The effects of reading from different mediums (computer screen and paper) on blink rates and lacrimation.

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Abstract

Aim: To evaluate the difference, in lacrimation levels and blink rates, when reading from a Visual Display Unit (VDU) compared with reading from paper.

Procedure: 27 ocularly healthy volunteers were measured for lacrimation (phenol red thread test) and non-invasive tear film break up time (NIBUT) pre and post- reading. Duration of reading was 50 minutes from both mediums (VDU and paper). Blink rates were recorded during reading and averaged at 10-minute intervals.

Results: The blink rates showed a statistical significant increase when subjects read from the VDU. The results showed no significant difference in lacrimation levels before and after reading from either medium.

Conclusion: People who use computers should be advised that computer use increases their blink rates. It has been proven in previous research that regular computer users have decreased lacrimal counts. Therefore, it is recommended that computers should be placed at a lower height to the eyes with the screen tilted upwards, and people who experience dry eye symptoms should use lubricating eye drops.

Key Words: Visual Display Unit (VDU), dry eye, lacrimation, blink rates, reading, paper, computer terminal.

Introduction

Since their introduction into the community, computers have played an increasing role in daily activities and office work, replacing conventional bookwork and reading activities for many people.[1] Computers, as a relatively new technology, are frequently blamed for ocular problems and for this reason should be managed appropriately and in a different way to other near activities.[2] Computer work and conventional bookwork both require reading for extended periods at a position close to the eyes. Therefore, the usage of the two mediums will be considered as near activities. However computer work is generally performed in primary position, at a medium distance (50–70cm), whereas bookwork is usually performed in depression and at a closer distance (30–40cm).[3] Computers are also light emitting, while paper is light reflective. If these two activities require reading in the close position then similar symptomology should occur and general advice for management of near activities can thus be given. However, if symptomology is different then people should be advised to adjust when reading from either computer or print.

Participants in an OHS (Occupational Health and Safety) vision screening program[4] reported working with computer screens for a high percentage of their work day (5-8 hours). In response to the increased use of computers in the workplace and reports of ocular discomfort with use, a number of anecdotally based documents advising people how to use a VDU have been generated throughout the World Wide Web. These educative documents describe many symptoms that can be associated with computer use such as sore, tired, red and dry eyes, burning sensations, fatigue and blurry vision.[3,5-8] Twombly[5] assumes that computer use causes decreased blink rates. Evidence based articles have shown that symptoms associated with computer use usually occur after 50 minutes of activity.[6,9] Tsubota, Nakamori, Miyake, Matsumoto and Shintani[10,11] states that VDU work is one of the main causes of decreased blink rates.

Dry eye, according to Lemp and Marquardt[12] can be caused by a dysfunction in any of the three differing functional layers of the tear film. The outer lipid layer of the tear film prevents evaporation of the underlying aqueous layer, while the middle aqueous layer contains lysozymes, which nourishes and protects the cornea from invading organisms. The layer closest to the cornea is the inner mucous layer. This layer stabilises the tear film by coating the hydrophobic corneal surface with a hydrophilic layer, over which tears can spread and adhere to the cornea. The tear film covers the outermost surface of the cornea and eye.[13] Constant lubrication of the cornea is essential to maintain its optical surface. If the cornea is not kept wet, it rapidly dries and symptoms of dry, gritty, heavy eyes and occasional blurring can occur. If dry eye becomes a serious condition and no treatment is sought, the cornea can scar and result in blindness.[13] Another natural response is for the tear film to decrease with age.[14]

Asthenopic symptoms are reported to occur when reading print presented on paper[15,16] but there is no reference to the existence of dry eye associated with this activity. This would suggest VDU use specifically causes dry eye problems. In a study by Nakaishi and Yamanda,[17] VDU users with and without asthenopic symptoms were compared. The occurrence of dry eye was more apparent in VDU workers with symptoms.

