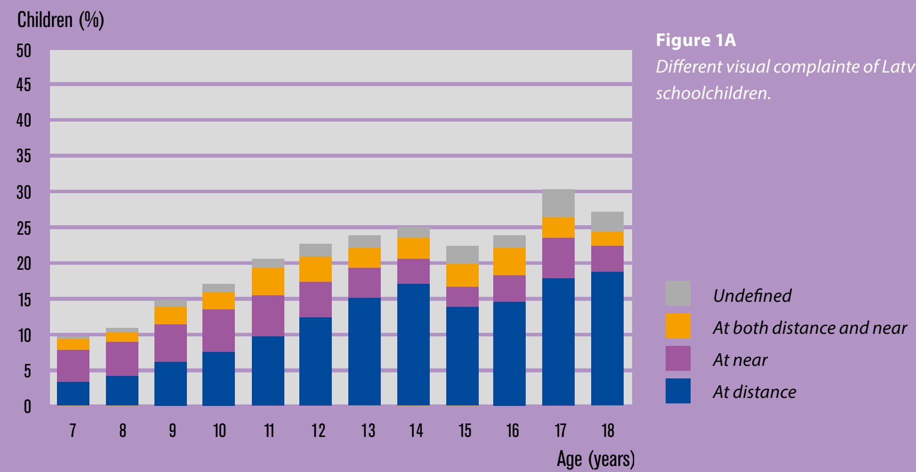


Figure 1A
Different visual complainte of Latvian schoolchildren.

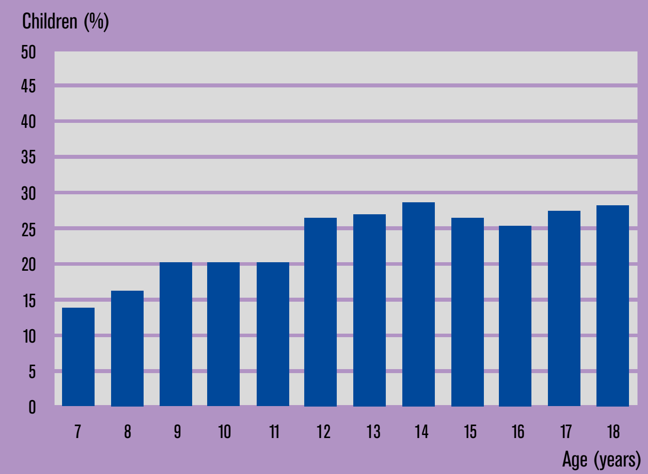


Figure 1B
Decreased visual acuity at a distance of 3 meter.

STANDARD AND SPECIAL SCHOOLS

Children with learning difficulties were more likely to have a positive hyperopia test *(Figure 2A)* and had more cases of esophoria, which could be the reason for eye complaints during reading.

Standard schools
Special schools

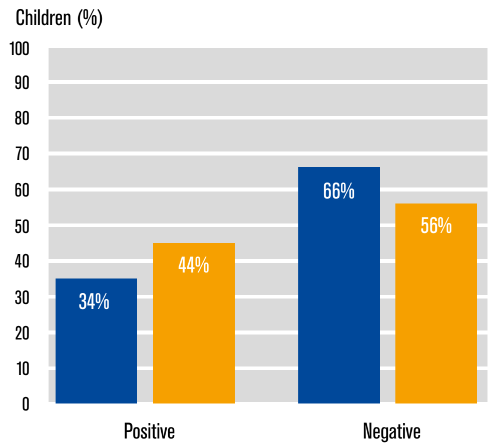


Figure 2A

Children with learning difficulties were more likely to have a positive hyperopia test (2A), and the same children had more esophoria at near largen then 4 prismatic dioptres, compared to children from the standard schools (2B).
This may show yhat children with learning difficulties had hypermetropia yhat could influence eye fatigue and vergence system balance during reading.

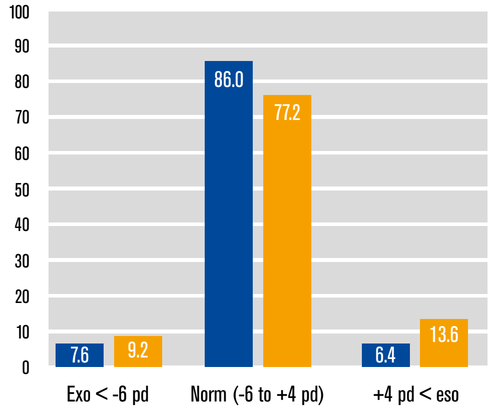


Figure 2B

Accommodation and vergence problems were not linked to age. Children with learning difficulties had problems with accommodation stimulation (response to the -2.00 D lens) and a significantly slower accommodation response to +2.00 D lens *(Figure 3)*. Dusek et al. (2010) and Palomo-Alvarez and Puell (2008) similarly demonstrated that children with reading and writing difficul-ties had reduced accommodation amplitude and binocular accommodative facility. Our data also reflected the findings of Dusek et al. (2010), Palomo-Alvarez and Puell (2008, 2010) and Quaid and Simpson (2013), showing that children with learning difficulties had reduced vergence facility, a slower vergence response and the near point of convergence was more remote.

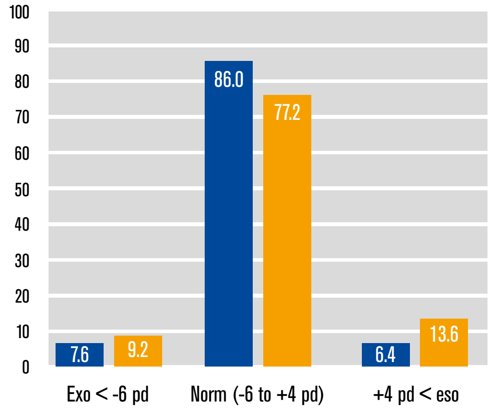


Figure 3

A comparison of the two groups of children showed a statisti-cally significant difference in accommodation. Children with learning difficulties had a more reduced response of accom-modation constriction and relaxing.

Among Latvian schoolchildren, only 4% of boys have colour vision defects, but a comparison of the two groups showed that girls from the standard schools had 0.3% colour vision problems (we could not find any colour vision defects in girls in the special schools), and boys from the special schools had up to four time more colour vision defects (12.7%) than boys from the standard school (3.3%).

STEREOVISION

The children with learning difficulties had more significantly reduced stereovision *(Figure 4)* or lacked stereovision in 13.7% of cases. At the end of the vision screening, we checked the reading speed of all children using specially created and modified reading tests for different ages. These results showed reduced reading speed *(Figure 5)* in children with learning difficulties.

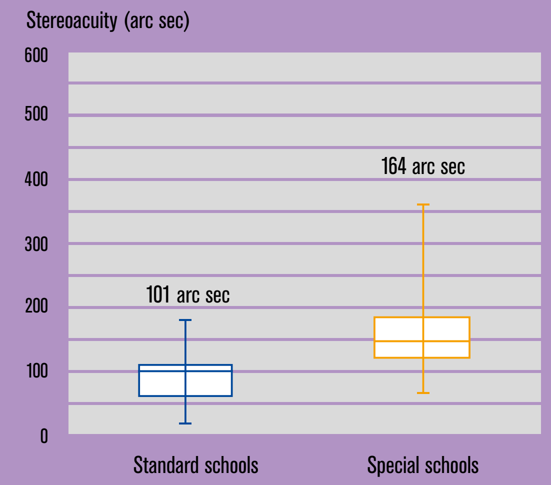


Figure 4
Children with learning difficulties had reduced stereoacuity, measured using the TNO stereotest (global stereovision).

Standard schools
Special schools

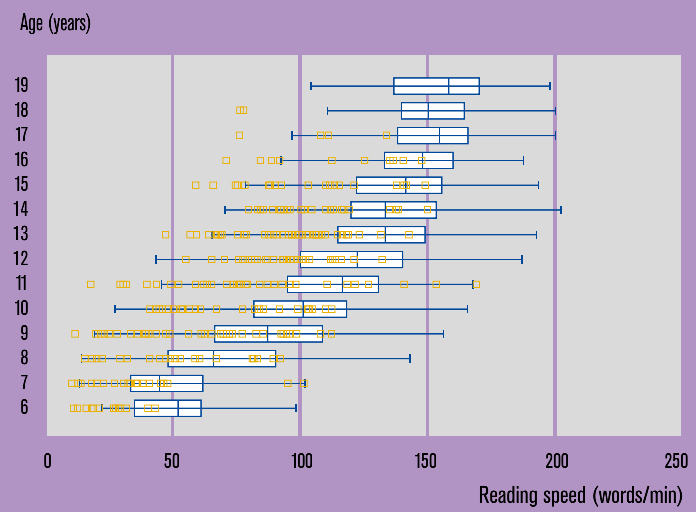


Figure 5
Reading speed. The yellow squares show the reduced reading speed of the children with learning difficulties.

