Management of digital eye strain

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REVIEW

Management of digital eye strain

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Digital eye strain, an emerging public health issue, is a condition characterised by visual disturbance and/or ocular discomfort related to the use of digital devices and resulting from a range of stresses on the ocular environment. This review aims to provide an overview of the extensive literature on digital eye strain research with particular reference to the clinical management of symptoms. As many as 90 per cent of digital device users experience symptoms of digital eye strain. Many studies suggest that the following factors are associated with digital eye strain: uncorrected refractive error (including presbyopia), accommodative and vergence anomalies, altered blinking pattern (reduced rate and incomplete blinking), excessive exposure to intense light, closer working distance, and smaller font size. Since a symptom may be caused by one or more factors, a holistic approach should be adopted. The following management strategies have been suggested: (i) appropriate correction of refractive error, including astigmatism and presbyopia; (ii) management of vergence anomalies, with the aim of inducing or leaving a small amount of heterophoria (~1.5$^{\Delta}$ Exo); (iii) blinking exercise/training to maintain normal blinking pattern; (iv) use of lubricating eye drops (artificial tears) to help alleviate dry eye-related symptoms; (v) contact lenses with enhanced comfort, particularly at end-of-day and in challenging environments; (vi) prescription of colour filters in all vision correction options, especially blue light-absorbing filters; and (vii) management of accommodative anomalies. Prevention is the main strategy for management of digital eye strain, which involves: (i) ensuring an ergonomic work environment and practice (through patient education and the implementation of ergonomic workplace policies); and (ii) visual examination and eye care to treat visual disorders. Special consideration is needed for people at a high risk of digital eye strain, such as computer workers and contact lens wearers.

Key words: digital devices, digital eye strain, management

Digital eye strain or computer vision syndrome involves a group of ocular and non-ocular symptoms among the users of visual display units; of those, ocular symptoms are more common.[1] The term ‘computer vision syndrome’ has been widely used in the literature; however, since many other digital devices are now in common use, ‘digital eye strain’ seems a more appropriate term.

Ocular symptoms of digital eye strain include tearing, tired eyes, blurred vision, general fatigue, burning sensation, redness and double vision. For non-ocular symptoms, these include stiff neck, general fatigue, headache and backache.[1–11] A list of digital eye strain symptoms, categorised according to aetiology, is presented in Table 1. The prevalence of symptoms due to digital eye strain is estimated to range from 25 to 93 per cent, as reported by various investigators.[10–19] Estimates of the prevalence of digital eye strain from recent studies are listed in Table 2.

The use of digital devices has become an essential part of everyday life. Many people use these devices in almost every aspect of their vocational as well as non-vocational activities. Furthermore, use of digital devices continues to increase each year. In 2016, adult Americans viewed digital media for an average of 5.6 hours per day.[20] Devices used were: mobile phones (3.1 hours), desktops and laptops (2.2 hours), and other devices (including game consoles, 0.4 hours). In 2016, 78 per cent of adult Americans owned computers, 77 per cent owned smartphones, 51 per cent owned tablets, and 22 per cent owned e-readers.[21] Many studies have observed that increased use of digital devices correlates with increased symptoms of digital eye strain.[22] Therefore, an increase in the incidence and severity of digital eye strain should be expected unless there are improvements in the management of digital eye strain.

This review aims to provide an overview of the extensive literature on digital eye strain research (Table 3), with particular reference to the clinical management of symptoms arising from the use of digital devices.

Definition of digital eye strain

Digital eye strain is a condition characterised by visual disturbance and/or ocular discomfort related to the use of digital devices and resulting from a range of stresses on the ocular system, including glare, defocus, accommodation dysfunction, fixation disparity, dryness, fatigue and discomfort.[23] A recent report showed that 65 per cent of American adults experience some sort of digital eye strain after prolonged use of

Eye strain types	Symptoms	Cause/source
Vision-related	• Frontal headache • Sore eyes • Heaviness • Diplopia	• Astigmatism • Hyperopia • Myopia • Presbyopia • Accommodative anomalies
Oculomotor-related	• Focusing difficulty • Other symptoms similar to vision-related eye strain • Diplopia	• Fixation disparity • Poor convergence
Dry eye or ocular surface-related	• Dryness • Itchiness • Irritation/scratchiness • Redness • Burning • Blurred vision • Tearing/sore eyes	• Dry eye • Contact lens wear • Corneal, conjunctival and/or eyelid pathology • Reduced/poor blinking • Environment • General health • Changes in medication • Age
Extraocular or environmental factor-related	• Neck/shoulder/back pain • Glare • Headache	• Posture • Lighting • Temperature/humidity
Device-related	• Depends on type of digital device • Most symptoms similar to vision-related eye strain	• Small screen • Reduced working distance and font size • Screen illumination and spectrum of light • Screen resolution and contrast • Reduced blink rate • Incomplete blinks

Table 1. Types, symptoms and sources of digital eye strain

electronic devices[9] and, with Americans now spending 60 hours a week accessing content,[20] eye-care practitioners are increasingly called upon to manage such patients.