Yaginuma, Yamada, and Nagai[18] conducted a comparable experiment involving VDU users and non-VDU users (controls). Both groups carried out VDU work for 120 minutes while the experimenters measured blink rate and lacrimation. Lacrimation refers to the production of the aqueous layer of the tear film produced by the lacrimal gland. From the results, they reported that lacrimal secretion rates in the control group, were normal (20.5mm of wetting on the phenol red thread test [PRTT]) before VDU work and decreased after VDU work (18mm).

It is important to note that VDU users in general tend to have drier eyes at base line (10-11mm average). The amount of dryness changes for users hence non-VDU users developed drier eyes when using the computer, while VDU users continue to have the same level of dry eyes.[18] The authors suggest that accumulated VDU operation for consecutive days may create an abnormality in the oily layer of the tear film resulting in increased evaporation of the tear film and dry eye.[18] This raises one aspect of the normal function of lubrication of the eye; another aspect is blink rates.

The blink rate is an adaptive response to dry eyes. Blinking is essential to wipe the cornea free from debris and to keep the tear film evenly spread.[13] Blink rates can vary due to many different reasons including increased tear evaporation, ocular surface drying, and psychiatric conditions. As a person gazes (stares) they blink less and as a result, tears evaporate causing dry eye.[18] Additionally, blink rates can increase as a result of dry eye. Thus, as eyes become dry, a person will blink more frequently to attempt to increase lubrication. Increased blink frequency has been shown to be correlated with reduced tear film break up time (BUT).[12] Therefore, during the course of reading or concentrating on a task (gaze), a person may have decreased blink rates, and as their eyes become relatively dryer, they will increase their blinking to lubricate the eye more, and enhance ocular comfort.

Several researchers have investigated the effects of near activities including VDU and hard copy reading on subjects' blink rates.[9,10,18,19] The research investigated a range of variables including distance (accommodation), height, mediums, time on task, lacrimation, and physiological fatigue. In two separate studies[18,20] the relationship between blink rates and lacrimation associated with VDU work was investigated. Overall, it was found that blink rates are increased when reading from a VDU. Nakamori, Odawara, Nakajima, Mizutani, and Tsubota[20] account for the increased blink interval (decreased blink rate) in terms of being a response to the ocular surface drying.

Mourant, Lakshmanan, and Chantadisai[19] compared VDU search tasks to hard copy and measured physiological fatigue through accommodation and blink rates. They found that two hours of VDU use produced measurable fatigue in the accommodation mechanism of the eyes and higher blink rates (4.94 mean). Such visual fatigue was also present in the hard copy task (3.76 mean) but to a lesser extent. Mourant et al.[19] account the increased blink rates to be suggestive of the ocular muscles being more highly stressed when viewing VDU characters.

Tsubota and Nakamori[10] compared paper reading and VDU reading and its effects on tear film. They found that blink rates decreased when viewing text on the computer screen (7 per minute) and increased when reading a book (10 per minute) at table height, and were higher still when subjects were under relaxed conditions (22 per minute). Tear evaporation was also evaluated and it was found that there was an increase in tear evaporation when VDU viewing was performed. It is important to note that the subjects' blink rates could have been affected by the position of gaze for the three situations as investigated by Cho, Sheng, Chan, Lee, and Tam.[21] Tsubota et al.10 mention that tear evaporation increases with increased ocular surface area. Since the subjects performed the activities at different heights, i.e. VDU work at primary position and reading in depression, then the evaporation of the tear film could be due to the difference in height of the two mediums. This identifies a need for research which investigates tear film and blink rates when reading from the two mediums at the same height and distance from the subjects.

Whilst the symptoms of dry eyes and reduced blink rates have been investigated in relation to VDU use,[5,7,17,18,22,23] limited research has been undertaken in relation to the parallel near activity of reading. Therefore, these two symptoms form the basis of this study which aims to investigate whether there is a difference in blink rates and tear production as elicited in two situations: (1) when reading from a computer specifically, and (2) when engaging in general near activities as represented by reading from paper. The following research questions were explored.