A SURVEY OF NEAR VISUAL FUNCTION

CONCLUSION

Children with learning difficulties had significantly more visual complaints.

These results demonstrate a wide range of near-vision problems in schoolchildren. Children do not always complain; it is easier for a child not to read than tell their parents or teacher about any visual discomfort during reading. One way to identify children with near-vision problems is vision screening performed in second, fourth and sixth grades, when children rarely complain or do not relate their complaints with vision problems. Early detection and correction of near-vision problems, especially balancing accommodation and vergence system functions, should be the first steps in helping a child to maintain their interest in learning and overcome some learning problem.

Today, the use of smartphones and tablets by adults and children has increased and the distance between the eyes and devices has decreased to 20-25 cm.

As a consequence, disorders associated with binocular vision and imbalance between eye accommodation and vergence system will increase.

It is very important to check the visual function in children at these short distances or to develop the new visual screenings to perform at different distances.

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REFERENCES

1 Birnbaum, M.H. (1984). Near-point visual stress: A physiological model. Journal of the American Optometric Association, 55(11), 825-835.
2 Birnbaum, M.H. (1993). Vision disorders frequently interfere with reading and learning: They should be diagnosed and treated. Journal of Behavioral Optometry, 4(3), 66-71.
3 Bucci, M.P., Bremond-Gignac, D., and Kapoula, Z. (2008). Poor binocular coordination of saccades in dyslexic children, Graefe's Archive of Clinical Experimental Ophthalmology, 246, 417-428.
4 Bullimore, M.A., and Gilmartin, B. (1988). The accommodative response, refractive error and mental effort: 1. the sympathetic nervous system. Documenta Ophthalmologica, 69(4), 385-397.
5 Cooper, J., Feldman, J., Selenow, A., Fair, R., Buccerio, F., MacDonald, D., and Levy, M. (1987). Reduction of asthenopia after accommodative facility training. American Journal of Optometry and Physiological Optics, 64(6), 430-436.
6 Dusek, W., Pierscionek, B.K., and McClelland, J.F. (2010). A survey of visual function in an Austrian population of school-age children with reading and writing difficulties. BMC Ophthalmology, 10(16), 1-10.
7 Goldstand, S., Koslowe, K.C., and parush, S. (2005). Vision, visual-information processing, and aca-demic performance among seventh-grade schoolchildren: A more significant relationship than we thought? The American Journal of Occupational Therapy, 59(4), 377-389.
8 Quaid, P., and Simpson, T. (2013). Association between reading speed, cycloplegic refractive error, and oculomotor function in reading disabled children versus controls. Graefe's Archive of Clin-ical Experimental Ophthalmology, 251, 169-187.
9 Evans, B.J.W. (1998). The underachieving child. Ophthalmic and Physiological Optics, 18(2), 153-159.
10 Evans, B.J.W., Patel, R., Wilkins, A.J., Lightstone, A., Eperjesi, F., Speedwell, L., and Duffy, J. (1999). A review of the management of 323 consecutive patients seen in a specific learning difficulties clinic. Ophthalmic and Physiological Optics, 19(6), 454-466.
11 Kulp, M.T., and Schmidt, P.P. (1996). Effect of oculomotor and other visual skills on reading per-formance: A literature review. Optometry and Vision Science, 73(4), 283-292.
12 Palomo-Alvarez, C., and Puell, M.C. (2008). Accommodative function in school children with read-ing difficulties. Graefe's Archive of Clinical Experimental Ophthalmology, 246, 1769-1774.
13 Palomo-Alvarez, C., and Puell, M.C. (2010). Binocular function in school children with reading dif-ficulties. Graefe's Archive of Clinical Experimental Ophthalmology, 248, 885-892.

BLUE LIGHT-FILTERING

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Clinical performance of blue light-filtering spectacle lenses

A large number of spectacle lenses are prescribed not just for corrective purposes but also to protect the eyes from the undesirable effects of ultraviolet (UV), visible and infrared (IR) radiation or to improve vision quality.

For radiation to have an effect it must be absorbed (Grotthuss-Draper law), so radiation that is reflected or transmitted completely does not have an effect. The absorption of radiation by a specific tissue depends on its molecular structure and chemical composition, and the effect is proportional to the absorption of the radiant energy per unit of mass or volume[1] *(Figure 1).*

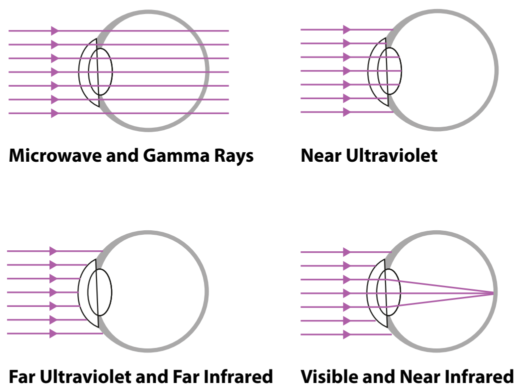


Figure 1.
Diagrammatic representation of absorption by the eye for different wavelengths.

RADIATION TRANSMITTANCE

A knowledge of the radiation transmittance properties of different structures of the eye is important in explaining its effects on those structures. For example, ocular media transmit 70-90% of the visible spectrum and IR below 1,400nm to the retina.

The UV radiation incident on the different surfaces of the ocular media show that a small but significant UV waveband reaches the retina of the phakic eye beginning at 305nm, peaking at about 3% at 320nm and decreasing to less than 1% above 340nm. Thus, the retina is provided partial protection against UV radiation because the crystalline lens absorbs the major portion of the UV as it passes through the ocular media to impinge the retina. The transmittance of the visible spectrum begins at about 380nm and increases very rapidly to 70% at 450nm, whereas an 80-90% transmittance is maintained throughout the rest of the visible spectrum[2].
The spectral transmittance of the ocular media changes as the eye ages, with a significant reduction in the range of wavelengths between 420nm and 560nm *(Figure 3)*, changes induced mainly by the crystalline lens[3].

THE EFFECT OF RADIATION

The effect of radiation on a tissue depends not only on its absorption but also in its energy (E) per photon, as per *equation 1.*
It is evident that E is wavelength dependent and the shorter wavelengths present the highest E value[4]. The effect is also cumulative, so despite a low level of irradiance, the effect is related to the length of exposure over long periods of time.
The necessity to protect against the effects of UV radiation is well known, and eye care practitioners routinely prescribe ophthalmic and contact lenses with a UV filter for this reason.

$$E = \frac{1240}{\lambda}$$

E = energy (eV)
λ = wavelenght (nm)

Equation 1
Equation to calculate the energy per photon in function of wavelength.

BLUE LIGHT

In recent years, there has been increasing interest in the effects of blue light, which includes the range of wavelengths between 380nm and 500nm (range divided into 'blue violet' between 380nm and 440nm and 'blue turquoise' between 441nm and 500nm) *(Figure 5)*, in part because this is the part of the visible spectrum that carries the highest amount of energy (E) per photon to the retina *(Figure 6)* and also because there is an increased number of sources that emit high values of blue light.

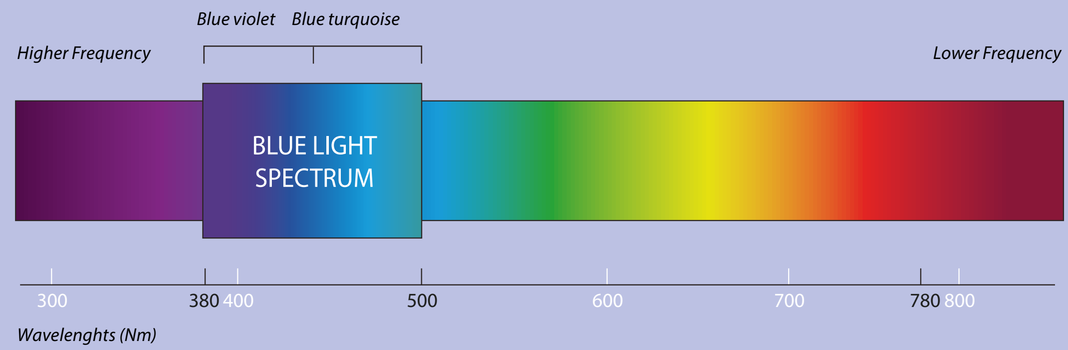


Figure 5.
Blue light spectrum.

