Vision and Computer Use – a Literature Review

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ABSTRACT

Literature from international and national sources has been reviewed to establish whether there is evidence that vision is affected by computer use. The sources used include electronic databases, refereed articles, brochures, policy documents and conference presentations. The ocular function of computer users was also evaluated against Hazpak Occupational Health and Safety criteria[1].

The literature revealed that visual discomfort was caused by ocular and environmental problems. The ocular problems included a transient increase in accommodation, inappropriate focal length of spectacles and reduced lacrimation. The environmental factors included "time on task", surround luminance, screen qualities, screen position and document source position, as well as screen distance and work station contamination. The Hazpak analysis of risk for vision problems caused by computer use, revealed a low level of importance and low risk.

Strategies to support vision comfort included appropriate spectacle correction (focal length and single focus lenses), managing "time on task" to reduce stress on ocular function, actions to decrease dry eyes, and ensuring screen qualities assist easy visual appreciation and comfort of viewing. It is concluded that computer users may experience vision discomfort but this can be managed with appropriate vision treatment and judicious attention to environmental issues.

Key Words: computer use; vision; OHS assessment; environmental factors.

INTRODUCTION

Computers are increasingly being used by a wide range of people in the community for work, education, entertainment and pleasure. Interviews of employees during Occupational Health and Safety assessments (OHS) have revealed that computers are used for work purposes between 5 and 10 hours a day [2] with the hours of use for leisure purposes being unmeasured. This level of use places the computer under scrutiny as a potential work place hazard, particularly because it includes an electronic screen, which is potentially associated with radiation and it "requires sustained focus at a distance between 50 and 150 cms"[3]. Computer users may experience a range of symptoms which for the purposes of this review will be defined as visual discomfort. The symptoms include blurred vision, problems finding an appropriate focal length for the computer screen and aesthenopia. The Occupational Health and Safety Act [4] has raised awareness of safety in the work environment with an expectation that the workplace will be safe. To support this fines have been introduced for both the employing company and the supervisor to ensure compliance with standards[4]. These factors together raise the possibility that computers are harmful for the eyes and that users require special management strategies.

This review of the literature, which includes both broad based information from web sources and printed advertising material as well as evidence from peer reviewed publications, will consider whether the use of computers can cause problems for the eyes. It will explore the best strategies to support ocular comfort when using computers. The paper will also introduce an OHS method of evaluating the impact of the computer on vision.

COMPUTER TRIGGERED CHANGE TO EYE FUNCTION

Radiation

A computer is an electronic device, which emits rather than reflects light. The emission involves radiation and there is concern that this is harmful to the eyes. Several sources deny that the radiation is harmful[5,6] reporting that the "wavelengths are well below any exposure doses"[7] and that computers "emit little or no harmful ionizing radiation (X ray) or non ionizing radiation (ultraviolet)" and that in computer based equipment the radiation emitted is less than fluorescent lights". The Royal College of Ophthalmologists[6] comment that there is "no published evidence" that computers cause harm to the eyes. This view is further supported by the American Academy of Ophthalmology[5] which states that there is "no convincing evidence that computers are harmful to the eyes".

Dillon[8], Cole Maddocks and Sharpe[9] support that there is no relationship between the long term use of computer and permanent changes in the visual system. Cole et al[9] in a study of computer users compared to non computer users, reported that for the two groups there was no significant difference in the increases of diseases of the external eye, cornea, anterior chamber, iris, pupil, optic nerve head, vitreous or lens. The American Academy of Ophthalmology reports that the radiation from computers is below the levels that produces cataracts or other conditions that are susceptible to light[5]. When the recommendation from professional societies state that there is no evidence of harm to the eyes and evidence from research supports that there is no development of pathology, then it can be concluded that radiation from the screen is not a cause of adverse effect to the visual system.

