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1 author:

Mark Rosenfield
State University of New York College of Optometry

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Mark Rosenfield MCOptom PhD FAAO

SUNY College of Optometry, New York, USA

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Abstract

Computer vision syndrome, also known as digital eye strain, is the combination of eye and vision problems associated with the use of computers (including desktop, laptop and tablets) and other electronic displays (eg smartphones and electronic reading devices). In today's world, the viewing of digital screens for both vocational and avocational activities is virtually universal. Digital electronic displays differ significantly from printed materials in terms of the within-task symptoms experienced. Many individuals spend 10 or more hours per day viewing these displays, frequently without adequate breaks. In addition, the small size of some portable screens may necessitate reduced font sizes, leading to closer viewing distances, which will increase the demands on both accommodation and vergence. Differences in blink patterns between hard-copy and electronic displays have also been observed. Digital eye strain has been shown to have a significant impact on both visual comfort and occupational productivity, since around 40% of adults and up to 80% of teenagers may experience significant visual symptoms (principally eye strain, tired and dry eyes), both during and immediately after viewing electronic displays. This paper reviews the principal ocular causes for this condition, and discusses how the standard eye examination should be modified to meet today's visual demands. It is incumbent upon all eye care practitioners to have a good understanding of the symptoms associated with, and the physiology underlying problems while viewing digital displays. As modern society continues to move towards even greater use of electronic devices for both work and leisure activities, an inability to satisfy these visual requirements will present significant lifestyle difficulties for patients.

Introduction

In the modern world, the viewing of electronic displays has become a huge part of daily living at home, at work, during leisure time and on the move. The use of desktop, laptop and tablet computers, smartphones and electronic reading devices has become ubiquitous (Rosenfield et al. 2012a). For example, in 2011 the US Department of Commerce reported that 96% of working Americans use the internet as an integral part of their job (http://2010-2014.commerce.gov/news/fact-sheets/2011/05/13/fact-sheet-digital-literacy), and it is likely that this percentage has increased further since the time of publication. Indeed, while the 'paperless office' has been forecast for many years without ever coming to fruition, we may be moving closer to the day when hard-copy printed material will finally be superseded by a digital alternative.

The number of hours that individuals view electronic screens is substantial. For example, it was reported in 2013 that adults in the USA spend an average of 9.7 hours per day looking at digital media (including computers, mobile devices and television: http://adage.com/article/digital/americans-spend-time-digital-devices-tv/243414/). In addition, an investigation of over 2000 American children between 8 and 18 years of age found that, in an average day, they spend approximately 7.5 hours viewing entertainment media (comprising 4.5 hours watching television, 1.5 hours on a computer and over an hour playing computer games; Rideout et al. 2010). Providing further evidence for the omnipresence of technology, on average users may check their smartphones about 1500 times per week or 221 times per day (equivalent to every 4.3 minutes, assuming a 16-hour day: http://www.tecmark.co.uk/smartphone-usage-data-uk-2014). Evidence that the need for instant communication nowadays is so strong comes from the finding that when people first wake up, 35% reach for their phones, ahead of coffee (17%), a toothbrush (13%) or their significant other (10%) (http://newsroom.bankofamerica.com/files/doc_library/additional/2015_BAC_Trends_in_Consumer_Mobility_Report.pdf)! This dependence may even have an impact on systemic and ocular health. In children, increased screen time, when combined with a reduction in physical activity, has been shown to produce a significant decrease in the calibre of retinal arterioles (Gopinath et al. 2011).

It should also be noted that viewing digital electronic screens is not confined to adults, teenagers and older children. A literature review by Vanderloo (2014) reported that preschoolers spend up to 2.4 hours per day watching electronic screens. As a result, the American Academy of

Date of acceptance: 17 September 2015. Address for correspondence: Prof. M Rosenfield, SUNY College of Optometry, 33 West 42nd Street, New York NY 10036, USA. Rosenfield@sunyopt.edu

Pediatrics (2013) recommended that children under 2 years should not spend any time watching electronic screens.