Color	Wavelenght	Frequency	Photon energy
Violet	380-450 nm	668-789 THz	2.75-3.26 eV
Blue	450-496 nm	606-668 THz	2.50-2.75 eV
Green	495-570 nm	526-606 THz	2.17-2.50 eV
Yellow	570-590 nm	506-526 THz	2.10-2.17 eV
Orange	590-620 nm	484-506 THz	2.00-2.10 eV
Red	620-750 nm	400-484 THz	1.65-2.00 eV

Figure 6.
Energy values (eV) for different wavelength ranges in the visible spectrum.

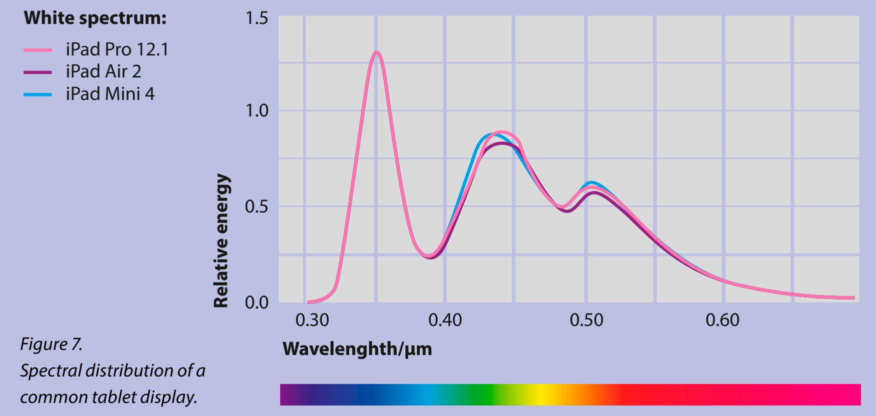
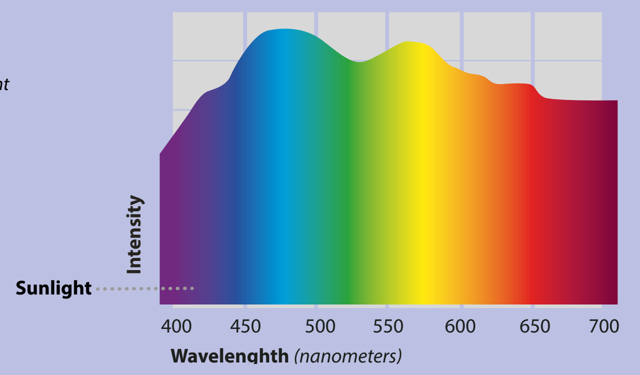
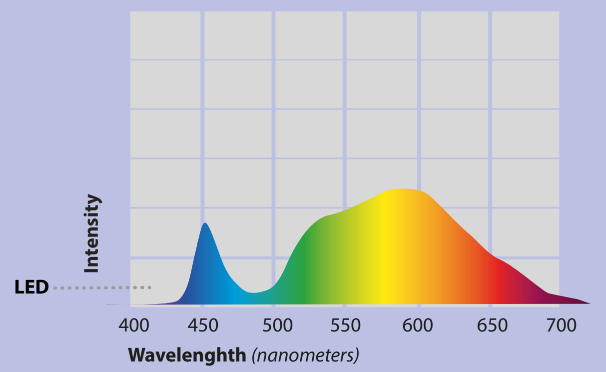


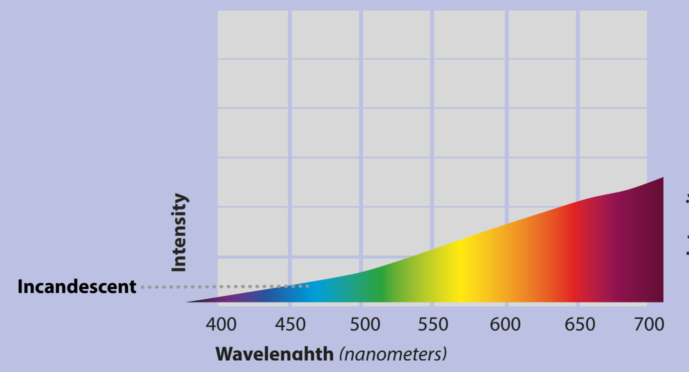
Figure 7.
Spectral distribution of a common tablet display.

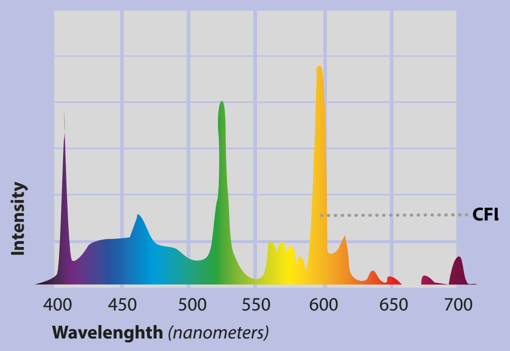
Although the greatest source of blue light remains the sun, additional sources that emit high values of blue light, with a peak close to 460nm (+/-10nm), include mobile devices (telephones, tablets, e-readers, video display terminals) *(Figure 7)* as well as 'coldwhite' light-emitting diodes (LEDs) in most backlit screens, televisions etc. LED lighting has largely replaced traditional incandescent bulbs and fluorescent tubes as the most energy-efficient form of lighting and is also used in car headlights instead of halogen lamps *(Figure 8).*

Figure 8.
Spectral distribution of sunlight and of different light sources.









An extensive body of peer-reviewed research from animal and in vitro studies strongly suggests there is a 'blue light hazard' in the range of 415nm-455nm, with a peak around 440nm, which may play a role in a complex set of cellular events within the retina (lipid peroxidation, deterioration of lysosome function and accumulation of lipofuscin) and produce photochemical damage to the retinal pigment epithelium (RPE) through oxidative stresses, with an increased potential risk of age-related macular degeneration (AMD).[5-13] Although the results of a recent study[14] suggest that even under extreme, long-term viewing conditions, the level of blue light emitted from LED lamps, computer screens, tablets, laptops and smartphones is low compared with international exposure limits and it not a cause for concern for public health.

Blue light exposure has also been linked to various other effects, such as higher reduction of visual quality in subjects with tear film instability[15] and increased glare sensation[16-17]. Effects relate to the highest value of forward ocular scattering with shorter wavelengths *(Figure 9)* as evaluated by the simplified equation 2.[18]

$$S = \frac{1}{\lambda^4}$$

S = scattering
λ = wavelenght (nm)

Equation 2
Simplified equation for Rayleigh scattering calculation.

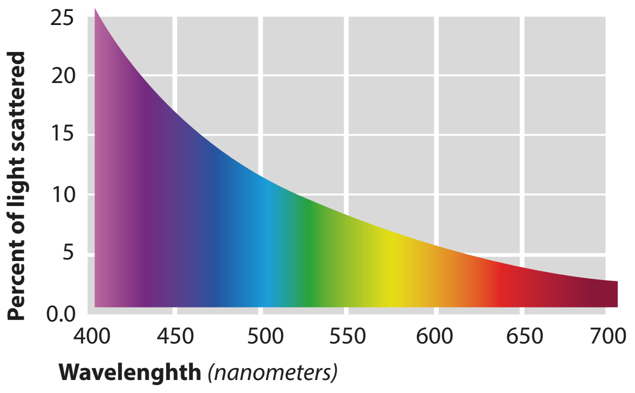


Figure 9.
Rayleigh scattering for different wavelengths in the visible spectrum.

LIGHT SCATTERED

The light scattered results in a veil of stray light over the retinal image. Complaints may include hazy vision, increased glare, loss of contrast and colour, and may also aggravate other symptoms, including photophobia, leading to headaches and physical and mental fatigue caused by long exposure to video display terminals (VDTs) or other electronic screen-based devices. The forward scattering in the human eye can be modelled as the sum of three components with different spectral characters[19].
Each individual subject starts with a base (S_{base}) of retinal stray light that is strongly wavelength dependent, according to Rayleigh scattering. If the eye is less than perfectly pigmented, extra stray light is added, according to S_{pigm} on the long wavelength side. In addition, stray light is added for all wavelengths when the eye ages, according to S_{age} .

POSITIVE EFFECTS

It is important to remember that blue light also has some positive effects necessary for normal visual function. These include colour discrimination[20] and night vision[21].
Other positive effects of short wavelength light exposure on the eye have been evaluated. For example, 'blue violet' light was recently shown[22] to have a positive effect on prevention of myopia progression in chicks with a light exposure in the range of 360-400nm. These results suggested that the more 'myopic defocus' of blue light associated with longitudinal chromatic aberration provides a myopically defocused stimulus resulting in reduced eye growth.

CIRCADIAN RHYTHMS

Other effects are related to 'blue turquoise' light with a peak close to 480nm, which has a strong link to pupillary reflex and circadian rhythms[23]. This last effect can be explained by the small percentage of retinal ganglion cells that contain a pigment, melanopsin, whose absorption of blue light triggers a mechanism in the brain that regulates melatonin levels in the blood.

