Current Eye Research, 36(3), 190–197, 2011

ISSN: 0271-3683 print/ 1460-2202 online
DOI: 10.3109/02713683.2010.544442

informa
healthcare

ORIGINAL ARTICLE

Blink Rate, Blink Amplitude, and Tear Film Integrity during Dynamic Visual Display Terminal Tasks

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ABSTRACT

Purpose: The present study aimed at investigating the influence of the level of dynamism of two different visual display terminal tasks on spontaneous eyeblink rate, blink amplitude, and tear film integrity.

Material and Methods: A total of 25 healthy, young volunteers participated in the study. Blink rate and blink amplitude were recorded in silent primary gaze conditions and while subjects were playing two computer games of similar cognitive demands but different rate of visual information presentation. For each experimental condition, tear volume was evaluated by measuring meniscus height and with the red phenol thread test. Fluorescein and non-invasive break-up time tests, as well as the observation of interference patterns and the estimation of the dry area extension, were employed to assess tear stability.

Results: Statistically significant differences were revealed in blink rate ($F = 595.85$, $p < 0.001$) and blink amplitude ($\chi^2 = 34.00$, $p < 0.001$), with blink rate during fast- and slow-paced game play decreasing to almost 1/3 and 1/2 of baseline levels, respectively, and with a larger percentage of incomplete blinks during dynamic tasks. Fluorescein and non-invasive break-up time tests and dry area extension were able to differentiate between experimental conditions in general ($F = 408.42$, $p < 0.001$; $F = 163.49$, $p < 0.001$; $\chi^2 = 20.74$, $p < 0.001$), as well as between fast- and slow-paced games, thus suggesting that tear quality was more affected than tear volume.

Conclusions: Blink rate, blink amplitude, and tear film stability were compromised during the most dynamic visual display terminal task, suggesting a negative influence of not only the cognitive aspects of the task, but also of the rate at which new visual information is presented. Frequent breaks and blinking awareness training are recommended for visual display terminal users requiring prolonged periods of visually demanding dynamic computer play or work.

KEYWORDS: Dry eye; Eyeblink; Tear break-up time; Visual display terminal; Visual fatigue

INTRODUCTION

The number of personal computers in use around the world had surpassed the 1 billion mark in 2008, with strong growth in emerging markets set to double this number by early 2014. Nowadays, computers are not restricted to the workplace. Users of visual display terminals (VDT) commonly complain of symptoms of musculoskeletal discomfort, stress, somatic disorders, and visual fatigue.[1–4] Visual fatigue among VDT users was first documented by Hultgren and Knave in 1974[5] to describe a constellation of symptoms, later

Received 02 October 2010; accepted 28 November 2010

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grouped under the term "Computer Vision Syndrome" (CSV),[6–10] including eyestrain, tired eyes, irritation, burning sensation, dry eye, redness, blurred vision at near and double vision. These symptoms have been found to depend on the number of hours of VDT exposure,[11,12] distance from the screen,[13,14] screen type (CRT versus LCD),[14,15] and environmental factors, such as background luminance; glare sources; and room humidity, temperature, and ventilation;[16–18] among others.

Dry eye is considered as the most frequently reported ocular complaint in VDT users.[1,19] As such, it has been associated with an alteration in blinking patterns (frequency, amplitude, and interblink regularity) and with a major palpebral aperture, determined by screen position, both resulting in larger exposure of the ocular surface and increased tear film evaporation and instability.[20–26]

Spontaneous eyeblink rate (SEBR), although presenting a high intersubject variability, is believed to be initially governed by some central pacemaker, with further refinement and modulation by a range of external factors and internal co-regulators.[21] Thus, whereas corneal trigeminal terminals have been observed to respond to surface drying and irritation by increasing blink rate, and the instillation of topical anesthetic or elastoviscous artificial tears has been found to lower SEBR,[22,23,27,28] these external factors seem to be at least partially inhibited by internal modulators closely related to the complexity of the visual task, that is, to attention or cognitive aspects. Indeed, SEBR has been found to increase from 4.5 blinks/min while reading to 17 blinks/min at rest, with a further increment to 26 blinks/min during conversation.[29] Doughty reported similar changes in SEBR,[21] while describing a significant difference in eyeblink patterns between tasks, with eyeblinks during conversation displaying a highly irregular behavior in which most eyeblinks were grouped into short sequences.