Given the substantial number of hours being devoted to viewing screens, it is of significant concern to optometrists that the magnitude of ocular and visual symptoms is significantly higher when viewing these digital displays when compared with hard-copy printed materials (Chu et al. 2011). Although it is difficult to estimate accurately the prevalence of symptoms associated with electronic screens, as both working conditions and the methods used to quantify symptoms vary widely, an investigation of computer users in New York City noted that 40% of subjects reported tired eyes 'at least half the time', while 32% and 31% reported dry eye and eye discomfort, respectively, with this same frequency (Portello et al. 2012). Symptoms varied significantly with gender (being greater in females), ethnicity (being greater in Hispanics) and the use of rewetting drops. A significant positive correlation was observed between computer-related visual symptoms and the Ocular Surface Disease Index, a measure of dry eye. In addition, a recent survey of 200 children between 10 and 17 years of age by the American Optometric Association indicated that 80% of participants reported that their eyes burned, itched and felt tired or blurry after using a digital electronic device (http://aoa.uberflip.com/i/348635, page 20).

These ocular and visual symptoms have been collectively termed computer vision syndrome (CVS) or digital eye strain (DES). The latter term is preferable, since the public may not consider portable devices such as smartphones and tablets to be computers. However, it is important that the optometrist questions every patient about their use of technology. A comprehensive history at the start of the examination should collect information on the number and type of devices being used and the nature of the task demands. A list of areas that should be included in the case history is shown in Table 1. Simply asking patients whether they use a computer and recording this as a yes or no answer in the patient record is inadequate.

Table 1. Areas that should be addressed when conducting a complete case history on any patient who uses a digital device

Number and type of devices being used (including desktop, laptop and tablet computers and smartphones)
Viewing distance and gaze angle for each device
Duration of use for each device
Monitor size (for a desktop computer, also ask about the number of monitors being used)
Type of task being performed on each device
The size of the critical detail being observed during the task

As noted in Table 1, there are a number of areas that must be discussed, since new technologies are used very differently from traditional printed materials. These differences are discussed in greater detail below.

Gaze angle

A pertinent issue is the specific gaze angle being adopted when viewing digital devices. This can present a significant problem during the eye examination, as it may be difficult to replicate in the examination room, particularly when a phoropter is being used. Long et al. (2014) noted that, while desktop and laptop computers are most commonly viewed in primary and down gaze, respectively (although this may vary with a desktop computer if multiple monitors are being used), hand-held devices such as tablet computers and smartphones may be positioned in almost any direction, sometimes even being held to the side, thereby requiring head and/or neck turn. Given that the magnitude of both heterophoria (Von Noorden 1985) and the amplitude of accommodation (Rosenfield 1997) can vary significantly with the angle of gaze, it is important that testing be conducted using conditions that replicate the habitual working conditions as closely as possible.

Text size

In addition, the size of the text being observed, particularly on hand-held devices, may be very small. For example, Bababekova et al. (2011) reported a range of visual acuity demands when viewing a webpage on a smartphone from 6/5.9 to 6/28.5 (with a mean of 6/15.1). While this may not seem overly demanding, it should also be noted that an acuity reserve is required to allow comfortable reading for a sustained period of time. Attempting to read text of a size at or close to the threshold of resolution for an extended interval may produce significant discomfort (Ko et al. 2014). Kochurova et al. (2015) demonstrated that a two-times reserve was appropriate for young, visually normal subjects when reading from a laptop computer, ie for sustained comfortable reading, the text size should be at least twice the individual's visual acuity. However, higher values may be necessary for older patients, or individuals with visual abnormalities. Therefore, the smallest-sized text recorded by Bababekova et al. (2011) (around 6/6) would necessitate near visual acuity of 6/3. Few, if any, practitioners record near visual acuity to this degree during a standard eye examination.

Glare

Some patients may report significant discomfort from glare while viewing digital screens. Accordingly, it is important that optometrists discuss both appropriate lighting and the use of window shades, as well as proper screen and operator positioning. Any reflections on the computer display, desktop equipment and/or input devices from windows and luminaires are likely to result in both symptoms and a loss of work efficiency. Relatively simple advice regarding the placement of desktop screens perpendicular to fluorescent tubes, and not directly in front of or behind an unshaded window may be extremely beneficial to the patient. For older patients with less transparent ocular media, the effects of glare may be more disabling. For these individuals, a valuable clinical test is to measure visual resolution in the presence of a glare source, such as the Marco brightness acuity tester (Marco Ophthalmic, Jacksonville, FL, USA). In order to provide useful advice on the placement of localised lighting (such as a desk lamp for an individual who needs to be able to view both a desktop or laptop monitor and hard-copy printed materials simultaneously), careful questioning by the optometrist as to the precise task requirements is critical.

