Contact Lens and Anterior Eye 46 (2023) 101744

Contents lists available at ScienceDirect

Contact Lens and Anterior Eye

journal homepage: www.elsevier.com/locate/clae

The effects of breaks on digital eye strain, dry eye and binocular vision: Testing the 20-20-20 rule

Cristian Talens-Estarelles [a], Alejandro Cerviño [a], Santiago García-Lázaro [a,*], Andrej Fogelton [b], Amy Sheppard [c], James S. Wolffsohn [c]

[a] Optometry Research Group, Department of Optics & Optometry & Vision Sciences, University of Valencia, Valencia, Spain
[b] Vision and Graphics Group, Faculty of Informatics and Information Technologies, Slovak University of Technology in Bratislava, Ilkovičova 2, Bratislava 842 16, Slovakia
[c] Optometry and Vision Sciences, Aston University, Birmingham, UK

A R T I C L E I N F O

Keywords:
Binocular vision
Computer vision syndrome
Digital eye strain
Dry eye
Dry eye symptoms
20-20-20 rule

A B S T R A C T

Purpose: To evaluate the benefits on the eyes of taking breaks based on the 20-20-20 rule.
Methods: Bespoke computer software using the laptop webcam to assess user breaks, eye gaze and blinking, and emitting personalized reminders of breaks based on the 20-20-20 rule, was downloaded onto the laptops of 29 symptomatic computer users. Digital eye strain (DES), binocular vision and dry eye were assessed before and after two weeks of using the reminders and one week after the discontinuation of the strategy. Binocular measurements included visual acuity, accommodative posture, stereopsis, fixation disparity, ocular alignment, accommodative facility, positive/negative vergences and near point of convergence. Symptoms were evaluated using the computer vision syndrome questionnaire, ocular surface disease index (OSDI), and symptom assessment in dry eye questionnaire (SANDE) versions one and two. Dry eye signs were assessed by measuring tear meniscus height, conjunctival redness, blink rate and incomplete blinking, lipid layer thickness, non-invasive keratograph break-up time, corneal and conjunctival staining and lid wiper epitheliopathy.
Results: A decrease in the duration of computer work and the duration of breaks, along with an increase in the number of breaks taken per day was observed as a result of the 20-20-20 rule reminders ($p \leq 0.015$). No changes on any binocular parameter were observed after the management period ($p \geq 0.051$), except for an increase in accommodative facility ($p = 0.010$). Dry eye symptoms and DES decreased with the rule reminders ($p \leq 0.045$), although this improvement was not maintained one week after discontinuation ($p > 0.05$). No changes on any ocular surface and tear film parameter were observed with the rule reminders ($p \geq 0.089$).
Conclusions: The 20-20-20 rule is an effective strategy for reducing DES and dry eye symptoms, although 2 weeks was not enough to considerably improve binocular vision or dry eye signs.

1. Introduction

Prolonged computer use has been associated with several eye and vision problems; these eye-related complaints have been grouped under the term "computer vision syndrome", or more broadly "digital eye strain" (DES).[1,2] With the emergence of new technologies DES has become increasingly prevalent. According to recent findings, the prevalence of DES lies between 65 % and 33 % – a wide range is probably attributable to the range of methodologies that have been applied to identify sufferers and the different population groups analysed; they tend to be highest amongst young adults with an estimated prevalence of 74 to 77 % [3–5].

Ocular symptoms associated with DES are often split into two main and distinct categories based on the type of sensation and perceived location.[6,7] The first group, termed external symptoms, is related to dry eye and includes symptoms of burning, irritation, dryness, tearing, foreign body sensation, sensitivity to bright lights and discomfort. The second group, termed internal symptoms, encompasses symptoms of eyestrain, eye ache, headache, diplopia, blurred vision and difficulty in refocusing, and is linked to accommodative and/or binocular vision

* Corresponding author at: Optometry Research Group. Department of Optics & Optometry & Vision Sciences, University of Valencia, Dr. Moliner, 50 46100 Burjassot Valencia, Spain
E-mail address: santiago.garcia-lazaro@uv.es (S. García-Lázaro).

https://doi.org/10.1016/j.clae.2022.101744
Received 2 May 2022; Received in revised form 5 August 2022; Accepted 5 August 2022
Available online 11 August 2022

stress.

DES is highly influenced by the visual demand and the duration of a given task.[8,9] For instance, Portello et al.[7] observed a positive correlation between the symptom score and the time spent working on a computer. Longer periods of screen visualization have been associated with greater tear film and ocular surface abnormalities, and accommodative and vergence disturbances.[8–10] Accordingly, limiting the amount of time spent in front of a digital display is expected to have a positive impact on DES.[8,9,11] Based on this principle, frequent screen users are often advised to follow the 20-20-20 rule which instructs them to briefly look away from the screen for at least 20 s to a distant scene at least 20 feet (6 m) away after every 20 min of continuous work.[12,13] With the rise of display use, this general rule of visual ergonomics has become increasingly popular and is widely recommended by specialists in the field of vision, although only one study has examined this approach, reporting a benefit, but with no evidence of compliance.[14].