When the retina is exposed to light with a blue component, its absorption by melanopsin initiates a process whereby melatonin production is suppressed and the individual exposed 'wakes up'. By contrast, switching off absorption at night regulates melatonin production and the individual goes to sleep[24]. The disturbance of these rhythms is linked to a wide range of systemic diseases such as sleep disorders, depression, anxiety, obesity, diabetes, heart disease, stroke and cancer[25-30].

A number of studies have considered the effect of smartphones[31] and eReaders[32] on circadian rhythms, highlighting how the use of these devices can modify the regular sleep/wake cycle. A recent review highlights consistent associations between media and sleep in children and adolescents between 5-17 years old from diverse geographic regions around the world[33].

Over 60 observational studies using cross-sectional or prospective approaches were examined for associations between screen time (i.e. television, computers, video games, mobile devices) and a variety of sleep parameters. In over 90% of these studies, more screen time was associated with delayed bedtimes and shorter total sleep time among children and adolescents. Computer use was more consistently associated with such poor sleep outcomes than television, perhaps because watching television may be less interactive than computer-based activities.

BLUE LIGHT-FILTERING

Taking all these considerations into account, it is evident the complex role a blue light ophthalmic filter must play in order to correctly manage all the effects of this part of the visible spectrum. While blue light-filtering intraocular lenses (IOLs) have been widely tested in laboratory and clinical studies[34-42], the clinical performance of similar products for spectacle lenses in the few published studies in which it was evaluated are controversial[43-44]. Neither is it possible to use the results obtained with IOLs to support the performance of ophthalmic filters because IOLs are used behind the cornea and iris and without the filtering effect of the crystalline lens.

Before considering the clinical effects of blue light ophthalmic filters on the eye and visual function, it is important to remember the ways already available to manufacturers to modulate the transmittance of different wavelengths.

REFLECTION AND ABSORPTION

Transmittance of a certain wavelength or range of wavelength can be defined as the light that remains, on passing through a medium, after losses from reflection and absorption have been accounted for[45].

Taking this into account, a manufacturer can decide to reduce the transmittance of a specific wavelength using a treatment, on the anterior and posterior surface of the filter, to increase reflection or absorption or a combination of both.

GLARE AND COLOUR DISCRIMINATION TESTS

Recently, the clinical performance (contrast sensitivity with and without glare and colour discrimination tests) and the subjective perception of different blue light ophthalmic filters (BF clear lens with blue light anti-reflection coating, BT brown-tinted lens and AR clear lens with conventional anti-reflection coating as a control) were evaluated in a trial on two groups of VDTs users – young adults (18-35 years) and middle-aged adults (40-55 years) – for a minimum of two hours per day [46].

More than a third of subjects found that a clear lens with a blue light-filtering coating improved their vision

The authors' conclusions suggest that blue light-filtering lenses modestly filter short-wavelength light and do not markedly degrade visual performance. More than a third of subjects involved in the trial found that a clear lens with a blue light-filtering coating provided better anti-glare performance and improved their vision for computer and mobile digital screens. An interesting result from this study was related to the participants' preferences.

Young adults preferred the clear lens with a conventional anti-reflection coating (50%) and the clear lens with a blue light anti-reflection coating (47.5%), compared with the brown-tinted lens (2.5%). However, the middle-aged adults preferred the clear lens with a blue filter anti-reflection coating (60%) to the other two lens types (AR 22.5% and BT 17.5%).

These results could be explained by the different transmittance of the eye between age groups, with lower transmittance and higher ocular scattering of blue light in the middle-aged group. In this age group, the use of a blue light filter can be more useful for reducing the effect of ocular scattering, with a positive impact on subjective visual quality.

POSITIVE EFFECT

The reduction of ocular scattering induced by a short tear film break-up time (BUT) in dry eye patients was also considered to explain the positive effect of a 50% blue light filter used to ameliorate visual impairment associated with tear instability[15] *(Figure 14).*

The increase of ocular scattering associated with tear film instability in dry eye was evaluated in a clinical trial where it was found that intraocular scattering increases with time after a blink in short BUT eyes, while there is no impact on the scattering, even after blink suppression, in normal eyes[47].

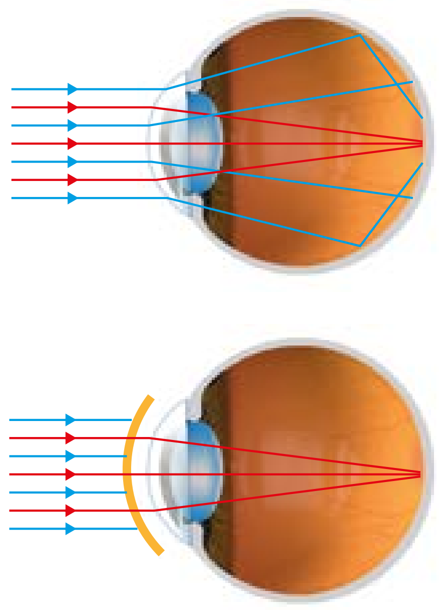


Figure 14.
Effect of the blue light filter on ocular scattering.
The red and blue lines represent red and blue light respectively.
In a part, which shows an eye with an unstable tear film without a blue light filter, blue light is more scattered than red light.B part shows the effect of a blue light filter in an unstable tear film..

REDUCING EYE FATIGUE

The positive effect of blue light filters in reducing eye fatigue in VDT users was shown in a clinical study where a subjective evaluation of eye fatigue was measured via a questionnaire, and an objective evaluation measured the critical flicker frequency (CFF) that reduces its value with eye strain[48]. In this study, two blue light filters with different transmittance and a control lens were used on a group of subjects aged between 28-39 during two hours of VDT use.

CFF presented a statistically significant decrease with the control lens, whereas no significant decreases were observed with the blue light filters [49].

These results were confirmed in another study[50] in which 36 healthy subjects were randomized to wear no-blue blocking, low- blue blocking or high- blue blocking lenses (Figure 16) while performing a two-hour computer task. The results suggested that high-blocking lenses reduce eye fatigue associated with computer use as measured quantitatively by the change in CFF . Moreover, subjects wearing high-blocking lenses reported fewer symptoms associated with eye strain after computer use compared with subjects not wearing the high-blocking lenses.

LED SCREENS IN THE EVENING

A further positive effect of a blue light filter (with 30% transmittance) was found in a clinical study with a group of adolescents aged between 15-17, considering their use as a countermeasure for alertness effects induced by light exposure from LED screens in the evening[51]. Compared with clear lenses, the use of a blue light filter for three hours before sleep significantly attenuated LED-induced melatonin suppression in the evening and decreased vigilant attention and subjective alertness before bedtime.

More controversial is the use of blue light filters in the prevention of age-related macular degeneration (AMD)[44]. A number of articles have been published on the use of blue light filters to reduce the phototoxic potential of light, but at present no large-scale clinical trial has been carried out to support blue light ophthalmic filter use in AMD prevention.

Blue light filters
reduce ocular scattering and increase vision quality.

CONCLUSION

Blue light-filtering lenses can be considered a powerful support to manage the challenges that the technological world, characterised by an increased number of sources of blue light, imposes on the eyes and visual system, as evidenced by the results of the reported studies. Analyzing the results of the studies, it is important to remember that the generic heading 'blue light filtering' encompasses lenses with different absorptions of blue light, and often the transmittance curves are not available, making it difficult to generalise the positive effects across all the products available on the market. In conclusion, to consider some guidelines for the prescription of these lenses, we can use some indications divided by age group and visual task:

- **Adolescents and young adults:**
Blue light filters are indicated to regulate the circadian rhythms in this age group since multimedia are used during the day and until bedtime, increasing light exposure, particularly in the blue light range. Blue light filters can be useful to reduce eye fatigue too.
Particular attention must be paid to the prescription of blue light filters for adolescents in order not to reduce the possible positive effects of short wavelengths on prevention of myopia progression.

- **Middle-aged adults:**
Blue light filters are indicated in this age group to reduce ocular scattering and increase vision quality. Particular indications are associated with VDT users to reduce the causes of eye fatigue, such as instability of the tear film, or night driving to reduce the stray light effect introduced by LED lighting and to improve the visibility of on-board equipment.

- **Older adults:** Blue light filters are indicated in this age group to reduce ocular scattering induced by ocular media and tear film instability, increasing vision quality. Blue light filters can also be indicated for pseudophakic eyes with IOLs without a blue light filter to increase the protection of the retina.