Correcting refractive errors

Determining the appropriate refractive correction for the digital user also presents challenges for the optometrist. Required working distances may vary from 70cm (for a desktop monitor) to 17.5cm for a smartphone (Bababekova et al. 2011; Long et al. 2014). These distances correspond to dioptric demands from 1.4D to 5.7D. For the presbyopic patient, it is unlikely that a single pair of correcting lenses will provide clear vision across this dioptric range. Given the previously mentioned variation in gaze angle for different devices, bifocal and progressive addition lenses, with the near addition positioned in the lower part of the lens, may also be unsuccessful. Accordingly, it may be necessary to prescribe multiple pairs of spectacles, of different formats (eg single-vision, bifocals, trifocals) for the various working distances and gaze angles required by the patient. Occupational prescriptions, perhaps combining an intermediate and near correction, are frequently useful. Progressive addition lenses may be unsuccessful due to the narrow width of the reading area. Care should be taken to ensure that the near addition lens prescribed for a presbyopic patient is appropriate for the preferred (or, in some cases, required) viewing distance(s). As noted above, viewing distances that differ markedly from 40cm (2.50D) are frequently adopted.

Additionally, the correction of small amounts of astigmatism may be important. In two similar experiments, Wiggins and Daum (1991) and Wiggins et al. (1992) examined the effect of uncorrected astigmatism while reading material from a computer screen. In both studies, the authors observed that the presence of 0.50–1.00D of uncorrected astigmatism produced a significant increase in symptoms. While astigmatism is typically corrected in spectacle wearers, it is not unusual in contact lens patients to leave small to moderate amounts of astigmatism uncorrected. Given that the physical presence of a contact lens on the cornea may also exacerbate the symptoms associated with DES (Rosenfield 2011), it may be particularly important in these patients that visual discomfort is not aggravated further by the presence of uncorrected astigmatism. Additionally, patients with less than 1D of simple myopic or simple hyperopic astigmatism, where one meridian is emmetropic, may on occasions be left uncorrected. Further, patients purchasing ready-made (spherical), over-the-counter reading glasses may also experience uncorrected astigmatism. Therefore, it may be necessary to correct astigmatism in those patients whose visual demands require them to view information on an electronic screen.

In addition to the discomfort experienced during computer operation, symptoms of DES may also have a significant economic impact. Ocular and visual discomfort can increase the number of errors made during a computer task as well as necessitating more frequent breaks. Musculoskeletal injuries associated with computer use may account for at least half of all reported work-related injuries in the USA (Bohr, 2000). Indeed, Speklé et al. (2010) noted that conservative estimates of the cost of musculoskeletal disorders to the USA economy as reported in 2001, when measured by compensation costs, lost wages and reduced productivity, were between 45 and 54 billion dollars annually or 0.8% of gross domestic product. Further, the prevalence of neck, shoulder and arm symptoms in computer workers may be as high as 62% (Wahlstrom 2005). In addition to productivity costs, it was estimated in 2002 that employers in the USA paid approximately $20 billion annually in workers' compensation resulting from work-related musculoskeletal disorders (Chindlea 2008).

When considering DES specifically, Daum et al. (2004) estimated that provision of an appropriate refractive correction alone could produce at least a 2.5% increase in productivity. This would result in a highly favourable cost–benefit ratio to an employer who provided computer-specific eyewear to employees. Accordingly, it is clear that the economic impact of DES is extremely high, and minimising symptoms that reduce occupational efficiency will result in substantial financial benefits (Rosenfield et al. 2012b).

Accommodation and convergence

Given the significant near-vision demands associated with viewing digital screens, a comprehensive assessment of the accommodation and vergence system should be included for all users of digital screens. Parameters to be quantified are listed in Table 2. The use of Cross–Nott retinoscopy (Rosenfield 1997) and associated phoria (ie prism to eliminate fixation disparity) to assess the actual accommodative and vergence response for the specific task demands is particularly important. Failure to maintain an appropriate oculomotor response will result in symptoms and/or loss of clear and single binocular vision. While the assessment of the maximum accommodation (ie amplitude) and vergence (near point) responses is useful, these measures may not provide an indication of the actual response that is maintained during a sustained task. Tests that assess the ability of the patient to make rapid and accurate changes in the oculomotor responses, such as accommodative and vergence facility using lens and prism flippers, respectively, are especially useful for individuals whose task may require them to change fixation from a distant stimulus (perhaps viewing across an office) to an intermediate (such as a desktop computer) or near target (viewing hard-copy printed materials or a smartphone). The Hart chart test, whereby patients have to switch from one target distance to another, and to report when they have clear and single vision at each distance, is an alternative, and possibly superior, method of testing the flexibility of accommodation and vergence, compared with the use of lens or prism flippers. This more naturalistic method, where a patient fixates fine detail at different viewing distances, involves all of the cues to the oculomotor system, including tonic, proximal, retinal disparity and defocus, as well as testing the interaction between