The typical digital consumer now owns about four devices.[24] The wide diversity of digital devices in use brings with it a wide range of working distances, font sizes, viewing angles, light intensities and contrasts. Consequently, a wide range of potential symptoms may present in the consulting room.

Digital eye strain may present as a single 'obvious' symptom or a vague collection of asthenopia-type symptoms. Since these may be caused by one or more underlying factors, a holistic approach should be adopted in the investigation and management of patient complaints. As with any examination, accurate history- and symptom-taking is essential. However, an understanding of the tasks and working conditions undertaken with particular digital devices is also important in order to correctly assess the underlying cause(s).

A number of factors are associated with the development of digital eye strain. The following section discusses important physiological and environmental factors associated with digital eye strain that are reported in the literature.

Effect of digital devices on the eye

Accommodation

Visual accommodation is the process by which the eye changes focus to maintain a clear image, and requires both a change in optical lens power and alignment of the eyes (vergence). Visual blur is an important stimulus of accommodation and drives the ocular-motor system to alter refractive power so that the retinal image is precisely focused. Conveniently though, the blur induced by small degrees of accommodative lag (under-accommodation) or lead (over-accommodation) goes unnoticed due to depth of focus.

Investigations of accommodation in relation to the use of visual display units have been conducted among young, adult subjects (usually in their twenties) rather than in presbyopic subjects. Presbyopic subjects may experience additional visual stress due to age-related loss of accommodation, especially since intermediate vision, needed for viewing digital devices, is often uncorrected. Two components of accommodation have been investigated in relation to visual display unit use: accommodative lag and microfluctuation.

The effect of visual display unit use on accommodation is disputed. Some studies have demonstrated an increase in lag of accommodation when viewing visual display units (computer at 50 cm viewing distance and Amazon Kindle and Apple iPod) compared to viewing hard copy,[25,26] while other studies[27,28] have failed to find any change in accommodation over time during visual display unit use (laptop at 50 cm and purpose-made screen at various distances). In addition, Collier and Rosenfield[27] found no difference in accommodation between symptomatic and non-symptomatic laptop users. The authors concluded that digital

First author	Subjects	Method	Prevalence
Cole BL[10]	Office workers	Longitudinal survey	86% VDU users and 79% non-VDU users reported some symptoms.
Portello JK[11]	Office workers	Questionnaire	Tired eyes 39.8%; dry eyes 32%; discomfort 31%; and irritation or burning 28%.
Chalmers RL[12]	CL wearers – unselected clinical population	Questionnaire	Higher incidence in CL wearers: 76.8% especially late in day (12.7% before 12:00 hours versus 41.1% after 12:00 hours).
González-Méijome J[13]	CL wearers and non-wearers	Questionnaire	Prevalence of symptoms were: redness 22.2%; itchiness 21.3%; tearing 13.4%; burning 32.7%; and scratchiness 10.5%.
Hagan S[14]	Office workers	Online survey using questionnaire	At least one dry eye symptom reported by 68% male and 73% female non-CL wearers compared to 83% male and 87% female CL wearers.
Reddy SC[15]	University students	Questionnaire	Overall DES = 89.9%. Headache 19.7%; irritation or heaviness 16.4%; dry eye 13.6%; and blurred vision 10.2%.
Logaraj M[16]	University students	Questionnaire	81.9% of engineering students. 78.6% of medical students.
Shantakumari N[17]	University students	Questionnaire	Prevalence of symptoms were: headache 53.3%; burning sensation 54.8%; and tired eyes 48%.
Tauste A[18]	Office workers	Questionnaire	65% of CL wearers. 50% of non-CL wearers.
Ranasinghe P[19]	Office workers	Questionnaire	One-year prevalence of DES = 67.4%.

CL: contact lens, DES: digital eye strain, VDU: visual display unit.

Table 2. Prevalence of DES symptoms among VDU users

eye strain is not related to the accommodative response but may be related to vergence. Rosenfield et al.[29] proposed that accommodative infacility, rather than the lag, may lead to symptoms.

The effect of visual display unit use on microfluctuation is also disputed. Two types of microfluctuation have been described: low frequency (less than 0.6 Hz), which is attributed to respiration, and high frequency (1.0–2.3 Hz), which is attributed to arterial pulse.[30–32] Gray et al.[33] observed a subtle increase in low-frequency microfluctuation after 20 minutes of viewing a projected image (unknown viewing distance) in a symptomatic subject; however, the overall change was not statistically significant. Stereoscopic targets (two versus three dimensions) seem to have no effect on microfluctuation;[34] however, coloured filters do appear to have some influence.

Irlen colour filter lenses are reported to aid the treatment of a number of reading disorders. A study by Ciuffreda et al.[35] examined the steady-state accommodation response in a group of Irlen colour filter spectacle lens wearers. The study found no significant difference between mean levels of accommodation with or without the use of the coloured lenses. The authors concluded that coloured lenses do not improve accommodative accuracy at near.