REFERENCES

1. Pitts D, Kleinstein R. Environmental Vision. Butterworth-Heineman, 1993, 151-220.
2. Lund D., et al., A Computerized Approach to Transmission and Absorption Characteristics of the Human Eye, in CIE 203:2012. 2012, International Commission on Illumination.
3. Lerman S. Radiant Energy and the Eye. New York: MacMillan Publishing Company. 1980, 131-164.
4. Pitts D, Kleinstein, R.N. Environmental Vision. Eds. Butterworth-Heineman, Stoneham MA, 1993, 87-91.
5. Margrain T, et al. Do Blue Light filters confer protection against Age-Related Macular Degeneration? Progress in Retinal and Eye Research. 2004; 23: 523-531.
6. Shang Y, et al. White Light Emitting Diodes (LEDs) at domestic lighting levels and retinal Injury in a rat model. Environ Health Perspect 2014; 122, 269-276.
7. Taylor H, et al. The long-term effects of visible light on the eye. Arch. Ophthalmol.1992; 110: 99-104.
8. Cruickshanks K, et al. Sunlight and age-related macular degeneration. The Beaver Dam Eye Study. Arch. Ophthalmol. 1993; 111: 514-518.
9. Arnault E, et al. Photoxic Action Spectrum on a Retinal Pigment Epithelium Model of Age-Related Macular Degeneration Exposed to Sunlight Normalized Conditions. PLoS ONE. 2013;8(8): e71398. doi:10.1371/journal.pone.0071398.
10. Kuse Y, et al. Damage of photoreceptor-derived cells in culture induced by light emitting diode-derived blue light. Scientific Report 42014., 5223; DOI:10.1038/srep05223.
11. Noell, W et al. Retinal damage by visible light. Invest Ophtalmol. 1966; 5: 450-473
12. Igvere P, et al. Age-Related maculopathy and the impact of blue light hazard. Acta Ophtalmol Scand.2006; 84: 4-15.
13. Arnault E, el al. Phototoxic Action Spectrum on a Retinal Pigment Epithelium Model of Aged-Related Macular Degeneration Exposed to Sunlight Normalized Conditions. PLoS ONE. 2013; 8(8): e71398. doi:10.10371/journal. pone.0071388.
14. O'Hagan J, et al. Low-energy light bulbs, computers, tablets and the blue light hazard. Eye (Lond). 2016; 30: 230-233.
15. Kaido M, et al. Reducing Short-Wavelength Blue Light in Dry Eye Patients with Unstable Tear Film Improves Performance on Test Visual Acuity, PLoS ONE. 2016; 11(4): e0152936. Doi:10.1371/journal.pone,0152936.
16. Sivak M et al. Blue content of LED head lamps and discomfort glare. UMTRI-2005-2.
17. Gray R, et al. Reduced effect of glare disability on driving performance in patients with blue light-filtering IOLs. J. Cataract Refract. Surg. 2011; 37:38-44.
18. Piñero D, et al. Ocular Scattering. Optom Vis Sci. 2010; 87: 682-696.
19. Coppens J, et al. Wavelength dependence of intraocular stray light. Exp. Eye Res. 2006; 82: 688-692.
20. Kiser A, et al. Visual function and performance with blue-light blocking filters in age-related macular degeneration. Clin exp Ophthalm. 2008; 36: 514-520.
21. Griswold M, Stark W. Scotopic spectral sensitivity of phakic and aphakic observers extending into the near ultraviolet. Vis res.1992; 32: 1739-1743.
22. Torii H. Violet light exposure can be a preventive strategy against myopia progression. EBio Medicine. 2017; 15: 210-219.
23. Zaidi FH, et al. Short wavelength light sensitivity of circadian, pupillary, and visual awareness in humans lacking an outer retina. Curr Biol 2007; 17(24):2122-2128.
24. Hatori M, et al. Global rise of potential health hazards caused by blue light-induced circadian disruption in modern aging societies. NPJ Aging Mech Dis. 2017; 16: 3:9.
25. Flo E, et al. Shift-related sleep problems vary according to work schedule. Occup Environ Med 2013; 70:238-245.
26. Vyas M, et al. Shift work and vascular events: systematic review and meta-analysis. BMJ 2012; 345:e4800.
27. Kolstad H. Nightshift work and risk of breast cancer and other cancers-a critical review of the epidemiologic evidence. Scand J Work Environ Health 2008; 34:5-22.
28. Bara A, Arber S. Working shifts and mental health-findings from the British Household Panel Survey (1995-2005). Scand J Work Environ Health 2009; 35:361-367.
29. Karlsson B, et al. Is there an association between shift work and having a metabolic syndrome? Results from a population bases study of 27485 people. Occup Environ Med 2001; 58:747-752.
30. Morikawa Y, et al. Shift work and the risk of diabetes mellitus among Japanese male factory workers. Scand J Work Environ Health 2005; 31:179-183.
31. Oh J, et al. Analysis of circadian properties and healthy levels of blue light from smartphones at night. Sci Rep. 2015; 18;5:11325. doi: 10.1038/srep11325.
32. Chang A, et al. Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness. Proc Natl Acad Sci U S A. 2015; 27;112:1232-1237.
33. Hale L, Guan S. Screen time and sleep among school-aged children and adolescents: a systematic literature review. Sleep Med Rev. 2015; 21:50-58

34. Nishi T. The effect of blue-blocking intraocular lenses on circadian biological rhythm: protocol for a randomised controlled trial (CLOCK-IOL colour study). BMJ Open. 2015; 12;5:e007930. doi: 10.1136/bmjopen-2015-007930.
35. Hammond B. Attenuating photostress and glare disability in pseudophakic patients through the addition of a short-wave absorbing filter. J Ophthalmol. 2015;2015:607635. doi: 10.1155/2015/607635. Epub 2015 Mar 9.
36. Lavric A, Pompe M. Do blue-light filtering intraocular lenses affect visual function? Optom Vis Sci. 2014; 91:1348-1354.
37. Gray R, et al. Effects of a blue light-filtering intraocular lens on driving safety in glare conditions. J Cataract Refract Surg. 2012; 38:816-822.
38. Zhu X, et al. Comparison of blue light-filtering IOLs and UV light-filtering IOLs for cataract surgery: a meta-analysis. PLoS One. 2012; 7(3):e33013. doi: 10.1371/journal.pone.0033013.
39. Kara-Junior N. et al. Effects of blue light-filtering intraocular lenses on the macula, contrast sensitivity, and color vision after a long-term follow-up. J Cataract Refract Surg. 2011; 37:2115-2119.
40. Gray R et al. Reduced effect of glare disability on driving performance in patients with blue light-filtering intraocular lenses. J Cataract Refract Surg. 2011; 37:38-44.
41. Wirtitsch M, et al. Influence of blue-light-filtering intraocular lenses on color perception and contrast acuity. Ophthalmology. 2009; 116:39-45.
42. Greenstein V, et al Scotopic sensitivity and color vision with a blue-light-absorbing intraocular lens. J Cataract Refract Surg. 2007; 33:667-672.
43. Lawrenson JG, Hull CC & Downie LE. The effect of blue-light blocking spectacle lenses on visual performance, macular health and the sleep-wake cycle: a systematic review of the literature. Ophthalmic Physiol Opt. 2017; 37: 644-654.
44. Downie LE. Blue-light filtering ophthalmic lenses: to prescribe, or not to prescribe? Ophthalmic Physiol Opt. 2017; 37(6):640-643.¬
45. .Jalie M. Principles of ophthalmic lenses 5 ed. Abdo editions. 2016; 181-193
46. WingLeung T, et al. Blue-Light Filtering Spectacle Lenses: Optical and Clinical Performances. PLoS One. 2017; 3;12:e0169114.
47. Kobashi H, et al. Longitudinal assessment of optical quality and intraocular scattering using the double-pass instrument in normal eyes and eyes with short tear breakup time. PLoS One. 2013; 8: e82427 doi:10.1371/journal.pone.0082427.
48. Chi CF, Lin FT. A comparison of seven visual fatigue assessment techniques in three data-acquisition VDT tasks. Human Factors. 1998; 40: 577-590.
49. Ide T, et al. Effect of Blue-Light reducing Eye Glasses on Critical Flicker Frequency. Asia Pac J Ophthalmol (Phila). 2015; 4:80-85.
50. Lin JB, et al. Short-Wavelength Light-Blocking Eyeglasses Attenuate Symptoms of Eye Fatigue. Invest Ophthalmol Vis Sci. 2017; 58(1):442-447.
51. van der Lely S. Blue blocker glasses as a countermeasure for alerting effects of evening light-emitting diode screen exposure in male teenagers. J Adolesc Health. 2015; 56:113-119.

BEATING THE BLUES

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Blue light and its effects on the eyes

Blue light has a wavelength between 380-500 nanometres (nm). This high-frequency range of visible light sits next to the UV spectrum that is well known for its tissue-damaging effects. The lens in the human eye naturally absorbs UVA and UVB, preventing 99% of UV penetration. However, high-frequency visible blue light enters the eye in full, having its effects in three categories.