Blinking in VDT users has been studied both in general and in task-oriented conditions. Acosta and coworkers[22] noted a 42% reduction in blinking rate when subjects performed an attentive computer task, with independence of the actual duration of the task (10 or 30 min). Similarly, a reduction of 33.5% in SEBR was encountered by Freudenthaler et al.,[23] although these authors opted for measuring baseline SEBR during casual conversation, which has been found to increase blink rates. Skotte and coworkers[24] measured SEBR during two different computer tasks: passive watching of a film and an interactive task requiring subjects to connect a sequence of small dots. These authors described a change from 16 blinks/min to 5 blinks/min when comparing passive and active tasks, respectively. Himebaugh et al.[26] recorded SEBR and blink amplitude of healthy and dry eye subjects while performing four different tasks, defined as either low concentration (looking at a blank computer screen and watching a movie) or high concentration (playing a computer game and viewing a series of rapidly changing letters) VDT tasks. They encountered reduced blinking rates, more pronounced in healthy than dry eye subjects, during high concentration activities and described a higher fluctuation in SEBR during the computer game trial, with an associated blink amplitude of about 50%, an absence of full blinks and a consistent inferior area of tear break-up.

It is interesting to note that blinking is associated with visual suppression, not only during the actual blink interval, but also occurring 50 to 100 ms before a blink, and outlasting it by an additional 100 to 150 ms, that is, it may be assumed that about 400 ms of time are lost per blink.[30,31] Besides, the degree of visual suppression has been found to increase with blink amplitude.[32] Therefore, the correct regulation of blink timing may be of capital importance to prevent the loss of critical information from the uninterrupted flow of visual input, as has been revealed by a recent study by Nakano and coworkers.[33] It may be speculated whether, given VDT tasks of equivalent complexity or cognitive demands, blinking rate may be further influenced by the frequency in which new information is displayed on the screen and presented to the observer.

The aim of the present study was to explore SEBR and blink amplitude of healthy subjects during two VTD tasks of similar concentration requirements but different rate of visual information presentation. In addition, tear film integrity was assessed in order to determine whether SEBR and blink amplitude alterations resulted in detectable changes in tear volume and/or stability.

METHODS

Subjects

A total of 25 healthy volunteers (12 males, 13 females) aged between 21 and 28 years (mean age 24.4 years; SD = 1.66 years) were enrolled in the study. None of the participants had been previously diagnosed with dry eye, nor presented any significant complaint of ocular dryness and irritation (mean self-reported Ocular Surface Disease Index score of 12.64; SD = 4.23). All participants had binocular corrected distance and near visual acuity ≥ 1 and were asked to refrain from wearing contact lenses from one week prior to baseline measurements through the duration of the study. Exclusion criteria were manifest or latent binocular visual imbalance, color vision anomalies, existing ocular pathology, ongoing ocular treatment or use of artificial tear substitutes and history of ocular or refractive surgery.

Participants were occasional players of computer games and had some experience in games comparable to those employed for the purposes of the present study. Time allocation to computer work and entertainment was similar among all subjects.

All participants provided written informed consent after the nature of the study was explained to them. The study was conducted in accord with the Declaration of Helsinki tenets of 1975 (as revised in Tokyo in 2004).