Simmers et al.[36] measured microfluctuations in four different conditions: prescribed tinted lens of a colour specific to the patient; prescribed tinted lens of nonspecific colour; neutral density filter; and no lens conditions. The low-frequency component of microfluctuations was significantly greater in the no lens condition than in the three lens conditions. The greater stability of sustained accommodation responses found with tinted lenses appears independent of the colour specificity of the lens and may be related to the reduction in luminance. The investigators[36] proposed that the subtle fluctuation during attempted sustained focusing with no filter may be an indicator of visual stress. This suggests that the reason behind visual fatigue may be due to the microfluctuation of accommodation, particularly that of the low-frequency component.

Vergence

Computer screen use can put excessive demands on the eyes with respect to convergence.[28,37] One study reported a significant decrease in vergence ability after eight hours computer work (40 cm viewing distance).[38] Wee et al.[39] reported that near point of convergence recedes and digital eye strain symptoms increase after watching 3-D movies. In contrast, Yeow and Taylor[40] found no significant change in the near point of convergence after up to four hours of computer use among office workers. Further, in a separate longitudinal study lasting over two years, the authors[41] observed a decline in near point of convergence with age, although the rate at which it decreased was similar between computer users and non-users. Heterophoria and associated phorias also did not differ between the groups. Another study[42] found no change in fixation disparity following 30 minutes of computer-related tasks (viewing distances of 85, 47, 31 and 25 cm), which was consistent with an earlier study[43] which found no significant change in near point of

First author	Outcome variables	Instrument/method	Main findings
Penisten DK[140]	Lag of accommodation	Dynamic retinoscopy	No difference for printed paper target and VDU.
Collier JD[27]	Accommodation and convergence	Reading text on laptop	Subjects with fixation disparity more comfortable than orthophoric. Accommodation lag was 0.93 D.
Gray LS[33]	Accommodative microfluctuation and pupil response	Autorefractor	No variation in microfluctuation, no interaction with pupil reaction.
Hayes JR[5]	Visual and physical symptoms	Questionnaire	Eye symptoms correlated with time spent, job demand, ergonomics and lightings.
Portello JK[11]	Post-task ocular and visual symptoms	Reading on computer, questionnaire	Incomplete blink in 16.1%. Symptom scores correlated to incomplete blink. Blink rate and completeness associated with DES.
Patel S[50]	Blink rate and tear film stability	Slitlamp, video recording	Five-fold drop in blink rate but tear film stability unaffected.
Himebaugh NL[53]	Blinking, TBUT and ocular symptoms	Movie on television screen, computer games	Higher blinking rate among dry eye subjects. Reduced blinking rate. No difference in amplitude of blink (completeness).
Chu C[56]	Whether the symptoms are related to VDU use	Questionnaire	Blurred vision and mean symptom score more during computer use.
Jansen ME[61]	Blink parameters, tear stability	Questionnaire	Reduced blink rate. Larger tear break area among CL wearers. Completeness of blink correlated with discomfort. CL decreases tear film instability.
Daum KM[67]	Effect of astigmatism correction on productivity and comfort	Computer text	Fully corrected astigmats performed at least 2.5% better.
Chu C[86]	Blink rate	Reading either on computer screen or hard copy	Higher percentage of incomplete blinks. Higher total symptoms score for computer screen reading.
Hue JE[26]	Lag of accommodation, reading rate and ocular symptoms	Reading on electronic tablets and hard copy	Reading electronic tablets can increase symptoms, cause larger lag of accommodation and reduce reading rate.
Bhargava R[75]	Symptoms, TBUT, Schirmer test values and CIC	Dry eye questionnaire	Higher dry eye scores and reduced TBUT, Schirmer's, and CIC in computer users. Association of dry eye with TBUT and CIC scores.
Schulze MM[62]	Blink rate (with spectacle wear and silicone hydrogel contact lens wear)	Watching movies and solving puzzle on computer screens, reading and playing games on tablets	Digital device tasks associated with increased concentration resulted in a reduced blink rate. Blink rate during tasks was higher with silicone hydrogel contact lens wear than with spectacle wear.

CIC: conjunctival impression cytology, CL: contact lens, DES: digital eye strain, TBUT: tear break-up time, VDU: video display unit.

Table 3. Summary of key studies and their findings in relation to VDU use

convergence, vergence or heterophorias after five hours sustained computer work.

A large-scale study noted symptoms with computer use but no association with binocular function. Cole et al.[10] followed 692 computer users and 624 control office workers over a six-year period and monitored both convergence and heterophorias. A higher proportion of computer users reported digital eye strain symptoms (86 per cent versus 76 per cent); these included glare sensitivity, ache, sore eyes, blurred vision and ocular fatigue.

Vergence response appears to be related to symptoms of discomfort while reading from a digital device. Collier and Rosenfield[27] monitored phorias and asked subjects to rate the level of ocular discomfort (1–10 scale) before and after 30 minutes of reading aloud from a laptop (50 cm viewing distance). They observed a positive correlation, with the greatest discomfort reported by subjects who had less than 1^{Δ} exo- or esophorias. The authors concluded that a slightly smaller vergence response might reduce symptoms.