Visual Discomfort / Computer Triggered Symptoms

Symptoms of discomfort, such as sore tired eyes, which arise in association with use of the computer, can suggest some form of harm being generated

through use of the device. Systems Concept[10] in a web document relating to display screen regulations and Dillon[8], report the existence of short term visual discomfort, but no long term damage in people who use computers. Ocular fatigue is reported by many authors[8,11,12,13] but is then attributed to poor work station set up, general fatigue, excessive time spent on computer work, intensity of work and psychosocial issues. Management of these issues is recommended as a first step to reduce ocular discomfort. Other sources[8,14] reported computer users who experienced symptoms but did not undertake treatment and showed no evidence of change in their symptoms over a 24 to 30 month time frame. This suggests that continued use of a computer does not cause the ocular condition to deteriorate otherwise the symptoms would have increased or other visual changes would have occurred. In fact Dillon[8] suggests that "pre existing poor eyesight influences subjective reports of visual fatigue", rather than computer use causing sight problems. Oftedal, Nyvang and Moen[15] found an interesting response when filters with adaptations to screen out electric fields were fitted to the computer screen and without the knowledge of the user, were either not activated or activated. In both cases the symptoms decreased compared to working with the computer and no adaptive screen. The outcome supports a strong placebo / Hawthorne effect and reinforces that computers themselves do not cause ocular discomfort.

Visual Acuity

Wulff[14] found that computer operators (n=52) who had an initial and then a repeat assessment of their visual acuity after 2 years showed no significant difference in their vision. Cole et al[9] and Futyma[16] assessed two groups, one used computers and the other did not. Both studies found that the visual acuity standard was the same regardless of whether the computer was or was not used. The study by Futyma demonstrates no change over a period of between 5 and 12 years of computer use. These studies support the conclusion that computer use does not affect visual acuity.

Refractive errors

Grignolo, DiBari, Bellan, Camarino and Maina[17] carried out a long term study of computer operators (n = 6000) and found that changes in the refractive state of their eyes was not related to computer use but was largely age related. Rechichi and Scullica[18] found that over a 6 year period, employees (n = 23,000) who used a computer for 6 hours a day, did not induce or worsen their refractive state. Cole et al[9] reported a population matched study of computer users compared with non computer users and found no statistically significant difference between those who wore glasses or not. Cole did report a greater incidence of myopia in the computer users but concluded that the reported myopia was due to chance rather than related to computer use. As will be discussed later the myopia may be related to an increase in accommodation capacity following work activities. Rose, Morgan, Smith and Mitchell[19] reported an increase in myopia in children and hypothesised it to be related to an increase in long periods of close work but there is no similar report in adult computer users.

The correction of the refractive errors did however, raise discussion about the relationship between the focal length of spectacles and the conventional distance and position that the computer screen is from the eyes. Piccoli[20] found the preferred working distance of computer operators to range between 48.42 cms and 65.33 cms which is supported by the recommendation of the Royal College of Ophthalmologists[6] and the regulations of Systems Concept[10] that the distance be between 50 and 60 cms. This distance causes particular problems for presbyopic computer users who conventionally are prescribed spectacles with a focal length of 30 cms. This incompatible focal length, results in the computer screen being out of focus at the 50 cm range and raises the need for the user to move their head and eyes closer to the screen in order to see. This could results in neck, not vision, discomfort[21].

In addition the presbyopic people who have bi, tri or multifocals may find the position of the near correction in the lower part of the lens to be inappropriate. This is because the information on the screen is only clear when seen through the reading segment, which is positioned in the lower half of the spectacle lens. When the screen is set in an elevated position, the user has to position their near correction over the screen which results in raising the chin. The resultant "chin up posture" to see the screen can again cause neck discomfort. In reality the refractive error is not causing the problem, the format of the optical correction is the problem. Spectacles with a longer focal length are required and either a pair of single focus spectacles for computer use or adjustment of the screen height to be within the near add position is required. The only form of screen set up where conventional multifocals are appropriate is for people who use a lap top computers which are positioned on a desk so the screen is lower and in the field of the reading segment.

Accommodation

Several authors have considered accommodation and measured outcomes in different circumstances that is: computer use compared with non computer use[16,20]; short periods of use[22] compared to long periods of use[13,16], young users with responsive accommodation compared to older users with less responsive accommodation[13]; and use over several years[9]. Dillon[8] identified a significant statistical relationship between symptoms of visual fatigue and a change in accommodation in computer users. Piccoli[20] reported an excess of accommodation, measured by refraction, at the end of an hour of close work. The increase was more marked after computer use than other office activities. Gunnarsson[23] similarly found an increase in measured accommodation after a work session of 8 hours (8am to 4 pm) but only in younger employees. In the older employees there was no change. On the other side of the argument, Gray, Gilmartin & Winn[22] reported no change in accommodation in asymptomatic individuals after 25 minutes of computer or hard copy work. Futyma[16] also found no change in accommodation for people who used a computer 5.6 hours a day, 6 days a week for between 5 and 12 years. Cole et al[9] in a study of people who were followed up over several years, found no difference in