Experimental Setting

Blink rate, blink amplitude and tear film integrity were evaluated in baseline conditions and during two different VDT tasks. Baseline conditions (BL) were defined as those in which subjects, while seated and not engaged in conversation, were directing their gaze to a distant target with the line of sight, in accordance with the recommended procedure for baseline measurements proposed by other authors.[21] VDT tasks required subjects to play two different computer games: Quake III Arena (id Software, Mesquite, Texas, US) and Age of Empires II (Ensemble Studios, Dallas, Texas, US). Quake III Arena (G1) is a fast-paced multiplayer first-person shooter 3D game in which players run through maze-like environments and simultaneously fight multiple opponents with a variety of weapons in order to score as many *frags* as possible in a limited time (Figure 1). Age of Empires II (G2) is a slow-paced real-time strategy 2D isometric game which focuses on gathering resources, building and defending towns, amassing an army, and eventually conquering rival towns while advancing the player chosen civilization through the ages (Figure 2). Both games were displayed on a 20 inch liquid crystal display (TFT-LCD) computer screen set to a resolution of 1280 per 1024 pixels, 32 bit color configuration, and 75 Hz refresh rate. Display luminance was adjusted to an equivalent level for both experimental gaming conditions. Games were played without sound and with the aid of a keyboard and mouse combination.

Subjects viewed the display from a distance of 50 cm with head fixed in a chin and forehead rest, which height could be adjusted, as well as that of the chair and computer desk, to ensure subject comfort and to align the centre of the screen at the level of the subject's eyes. The inclination angle of the screen was of 100 degrees from the plane of the computer desk.

Room illuminance was provided by indirect lighting in order to avoid any glare sources, and was maintained at about 300 lx. Room temperature and humidity were constantly monitored throughout the experimental sessions and remained stable at 22.5 ± 0.5°C and 48.2 ± 2%, respectively.

Procedure

After an initial examination, which served to define our final sample, SEBR, blink amplitude and tear film integrity were evaluated in three separate sessions at approximately the same time of day and with a rest period of 7 days between sessions. During each session subjects were randomly allocated to BL, G1, or G2 experimental settings until all participants had been examined in all conditions. At G1 and G2 experimental settings subjects were instructed to play the respective computer game during 20 min.

Blink rate and amplitude were recorded with a digital video camera set at 25 images per second, fixed to the frame of the monitor during G1 and G2

FIGURE 1 Screen capture of Quake III Arena (id Software).

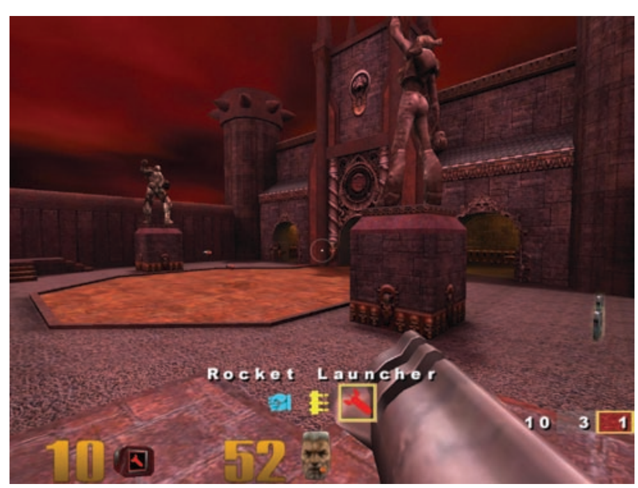

FIGURE 2 Screen capture of Age of Empires II (Ensemble Studios).

and concealed elsewhere during BL. Subjects were not actively told that their eyeblinks were being recorded. Blink rate and amplitude were measured over a period of 5 min (corresponding to the minutes 15 to 20 of playing time during G1 and G2 experimental conditions, and following a minimum of 10 min of acclimatization time for BL conditions). Blink rate included complete and incomplete blinks, in which a complete blink was defined by a downward movement of the upper eyelid covering more than 75% of the cornea. Minor twitches of the upper eyelid, covering less than 30% of the cornea, were not taken into account to determine SEBR. Blinks covering between 30 and 75% of the cornea were counted as incomplete blinks.