380-420NM

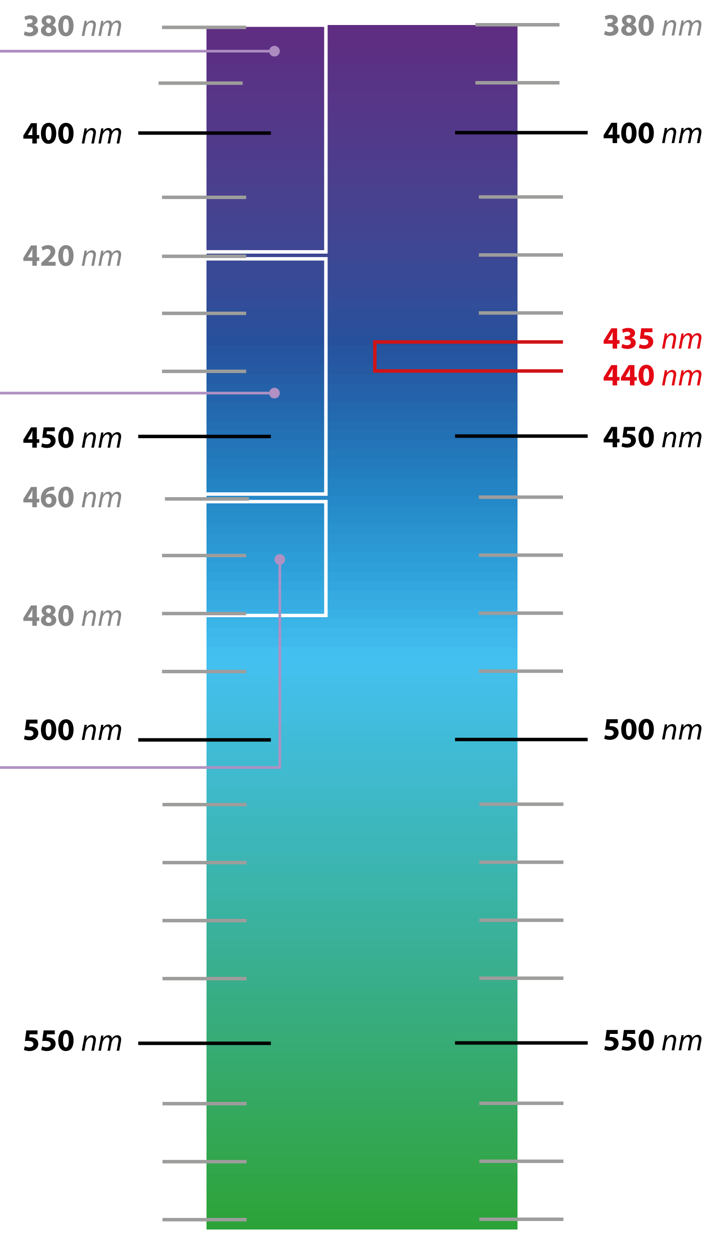
The highest frequencies of blue light between the ranges of 380-420nm have the greatest convergence effects and thus focus in front of the retina by up to a full dioptre. This, in turn, causes the blue light to scatter, resulting in visual scatter and haze. This is called chromatic aberration.

420-460NM

Blue light between 420-460nm comprises the most retinal-insulting wavelengths.
Specifically, the 435-440nm range is considered the most harmful to the human eye. This accumulation of blue light over a lifetime is the cause of macular changes leading to degenerative effects.

460-480NM

The wavelengths between 460-480nm have the greatest effect in suppressing melatonin production. Within the macula are intrinsic photosensitive retinal ganglion cells that are designed to control melatonin production and regulate our circadian rhythms.
Melatonin is the most potent antioxidant we produce, helping to heal our body as we sleep.



LED AND COMPACT FLUORESCENT LIGHTBULBS

Blue light has always been a significant part of our world, with the strongest source being the sun. However, over the past 10 years, new sources of blue light have emerged. LED and compact fluorescent lightbulbs have replaced the energy-consuming incandescent bulbs of the past.
These new light sources emit 32-34% blue light compared with the 4% an incandescent bulb emits.

Our youth are the most susceptible to blue light.
We do not know what the long-term effects of blue light will be over a lifetime of exposure.

We are also surrounded by devices that have LED backlit screens. Typically, these screens are held at close distances for prolonged periods and at all times of day and night.

Light pollution due to highly efficient LED lighting has changed the way we see at night. Streetlights, parking lot lights and headlights are filling our nights with blue light. Many cities are introducing LED bulbs, saving millions in energy costs. It is estimated that by 2023, 94% of streetlights worldwide will be LED. This increase in blue light at night only increases glare and accommodative stress, especially in rain or snow.

In the past, it was only the sun that emitted high-energy blue light.

CONCLUSION

In a very short time, the way our world is lit has changed. In the past, it was only the sun that emitted high-energy blue light. Now we are surrounded by blue light all the time, with a potentially widespread and negative impact on our circadian rhythms and macula health.

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EVALUATING

Evaluating the efficiency of spectacle lenses with accommodative support and a blue light filter in reducing computer vision syndrome/digital eye strain symptoms in comparison with habitual glasses.

ABSTRACT

Background: The aim of this trial was to determine whether the use of spectacle lenses with accommodative and blue light filter reduced the symptoms of digital eye strain.

Methods: Thirty-one healthy volunteers were enrolled on this study according to the inclusion and exclusion criteria. Inclusion criteria were:

1 **age 21-40 years;**
2 **wearing spectacles the last 6 months;**
3 **spending two or more hours per day using digital devices;**
4 **having digital eye-strain symptoms with the minimum score of six points in the CVS-Q;**
3 **not wearing single vision lenses with accommodative support**
4 **spherical power: +/- 5.00 and cylindrical power: minus cylinder ≤ 2.00;**
5 **giving written consent to participate in the study.**

The primary outcome was reduction in in the severity of visual symptoms related to digital device use. Secondary outcomes were measures of visual performance, including:

a **visual acuity,**
b **amplitude of accommodation (AA),**
c **MEM retinoscopy,**
d **visual experience score,**
e **satisfaction score.**

Results: Thirteen (42%) subjects reported that they experienced eye-strain symptoms after one to two hours of digital device use. There was a significant reduction in the severity of visual symptoms related to digital device use ($p<0.01$). There was a significant improvement in the visual experience with the new spectacles after one month of wearing them ($p<0.01$).

42% **reported that they experienced eye-strain symptoms after one to two hours of digital device use.**

Conclusion: The use of spectacle lenses with accommodative support and blue light filter may be advantageous for users of digital devices who suffer from CVS. The viewing distances measured were closer than those previously reported in the literature.

Key words: Computer vision syndrome, digital eye strain, eye fatigue, digital device, viewing distance, lenses with accommodative support.

78%
use digital devices for more than two hours each day.

Almost nine in ten adults (87%) use digital devices for more than two hours each day, while 52.2% report using two digital devices simultaneously1. A combination of factors, including the proximity at which digital screens are viewed, the frequency and length of time of use, and exposure to blue light emitted by backlit displays, can take a toll on the visual system and lead to computer vision syndrome (CVS) also known as digital eye strain.

CVS is characterised by dry, irritated eyes, blurred vision, neck/shoulder and back pain due to poor posture and headaches from repeated eye strain.

Many people experience visual discomfort after two or more hours in front of digital screens, which include desktop and laptop computers, tablets, smartphones and televisions. The vision industry has identified CVS as a challenge for eye comfort and health. In recent years, special optimised lenses and innovative coatings have been developed to help alleviate CVS, eliminate glare and filter out harmful blue light. Furthermore, these solutions have been shown to improve visual acuity, visual comfort and precision.

SUBJECTS AND METHODS

Participants

Thirty-one healthy volunteers, 22 (71%) women and nine (29%) men with a mean age of 32.23 ± 5.45 years, were enrolled on this study according to the inclusion and exclusion criteria. Pre-screening was done online using a primary selection questionnaire, which included questions about the intensity of digital device use as well as a validated computer vision syndrome questionnaire (CVS-Q) 2.
Subjects who spent two or more hours per day using digital devices and had digital eye-strain symptoms with the minimum score of six points in the CVS-Q were invited for optometric screening.

All the volunteers were spectacle wearers and had habitually worn single vision spectacles with the same correction for 11.1 ± 9.23 months (range 1-48 months) before being recruited. None of them had worn single vision lenses with accommodative support (e.g. Hoya Remark, Essilor Anti-fatigue/Eyezen, Zeiss digital lenses) in the past. Four (13%) subjects were hyperopes and 27 (87%) were myopes with mean distance spherical equivalent power for the right eye (-) 2.17 ± 1.63 and for the left eye (-) 2.31 ± 1.59.