the accommodation amplitude between computer and non computer users. Overall, there is no clear evidence that accommodation is permanently affected by computer use. There is some evidence that accommodation is temporarily affected if any near activity is undertaken, whether computer or general office work[12]. It is however more affected if the close activity is with a computer, is undertaken for one hour or more, and the person is in the age group where accommodation is flexible[12]. Potentially, when working on a computer, the ocular use is more concentrated in the one near position and this near activity is a precursor to the development of myopia[19] presumably through a link to sustained accommodation. The above studies identify some increase in accommodation associated with computer use but there is insufficient evidence to link to an ongoing change into myopia. The outcome supports short periods of computer use with breaks to decrease the accommodation effort.

Eye Movement disorders (incorporating heterophorias and convergence)

Cole et al[9] found that there was no difference in the near heterophorias between computer and non computer users. Grinoli[17] found that there was no change in the near hetrophoria over time and that office work helped to improve the condition although what was meant by this was not identified.

The reported convergence responses included all possibilities. Gunnarsson[13] reported that convergence increased with computer use and decreased following rest breaks. Piccoli[20] reported a decrease in convergence at the end of a work period. Futyma[16] reported no change in convergence in association with work sessions and Wulff[14] reported no change in the clinical measurement over a 2 year period. Dillon[8] and Iribarren[24] both report an association of symptoms with convergence defects. Matsouoka, Nakamura and Kobatake[25] reported that computer operators who had symptoms of ocular discomfort had a higher incidence of exophoria and convergence insufficiency.

These outcomes suggest that, for some computer users, there is no change, for some there is improvement and for other users there is a decrease in ocular function. As all computer users are not adversely affected, use of the computer, cannot be identified as the sole cause of eye movement problems. Decrease in the control of a heterophoria (particularly an exophoria) and convergence are commonly seen clinical condition. The reason for change is more likely to be associated with close activity that occurs with computer use.

Stereopsis

Futyma[16] reported no change in the stereopsis of non computer users compared with computer users when the use was 5.6 hours a day, 6 days a week over a period of 5 and 12 years. Wulff[14] reported a follow up after 2 years where there was no significant difference in the response.

Blink Rate and Tear Flow

Blink rate and tear flow are linked to dry eyes and general ocular symptoms. It is reported that computer tasks causes people to stare[26,27] and blink less[27,28,29]. Acosta[29] found that drying of the cornea and conjunctiva increased the blink rate but in computer users the blink rate was decreased. He hypothesised that the decreased blink rate that occurs in computer users is because the central neural mechanism over-road the peripheral sensory input and consequently led to a decreased blink rate. The position of the eyes also is reported to have an effect on blink rate with Doughty[30] reporting that when the eyes are in the reading position, the blink rate is less than when the eyes are looking in the primary position.

Reduced lacrimation when using a computer has been reported. Nakaishi Hitoshi, Yamada & Yuichi[31] reported 34% of computer users with symptoms had dry eyes compared to 10% of non computer users. Yaginuma[27] reported that the reduction in lacrimation that occurred at the time of using the computer had a long term effect (26% lacrimation decrease when a computer is used 100 hours a month and 36% decrease for use of greater than 100 hours a month).

Dry eyes, decreased blink rates and associated symptoms, such as a foreign body sensation, are reported[8,27,29,30,31] in association with computer use. Several authors suggest methods to overcome dry eyes will lead to an increase in comfort. These methods include instillation of elasto viscose drops[29], the use of a gelatin rod[27] and an increase in blink rate[30].

The evidence in this area supports that computer users blink less, have reduced lacrimation, and experience symptoms associated with dry eyes. If this is acknowledged, then, mechanisms to assist increasing lubrication in the eyes of computer users are important especially if they are symptomatic. Strategies should include advice to blink as much as possible and to use some form of lubricant as the need arises.

THE ENVIRONMENT, THE EYES AND COMPUTER USE

Jackson, Barnett, Stevens, Mcclure, Patterson & McReynolds[32] reported that of 571 employees who used computers, the successful management of the users with problems required modification of the work-station ergonomics, variation in working pattern variation. In 5% of the employees there was a need for attention to vision problems. The issue of the environment is therefore an important consideration for all computer user.