At the end of the baseline session and immediately after the completion of the 20 min G1 or G2 VDT tasks, subjects underwent a battery of standard clinical tests of tear film evaluation. These testing procedures, which are well described in published literature, were performed in the following order: tear meniscus height measurement,[34] non-invasive break-up time (NIBUT) and interference patterns evaluation[35] (Tearscope®, Keeler Ltd., Windsor, UK), phenol red thread test[36] (Zone-Quick, Showa Yakuhin Kako Co., Ltd, Tokyo, Japan and Menicon, Spain), fluorescein tear break-up time (BUT) measurement[37] and corneal dry area estimation (observed with a n. 12 yellow Wratten filter).[38] Corneal dry area was defined as the ratio between the total exposed cornea surface and the actual area of tear break-up, and graded in a 0 to 3 scale. At the end of the study all participants were asked to report in which experimental setting (G1 or G2) they felt less comfortable in terms of visual fatigue and ocular dryness.

A sole, skilled optometrist viewed and scored all video recordings and performed all tear film evaluation tests in order to prevent any between-examiner variability that could arise from multiple examiners. The examiner was masked to the experimental conditions (BL, G1, or G2) that each particular subject had been allocated to.

Data Analysis

Statistical analysis of the data was performed with the SPSS software 17.0 for Windows. All data were examined for normality using the Kolmogorov-Smirnov test. No statistical difference could be found between right and left eyes. Therefore, data from right eyes was arbitrarily chosen for statistical purposes. Comparisons between BL, G1, and G2 experimental settings were performed with an analysis of variance test (ANOVA) for repeated measures and, whenever a main effect reached statistical significance, post-hoc pair-wise comparisons were explored with a Bonferroni analysis. The Mauchly's test was employed to evaluate the assumption of sphericity and the Greenhouse-Geisser correction was applied when necessary. The non-parametric Friedman's test for repeated measures and the Wilcoxon signed-rank test were used to evaluate the differences between experimental settings in corneal dry area extension, interference patterns, and blink amplitude. Pearson and Spearman's rho correlation tests were employed to determine the relationship between SEBR and blink amplitude and the clinical dry eye tests. Choice questions were submitted to a Chi-square test. A p-value of 0.05 or less was considered to denote statistical significance throughout the study.

RESULTS

Tables 1 and 2 provide a summary of the recorded blink rates and blink amplitudes, as well as of the results of the various clinical tear film evaluation tests, as measured at baseline conditions and while participants were playing computer games with high (G1) and low (G2) rates of visual information presentation. Statistically significant differences were revealed between BL, G1, and G2 for both SEBR ($F = 595.85$; $p < 0.001$) and blink amplitude ($\chi^2 = 34.00$; $p < 0.001$), with SEBR at G1 and G2 decreasing to almost one-third and one-half of that recorded at BL, respectively. The percentage of incomplete blinks also increased from BL to G2 and to G1, although while SEBR displayed a statistically significant difference between G1 and G2, blink amplitude differences between both game conditions failed to reach statistical significance.

Clinical tear film tests commonly considered to assess tear volume, that is, meniscus height evaluation and the phenol red thread test, were found to offer contradictory results. Indeed, whereas statistically significant differences in meniscus height ($F = 27.71$; $p < 0.001$) were found between the three testing conditions, the results for the phenol red thread test were similar at BL, G1, and G2. A post-hoc Bonferroni analysis of the meniscus height measurement data, however, disclosed that this test was only capable of differentiating between BL and G1 and between BL and G2, but considered G1 and G2 experimental settings to be equivalent.

Fluorescein and non-invasive break-up time tests were both found to be sensitive enough to differentiate between BL, G1, and G2 in general ($F = 408.42$; $p < 0.001$ and $F = 163.49$; $p < 0.001$, respectively), as well as between G1 and G2 conditions. BUT and NIBUT scores were highest at BL conditions, with a reduction during G1 and, although less marked, during G2 tasks. Statistically significant differences were also disclosed between the three testing conditions in the extension of the tear break-up area ($\chi^2 = 20.74$; $p < 0.001$) and in the observed interference patterns arising from the lipid layer of the tear film ($\chi^2 = 9.33$; $p = 0.009$), although a post-hoc Wilcoxon signed-rank test analysis revealed that whereas the former test could discern between G1 and G2 settings, the latter regarded G1 and G2 as similar. The extension of the dryness area increased significantly when participants were engaged in the fast-paced game, with almost half of them presenting grade 3 dry areas, as compared with only 16% and 8% of subjects displaying this grade when playing the slower game and at baseline conditions, respectively.