Table 2. Tests of accommodation and vergence that should be included in an assessment of the near-vision system for a viewer of digital screens. Accommodation testing refers to pre-presbyopic patients only

Accommodation testing
Subjective amplitude of accommodation (push-up or minus lens)
Accommodative response at preferred working distance (Cross–Nott retinoscopy)
Monocular and binocular accommodative facility (±2.00 lenses or Hart chart)
Negative and positive relative accommodation
Vergence testing
Near point of convergence
Distance and near heterophoria (near to be performed at the preferred and/or required working distance)
Presence of A- and V-patterns
Horizontal fixation disparity/associated phoria at preferred and/or required working distance
Vergence facility (using 12Δ base-out/3Δ base-in prisms or Hart chart)
Base-in and base-out vergence ranges
Stereopsis

accommodation and vergence. It should be noted that the Hart chart test does not require the practitioner to purchase any specialised equipment. Simply having the patient change fixation from a standard distance visual acuity chart to a near acuity chart held at an intermediate or near distance will work just as well. The patient is instructed to report when the fine detail on each chart appears both clear and single. The number of cycles (ie the number of times the patient is able to report clear and single vision at both distance and near) that the patient is able to complete in a 60-second period should be recorded, as well as any difficulty in clearing one of the targets quickly.

Dry eye

Dry eye has previously been cited as a major contributor to DES. For example, Uchino et al. (2008) observed symptoms of dry eye in 10.1% of male and 21.5% of female Japanese office workers using visual display terminals. Furthermore, longer periods of computer work were also associated with a higher prevalence of dry eye (Rossignol et al. 1987). In an extensive review, Blehm et al. (2005) noted that computer users often report eye dryness, burning and grittiness after an extended period of work. Rosenfield (2011) suggested that these ocular surface-related symptoms may result from one or more of the following factors:

1. Environmental factors producing corneal drying. These could include low ambient humidity, high forced-air heating or air-conditioning settings or the use of ventilation fans, excess static electricity or airborne contaminants.
2. Increased corneal exposure. Desktop computers are commonly used with the eyes in the primary position, whereas hard-copy text is more commonly read with the eyes depressed. The increased corneal exposure associated with the higher gaze angle could also result in an increased rate of tear evaporation. It should also be noted that laptop computers are more typically used in downward gaze, while both tablet computers and smartphones can be held in either primary or downward gaze
3. Age and gender. The prevalence of dry eye increases with age and is higher in women than men (Gayton 2009; Salibello and Nilsen 1995; Schaumberg et al. 2003).
4. Systemic diseases and medications. Moss et al. (2000, 2008) reported that the incidence of dry eye was greater in subjects with arthritis, allergy or thyroid disease not treated with hormones. Additionally, the incidence was higher in individuals taking antihistamines, antianxiety medications, antidepressants, oral steroids or vitamins, as well as those with poorer self-rated health. Perhaps surprisingly, a lower incidence of dry eye was found with higher levels of alcohol consumption.

Blink rate

Another explanation for the higher prevalence of dry-eye symptoms when viewing digital screens may be due to changes in blink patterns. Several investigations have reported that the blink rate is reduced during computer operation (Patel et al. 1991; Schlote et al. 2004; Tsubota and Nakamori 1993; Wong et al. 2002). For example, Tsubota and Nakamori (1993) compared the rate of blinking in 104 office workers when they were relaxed, reading a book or viewing text on an electronic screen. Mean blink rates were 22/minute while relaxed, but only 10/minute and 7/minute when viewing the book or screen, respectively. However, these three testing conditions varied not only in the method of presentation, but also in task format. It has been noted that blink rate decreases as font size and contrast are reduced (Gowrisankaran et al. 2007), or the cognitive demand of the task increases

(Cardona et al. 2011; Himebaugh et al. 2009; Jansen et al. 2010). Therefore, the differences observed by Tsubota and Nakamori may be related to changes in task difficulty, rather than being a consequence of changing from printed material to an electronic display. Indeed, a recent study in our laboratory compared blink rates when reading identical text from a desktop computer screen versus hard-copy printed materials (Chu et al. 2014). No significant difference in the mean blink rates was found, leading to the conclusion that previously observed differences were more likely to be produced by changes in cognitive demand rather than the method of presentation.