"Time on Task"

Studies that investigate computer use report symptoms of ocular fatigue[8,10,23,24,32,33]. There is no consensus about the cause of the symptoms but time on task is raised as a major reason for the fatigue. A variety of hours undertaking computer tasks were linked to fatigue. Travers[33] reported a general increase of symptoms as computer usage increased. Dillon[8] citing Matthew reported a linear increase in discomfort with time and Tyrell and Liebowitz[8] reported continuous reading of computer text for just under 2 hours was linked to ocular fatigue. Systems concept[10] reported 4 hours computer use and Mourant[12] reported 2 to 3 hours of use was linked to discomfort.

A variation to "time on task" was exposure to computers over time. A number of authors[8,14,21] who

have undertaken a longitudinal study of computer users reported no change in the level of visual symptoms, over an extended period.

These results support a change in vision function as the user is exposed to computer use. The exposure can be for a given period or over time. Ensuring breaks from using the computer would be a prudent way to minimise such symptoms.

Computer use compared with near tasks

There is a logic that computer use is the same as pen and paper tasks, reading, and general office duties. All these tasks are performed in the near position and can involve continuous focus. Therefore there should be no difference in the ocular discomfort that is experienced by computer and non-computer users. Several authors[8,9,14] report findings that support this. Piccoli[20] et al reported an increase in discomfort with computer use compared to other near tasks and Mourant[12] reported that computer use caused a more rapid onset of the discomfort. The intensity of the work activity also has been reported to have an impact with Jackson[32] reporting uninterrupted use of the computer being linked to a greater incidence of symptoms[5].

The issues of "time on task" and intensity of task being linked to ocular discomfort adds support to the guidelines presented by the National Safety Council of Australia[34] and the American Academy of Ophthalmology[5] that there should be regular rest breaks. The frequency and amount of the break varies with the National Safety Council recommending 15 minutes every hour and that employees should not spend more than half their working day on computer activities. Mourant[12] reported recovery from discomfort following a rest which supports the use of regular breaks.

Surround luminance

Glare appears to have an influence on ocular function. Wolksa and Switula[35] report a tendency for a change in ocular function particularly a reduction in accommodation amplitude. Dillon[8] and Travers[33] report a link between glare and visual symptoms with the symptoms ranging between problems with reflections to aesthenopic responses. Collins[21] reported no significant association between glare and visual symptoms and that problems from glare only arose when windows were in the users fields of view. Management of glare is advised to be that lighting should be set up to avoid reflections[5]. This can be evaluated by observing if the users reflection can be seen before the computer is switched on[36]. If this does occur there is too much reflection and indirect glare and discomfort is likely.

Low illumination has also been reported to be problematic for computere users. Dillon[8] reported problems reading the key board, source documents and other information as well as visual fatigue, in low illumination.

Screen qualities

Cathode ray tubes (CRT) are reported to be associated with better visual comfort than liquid crystal display screens (LCD)[35] with the LCD which have poor figure to background contrast and are more difficult to focus. The use of a filter over the screen is reported to result in a reduction in surround reflections and appreciation of screen flicker[15,21,33].

Screen and Document source

The American Academy of Ophthalmology[5] recommends that the distance of the computer screen should be "a little further away than normal reading distance". Dillon[8] reported that closer positioning of the screen induced more ocular and musculo skeletal strain. The best choice is reported by Jaschinski & Kylain[37] report that choice of screen distance is individual but is probably best between 60and 100 cms. This will of course be affected by, the optical correction and the effective focal length of any spectacles that are worn.

The position of the screen is advised by The American Academy of Ophthalmology[5] to be "at or a little below eye level" and Burt[36] recommends that the screen should be approximately at the middle of the forehead. Jaschinski[37] et al reported that when the screen was positioned at or above the straight ahead position (zero point) there was greater eye strain. They recommended that the screen should be positioned between horizontal and 16 degrees downward.