Accordingly, in the present study, a computer software was developed using the laptop webcam to assess user breaks, eye gaze and blinking and could emit personalized regular reminders of rest based on the 20-20-20 rule in order to evaluate, for the first time, the potential benefits of this rule on DES, dry eye and the accommodative and binocular vision systems in a sample of young, symptomatic, regular computer users.

2. Methods

2.1. Participants

Twenty-nine symptomatic volunteers participated in this prospective, longitudinal, controlled clinical study. Inclusion criteria were DES (computer vision syndrome questionnaire (CVS-Q) score ≥ 6 at baseline), best-corrected distance visual acuity (BCDVA) greater or equal to 20/30 (0.17 logMAR) in both eyes, and reported computer use for a minimum of 4 h a day, at least 5 days per week. Exclusion criteria included anterior or posterior segment pathologies, history of eye surgery in the past 6 months, binocular disorders (i.e., strabismus, amblyopia, anisometropia, etc.) and stereopsis lower than 120 arc seconds. Participants receiving treatment for dry eye, actively taking measures to reduce DES (i.e., artificial tear substitutes, planned regular short breaks, screen filters or specialty spectacles), taking temporary medication known to contribute to dry eye or those who made changes in contact lens wear during the study period were excluded.

The study followed the tenets of the Declaration of Helsinki, and a favourable opinion from the ethical committee of Aston University was obtained. All the participants were informed about the nature of the study and gave their written consent.

2.2. Study software

A downloadable computer software (eyeblink https://www.blinkingmatters.com/) was modified by the developer (A.F.) for the study as a tool for the 20-20-20 reminders. Using the built-in camera of the participant’s laptop computer the software checked user presence and gaze direction every 10 s. The software considered the user as looking at the screen if they were within range of the camera and their gaze angle (angle of gaze with respect to the centre of the screen) was equal to or less than that of the screen (maximum angle of gaze determined by looking at the corners of the screen) (Fig. 1). Two consecutive readings with either an absence or a gaze angle greater than the screen angle were considered a break. In case a natural break was detected the timer was reset to 0. After 20 min of continuous screen viewing the software issued a message asking the user to rest for 20 s while looking at a distant target located at least 20 feet away (Fig. 2). The break reminder was accompanied by an acoustic signal (beeping signal) if enabled by the user to ensure it did not go unnoticed. The reminder could not be

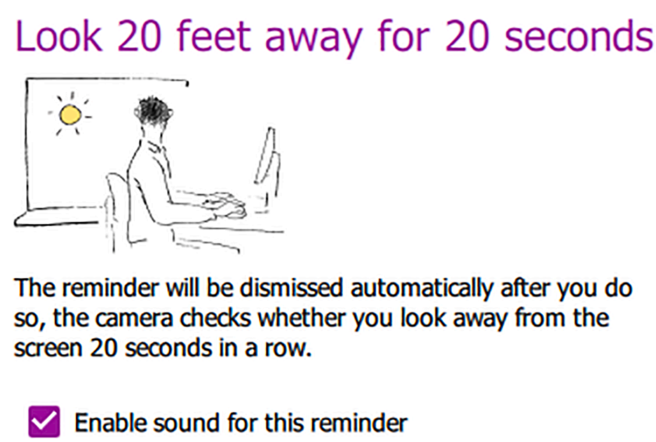

Fig. 2. 20-20-20 rule break reminder issued by the software.