While screen use may not alter the overall number of blinks, Chu et al. (2014) observed a significantly higher percentage of incomplete blinks when subjects read from a computer (7.02%) in comparison with reading hard-copy, printed materials (4.33%). However, it is uncertain whether changes in cognitive demand also alter the percentage of incomplete blinks. This may be important, given that a significant correlation was found between post-task symptom scores and the percentage of blinks deemed incomplete (Chu et al. 2014). Interestingly, increasing the overall blink rate (by means of an audible signal) does not produce a significant reduction in symptoms of DES (Rosenfield and Portello 2015). This might imply that it is the presence of incomplete blinks, rather than changes in the overall blink rate, that is responsible for symptoms. McMonnies (2007) reported that incomplete blinking would lead to reduced tear layer thickness over the inferior cornea, resulting in significant evaporation and tear break-up. Current work in our laboratory is examining the effect of blink efficiency exercises to reduce the rate of incomplete blinking on DES symptoms.

Asthenopia

In a review of asthenopia, Sheedy et al. (2003) noted that symptoms commonly associated with this diagnostic term included eye strain, eye fatigue, discomfort, burning, irritation, pain, ache, sore eyes, diplopia, photophobia, blur, itching, tearing, dryness and foreign-body sensation. While investigating the effect of several symptom-inducing conditions on asthenopia, these authors determined that two broad categories of symptoms existed. The first group, termed external symptoms, included burning, irritation, ocular dryness and tearing, and was related to dry eye. The second group, termed internal symptoms, included eye strain, headache, eye ache, diplopia and blur, and is generally caused by refractive, accommodative or vergence anomalies. Accordingly, the authors proposed that the underlying problem could be identified by the location and/or description of symptoms.

It has been suggested that the poorer image quality of the electronic screen, when compared with printed materials, may be responsible for the change in blink rate (Chu et al. 2011). However, Gowrisankaran et al. (2012) observed that degrading the image quality by either inducing 1.00D of uncorrected astigmatism or presenting the target at only 7% contrast did not produce a significant change in blink rate for a given level of cognitive load. Further, Gowrisankaran et al. (2007) reported that induced refractive error, glare, reduced contrast and accommodative stress (varying the accommodative stimulus by ±1.50D during the course of the task) actually produced an increase in blink rate. Additionally, Miyake-Kashima et al. (2005) found that introduction of an anti-reflection film over a computer monitor to reduce glare produced a significant reduction in blink rate. Therefore, it does not seem that the digital screen itself represents a degraded visual stimulus that is responsible for significant changes in blink rate.

The blue light hypothesis

It has recently been suggested that the blue light emitted from digital displays may be a cause of DES, although there is no published evidence to support this claim. Blue light is generally considered to comprise wavelengths between 380 and approximately 500nm. Fortunately, the human retina is protected from short-wavelength radiation, which is particularly damaging, by the cornea which absorbs wavelengths below 295 nm and the crystalline lens which absorbs below 400nm (Margrain et al. 2004). However, shorter wavelengths have higher energy, and therefore reduced exposure times may still result in photochemical damage. Visible blue light can easily reach the retina and may cause oxidative stress in the outer segments of the photoreceptors as well as the retinal pigment epithelium. These factors have been implicated in the development of age-related macular degeneration (Taylor et al. 1990). Certain groups may be particularly susceptible to blue light damage, such as children (because of the transparency of their crystalline lens) and both aphakic and pseudophakic individuals who either cannot filter out short wavelengths, or fail to do so adequately.