Subjects were excluded if they had any systemic or ocular disease (except for refractive error), prior eye surgery or trauma. Subjects who regularly used eye drops or contact lenses were also excluded.
The study followed the tenets of the Declaration of Helsinki. After the protocol, had been fully explained, all subjects provided written informed consent to participate in the study.

Design of the study

The subjects attended three appointments.

FIRST APPOINTMENT

During the first appointment, anamnesis, current spectacle analysis, preliminary investigation, subjective refraction, amplitude of accommodation (AA) and MEM retinoscopy were performed.

1. **Visual acuity for far:**
24 (77%) subjects had visual acuity 6/6; 3 (10%) subjects had 6/5; 3 (10%) subjects had 6/6 in one eye and 6/9 in the other; 1 (3%) subject had 6/9 in one eye and 6/12 in the other.
After the subjective refraction, the prescription stayed the same for 17 subjects (55%), spherical power was increased by (-) 0.25D for 11 subjects (35%) and by (-) 0.5D for 3 subjects (10%).

2. **AA was measured using the push-up method with Royal Air Force (RAF) ruler.**
Average AA was 7.41 ± 2.02D in the range 4-11D: 4.0D – two subjects; 4.5D – three subjects; 4.75D – one subject; 5.0D – one subject; 5.5D – one subject; 6.0D – one subject; 6.5D – two subjects; 7.0D – one subject; 7.5D – two subjects; 8.0D – five subjects; 8.5D – two subjects; 9.0D – six subjects; 10.0D – three subjects; 11.0D – one subject.

3. **Average MEM retinoscopy was 0.68D ± 0.20 in the range 0.25-1.0D:**
0.25D in each eye – two subjects; 0.5D in each eye – eight subjects; 0.75D in each eye – 16 subjects; 1.0D in each eye – three subjects; one subject had 0.5D in one eye and 0.75D in the other; and one subject had 0.75D in one eye and 1.0D in the other; 26 (84%) subjects had an MEM retinoscopy score in the normal range.

Based on the results of the AA and MEM retinoscopy measurements, the functional power level of +0.53 was given to 19 (61%) subjects who had an AA and MEM retinoscopy score in the normal range; and +0.88D was given to 12 (39%) subjects who had AA of ≤ 7.0D and MEM retinoscopy of 0.75-1.0D.

The subjects were also asked to fill in detailed visual experience questionnaires. Spectacle frames were selected, adjusted and fitted and spectacle lenses with the chosen functional power level made from 1.6 material with blue light filter and anti-reflation coating were ordered.

SECOND APPOINTMENT

During the second appointment, the spectacles were individually fitted and centration was checked. Visual acuity was measured, and after 15 minutes of wearing the new spectacles, subjects were asked to complete a first-impressions satisfaction questionnaire. Thereafter, the subjects were instructed to wear the spectacles every day for one month.

THIRD APPOINTMENT

During the third and final appointment, after one month of wearing spectacle lenses with accommodative support and blue light filter, the subjects' visual functions were checked, e.g. visual acuity, AA, MEM retinoscopy.

1. **Far visual acuity:**
28 (90%) subjects had 6/6 and three (10%) subjects had 6/5.

2. **Average AA increased 7.88D ± 2.13 in the range 3.75-12D:**
3.75D – one subject; 4.0D – one subject; 5.0D – three subjects; 6.0D – three subjects; 6.5D – one subject; 7.0D – two subjects; 7.5D – three subjects; 8.0D – three subjects; 8.5D – two subjects; 9.0D – five subjects; 10.0D – four subjects; 10.5D – one subject; 12.0D – two subjects.

3. **Average MEM retinoscopy was 0.60D ± 0.16 in the range 0.25-1.0D:**
0.25D – one subject; 0.5D – 17 subjects; 0.75D – 11 subjects; 1.0D – one subject; - one subject had 0.5D in one eye and 0.75 in the other.

The subjects were also asked to fill in the CVS-Q, visual experience and satisfaction questionnaires.

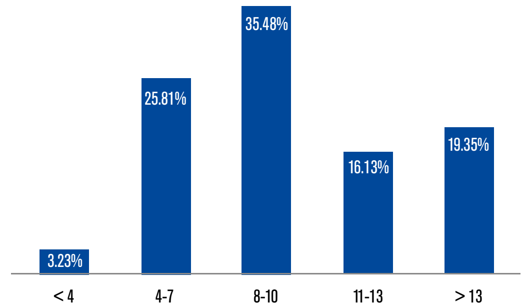
DATA ANALYSIS

Data and statistical analyses were carried out using IBM SPSS Statistics software (version 22) and Microsoft Excel 2013. The differences between means were tested using a paired-samples t-test. Other tests were not employed, since the distribution of the differences between the scores of the two related groups were normally distributed. The significance level was set at $P < 0.05$.

RESULTS

I. Digital device use

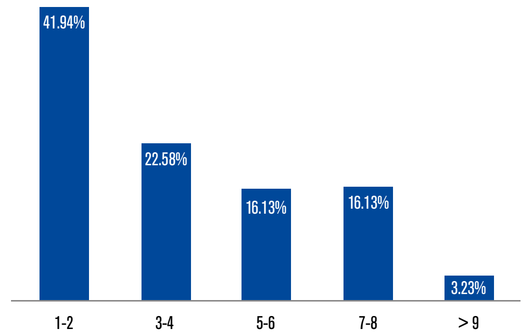
Digital device use was evaluated using the data from the detailed questionnaire. All subjects (100%) answered that they used smartphones. The laptop was named as the second-most-used digital device. Tablets and desktop computers were used less often compared to smartphones and laptops. Laptops and desktops were usually used at work; at home, subjects preferred to use smartphones and tablets. Smartphones were used everywhere.



Usage of digital devices (hour/day)

Thirty (97%) subjects used digital devices for four or more hours per day; 11 (35%) used digital devices for 11-13 hours per day.

Only three (10%) subjects used one digital device (smartphone) and 28 (90%) subjects used two or more digital devices; 14 (45%) used two devices (in most cases smartphone and laptop); ten (32%) used three devices (smartphone, laptop, desktop or tablet); and four (13%) used all aforementioned devices.



Appearance of eyestrain symptoms (hours of use)

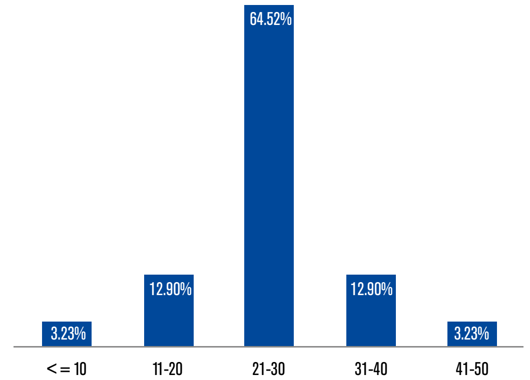
Thirteen (42%) subjects reported that they experienced eye-strain symptoms after one to two hours of digital device use.

Laptops are the second-most-used digital device.

Subjects used a laptop for between three and 13 hours a day. Nine subjects (29%) did not use a laptop. Eighteen (58%) subjects used a laptop at a distance of between 30-60cm.

Seventeen (55%) subjects used a desktop computer at a distance of between 40-70cm. Nine (29%) subjects did not use a desktop.

Tablets are mostly used (by 14 or 45% of the subjects) at a distance of 21-40cm. This is similar to the distance to smartphones. Thirteen (42%) subjects did not use a tablet.



Viewing distance to smartphone (cm)

Smartphones were used for two-five hours per day. Twenty-eight (90%) subjects used their smartphones at a distance of 11-40cm, 20 (64.5%) at a distance of 20-30cm.

II. Visual functions

1 **Visual acuity:**
Visual acuity increased due to the new correction.

2 **AA:**
Comparing the result from the first appointment with the result after wearing Remark lenses for one month, AA increased in 17 (55%) cases, stayed the same in nine (29%) cases and decreased in five (16%) cases.

3 **MEM retinoscopy:**
Comparing the result from the first appointment with the result after wearing Remark lenses for one month, 29 (93.5 %) subjects had MEM in the normal range, and there was a slight improvement in the score.