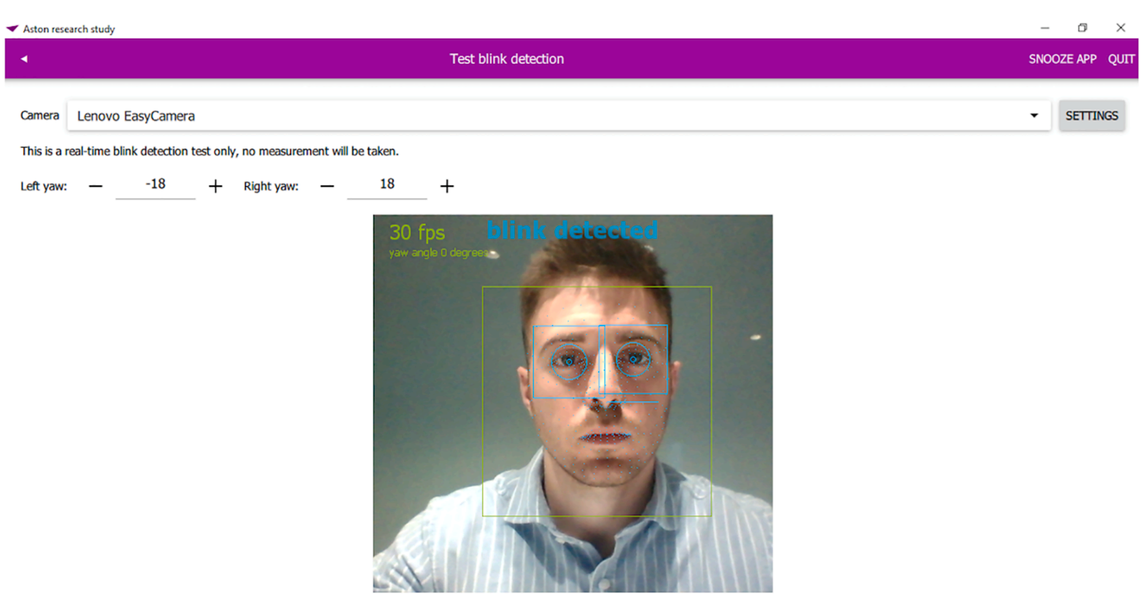

Fig. 1. Eye blink and gaze detection software testing. The green square indicates that the user is looking at the screen.

manually removed by the user and disappeared automatically from the screen once the task was correctly performed. Additionally, the tool app measured the average blink rate and blink length every 20 min for 3 min. If the 20-20-20 rule reminder was active the blink measurement was performed in between the rule reminders. The tool app used the motion-based blink detection algorithm to gather blink data.[15].

2.3. Experimental conditions

All measurements were taken in the same laboratory. The approximate duration of each session was 45 min. All the sessions were carried out on the same day of the week, at the same time of day (mornings from 9 to 11 am) and under the same, constant environmental conditions (temperature and humidity). In addition, participants were asked not to use other digital displays 30 min before the session. Likewise, contact lens wearers were instructed to remove their contact lenses at least 24 h before the visit.

The laboratory was set up 15 min before each visit. To minimize the effects of outdoor conditions on the way to the laboratory, a 20-minute acclimatization period was left between the entry of the participants into the room and tear film measurements. The whole experiment was carried out under constant background illumination. The room was free from ambient lighting. Room temperature and humidity were constantly monitored and remained stable at 21.5 ± 0.7 °C and 40.9 ± 4.9 %, respectively.

2.4. Measurements and procedure

Potential participants were sought from the university and advertisements to see if they were likely to meet the study criteria. Each participant made a total of 4 visits: 3 on-site and 1 online, with a period of two weeks between visits for visits 1 – 2 and 2 – 3 and of one week for visits 3 – 4. At visit 1, one of the authors checked whether or not each volunteer met the inclusion/exclusion criteria before initiating the experiment. Next, participants were instructed to simulate their workstation design by placing themselves in front of their laptop as they normally would while considering variables such as the tilt angle of the screen and the height of the chair and the table. Then, their working distance (WD) was measured using a millimetre incremented ruler as the distance from the centre of the screen to their eyes.

Following this, baseline measurements were taken. DES, dry eye signs and symptoms, accommodation and binocular vision were assessed. DES was evaluated using the CVS-Q questionnaire.[16] Dry eye symptoms were evaluated using the ocular surface disease index (OSDI) questionnaire,[17] the 5-item dry eye questionnaire (DEQ-5) [18] and the symptom assessment in dry eye questionnaire version I (SANDE I).[19].

Accommodation and vision were subsequently assessed by measuring monocular BCDVA and best-corrected near visual acuity (BCNVA), accommodative posture (i.e., lag/lead), stereopsis, fixation disparity, ocular alignment, binocular accommodative facility, horizontal fusional reserves and near point of convergence (NPC). The order of the measurements was chosen to minimize the effects of fatigue. Measurements were either taken at the participants' WD or both distance (6 m) and WD, depending on the parameter. Due to the higher variability of data, fusional reserves and NPC were measured three times and an average value was obtained. Participants were instructed to rest for 30 s by looking at a distance visual acuity chart between repeated measurements. Also, a rest period of approximately-one minute was left between test procedures. Measurements were undertaken with the participants' distance spectacle correction.