Additionally, exposure to blue light has been widely reported to be involved in the regulation of circadian rhythm and the sleep cycle, and irregular light environments may lead to sleep deprivation, possibly affecting mood and task performance (see LeGates et al. 2014). Indeed, it has been proposed that the use of electronic devices by adolescents, particularly at night time, leads to an increased risk of shorter sleep duration, longer sleep-onset latency and increased sleep deficiency (Hysing et al. 2015). Accordingly, the use of spectacle lenses containing filters to reduce the transmission of blue light has been proposed as a possible treatment modality for DES. However, it must be noted that exposure to sunlight delivers far more illumination when compared with any form of artificial lighting. For example, while sunlight may vary between 6000 and 70 000 lux (Wang et al. 2015), its output exceeds typical levels of artificial lighting by a factor of 100 times or more. Further, the amount of short-wavelength radiation being emitted from digital screens is far smaller than from most artificial light sources.

Nevertheless, a recent study by Cheng et al. (2014) suggested that there may be some benefit from wearing blue filters during a computer task. These authors examined the effect of low-, medium- and high-density blue filters (in the form of wraparound goggles) worn during computer work in groups of dry-eye and normal subjects (n = 20 for each group). They observed a significant reduction in DES-related symptoms in the dry-eye group (but not in the normal subjects). This effect was seen for all filter densities. However, the study did not include a control condition, and so a placebo effect, where the subjects were aware that they were receiving treatment, cannot be ruled out. Further, the wraparound goggles may have reduced tear evaporation in the dry-eye subjects. Given that several blue-filter lenses are now being marketed specifically for the treatment of DES (eg Hoya Blue Control, SeeCoat Blue (Nikon) and Crizal Prevencia (Essilor)), further research is required to determine both the efficacy and mechanism of action of these filters.

Wearable technology

The area of wearable technology seems likely to expand dramatically over the next 5–10 years. At the time of writing, Google Glass (Figure 1), which projected a virtual image into the superior temporal field of the right eye, is no longer being marketed to the general public. However, it seems likely that similar products will become available in the future. These may present significant issues for the optometrist. For example, in the case of Google Glass, the image was only seen by one eye, thereby creating the potential for binocular rivalry and visual interference (where two images are not clearly distinguishable from one another). Interestingly, there were many anecdotal reports of headaches and other visual symptoms when individuals were first using the device. In addition, it produced significant loss of vision field in upper right gaze (Ianchulev et al. 2014). A subject who was driving, operating machinery or in motion could be severely, and dangerously, impacted by this visual field loss.

Figure 1. Although the Google Glass device pictured is not being sold at present, it represents the type of wearable technology which is likely to become more prevalent in the future.

Whereas this type of head-up display was once only available in military and commercial aviation, they are now found in motor vehicles to assist with navigation (Figure 2). Their advantages are that they reduce the number of eye movements away from the direction of travel (Tangmanee and Teeravarunyou 2012). However, they can also result in multiple, conflicting stimuli if the projected image lies in a different direction or perceived distance away from the real fixation target. Other forms of wearable technology may present different issues. For example, wrist-mounted displays such as the Apple Watch (Apple, Cupertino, CA, USA: Figure 3) may present extremely small-sized text due to the limited screen area (approximately 3.3cm by 4.2cm).

Figure 2. Head-up displays, as shown, are becoming more common in a wide range of cars (image from http://techdrive.co/2014/11/finally-time-head-displays-cars/s).

Figure 3. Wrist-mounted displays such as the Apple Watch (Apple, Cupertino, CA) may present other issues due to the limited screen area (approximately 3.3 × 4.2cm).

However, there may be significant value for spectacle-mounted technology in disabled individuals who require a hands-free device, such as to provide facial recognition for the visually impaired and to monitor eye and head movements in patients with Parkinson's disease (McNaney et al. 2014). It seems almost certain that the use of wearable technology will increase rapidly over the next few years, and spectacle frame designers are already developing more attractive options to accommodate these types of device.

In many regards, the visual conflicts described with the Google Glass type of device are not dissimilar from those experienced by users of spectacle-mounted biotic telescopes, where the telescopic device is mounted high on the carrier lens, so that the patient is able to move around while wearing the device, but can still use the telescope when required for 'spotting' a more detailed distance target. Indeed, the use of spectacle-mounted video cameras may become more common in visually normal individuals. For example, they are already used by a number of police forces for recording officers' actions. As the technology develops and gets smaller, one could easily imagine a video camera being hidden within a spectacle frame or lens, with its image being transmitted wirelessly to a recorder (perhaps a smartphone in one's pocket) or a remote location, where it can be viewed in real time by a third party. While this might be valuable for the training of a new employee (it would be an excellent way of recording an examination performed by a student optometrist for later review) or assisting a colleague away from his or her actual location, the security and privacy implications of being recorded by someone wearing an invisible device are also considerable (Rosenfield 2014).