Pupil

A number of studies have observed changes in pupil characteristics following near vision tasks. One study found that, under certain conditions, pupil dilation failed or was delayed following a concentrated near task.[44] Additionally, Tsuchiya et al.[45] found that these pupil after-effects can occur without changes in the tonic level of accommodation. However, it is not clear whether pupil after-effects correlate with digital eye strain. Saito et al.[46] found that, after four hours computer work, the pupil light reflex was delayed, and amplitude of the near reflex was decreased. The authors also observed visual fatigue following the work; however, they did not examine the potential association of visual fatigue with pupil reflex.

A similar study suggested that the visual fatigue experienced by computer users may be associated with hippus (rhythmic contraction of the pupil).[47] Taptagaporn and Saito[48] examined the change in pupil size following computer work using positive and negative display polarities. Only small changes in pupil size were observed for the positive display (dark character on bright background). In this study, a majority of the subjects preferred the positive display to the negative display. The authors concluded that a positive display is more ergonomic.

Blink characteristics

The use of digital devices reduces both blink rate and completeness of blinks, which are factors associated with digital eye strain. Many studies show that blink rate is reduced during computer use (3.6–11.6 blinks/minute)[49–53] compared to normal blinking (17–26 blinks/minute).[54,55] Patel et al.[50] found a five-fold reduction in mean blink rate (from 18.4 to 3.6 blinks/minute). Blink rate is also reduced in dry eye subjects during computer use, although blink rate is reduced more in non-dry eye subjects.[53] Portello et al.[49] have shown that blink characteristics correlate with symptoms of digital eye strain. Total symptom scores increased as blink rate decreased (r = 0.43) and as blinks became less complete (r = 0.63). Chu et al.[56] found no difference in blink rate between reading from a computer screen and a hard copy. However, the incidence of incomplete blinking was significantly higher when reading from the computer screen. Also, the total symptom score was significantly higher when reading from the computer screen. The results of the study suggest that some symptoms of digital eye strain are associated with incomplete blinking.

Eyelid physiology

Squinting (or narrowing of the palpebral aperture) is common during computer use, to enhance concentration, improve visual acuity and control glare.[57] While squinting, tension is increased in the orbicularis oculi muscle and there is evidence to suggest that overaction of the orbicularis muscle may cause eye pain and tired eyes. Thorud et al.[58] exposed healthy subjects to visual stressors during two hours of laptop work. Symptoms, blood flow to the orbicularis muscle and muscle load all increased significantly during the laptop work. The researchers found a positive correlation between eye-related pain and blood flow to the orbicularis muscle. They also found a positive correlation between eye-related tiredness and muscle load.

Symptoms and risk factors

Contact lens wear

Contact lens wear is considered a risk factor for abnormal tear physiology due to reduced tear film thickness coupled with the friction effect created by the lens surface and edges.[51,59] Contact lens wearers have been found to be as much as 12 times more likely than emmetropes, and five times more likely than spectacle wearers, to report dryness symptoms.[60]

An online survey among computer users revealed that 83 per cent of male and 87 per cent of female contact lens wearers have at least one dryness symptom compared to 68 per cent of male and 73 per cent of female non-contact lens wearers.[13] For contact lens wearers, dryness symptoms were more prominent among those using computers for 3–6 hours than among those using computers for fewer or more hours than this; the investigators did not explain the possible reason(s) for this discrepancy. A similar study also found a higher prevalence of dryness symptoms among contact lens wearers, with the symptoms being relieved after removal of the lens.[12]

Jansen et al.[61] examined soft contact lens wearers as they listened to music or played a video game with and without contact lenses. The area of tear film break-up was greatest when subjects wore contact lenses while playing the video game. The tear film break-up area correlated with discomfort with the game task. With contact lenses, blink rate did not change significantly between tasks; however, blink amplitude decreased significantly when playing video games. The blink amplitude correlated with severity of dry eye. The authors concluded that, even in fully adapted wearers, contact lenses provide sufficient ocular surface or lid stimulation to increase the rate of blinking. Schulze et al.[62] evaluated the relationship between digital device task difficulty and blink rate in silicone hydrogel contact lens wearers while using two digital devices: a personal computer and a tablet. They found that, similar to previous reports, digital device tasks associated with increased concentration resulted in a reduced blink rate.

Kojima et al.[63] administered a 29-item questionnaire among 69 contact lens wearing and 102 age and sex matched non-contact lens wearing office workers. The questions related to visual, environmental and dry eye symptoms. In addition to comparing symptom scores between two groups, the authors also examined for an association between duration of computer work and contact lens wear. The study found significant differences in dry eye, visual and environmental symptom scores between the two groups (Table 4). These symptoms increased with duration of computer work, and scores were significantly higher among contact lens wearers (Table 5).