Are the measurements of lacrimation, as tested with the phenol red thread test (PRTT) and the non invasive tear film break up time (NIBUT), the same when reading from paper as compared to when reading from a computer?

Does blink rates differ when reading from paper in comparison to reading from a computer?

Blink rates may increase or decrease while reading from both mediums, but computer work may show a higher increase.[18,19] Even though research has been conducted in this area, the variables of accommodation and distance have not previously been controlled. Therefore, blink rate was also examined when reading from the two different mediums.

METHOD

Sample

A total of 27 volunteers were recruited via convenience sampling. Each subject was provided with an information sheet detailing the procedures and signed the informed consent form. Ethical issues were resolved by using the least invasive measurement methods of lacrimation as possible, for example the phenol red thread test was used for the comfort of the patient instead of the more invasive Schirmer's tear test. To ensure there was no age related impact which could interfere with near performance (e.g. presbyopia and an increase in dry eye) the age range of the subjects was limited to between 18 and 31 years with a mean of 22 years (SD, 3.07) (19 females and 8 males). A history was taken to ensure good general and ocular health. Normal ocular function was ensured by subjects having an unaided Snellens visual acuity of 6/6 and N5 near vision, bifoveal BSV, a deviation which measured less than +/- 8 prism dioptres in the near position, full convergence (=< 5cm, with the royal air force [RAF] rule), and no anomalies of accommodation (RAF rule with N5 print). Red reflex and Slit lamp examinations demonstrated an absence of any obvious eye abnormalities.

Materials and apparatus

In order to provide an accurate measure of blink response a video camera was used. The frequency of each subject's blink was recorded on video.

The dryness of the eyes was measured with two tests: the non-invasive tear film break up time (NIBUT) and the phenol red thread test (PRTT). The NIBUT was chosen because it is a rapid way of assessing the quality of the tear film and it is non invasive. NIBUT was chosen because it does not use fluorescein and there is less chance of a reduction of tear film stablility.[24]

The PRTT was used for the measurement of lacrimation. The PRTT was selected because it is fast to use (15 seconds instead of 5 minutes) and less irritating for the eye particularly compared to the Schirmer's tear test.[17,25]

The NIBUT was measured first and then the PRTT. After testing the first 18 subjects it was found that excessive lacrimation was occurring in some subjects after performing the NIBUT which possibly compounded the PRTT results. A further nine subjects were tested in the opposite order (PRTT then NIBUT) to investigate the order effect of the two tests.

Procedure

A preliminary assessment was conducted to ensure that the criteria for inclusion in the study were met. The subjects were randomly assigned into two groups. Group one read from a computer for 50 minutes on the first visit and on the second visit they read from paper for 50 minutes; group two read from the different mediums in the reverse order. The subjects were exposed to each of these media for 50 minutes to comply with the reported onset of discomfort occurring with VDU use after 50 minutes.[6,9]

In order to undertake the reading tasks the subjects were set up in front of a cathode ray tube screen with 60cm between the subject and the screen. The distance was 60cm because this is the average distance at which a subject will prefer to read from a computer.[23] The same distance (60cm) and height was placed between the subject and the paper so that variations in distance and gaze height would not affect blink rates.[21] A head-rest was used to maintain head height and distance. Room environment was controlled (curtain and illumination constant). Across test sessions, tests were conducted in the same air conditioned room to control for humidity and temperature and its impact on tear film evaporation.[12] Ambient temperature was recorded as being between 22.1–24.6°C, and humidity between 33–49% (using a digital thermometer and humidity analyser). Subjects were asked to scroll through the material on the computer in a way that mimicked reading from paper (reading from the top of the screen down to the bottom then scrolling the material to the top). The reading material included National Geographic articles which were at a maximum of an 11th grade Flesch-Kincaid Grade Level score. After reading the material, the subjects were asked what they learnt from the material read. This was to ensure attention was kept at a high level whilst reading.