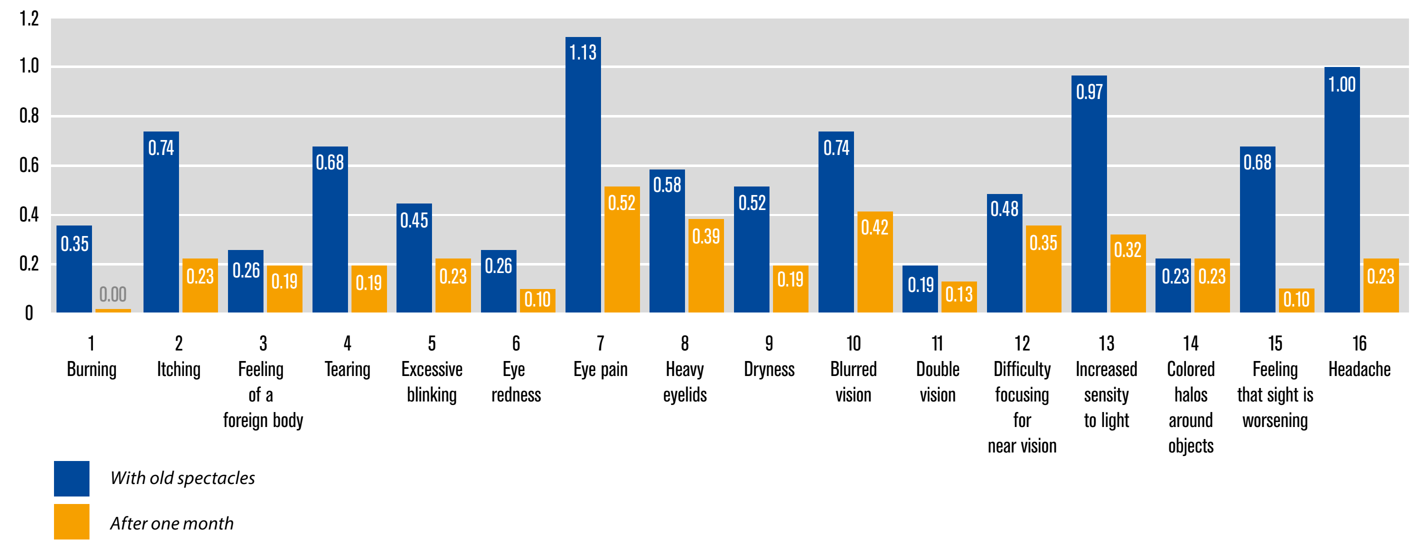
III. Questionnaire score analysis

1. Computer vision syndrome score analysis

The computer vision syndrome questionnaire (CVS-Q)1 was used to estimate the severity of visual symptoms related to the use of digital devices. All subjects filled in the CVS-Q twice: before the trial wearing their old glasses, when the score was 9.32 ± 3.25, and after one month of wearing the new spectacle lenses with accommodative support, when the score was 3.81 ± 3.33.
Comparing the CVS-Q scores before and after the trial, the severity of the symptoms reduced in 26 (84%) of the cases, stayed the same in two (6.5%) and increased in three (10 %). There was a significant reduction in the severity of visual symptoms related to digital device use (p<0.01).

Graph 1

Comparison of severity of computer vision syndrome symptoms before and after one month of wearing the spectacle lenses with accommodative support and blue light filter.



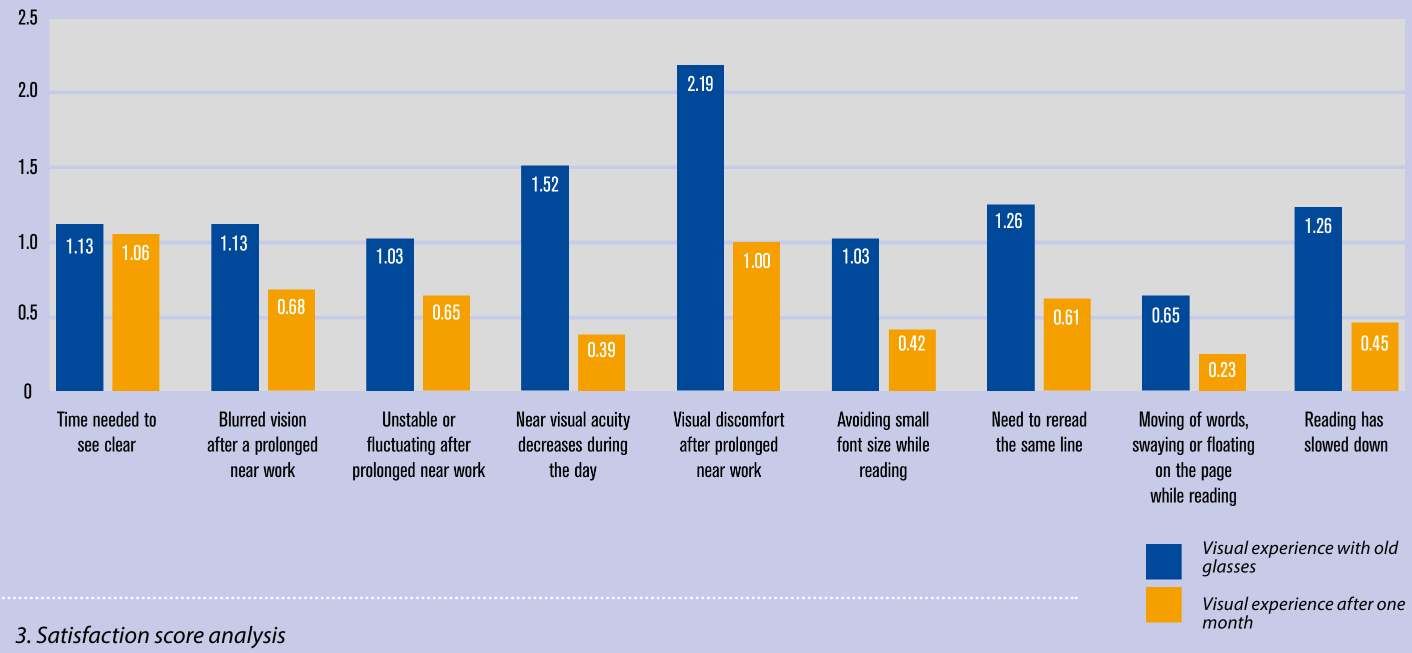
More detailed analysis of specific answers to the 16 questions was done in order to outline their values. Every question in the CVS-Q had two values, one for frequency (never = 0, occasionally = 1, often or always = 2) and the other for intensity (moderate = 1, intense = 2) of the symptom. The combined value is called 'severity' and is calculated by multiplying frequency by intensity.
Severity values are all the multiplication combinations of their respective scores: 0 x 0, 0 x 1 and 1 x 0 = 0; 1 x 1, 2 x 1 and 1 x 2 = 1; and 2 x 2 = 2.

2. Visual experience score analysis

All subjects also filled in the visual experience questionnaire twice: during the first appointment wearing their old spectacles and again during the third appointment wearing the new spectacles. The first score was 11.19 ± 6.23 and the second was 5.48 ± 4.09. There were nine symptom-related questions, and the frequency of each symptom was given a value (never = 0, rarely = 1, sometimes = 2, often = 3, always = 4). There was a significant improvement in the visual experience with the new spectacles after one month of wearing them (p<0.01). A comparison of all nine answers (mean values of the answers) to the visual experience questions with the old and new spectacles is presented in the following graph.

Graph 2

Comparison of severity of symptoms related to near work before and after one month of wearing the spectacle lenses with accommodative support and blue light filter.



3. Satisfaction score analysis

All subjects filled in the satisfaction questionnaire after 15 minutes and after one month of wearing the new spectacle lenses with accommodative support. The first satisfaction score was already quite high – 37.29 ± 4.96 (max. 52) – and increased at the end of the one-month trial to 39.52 ± 7.47. The activity with the highest improvement was reading.

CONCLUSION

The use of spectacle lenses with accommodative support with one of two functional power levels +0.53D/+0.88D, made from 1.6 material with blue light filter and anti-reflection coating, led to an improved AA score, a significant reduction of visual symptoms related to digital device use and increased satisfaction.
These findings provide evidence that the use of spectacle lenses with accommodation support and a blue light filter may be advantageous for users of digital devices who suffer from CVS.

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Authors' contribution

The author Chris Ang is considered co-first author, co-designed and conducted the study, co-analysed the
The author Dr. Dejan Dinevski co-analysed the data and co-write the manuscript.
The author Dr. Natalia Vlasak co-designed the study, co-analysed the data and co-wrote the manuscript.
Andria Kok is an employee of Hoya Vision Care Asia Pacific, co-designed the study and provided spectacles.

REFERENCES

1. The Vision Council (2017). Digital Eye Strain Report. Retrieved from www.thevisioncouncil.org/content/blue-light-exposure-and-digital-eye-strain/adults. Accessed 13 March 2017.
2. Segui, M. D. et al. (2015). 'A reliable and valid questionnaire was developed to measure computer vision syndrome at the workplace.' Journal of Clinical Epidemiology, 68(6): 662-73.

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