Several statistically significant correlations were encountered between blink rate and blink amplitude and the various clinical tear film evaluation tests. It is interesting to note, however, that these associations were dependent on the experimental settings (BL, G1, or G2) under which they were explored. Indeed, whereas a strong statistically significant correlation was found between blink amplitude and the extension of the dry area at BL (rho = 0.680; $p < 0.001$) and G1 (rho = 0.498; $p = 0.011$), with dryness increasing with incomplete blinking, the association between these factors failed to reach statistical significance during G2 experimental conditions. Likewise, blink rate displayed a positive correlation with NIBUT scores at G1 ($r = 0.504$; $p = 0.010$) and G2 ($r = 0.557$; $p = 0.004$), but not during baseline measurements. No other statistically significant associations were revealed between either SEBR or blink amplitude and any other tear film evaluation test.

TABLE 1 Summary of results for spontaneous blink rate, meniscus height, NIBUT, phenol red thread test, and BUT corresponding to baseline conditions (BL) and to computer games with high (G1) and low (G2) rates of visual information presentation

		Mean	SD	*F*	*p* (repeated measures)	*p* (pair-wise comparisons)
Spontaneous blink rate (blinks/min)	BL	24.36	4.06	595.85	< 0.001*	BL/G1 (< 0.001)*
	G1	8.96	3.62			BL/G2 (< 0.001)*
	G2	12.44	4.32			G1/G2 (< 0.001)*
Meniscus height (mm)	BL	0.334	0.085	27.71	< 0.001*	BL/G1 (< 0.001)*
	G1	0.274	0.060			BL/G2 (< 0.001)*
	G2	0.278	0.061			G1/G2 (0.982)
NIBUT (s)	BL	26.88	2.13	163.49	< 0.001*	BL/G1 (< 0.001)*
	G1	19.34	2.86			BL/G2 (< 0.001)*
	G2	22.78	2.71			G1/G2 (< 0.001)*
Phenol red thread test (mm)	BL	23.88	4.08	2.56	0.087	BL/G1 (0.204)
	G1	24.96	4.28			BL/G2 (1.000)
	G2	24.32	3.89			G1/G2 (0.207)
BUT (s)	BL	16.20	3.25	408.42	< 0.001*	BL/G1 (< 0.001)*
	G1	11.53	2.92			BL/G2 (< 0.001)*
	G2	13.13	3.06			G1/G2 (< 0.001)*

Results are displayed as mean ± SD. *Denotes a statistically significant difference.

TABLE 2 Summary of results for blink amplitude, interference patterns and dry area extension corresponding to baseline conditions (BL) and to computer games with high (G1) and low (G2) rates of visual information presentation

		Percentage (%)	χ^2	*p* (repeated measures)	*p* (pair-wise comparisons)
Blink amplitude	BL	Complete (20)/Incomplete (80)	34.00	< 0.001*	BL/G1 (< 0.001)*
	G1	Complete (8)/Incomplete (92)			BL/G2 (< 0.001)*
	G2	Complete (12)/Incomplete (88)			G1/G2 (1.000)
Interference patterns	BL	Close mesh (24)/ Wave (48)/Amorphous (28)	9.33	0.009*	BL/G1 (0.014)*
	G1	Close mesh (12)/ Wave (48)/Amorphous (40)			BL/G2 (0.046)*
	G2	Close mesh (16)/ Wave (48)/Amorphous (36)			G1/G2 (0.157)
Dry area extension	BL	1 (60)/2 (32)/3 (8)	20.74	< 0.001*	BL/G1 (< 0.001)*
	G1	1 (12)/2 (40)/3 (48)			BL/G2 (0.005)*
	G2	1 (24)/2 (60)/3 (16)			G1/G2 (0.008)*

Results are displayed as mean ± SD. *Denotes a statistically significant difference.