Finally, the ocular surface and tear film were examined using Keratograph 5 M (Oculus Optikgerate, Wetzlar, Germany). The testing procedures were performed in the following order, based on the guidelines of the TFOS DEWS II Diagnostic Methodology report:[20] tear meniscus height (TMH), limbal and bulbar conjunctival redness, spontaneous blinking pattern, lipid layer thickness (LLT), non-invasive keratograph break-up time (NIKBUT), corneal and conjunctival staining, lid wiper epitheliopathy (LWE) and upper and lower eyelid meibography. NIKBUT was measured 3 times and an average value was obtained. For the assessment of blinking, participants were instructed to look at the fixation target with no need to stare at the stimulus and were not actively told that their blink movements were being recorded. Small twitches of the upper eyelid with particularly small amplitudes were not counted as a blink.

A summary of the clinical tests and test procedures performed in the present study can be found in Table 1.

Finally, the study software was downloaded and installed onto the participants' laptops and the software settings were set. An identification number was assigned to each participant on the software. Then, the correct functioning of the software was checked, and the maximum screen angle was set by asking the participant to simulate their workstation design and to look at the top-right and top-left corners of the screen. For the first two weeks (visits 1 – 2) the participants were only instructed to use their laptops as usual while the 20-20-20 rule reminders were turned off. Participants were informed that the software

Table 1
Summary of the clinical tests and test procedures performed in the present study.

Parameter	Test
DES	CVS-Q (validated questionnaire)
Working distance[a]	Distance from screen to eyes; mm ruler
Visual acuity (D and N)[a]	ETDRS LogMar chart; R, L.
Accommodative posture[a]	Difference between accommodative demand at WD and change between distance Rx and WD Rx; Open field autorefractor (Grand Seiko WAM-5500 autorefractor, Grand Seiko Co. ltd., Hiroshima, Japan).
Stereopsis (WD)[a]	TNO test (random dot stereotest) (Laméris Ooctech BV, Nieuwegein, Netherlands).
Fixation disparity (WD)[a]	Minimum prism to eliminate disparity; Mallet unit. [21]
Ocular alignment (D and WD)[a]	Cover test.[22]
Binocular accommodative facility (WD)[a]	± 2.00 flippers, whilst viewing near target.
Horizontal near fusional reserves (WD)[a]	Prism bar; blur/break/recovery (values at the test ceiling, > 40, were scored as 45).[23]
Near point of convergence[a]	RAF rule push-up.[24]
Dry eye symptomatology	OSDI, DEQ-5, SANDE I and SANDE II (validated questionnaires).
Tear meniscus height	Oculus K5M.[25]
Conjunctival redness	Oculus K5M.[26]
Blinking pattern	Blink rate and % of incomplete blinks; Oculus K5M; 60 s video recording, hight frame rate option selected; Manually counted while played at 0.25 original speed.
Lipid layer thickness	Oculus K5M; [27] Guillon grading scale.[28]
Tear break-up time	Non-invasive keratograph break-up time; Oculus K5M.[29]
Corneal staining	Oculus K5M; fluorescein, blue light; Oxford grading scale.[30]
Conjunctival staining	Oculus K5M; lissamine green, white light; Oxford grading scale.[30]
Lid wiper epitheliopathy	Horizontal length and sagittal width; Oculus K5M; Lissamine green and fluorescein, white light.[31]
Meibomian glands dropout	Upper and lower infrared meibography; Oculus K5M; Ratio between eyelid area and gland loss area. Image J tool (Wayne Rasband; National Institutes of Health, Bethesda, MD).[32]

CVS-Q = Computer vision syndrome questionnaire; D = Distance (6 m); DEQ-5 = 5-item dry eye disease questionnaire; DES = Digital eye strain; ETDRS = Early treatment diabetic retinopathy study; L = Left eye; N = Near (40 cm); Oculus K5M = Oculus Keratograph 5 M®; OSDI = Ocular surface disease index; R = Right eye; RAF = Royal air force rule; Rx = Refraction; SANDE I = Symptom assessment questionnaire in dry eye, version 1; SANDE II = Symptom assessment questionnaire in dry eye, version 2; WD = Working distance; % = percentage. [a] Test undertaken with the participant's distance refraction.

would be collecting data about computer usage statistics and measuring their blink rate every 20 min.

At visits 2 and 3 the testing procedures were repeated, except for the measurement of DEQ-5, WD and eyelid miebography. The DEQ-5 questionnaire was not administered due to its lack of appropriateness to assess symptoms in the past two weeks. To further assess the change in dry eye symptomatology as compared to the previous visit, participants responded to the SANDE version II questionnaire (SANDE II),[19] asking them about the difference in the severity and frequency of symptoms compared to the previous visit. At the end of visit 2, the 20-20-20 rule reminders were enabled, and the participants were informed about the breaks. Two weeks later (visit 3), the software was uninstalled. Finally, one week after the discontinuation of the management strategy (visit 4), an online survey containing the CVS-Q, OSDI, SANDE I and SANDE II questionnaires was sent to the participants as a follow-up of symptoms. Fig. 3 displays a flowchart of the study design.