Whilst reading from both mediums, the frequency of blink of all subjects was recorded on video. A blink is defined as the complete covering of the cornea by the eyelid. Blink rate is the number of blinks that occur in a minute. The blinks were recorded and averaged at six, three-minute intervals: 0-3min, 9-12min, 19-22min, 29-32min, 39-42min and 47-50min. These blinks were then converted into a blink rate for the six different times.

Lacrimation and NIBUT was measured in each subject pre and post-reading from both mediums. Non-invasive tear film break up time is a measure of tear stability. The NIBUT was performed by using the Slit lamp on the widest aperture and dimmest light source at a 15-degree angle temporally focussing on the tear film. Each subject was asked to blink three times before keeping their eyes open for measurement of the NIBUT. The NIBUT was recorded as the interval between the last complete blink and the development of the first dry spot over the central part of the cornea,[12] or at the point at which the patient blinked or produced reflex tearing. The test was repeated three times for each eye and the average score was calculated. Normal values are above 25 seconds and a NIBUT of less than 10 seconds is considered abnormal.[26]

Lacrimation was measured using the PRTT. The PRTT was performed by placing the 3mm bent end of the thread into the inferior conjunctival sac on the temporal side of the eye. The patients were instructed to look straight ahead and blink normally whilst the thread was left in place for 15 seconds.[17,25] The length of colour change was measured in millimetres. The average wet length for normal eyes is approximately 17mm, and dry eye is defined as less than or equal to 10mm wet length.[17]

Design analysis

To investigate a possibility of dry eye occurring when reading from the two mediums (computer and paper), descriptive statistics were initially calculated on the PRTT and NIBUT results, and the distributions were examined for normality. Because the NIBUT data was skewed and not normally distributed, the non-parametric Wilcoxon Signed ranks test was used to test the hypothesis. To examine the PRTT results a two-factor repeated measures analysis of variance was performed on the data. The two factors were medium (VDU or Paper) and time (before and after).

To investigate the pattern of difference of the blink rates over time when reading from the two mediums an ANOVA with planned orthogonal contrasts was employed. The factors were medium (VDU or paper) and time (1, 10, 20, 30, 40, 48 minutes).

RESULTS

Preliminary Analysis; Order Effects

No significant order effect was found from the difference of scores when either BUT or PRTT was performed first. The test order scores are recorded in Table 1 for right and left eye (Table 1). Accordingly, order was not considered in further analyses.

Table 1 Mean rank NIBUT differences for order of testing

ORDER EFFECT	Test order	N	Mean Rank	Z=	P=
NIBUT RE VDU Difference	BUT 1st	18	12.28	-1.595	0.111
	PRTT 1st	9	17.44		
NIBUT LE VDU Difference	NIBUT 1st	18	12.94	-0.977	0.328
	PRTT 1st	9	16.11		
NIBUT RE Paper Difference	NIBUT 1st	18	13.56	-0.412	0.681
	PRTT 1st	9	14.89		
NIBUT LE Paper Difference	NIBUT 1st	18	12.22	-1.646	0.100
	PRTT 1st	9	17.56		

Phenol Red Thread Test (PRTT)

This section tests HA 1:

Phenol red thread test (PRTT) mean in paper reading is not equal to the mean in VDU reading.

To test HA 1 a two-factor repeated measures analysis of variance was performed. No significant difference was found between the two mediums (VDU and Paper) (right eye $F_{1,26} = 0.29$, $p = 0.595$, left eye $F_{1,26} = 0.25$, $p = 0.62$). No significant difference was found between the results from before reading to after reading (right eye $F_{1,26} = 0.0$, $p = 1.00$, left eye $F_{1,26} = 0.937$, $p = 0.342$). No significant interaction was found between the two mediums and time (right eye $F_{1,26} = 1.883$, $p = 0.182$, left eye $F_{1,26} = 0.703$, $p = 0.409$). Therefore, for PRTT results the null hypothesis is accepted.