Studies by Tauste et al.[18] and Ranasinghe et al.[19] also agree that contact lens wearers are more likely to experience digital eye strain than non-lens wearers. Ranasinghe et al.[19] found that contact lens wear is the second most significant risk factor for digital eye strain (odds ratio [OR]: 3.21) after pre-existing eye disease (OR: 4.49). Contact lenses probably increased the risk of digital eye strain because they can contribute to

Symptom scores	Contact lens wear (mean ± SD)			Duration of VDU use (mean ± SD)		
	Wearers	Non-wearers	p-value	≥ 4 hours	< 4 hours	p-value
Dry eye	39.1 ± 15.0	27.1 ± 15.6	0.001	37.5 ± 16.0	26.3 ± 14.8	< 0.001
Visual	29.2 ± 18.8	20.1 ± 12.9	0.002	20.3 ± 18.1	19.2 ± 12.4	0.01
Environmental	36.7 ± 5.4	15.3 ± 5.4	0.001	29.1 ± 18.8	18.7 ± 16.3	< 0.001
TBUT	4.1 ± 1.9	5.0 ± 2.9	0.106	4.4 ± 2.6	4.4 ± 2.6	0.234

TBUT: tear break-up time, VDU: video display unit.

Table 4. Comparisons of symptoms scores and tear film break-up time between contact lens wearers and non-wearers and by duration of VDU use[63]

symptoms of dryness, which was a commonly reported complaint (31.1 per cent of digital eye strain cases).[19]

Eye strain and headache

Eye strain is characterised by the feeling of pain, ache and tiredness of or around the eye.[64] The exact mechanism behind eye strain is not clear. However, uncorrected refractive error, particularly astigmatism, has been found to be a major cause of eye strain, especially for symptoms of headache and tired eyes.[3,10,13,56–67] For instance, Wiggins and Daum,[65,66] Gowrisankaran et al.[68] and Rosenfield et al.[69] found greater eye strain when astigmatism was deliberately induced while reading on a computer (unknown, 60 cm, and 50 cm viewing distances, respectively). Separately, Kotegawa et al.[70] reported that optimum correction of myopia improves symptoms among computer workers.

Several studies of student populations found that headache is one of the most common digital eye strain symptoms.[16,17,71–73] Other common symptoms include burning sensations and tired eyes. Headaches and tired eyes were a significant cause of interruption to the work of the students.[17] Headaches were less common when the screen is viewed at distances beyond 50 cm.[17] Studies show that the prevalence of headaches increases with increasing duration of computer use.[16,74] Ergonomic awareness and corrective measures may help to reduce the impact of digital eye strain.

Dryness

Dryness and associated symptoms in otherwise healthy eyes are commonly encountered by visual display unit users and have been cited by many investigators. Questionnaire studies have reported that the severity of dry eye is affected by the duration of computer use.[75–78] Additionally, use of air-conditioning and forced-air heating in office environments may contribute to dryness symptoms.[1]

In general, a higher prevalence of dryness symptoms is found in women compared to their male counterparts. A study conducted in the USA reported a 7.8 per cent prevalence rate of dryness among women[79] compared to 4.3 per cent among men.[80] The gender difference in visual display unit-related dryness symptom prevalence is supported by a report from Japan where 21.5 per cent of women had dryness compared to only 10.1 per cent of men experiencing the same symptoms.[8]

Many investigators believe that decreased blink rate could be the likely cause of dryness among visual display unit users.[50,51,81] Investigators have proposed that blink rate may be reduced by poor contrast,[82] decreased font size,[83] increased cognitive demand[53] and contact lens wear.[61,84] Incomplete blinking, leading to insufficient distribution of the tear film, has also been suggested as a cause of dry eye among visual display unit users.[53,85] This theory is supported by Chu et al.[56] who found a significant correlation between incomplete blinking and total dryness symptom scores.

Blurred vision and diplopia

Blurred vision is a common symptom experienced after prolonged computer use.[3,4,58,86,87] This may result from an accommodative infacility or an inaccurate accommodative response (that is, lead or lag) during visual display unit use. Another likely cause of blurred vision (and diplopia) is uncorrected refractive error, because computer glasses often seem to reduce symptoms.[88,89] However, other likely factors include abnormal tear physiology and associated unstable tear film, ocular muscle fatigue and vergence anomalies.

Glare

Two main types of glare have been described: discomfort glare and disability glare. Discomfort glare is the temporary irritation caused by light, and may be a response to the saturation of visual neurons. Disability glare is the temporary

Symptom scores	VDU use ≥ 4 hours with CL	VDU use < 4 hours with CL	VDU use ≥ 4 hours without CL	VDU use < 4 hours without CL	p-value
Dry eye	39.1 ± 14.9	38.2 ± 15.3	35.5 ± 16.9	21.0 ± 11.3	< 0.001
Visual	34.1 ± 19.0	21.2 ± 15.6	22.4 ± 15.1	18.4 ± 10.7	0.002
Environmental	37.6 ± 14.5	35.3 ± 17.1	20.6 ± 18.9	11.4 ± 9.0	< 0.001

CL: contact lens, VDU: video display unit.

Table 5. Comparisons of symptoms scores and tear film break-up time between contact lens wearers and non-wearers and by duration of VDU use. Each corresponding two groups were statistically significant.[63]

impairment of vision due to light, and can occur independently of discomfort glare. Disability glare is caused by the loss of retinal image contrast that results from intraocular light scatter.