Cross-over and masking were not possible in the study design as it was unknown how long the effects would last for. However, objective measures and real-time monitoring was used to minimize any placebo effect or researcher bias.

2.5. Statistical analysis

Data on user presence and blink data gathered by the software were downloaded and transferred into Microsoft Excel (Microsoft, Redmond, WA, USA) spreadsheets. Relevant computer usage statistics were then calculated for each participant, before and after the activation of the 20-20-20 rule reminders, including average blink rate, average blink duration, average duration of computer use per day (i.e., sum of the time spent in front of the computer per day), number of days of computer use, average duration of continuous (uninterrupted) computer work (i.e., average time looking at the computer screen without taking a break longer than 20 s), average duration of breaks and average number of natural, rule and total breaks taken per day.

The results were then evaluated using SPSS software v.26 (IBM Corp., Armonk, NY). The normality of data was assessed using the Shapiro-Wilk test. When normality could be assumed, a paired-sample *t*-test was used to examine the differences in computer usage before and after the activation of the 20-20-20 rule reminders. The non-parametric Wilcoxon paired signed-rank test was used when parametric test assumptions were not fulfilled. Additionally, the one-sample Wilcoxon signed-rank test was used to examine if the average number of rule reminder breaks taken per day was significantly greater than zero.

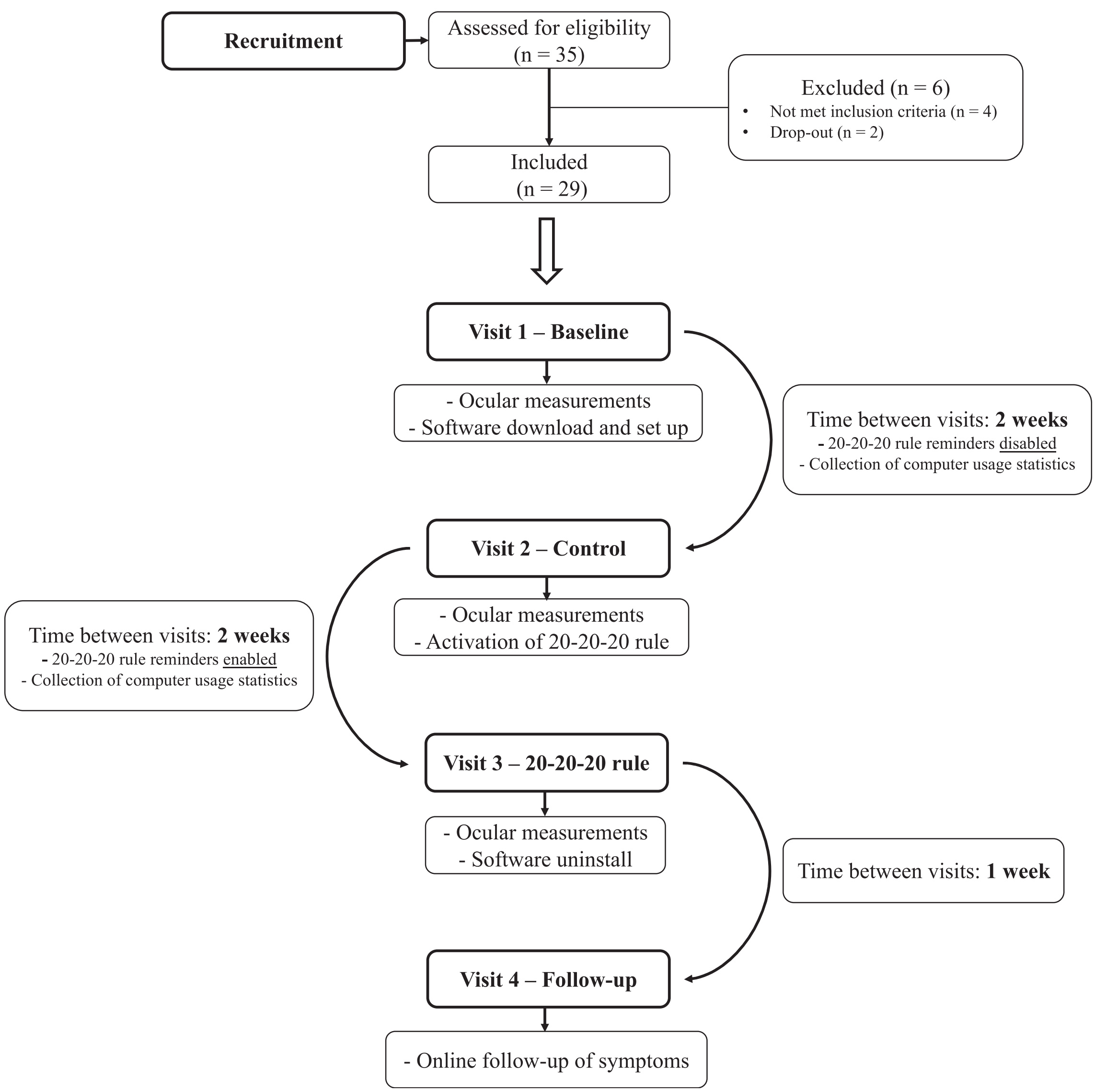

Fig. 3. Study flowchart.