Overall, when looking at Figures 1 and 2 it appears that there is an increase in lacrimation after reading from the VDU and a decrease in lacrimation when reading from paper. This difference is very small (2mm) and is not significant. Table 2 shows the descriptive statistics for PRTT results.

Figure 1 Right eye PRTT before and after reading (VDU vs Paper)

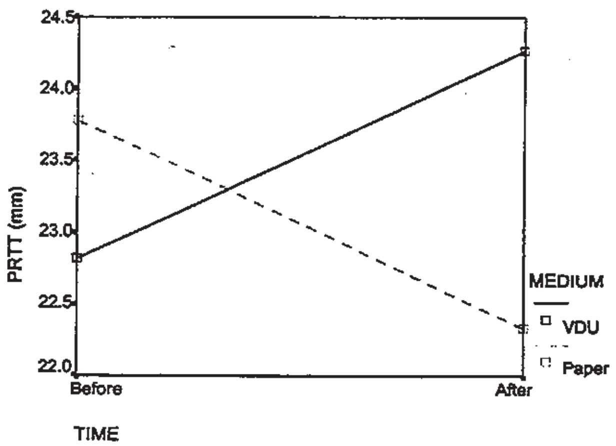


Figure 2 Left eye PRTT before and after reading (VDU vs Paper)

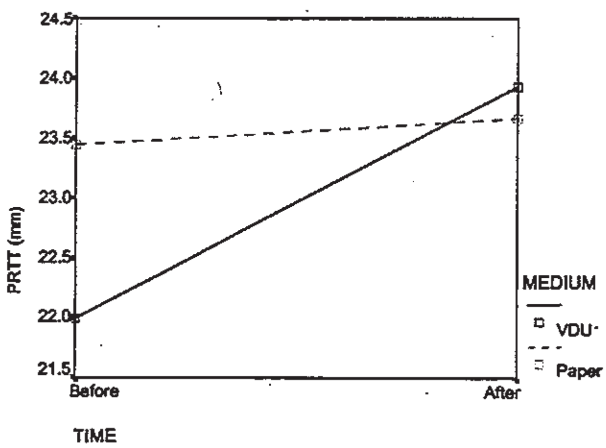


Table 2
Mean PRTT scores and standard deviations for right eye and left eye for VDU and Paper, before and after reading.

PRTT (mm)		Right		Left	
		Before	After	Before	After
VDU	M	22.81	24.26	22.00	23.93
	sd	7.2	6.91	8.64	7.88
Paper	M	23.78	22.33	23.44	23.67
	sd	6.10	7.97	7.27	8.29

M= Mean

Non invasive tear film break up time (NIBUT)

This section tests HA 2:

Non invasive tear film break up time (NIBUT) median in paper reading is not equal to the median in computer reading.

Table 3 displays results of NIBUT for paper and VDU. As the entire NIBUT results were highly skewed a Wilcoxon Signed Ranks Test was applied to analyse the results. The NIBUT results after reading appeared to be slightly larger than the NIBUT scores before reading but this difference was not significant. As can be seen from Table 3 no significant difference was found in the NIBUT results between reading from the computer or from paper. Therefore the null hypothesis is accepted, there is no significant difference between reading from computer or from paper in regard to NIBUT results.