Glare is commonly experienced by computer users,[3,4] has been found to reduce reading speed,[90] and may also be a major cause of digital eye strain symptoms.[58,91,92] The source of glare can be light from the visual display unit or from the surrounding environment, such as improper desk lighting.[93–96] Glare from surrounding lighting may have a negative effect on accommodation.[97]

Screen light

Modern digital devices, including computers, tablets, and smartphones, emit bright blue light also known as high-energy visible light.[9] This typically ranges in wavelength from between 450 and 495 nm. Various authors have suggested that excessive exposure to light, particularly to short wavelength light (toward ultraviolet in the spectrum), may result in glaucomatous changes in the ganglion cells,[98] damaged photoreceptors and retinal pigment epithelium,[99] cataract[100] and predisposition to macular degeneration.[101,102] However, the intensity and duration of blue light exposure in these studies far exceeded that of digital device use. Likewise, the wavelength of blue light is another important factor to consider. Knels et al.[103] observed a reduction in metabolic activity and transmembrane potential of mitochondria in R28 cells irradiated with 411 nm light but not with 471 nm light. Thus, no evidence currently exists to suggest that the visible blue light emitted from digital devices is able to damage the eye.

Management of digital eye strain

Ergonomic use of digital devices

Many studies suggest that ergonomic practices could be important for management of digital eye strain. Widely accepted ergonomic practices include the use of appropriate lighting, careful positioning of the digital device, adjusting image parameters (resolution, text size, contrast, luminance), and taking breaks.[1,3,81,82,104–110]

Many authors propose breaks as a management strategy.[1,16,17,107,111–113] However, Reddy et al.[15] found that breaks alone were not associated with reduced symptoms, whereas looking at far objects during breaks was. The 20/20/20 strategy (after 20 minutes of visual display unit use, looking at objects over 20 feet away for 20 seconds) is a relatively popular recommendation in the literature.[15,109,114,115]

Using antiglare screen filters is a less accepted ergonomic practice. Shantakumari et al.[17] and Ranasinghe et al.[19] found that the use of screen filters was associated with reduced digital eye strain. Conversely, Scullica et al.[111] found that screen filters did not reduce digital eye strain in their large population of subjects. Additionally, Reddy et al.[15] found that a radiation screen filter failed to reduce digital eye strain.

A few authors proposed that ergonomic awareness should be increased;[16,17,116] however, awareness of ergonomic practice alone is not sufficient,[19] and should be supported by ergonomic work environments.[1,3,7,96,111,114,117] In addition to ergonomic awareness, authors suggest improving air-conditioning[63] and enabling workers to adopt their preferred viewing distance.[28] The Health and Safety Executive has developed a checklist to ensure that all aspects of the computer workstation are

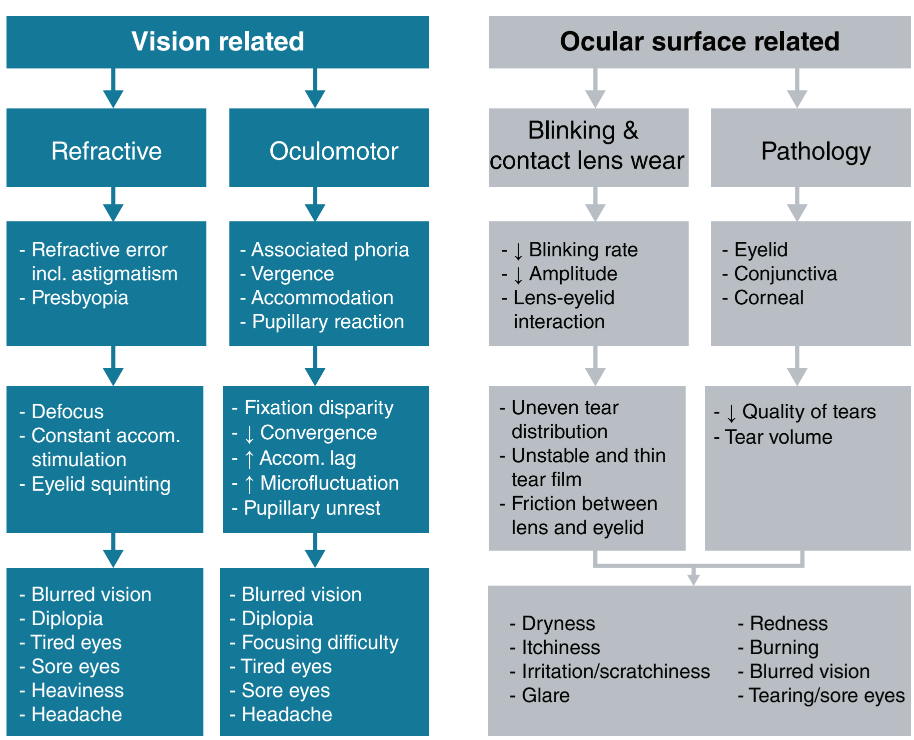

Figure 1. Types and symptomatology of digital eye strain – vision- and ocular surface-related[23]