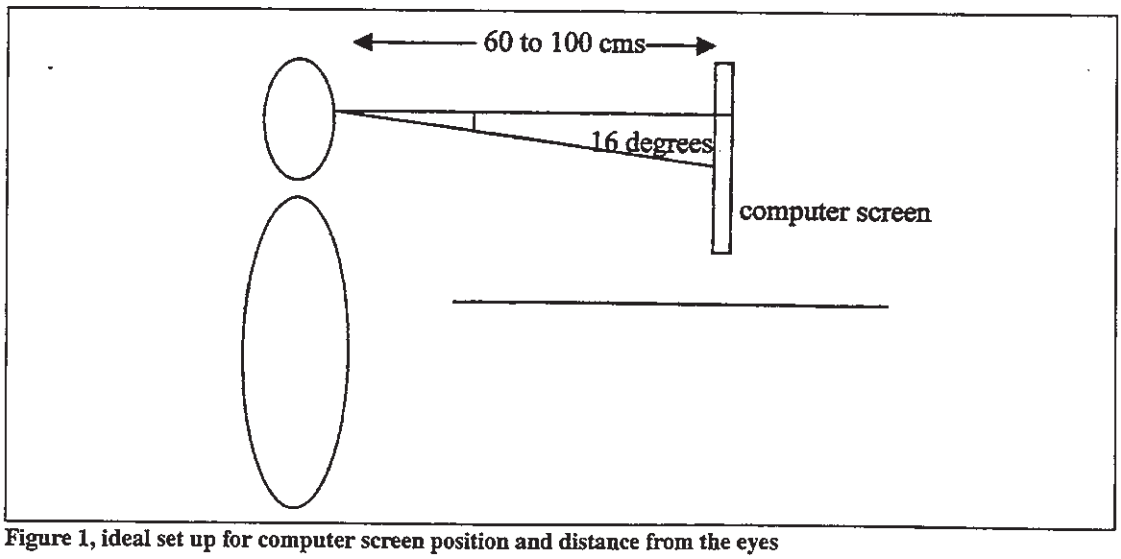

Figure 1, ideal set up for computer screen position and distance from the eyes

The position of the document source is recommended to be next to the computer screen[5,36] which ideally should be between 60 and 100 cms. As with the screen distance it was found that closer positioning of the source document induced more strain[8,37].

Text qualities

Collins et al[21] report screen legibility (character design, size and contrast) influenced the occurrence of visual symptoms. Ziefle[38] reported display resolution on a CRT screen of 60 to 120 dots per inch resulted in decreased performance for proof reading speed and accuracy compared with hard copy of 255 dots per inch. He also found that low resolution (dots per inch) increased fixation time, reaction time and symptoms. Dillon[8] reported less fatigue with low resolution. Miyao[39] found that for small characters high resolution was important for readability. The outcome suggests that overall high resolution of display material allows the user to be more effective and remain comfortable.

Work Station Contamination

Microbial samples taken from work stations showed the presence of bacteria and fungi[40]. Sites from which the samples were taken included the keyboard, mouse and screen. There was also high microbial pollution in the conjunctival sac of computer operators but less in the non-computer operators[40]. These contaminants could cause low-grade discomfort, which may be attributed to computer use or environmental issues such as glare. This result suggests a need for increased attention to the management of computer users with eye infections to prevent ongoing infection.

RISK ANALYSIS - OHS EVALUATION OF COMPUTER USE ON VISION

As mentioned earlier, computers are used for a significant part of the employment hours of many people. The computer has been identified as a potential hazard by professional[5] and union groups[34] Guidelnes for its use have been adopted in the workplace. For instance the Australian Council of Trade Union guidelines[34] recommend that computer users should not spend more than half their working day on computers. Table 1 presents a method of determining the risk level for visual problems arising from computer use. It is based on the document Hazpak which has been developed by Workcover. On the left side of the table are the Measurement Criteria that are used to determine whether a work situation has a level of risk attached to it. In the first Measurement section, "Severity Level Range", there are 4 choices. In the second Measurement section which addresses the "Liklihood of experiencing a severity level", there are 4 choices and in the final Measurement section the "Importance" can be ranked between 1 and 6. When a vision problem is analysed, it is matched to the most likely critera. An example is shown in the right hand columns. The "Severity Level" is minor, the "Liklihood" is minor (unlikely) and the "Importance" is at level 6.

Measurement Criteria	Likely outcome for Vision problems
Severity level range: • likely to kill/ cause permanent disability • long term illness / serious injury • medical attention several days off required • first aid required	Medical attention to manage reasons for discomfort could occur (change in spectacles, orthoptic treatment for convergence insufficiency). Time off from work is likely but only for a portion of a day. The total of days off might be 1 to 3 days
Likelihood of experiencing a 'severity level' range: • very likely • likely • unlikely • very unlikely	Unlikely
Importance of the issue: 1 = extremely important , 6 = may not need your immediate attention	Level 6

Table 1 test for computer use as a hazard based on the Hazpak1 model of analysis

It can be seen from the results that vision discomfort or dysfunction related to computer use is a minor problem. If visual problems arise in association with computer use, the treatment does not cause major disruption to work activities.