Table 3
Median NIBUT scores and ranges for right eye and left eye for VDU and paper, before and after reading

NIBUT (sec)		Right Eye			Left Eye		
		Before	After	Difference Sig.	Before	After	Difference Sig.
VDU	Median	15	15.3	Z= -0.312	25	12.9	Z= -1.345
	Range	4.9 - 122.9	3.7 - 116.1	P= 0.755	4.6 - 100.9	5.2 - 98.8	P= 0.178
Paper	Median	13	13.9		14.7	14.8	
	Range	6.3 - 156.9	5.4 - 93.1		6.7 - 138.7	5.8 - 209	

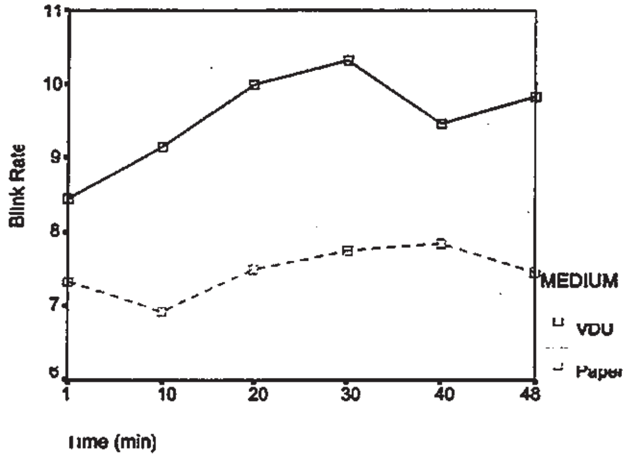
Blink Rates

The blink rates for VDU and paper were averaged at approximately 10-minute intervals (1, 10, 20, 30, 40, 48 min). The results were examined for normality. A portion of the averaged data was slightly skewed but the within-subjects contrasts are not affected by slight skewness.

After performing the within-subjects contrasts the test showed that there is a significant difference ($F_{1,26} = 6.689$, $p = 0.016$) between reading from a computer in comparison to reading from paper with regard to blink rates. The subjects' blink rates were higher when reading from a computer (Figure 3). There were no interactions between medium and time, indicating that the difference between the mediums was the same at all times.

The subjects in this sample had a peak in blink rate at 30 minutes after commencement of reading from a VDU. However, because the change in blink rates over time was not significant for a quadratic effect ($F_{1,26} = 2.647$, $p = 0.116$) only the subjects in the sample have a peak at 30 minutes and this peak cannot be applied to the total population.

Figure 3 Averages of blinks vs time via mediums



DISCUSSION

The current study demonstrates an important association between blink rates and the use of different mediums when reading. There was a statistical significant increase in blink rates when subjects were reading from the VDU. On the contrary, there was no significant difference found for both of the dry eye tests results (PRTT and NIBUT) pre and post-reading when subjects read from either medium. Although due to the low number of subjects in this study, it is possible that these non-significant results could be a type II error.

The significant increase in blink rates when subjects read from a VDU has been both supported[18-20] and condradicted[10] by previous research. Mourant et al.19 and Yaginuma et al.[18] found similar findings of increased blink rates with VDU work, when they compared hard copy search tasks to VDU search tasks. Nakamori et al.[20] found that VDU use was associated with decreased maximum blink intervals (increased blink rate).

The research of Tsubota et al.[10] presented a conflicting result. They found VDU users blink less when reading from a VDU. However, their study did not control for reading distance and therefore accommodation when subjects read from both mediums. They did not control for the effect of position of gaze on blink rates as found by Cho et al.[21]. Although Tsubota et al.[10] found decreased blinking when the subjects read from the computer in the primary position and increased blinking when subjects read from paper in depression, the research of Cho et al.[21] found that in the primary position people should blink more than when their eye position is in depression. The results of the current study were that blinks increased when reading from the VDU and decreased when reading from the hardcopy form. However, as seen in the current study, accommodation and height were controlled by the subjects using a head rest. The results from the current research may be more reliable because more variables were controlled.

There may be many reasons as to why the blink rates increased when subjects read from the VDU. Such reasons include the light source of the two mediums, increased concentration levels when reading from paper, time on task, and age of subjects.