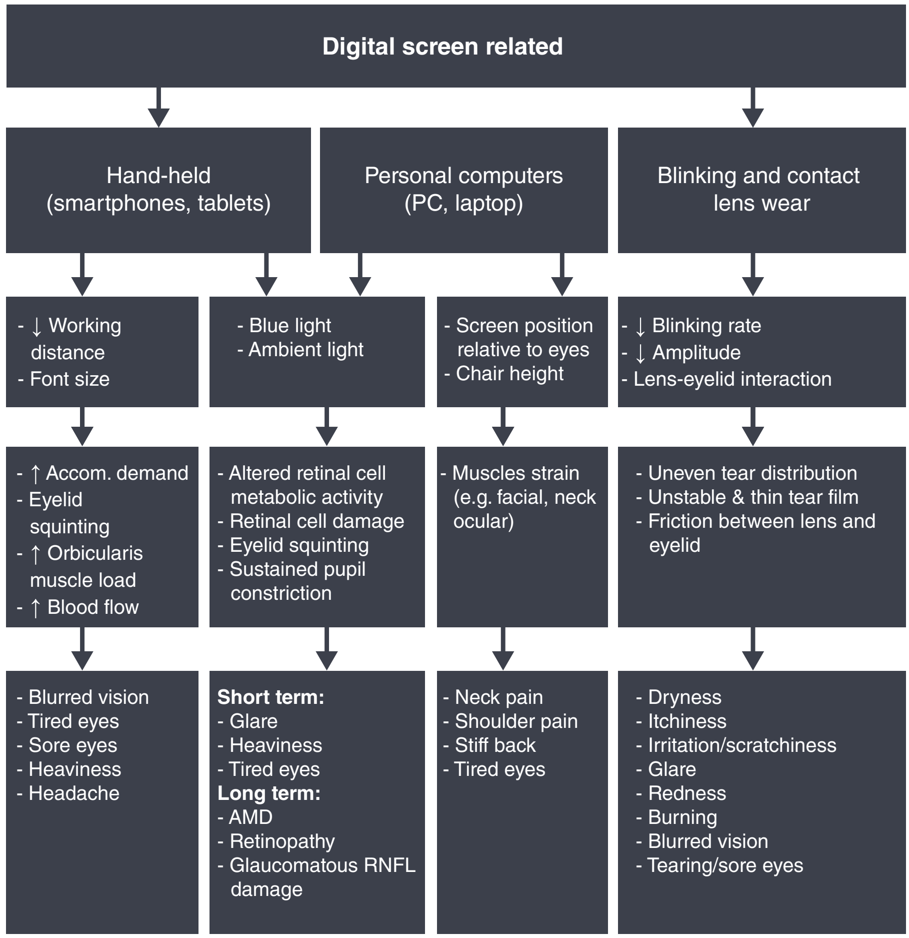

Figure 2. Type and symptomatology of the digital eye strain – device-related[23]

suitable and that equipment is appropriately used.[118]

Diagnosis

Several papers have given recommendations regarding the diagnosis of digital eye strain.[3,6,109,119,120] Clinicians are advised to have a good understanding of the symptoms and underlying physiology of digital eye strain to improve diagnosis and management.[6] Diagnosis should also be improved by updating the standard eye examination to suit the current visual demands,[6] and a specific eye examination should be developed for computer workers.[119] Vision screening for computer workers may also be beneficial.[3,109,120]

Since digital eye strain can have various underlying causes, management must be tailored to the individual patient.[119] So that appropriate management is selected, clinicians are advised to assess visual symptoms separately from specific ocular symptoms.[121] Clinicians are also advised to question patients about their use of digital devices, and provide information to improve ergonomic awareness.[11,108]

Correcting refractive error

Digital eye strain is worsened by eye conditions, and therefore, proper eye care is important for management of digital eye strain. The Vision Council[9] strongly recommends that people who suffer from digital eye strain should visit an eyecare professional. Studies recommend that refractive errors (such as presbyopia and astigmatism) be appropriately corrected.[65–70,74] Computer glasses provide appropriate correction for the viewing distances and angles needed at the computer workstation, have been found to relieve symptoms,[88,89,122] and are recommended in the literature.[67,70,81]

Digital eye strain may also be relieved by a near addition.[25,74] However, Dain et al.[4] have cautioned against the automatic prescribing of low plus lenses, since most symptomatic visual display unit users are emmetropic. When prescribing refractive corrections for use at near, clinicians should determine the working distance(s) being adopted by the patient, and consider performing examinations at these distances.[123] Additionally, changes in the design of lenses (especially for presbyopia) may be required to suit the current visual demands.[123]

Management of dryness symptoms

The literature suggests that dryness is a significant cause of digital eye strain. Several authors recommend the use of lubricating eye drops to relieve symptoms.[1,15,108,109,124] Lubricating eye drops seem to help relieve (although not eliminate) symptoms of dryness, tiredness and difficulty focusing.[15,124] Other treatment options are a dietary supplement of either omega-3 fatty acids or blueberry extract.[125–128] Bhargava et al.[125,126] observed that, after 45 days of omega-3 fatty acid treatment, patients demonstrated a significant improvement in dry eye symptoms and tear break-up time. Similarly, Park et al.[128] found that a four-week treatment with blueberry extract (species: *Vaccinium uliginosum*) significantly reduced overall subjective eye strain symptoms.