EYE COMFORT IN COMPUTER USE

The literature has shown that computer use does not directly affect the health of the eye. The impact of computer use is either to stress / tire the operation of the eyes (accommodation function, binocular single vision function, lacrimation) or to require a change in spectacles to meet the set up of the computer environment (working distance, document source distance). The literature supports appropriate management of the work environment to support comfortable use of the eyes ("time on task", surround light sources). Table 2 presents a summary of strategies, based on information from literature, to support comfortable ocular use for computer users.

Issue	Action
Spectacle correction	• The focal length of presbyopic lenses should be set to meet the working distance of the computer screen – 50 to 60 cms. • Single focus lenses will support eye movement between the screen, the source document and the key board, without having to move the head / neck to position the near add over the focal point
Time on task	Ensure regular breaks form computer use • 15 minutes non computer use every hour[34] • change from computer use to general office duties (telephone duties or consultation with colleagues)[34]
Convergence based aesthenopia	Orthoptic treatment
Lacrimation / dry eyes	• actively increase blink rate[30] • use lubricant drops[27,29]
Surround luminance	• reflection should be eliminated (added screen, change computer position) [5] • avoid light sources in the users field of view[21] • ensure light levels are sufficient to read the key board and source documents[8]
Screen qualities	• Good figure to background contrast[35] • High resolution text (dots per inch) to support speed and accuracy[38]
Computer Screen position	• Between 60 and 100 cms[37] • Between horizontal and 16 degrees downwards[37]
Source document position	• Between 60 and 100 cms[5,37] • At the same level as the screen[37]

Table 2 Strategies to support comfortable vision for computer users

DISCUSSION

This paper has looked at three aspects of computers and their impact on vision. Firstly, what literature has to say about the harm caused by computers and the basis for any visual discomfort that can arise. Secondly, the evaluation of computers as an OHS hazard for the eyes. Thirdly, the strategies that can be implemented to support safe and comfortable use of the eyes when using computers.

Jackson[32] has identified that 5% of computer users who experienced computer related problems have a vision problem, which indicates that the issue is minor. Consideration of all the information from literature supports that the possibility of computers actually causing a change to vision function is minimal. There is no impact from radiation[5,6], computer use does not change any ocular responses such as measurement of visual acuity[9,14,16], the function of the physical components of the eye (retina, cornea, lens[6]) ocular movements and binocular single vision[9,14,17]. There is a reported link between computer use and dry eyes[26,27] which appears in part to be related to use of the eyes in the near position[30]. This is managed by the computer user actively increasing their blink rate or using appropriate drops. There is also some evidence that a transient impact on accommodation occurs but this normalises once computer activity has ceased[12]. Vision discomfort is strongly linked to factors such as time on task[8,33] and intensity of the computer use[10], although it should be noted that all near tasks can be linked to ocular discomfort[8,10,14] particularly if carried out intensively and for a long period of time. Environmental factors such as surround luminance, screen qualities, screen position can be linked to ocular discomfort[9,33,35]. Incorrect or inappropriate spectacles prescription may also cause discomfort particularly when the computer user is presbyopic. The focal length needs to match the screen distance and the near lens needs to be aligned to the position of use.

The information from literature provides support that the impact of computer use on the eyes is unlikely to cause an OHS hazard. Analysis shows that in the event of discomfort arising it is likely to be ongoing, at a low level of annoyance and require medical attention by a non-urgent consultation[1]. Any problems can be managed through a minimal number of appointments and should not total more than one or two days. The liklihood of a computer based vision problem being a major safety issue is minor.

Strategies to assist computer users to be comfortable largely centre on managing the environment rather than managing ocular function. The environmental issues such as surround lighting, organisation of the computer setup, including the

screen presentation and appropriate management of the duration of computer sessions all impact on vision operation and comfort. When these are not in control visual symptoms occur.

When managing a patient experiencing ocular discomfort associated with close work, attention should be given to any existing eye defects and the relevant treatment given. Attention should be also be paid to computer use and the environmental issues that can cause discomfort. Counseling about time on computer task, lighting, computer set up and lacrimation can support comfortable computer use. These relatively simple approaches should ensure ocular comfort for computer users.

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