Variability in blink rates across the two mediums may have differed due to the light source of the two mediums. Computer screens are light emitting whereas paper is a light reflective medium. Increased blink rates, when the subjects read from the computer, may have been due to this light-emitting factor. The computer screen was brighter and had light flicker which could have produced a more irritative effect on the eyes causing the subjects to blink more. Conversely, the subjects in this study may have blinked less when reading from the paper version because there was decreased light reflecting from the paper, a possibility supported by the research of Tsubota et al.[27] who found that blink rates decrease with decreased illumination.

Many researchers have associated decreased blink rates with increased concentration and difficulty of activity.[10,18,27] In this study the decreased blink rates found when subjects read from paper may have been due to increased concentration levels. The subjects were exposed to an unnatural situation. The paper-reading situation was set up to mimic reading from a computer. Usually people read from paper at a much closer distance and at a lower height than what was the case in the reading situation. The subjects may have found that reading from the paper form was more difficult; they may have stared for longer periods, and therefore produced a lower blink rate. Further research should investigate if a closer distance would change the blink rates when reading from the two mediums.

Mourant et al.[19] found a statistically significant increase with time on task when performing visual search tasks on VDU and paper. Mourant et al.[19] account for the increase in blink rates with time on task causing fatigue in the human visual mechanism. However this research did not find any statistical significant difference between the 2 mediums for time on task.

Decreased blink rates can cause the eye to be susceptible to drying, and increased blink rates can be a reaction to the eyes becoming dry. However, if the tear film is stable low blink rates can be sufficient to prevent desiccation of the normal ocular surface.[28] It has been found previously that there is an increased incidence of decreased lacrimation, and decreased blink rates among more mature people.[14,19] As the subjects of this study were of a relatively young age (mean 22 years), their lacrimal production would have been sufficient to counteract the drying effect that the computer had on the eyes by increasing their blink rates. Inversely, the blink rates were reduced when subjects read from paper because there was a less drying effect on the eyes; subjects then blinked the required amount to lubricate the eye sufficiently. Further research on older subjects would be required to examine how their blink rates and lacrimation levels change when reading from different mediums. It is likely that older subjects wouldn't be able to overcome the drying affect that computer reading would have on the eyes because their lacrimal systems are insufficient.

Although the current study did not demonstrate any decrease in lacrimation (PRTT and NIBUT), previous work in the area[18] has shown a decrease in lacrimal counts, after reading from a computer, in those people who are non-computer users. Yaginuma et al.[18] found that computer users have decreased lacrimation levels at baseline. A computer user is defined as a person who uses a computer for a minimum of four hours per day for six months.[18] The subjects in the current study had varying amounts of computer use per day. The average amount of computer use by subjects of the current study was three hours per day but this range varied such that some subjects hardly ever used a computer and others regularly used a computer for up to eight hours per day. Therefore, because this extraneous variable (average hours of computer use) was not controlled for in the current study, it may have influenced the lacrimation test results. It would also be beneficial to replicate this research using increased illumination on the paper, so that luminance levels from the two mediums are roughly equal. Further research into the area of computer usage would be beneficial. The period of time required at the computer to produce decreased lacrimal counts could be investigated, for example. Also it would be valuable to find out how long a computer user needs to stop using a computer in order to regain baseline normal lubrication. This further research may have implications for occupational health and safety standards.

CONCLUSION

Contrary to advice given by Twombly[5] that people using computers should blink more often, the current study found that people are already increasing their blink rates when using computers. Rather than suggesting that people should change their behaviour when using computers, they should be supported in their present and typical action (blinking more). It is therefore needful to encourage people to continue to blink normally because it is a natural response to increase blink rates when reading from a computer.

Previous research has found that computer users have drier eyes than non-users.[18] Therefore it is suggested that people who use computers should place the screen at a lower height to the eyes, with the screen tilted upwards.[10,28] This decreases the surface area exposed and thus decreases tear film evaporation. If a patient is complaining of dry eye symptoms when using a computer they should be managed appropriately by using ocular lubricants.

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