A repeated-measures analysis of variance (ANOVA) was used to examine the statistical differences of the binocular vision and ocular surface results obtained for the different study visits. The Mauchly test was used to evaluate the assumption of sphericity. If sphericity could not be assumed, the Greenhouse-Geisser correction was applied. Whenever the repeated-measures ANOVA pointed to a statistical significance, post-hoc pairwise comparisons were carried out using Bonferroni correction. The non-parametric Friedman test for repeated measures with Dunn-Bonferroni post-hoc analysis was used when parametric test assumptions were not fulfilled. In parallel, a one-sample *t*-test or a one-sample Wilcoxon signed-rank test, depending on the distribution of data, was used to examine if the SANDE II score obtained during each visit was significantly greater than zero.

Finally, two-way mixed ANOVA were used to examine the influence of several variables on the effectiveness of the 20-20-20 rule in reducing DES. Between-subjects variables included: (1) duration of computer use as detected by the software (moderate < 4 h/day vs high ≥ 4 h/day), (2) number of natural breaks taken per day (few < 26 breaks/day vs many ≥ 26 breaks/day) and (3) severity of DES (CVS-Q score; mild < 10 vs moderate ≥ 10). Cut-off values were selected based on the median value of each distribution. The normality of the data was assessed using the Shapiro-Wilk test. The Levene test was used to evaluate the assumption of homogeneity of variance while the Mauchly test was used to evaluate the assumption of sphericity. P-values of < 0.05 were considered statistically significant.

Sample size was estimated based on the results of the first 10 participants using the G-Power tool.[33] With $\alpha = 0.05$ and power $(1-\beta) = 0.80$ the estimated sample size was that of 27 participants. A greater sample was initially recruited accounting for possible study dropouts.

3. Results

Thirty-five volunteers were initially recruited out of which 29 (9 men and 20 women) ranging in age from 18 to 43 years (27 ± 7) met the inclusion/exclusion criteria and completed all study visits. Out of the 29 participants, 22 were White, 5 Asian and 2 Hispanic/Latino. The average time of computer use reported by the participants was that of 7 ± 2 h a day, 6 ± 1 days a week.

Table 2 shows the data collected by the study software before and after enabling the 20-20-20 rule reminders along with the statistical results of the comparison. No statistically significant changes in average blink rate or blink duration during computer use were found before and after the activation of the rule reminders ($p = 0.820$ and $p = 0.404$, respectively). Likewise, no significant differences in the average duration of computer use per day and the total number of days of computer use were observed between the two study periods ($p = 0.853$ and $p = 0.793$, respectively). On the contrary, the average duration of continuous computer use and the average duration of breaks were significantly shorter when the rule reminders were on compared to when they were off ($p = 0.006$ and $p = 0.015$). Finally, the total number of breaks taken per day was significantly higher after the activation of the rule reminders compared to before ($p = 0.003$), while the number of 20-20-20 rule reminder breaks taken per day during weeks 3 – 4 was significantly higher than zero ($p < 0.005$). Conversely, the number of natural breaks taken did not vary significantly between both study periods ($p = 0.068$).

Table 3 shows the visual, accommodative and vergence results obtained before (visits 1 and 2) and after two weeks of compliance with the 20-20-20 rule reminders (visit 3), along with the statistical results of the comparison. No statistically significant differences in BCDVA, BCNVA, accommodative posture, stereopsis, fixation disparity, ocular alignment, fusional vergences (positive and negative) and near point of convergence were obtained between visits ($p \geq 0.074$). Conversely, binocular accommodative facility was significantly greater at visit 3 compared to visits 1 and 2 ($p = 0.010$ for both).