In addition, and although it was not considered to be a goal of the present study, possible associations between the various clinical tear film tests were explored. The appearance of interference patterns, that is, the thickness of the lipid layer of the tear film, was found to display a strong positive correlation with NIBUT scores at BL (rho = 0.752; $p < 0.001$), G1 (rho = 0.604; $p = 0.001$) and G2 (rho = 0.709; $p < 0.001$) and a still positive, but weaker association with tear meniscus height at BL (rho = 0.420; $p = 0.037$). Furthermore, a marginally significant correlation was also encountered between meniscus height and NIBUT scores at G1 ($r = 0.407$; $p = 0.043$), while a stronger, negative correlation between meniscus height and dry area extension (rho = -0.456; $p = 0.022$) was disclosed at G2 testing conditions, that is, the extension of the dry area was larger in those subjects presenting a smaller volume of tears in their meniscus reservoir.

Finally, when asked to report on which game session (G1 or G2) they felt less comfortable in terms of ocular fatigue and dryness sensation, 17 subjects (68%) described the fast-paced game as less comfortable than the slower-paced game. A chi-square analysis of this preference, however, was not found to reach statistical significance ($\chi^2 = 3.240$; $p = 0.072$).

DISCUSSION

The present study aimed at exploring the influence of the rate of visual information presentation on blinking rate, blinking amplitude and tear film integrity in a sample of young, healthy video display terminal users. Blinking characteristics were recorded, and tear film stability was evaluated, at baseline conditions and while participants were engaged in playing two different computer games of similar cognitive requirements but different rate of visual information presentation: a fast-paced game (G1) and a slow-paced game (G2).

Blinking has been shown to affect tear film integrity and, in turn, to be influenced by the type of visual task being performed. Several studies have investigated the relationship between the cognitive aspects of the visual task and the degree of change in SEBR and blink amplitude.[21–24,26,29] Their findings suggest that highly demanding visual tasks such as reading and VDT use result in a significant reduction in blink rate and blink amplitude, although this latter aspect has been also associated with the actual position of the computer screen.

Few studies have investigated the effect of target presentation rate on visual fatigue.[14,39,40] Chi and Lin[39] reported an increase in the subjective rating of visual discomfort of VDT operators working with rapidly moving targets. Similarly, Chi and coworkers[40] and Lin et al.[14] described a transient effect of the rapid eye movements associated with certain VDT tasks on visual fatigue and task performance. Other authors have documented a reduction in SEBR during such dynamic tasks as viewing a series of rapidly changing letters,[26] playing a computer game,[26] or connecting a sequence of small dots on the screen,[24] albeit these authors attributed these changes in SEBR to the increased cognitive demands associated with those tasks rather than to the rate in which new visual information was presented to the observers. Although the relationship between blinking and tear film integrity has been explored in previous studies, as far as we know, no attempt has been made to explore the influence of the rate of visual information presentation, as an independent factor from cognitive demands, on blinking and tear film integrity.

Subjects playing the fast-paced computer game (often described by players as "if you blink, you die") experienced a significant reduction in SEBR, which was less pronounced, but still significantly different from baseline values, during the slow-paced game. Overall, these results are in agreement with those reported in published literature regarding BL SEBR values,[21,29] as well as with those described by authors comparing active and passive VDT tasks,[22,24,26] albeit differences in the actual type of task prevent a direct comparison of absolute SEBR values. Also in agreement with published studies on blinking, a high intersubject variability was observed, as denoted by a manifest standard deviation in SEBR data.