Clinicians and patients should be aware that visual display unit users who wear contact lenses are at an increased risk of dry eye and digital eye strain.[13,18,19] Clinicians can manage contact lens-related dryness through choice of lens material, lens care and rewetting systems, and management of environmental factors.[12,115] Contact lens wearers may also require additional management; the report of the TFOS (Tear Film & Ocular Surface Society) International Workshop is available to download, and describes the causes and corresponding management strategies of contact lens-related discomfort.[129]

Improving blink rate

Several computer applications have been developed to encourage frequent blinking during computer use; typically these involve visual or audible prompts. One study found a significant increase in blink rate using a visual prompt of blink instructions on a white screen (desktop computer, 50 cm viewing distance).[130] However, the visual prompts were subjectively intrusive, although the reading rate was not compromised. Another study found that audial prompts also increased blink rate, but they did not reduce symptoms of digital eye strain (desktop computer, 50 cm viewing distance).[131] One explanation is that the completeness of blinks may have a greater effect on digital eye strain than blink rate.[49] Another possibility is that the subjects may have had a reduced cognitive demand due to reading aloud.[132] A reduced cognitive demand would have reduced the digital eye strain symptoms and therefore, affected the apparent influence of blink rate.

Non-intrusive strategies to increase blink rate also exist. Anti-reflection film placed over a screen can increase blink rate and reduce eye strain symptoms.[104] Reducing reflections from visual display units can improve the image and contrast displayed. The improved image requires less effort to view and thus increases blink rate and reduces eye strain symptoms.

Lens filters

An increase in microfluctuation of accommodation, particularly the low frequency component, seems to be associated with digital eye strain.[36] Some studies have reported that precision spectral filters (person-specific tinted lenses) can help control accommodative microfluctuation and thereby reduce symptoms in some subjects.[133,134] Specific tints are selected by systematically adjusting chromaticity (hue and saturation) using an Intuitive Colorimeter (Cerium Visual Technologies, Tenterden, Kent, UK) until optimum perception is achieved.[133] However, other studies have reported that precision spectral filters do not improve accommodative accuracy at near, and reduced visual stress may be due to reduced luminance.[35,36]

Nonetheless, lenses that use colour filters, including blue light filtering lenses and precision spectral filters, may help to reduce symptoms of digital eye strain. Blue light from digital devices may contribute to symptoms of visual fatigue, since blue light scatters in the eye, increasing the effort needed to maintain visual focus. A recent study found that lenses which sufficiently blocked blue light significantly reduced objective and subjective measures of eye fatigue during two hours of computer use.[135] The study compared 36 subjects (aged 21–39 years) randomised to either high-blocking, low-blocking or no-block spectacles. The high-blocking group demonstrated significantly less eye fatigue (as measured by critical flicker fusion frequency) and significantly fewer symptoms of ocular pain, heaviness and tiredness than the other groups. In contrast, another recent randomised controlled trial found that similar proportions of subjects (n = 80, aged 18–55 years) reported that eyestrain was improved, worsened or unchanged by blue-light filtering spectacles compared to clear lenses.[136] However, fewer subjects reported worse vision on computers and mobile devices with blue-light filtering spectacles than clear lenses. Furthermore, the blue-light filtering spectacles in this study appear as though they would have been categorised as low-blocking lenses in the former study. Nonetheless, further randomised controlled trials are needed to provide high-quality evidence for the effect of blue-blocking lenses on digital eye strain.[137]

DES symptom/cause	Strategy	References	Study results
Refractive error	Computer glasses correct astigmatism	65–70,88,89	Reduced symptoms
Microfluctuation of accommodation	Precision spectral filter	35,36,111,133,134,141	No consensus
Glare	Colour filter	15,17,19,111,133	Conflicting results
Dryness symptoms	Lubricating eye drops	124,125,142	Both strategies reduce dryness symptoms
	Omega-3 fatty acids		
Reduced blink rate	On-screen prompt	130	↑blink rate
	Audial prompt	131	↑blink rate, no DES change
	Wink glass	132	↑blink rate, ↑complete blinks
	Anti-reflection screen	104	↑blink rate, ↓DES symptoms

DES: digital eye strain.

Table 6. Management of DES

Conclusion

Prevention is the main strategy for management of digital eye strain.[4,8,138] Prevention involves: (i) ensuring an ergonomic work environment and practice (through patient education and the implementation of ergonomic workplace policies); and (ii) visual examination and eye care to treat visual disorders.[4,8,108,139] Special consideration is needed for people at a high risk of digital eye strain such as computer workers and contact lens wearers.[138]

Further suggested management strategies include maintaining normal blinking, using artificial tears, improving contact lens comfort, using tinted correction options, including blue light filters, and management of accommodation and vergence anomalies (Table 6). Additionally, since individuals with less than 1^{Δ} of phoria are more symptomatic, management of vergence anomalies may involve leaving a small amount of heterophoria. The mechanisms of digital eye strain from various sources are illustrated in Figures 1 and 2.

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