Table 4 displays the dry eye signs and symptomatology scores obtained before (visits 1 and 2) and after two weeks of compliance with the 20-20-20 rule reminders (visit 3), along with the symptoms reported one week after the discontinuation of the management strategy (visit 4). Statistically significant differences in dry eye symptoms and DES were obtained between visits ($p \leq 0.045$). The CVS-Q and the SANDE I severity score obtained at visit 3 were significantly lower than at visit 1 ($p = 0.008$ and $p = 0.045$, respectively). Likewise, a significantly lower CVS-Q, OSDI and SANDE I total score were obtained at visit 3 compared to visit 2 ($p = 0.008$, $p = 0.019$ and $p = 0.043$, respectively). In parallel, the SANDE II frequency and severity scores obtained at visit 3 were significantly lower than zero ($p < 0.005$ for both), while no significant differences with zero were observed at visit 2 ($p = 0.358$ and $p = 0.904$, respectively). Also, a SANDE II frequency score significantly greater than zero was obtained at visit 4 ($p = 0.005$), however, no significant difference was obtained in the severity score during the same visit ($p = 0.222$).

In parallel, no statistically significant differences between visits were obtained on any ocular surface or tear film parameter (TMH, conjunctival redness, percentage of incomplete blinks, LLT, NIKBUT, and ocular surface staining) ($p \geq 0.089$) except for the blink rate, which was significantly lower at visit 3 compared to visit 1 ($p = 0.040$).

Finally, the two-way mixed ANOVA did not reveal an influence of the duration of computer use ($p = 0.919$), the number of natural breaks taken per day ($p = 0.208$) or the severity of DES symptoms (i.e., CVS-Q score) ($p = 0.418$) on the effectiveness of the 20-20-20 rule in reducing DES.

Table 2
Data collected by the study software before (weeks 1 to 2) and after (weeks 3 to 4) the activation of the 20-20-20 rule reminders and statistical results of the comparison. Data are presented as mean ± SD (min – max).

Variable	Rule break reminders turned off (weeks 1 – 2) (n = 29)	Rule break reminders tuned on (weeks 3 – 4) (n = 29)	P-value
Blink rate (blinks/min)[a]	8 ± 4 (4 – 16)	9 ± 5 (3 – 19)	0.820[†]
Blink duration (ms)[a]	363 ± 44 (302 – 427)	356 ± 36 (292 – 412)	0.404[†]
Duration of computer use (hours/day)[a]	5 ± 3 (2 – 13)	5 ± 3 (2 – 12)	0.853[‡]
Days of computer use	12 ± 2 (10 – 15)	12 ± 3 (9 – 14)	0.793[‡]
Continuous computer use (min)[a]	11 ± 4 (4 – 21)	7 ± 3 (4 – 20)	0.006*[‡]
Duration of breaks (min)[a]	5 ± 3 (1 – 14)	4 ± 2 (2 – 7)	0.015*[‡]
Number of natural breaks (breaks/day)[a]	26 ± 13 (10 – 52)	31 ± 18 (7 – 69)	0.068[†]
Number of rule breaks (breaks/day)[a,b]	–	3 ± 2 (1 – 9)	< 0.005*[§]
Total number of breaks (breaks/day)[a]	26 ± 13 (10 – 52)	34 ± 18 (9 – 73)	0.003*[†]

min = minutes; ms = milliseconds. [a] Intra-average values. [b] Statistical comparison with value of 0. Asterisks denote statistically significant values ($p < 0.05$). [†] Paired-sample *t*-test. [‡] Wilcoxon paired signed-rank test. [§] One-sample Wilcoxon signed-rank test.

4. Discussion

4.1. Computer usage

According to the results of the present study, enabling the 20-20-20 rule reminders had a significant impact on how participants used their computers. Participants took more breaks per day in total when the 20-20-20 rule reminders were on compared to when they were off (34 with

Table 3
Visual, accommodative and vergence functions obtained before (visits 1 and 2) and after two weeks of compliance with the 20-20-20 rule reminders (visit 3) and statistical results of the comparison. Data are presented as mean ± SD (min – max).