The present experimental design assumed that both computer games provided a similar level of cognitive challenge to players, and that any discrepancies in SEBR and blink amplitude between games should be the result of differences in their rate of visual information presentation. Our results disclosed a decline in SEBR during both game tasks, which may be attributed to the higher cognitive demands of these tasks over silent primary gaze conditions, in addition to a further reduction in SEBR during the more dynamic game task (G1), which may reflect the contribution of a different mechanism. Indeed, visual reaction times, of capital importance during G1 gaming conditions, have been found to increase when a blink or a saccade coincided with the onset of a target stimulus.[41] Nakano and coworkers[33] suggested the presence of an internal mechanism that would signal the most appropriate time for a blink in order to minimize the chance of losing critical information while viewing a continuous stream of visual elements. In accordance with the present findings, this mechanism may help to explain differences in SEBR between G1 and G2, but would not influence other aspects of blinking, such as blink amplitude, which was found to be similar during G1 and G2, although both gaming conditions had a higher percentage of incomplete blinks than BL conditions.

The combined effect of a lowered blink rate and an increase in the percentage of incomplete blinks may be assumed to result in excessive tear film evaporation from the ocular surface and in a reduced expression of tear film components, that is, in a negative impact on both the quality and volume of the tear film. However, only some of the clinical tear film evaluation tests which were employed in the present study were able to detect these changes. Indeed, BUT, NIBUT, and dry area extension were found to distinguish between BL, G1, and G2 experimental settings, whereas meniscus height measurement, the phenol red thread test and the observation of interference patterns were not able to differentiate between G1 and G2. These results are in agreement with those of Himebaugh and coworkers[26] who reported consistent inferior tear break-up and dryness in non dry eye subjects playing a computer game, in contrast with dry eye subjects and also with healthy subjects while performing other types of VDT tasks. The present findings suggest that the performance of dynamic visual tasks may have a more pronounced effect on tear quality (as measured with BUT and NIBUT tests) than on tear volume. However, the fact that no statistically significant differences were found between G1 and G2 in the appearance of interference patterns, which is a test traditionally employed to evaluate the lipid layer of the tear film, prevents definite conclusions to be drawn and warrants further investigation. It is interesting to note that the phenol red thread test was the only clinical test of tear film evaluation that failed to distinguish between BL and VDT conditions. Nevertheless, on account of the insufficient absorption capabilities of the phenol red thread, no clear evidence supports this test to be a measure of tear production or volume, at least in non dry eye subjects.[42]

Blinking and tear film integrity were found to present only marginally significant correlations, mainly between SEBR and NIBUT at G1 and G2 and between blink amplitude and the extension of the dry area at BL and G1. These findings, in agreement with previous research,[23] partially support the absence of a direct relationship between blink characteristics and tear volume and quality, at least as measured with the most commonly employed tear film evaluation tests. Other authors, however, disclosed significant correlations between the inter-blink interval and the stability of the tear film in healthy VDT users[43] and between SEBR and BUT while subjects were at rest or engaged in a reading task.[44,45]

The fact that no statistically significant difference was encountered in the subjective appraisal of ocular comfort and dryness between G1 and G2 experimental settings, which has been previously reported in a study design comparing active and passive VDT tasks,[39] may be explained as another manifestation of the extensively documented lack of correlation between symptoms and clinical signs in dry eye.[46–48] However, it may be relevant to mention that most subjects reported more intense ocular discomfort when playing the fast-paced game.

In summary, we believe that the rate of visual information presentation, as an independent factor from cognitive requirements, may have a negative impact on blinking characteristics and tear film integrity of VDT users, thus contributing to visual fatigue, ocular discomfort, and subject performance when conducting highly dynamic tasks. Although blink rate and blink amplitude were not directly associated with the results of some of the most commonly employed objective tear film evaluation tests, tear film integrity while subjects were playing a fast-paced, and to a lesser but still significant extent, a slow-paced computer game was clearly compromised. Video display terminal users should be advised to take frequent breaks and to increase their awareness of the importance of complete, frequent blinking, particularly when engaged in very dynamic visual tasks.

***Declaration of interest*:** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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