Conclusion

It is possible that the technological revolution through which we are now living may be seen in the future as equivalent to the industrial revolution of the early 19th century. While the latter saw the development of manufacturing capabilities due to improved iron production processes, the harnessing of steam power and the development of the railways, this expansion comes from almost instantaneous communication around the world and access to vast sources of information. Clearly, the technology is here to stay. However, the visual demands of today are very different from those encountered in the past. Digital electronic devices differ significantly from printed materials in terms of their viewing distance, required gaze angle, degree of symptoms and blink patterns. Accordingly, the eye examination must be modified to meet these new demands.

A further issue to consider is the increasing number of older individuals in the population in western Europe and North America (Rosenthal 2009). For example, over the period from 1985 to 2010, the median age of the UK population has increased from 35.4 years to 39.7 years. This median age is projected to be over 42 years of age by 2035. Further, by 2035 it is anticipated that approximately 23% of the total UK population will be 65 years of age and older (http://www.ons.gov.uk/ons/dcp171776_258607.pdf). Accordingly, it seems likely that the prevalence of reported eye strain will continue to rise concurrent with this increase in the number of older people, with the associated age-related increases in hyperopia, astigmatism, dry eye and loss of media transparency, not to mention that all of these individuals will be presbyopic.

Given the remarkably high number of hours per day that many (or perhaps most) individuals now spend viewing small text on electronic screens at close working distances and varying gaze angles, it is incumbent upon all eye care practitioners to have a good understanding of the symptoms associated with, and the physiology underlying, DES. As modern society continues to move towards the greater use of electronic devices for both work and leisure activities, it seems likely that the visual demands that these units require will continue to increase. An inability to satisfy these visual requirements will present significant lifestyle difficulties for patients, as well as sizeable dissatisfaction and frustration.

Summary

Computer vision syndrome, also known as digital eye strain, is the combination of eye and vision problems associated with the use of computers and other electronic displays. Today, many individuals spend large numbers of hours viewing these screens. However, the visual demands differ significantly from those presented by traditional printed materials, with the result that up to 80% of users report significant symptoms both during and immediately after viewing electronic screens. This paper reviews the principal ocular causes for this condition, and discusses how the standard eye examination should be modified to meet today's visual demands.

Conflict of interest

The author has no financial interest in any of the products described in this paper.

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CET multiple choice questions

This article has been approved for one non-interactive point under the GOC's Enhanced CET Scheme. The reference and relevant competencies are stated at the head of the article. To gain your point visit the College's website www.college-optometrists.org/oip and complete the multiple choice questions online. The deadline for completion is 30 April 2017. Please note that the answers that you will find online are not presented in the same order as in the questions below, to comply with GOC requirements.

1. Which area is most importantly addressed when completing a case history on a patient who uses a digital device?
   - The screen resolution for each device
   - The software used on each device
   - The viewing distance and gaze angle for each device
   - Whether it has a retina display
2. Which of the following statements is correct?
   - American schoolchildren spend 7.5 hours a day watching television
   - Children under 2 years should not spend any time watching electronic screens
   - On average, adults in the USA spend 9.7 hours per day looking at their mobile phone
   - On average, US smartphone users check their smartphone 221 times per week
3. What visual reserve is recommended by the paper?
   - ×1.5
   - ×2
   - ×3
   - ×4
4. Based on the paper's recommended visual reserve, what visual acuity would be required to read comfortably on screen text which is 6/8 in size?
   - 6/3
   - 6/4
   - 6/5
   - 6/6
5. When viewing a digital device at a range of 17.5–70cm, what would be the corresponding dioptric demand?
   - 1.40–3.00D
   - 1.40–5.70D
   - 3.00–5.70D
   - 5.70–6.66D
6. What level of uncorrected astigmatism significantly increased digital eye strain?
   - 0.25–0.50DC
   - 0.50–1.00DC
   - 1.00–1.50DC
   - Over 1.50DC

CPD exercise

After reading this article, can you identify areas in which your knowledge of computer vision syndrome has been enhanced?

How do you feel you can use this knowledge to offer better patient advice?

Are there any areas you still feel you need to study and how might you do this?

Which areas outlined in this article would you benefit from reading in more depth, and why?