Variable		Visit 1 (Baseline) (n = 29)	Visit 2 (n = 29)	Visit 3 (20-20-20 rule) (n = 29)	p-value	Statistically significant post-hoc differences (p-value)
BCDVA	Right Eye	−0.08 ± 0,09 (-0.24 – 0.12)	−0.08 ± 0,09 (-0.26 – 0.16)	−0.09 ± 0,09 (-0.30 – 0.18)	0.443‡	—
	Left Eye	−0.09 ± 0,09 (-0.20 – 0.12)	−0.10 ± 0,10 (-0.26 – 0.12)	−0.09 ± 0,10 (-0.28 – 0.15)	0.498‡	—
BCNVA	Right Eye	−0.04 ± 0.11 (-0.20 – 0.20)	−0.03 ± 0.08 (-0.16 – 0.10)	−0.04 ± 0.08 (-0.20 – 0.08)	0.642†	—
	Left Eye	−0.05 ± 0.11 (-0.20 – 0.18)	−0.03 ± 0.07 (-0.18 – 0.12)	−0.04 ± 0.09 (-0.20 – 0.18)	0.888†	—
Accommodative posture (D)		0.65 ± 0.43 (-0.24 – 1.39)	0.65 ± 0.36 (0.05 – 1.33)	0.65 ± 0.45 (-0.03 – 1.50)	0.997†	—
Stereopsis (arc seconds)		60 ± 30 (15 – 120)	60 ± 27 (15 – 120)	30 ± 18 (15 – 60)	0.051‡	—
Fixation disparity (ΔD)		0 ± 1 (-2 – 1)	0 ± 1 (-2 – 12)	0 ± 1 (-3 – 2)	0.836‡	—
Ocular alignment (ΔD)	Distance	−1 ± 1 (-4 – 2)	−1 ± 1 (-4 – 1)	−1 ± 1 (-4 – 1)	0.463‡	—
	Working Distance	−2 ± 3 (-10 – 5)	−2 ± 3 (-10 – 4)	−2 ± 3 (-10 – 2)	0.074‡	—
Binocular accommodative facility (c.p.m.)		6 ± 5 (0 – 17)	5 ± 5 (0 – 17)	7 ± 5 (1 – 20)	<0.0005*‡	Visit 1 – Visit 3 (0.010) Visit 2 – Visit 3 (0.010)
Positive fusional vergences (ΔD)	Blur	12 ± 2 (9 – 18)	13 ± 3 (6 – 18)	14 ± 5 (6 – 25)	0.707†	—
	Break	21 ± 9 (4 – 40)	23 ± 10 (5 – 40)	23 ± 11 (9 – 40)	0.233‡	—
	Recovery	17 ± 9 (2 – 40)	19 ± 11 (2 – 40)	19 ± 11 (5 – 40)	0.261‡	—
Negative fusional vergences (ΔD)	Blur	11 ± 3 (6 – 16)	10 ± 3 (6 – 15)	9 ± 3 (4 – 15)	0.177†	—
	Break	15 ± 4 (9 – 22)	14 ± 4 (8 – 20)	13 ± 4 (7 – 20)	0.065†	—
	Recovery	11 ± 4 (5 – 20)	10 ± 3 (5 – 17)	9 ± 3 (5 – 17)	0.060†	—
Near point of convergence (cm)	Break	6 ± 3 (4 – 14)	6 ± 3 (4 – 17)	6 ± 3 (4 – 15)	0.700‡	—
	Recovery	7 ± 3 (4 – 15)	7 ± 3 (4 – 19)	7 ± 3 (4 – 17)	0.297‡	—

arc *sec* = seconds of arc; BCDVA = Best corrected distance visual acuity; BCNVA = Best corrected near visual acuity; c.p.m. = cycles per minute; D = diopters; **Δ**D = Prism diopters. Asterisks denote statistically significant values ($p < 0.05$). † Repeated-measures ANOVA. ‡ Friedman.

reminders on vs 27 with reminders off), which was partially attributed to the breaks taken following the instructions of the reminders. Conversely, the average number of natural (spontaneous) breaks taken per day did not change significantly, although a slight increase of 5 breaks per day, on average, was observed when the rule reminders were activated. This may be due to an increased consciousness of computer usage which some participants reported during their visits.

Additionally, the participants worked on their computers continuously for shorter periods when they followed the 20-20-20 rule than when they did not, probably due to the increase in the number of breaks taken per day which caused the gap between breaks to shorten. Likewise, the average duration of breaks was significantly reduced when the rule reminders were enabled. This may be attributed to the fact that the reminders instructed participants to rest for a brief period (20 s).

Furthermore, despite a significant change in computer usage between the two study periods, the average number of rule reminder breaks taken per day, although significantly greater than zero, was clinically small (i.e., 3 rule breaks per day on average). Considering that the participants' average natural duration of continuous computer use was of 11 min and that the 20-20-20 rule instructs individuals to rest after 20 min of continuous work, the rule did not require a clinically significant number of breaks.

Finally, it should be noted that the average duration of computer use per day recorded by the software, although noticeably high, was considerably smaller than the one reported by the participants during the recruitment phase of the study (4 h per day vs 7 h per day reported by participants). Individuals tend to subjectively overestimate their duration of computer use, probably because they do not always consider, the time spent on short breaks. This should be taken into consideration in future studies conducted on digital device users.

4.2. Binocular vision

According to previous research, the symptoms experienced with computer use may be associated with alterations in the accommodative and vergence systems.[34–38] For instance, Kwon et al.[34] found an increase in lag in a sample of young individuals after they played a computer game for 90 min. Similarly, Seo et al.[35] observed an increase in lag, along with a decrease in accommodative facility, after two hours of computer use. Also, there are reports that fusional convergence and divergence decline over 6 h of computer use per day,[36] that NPC recedes after only 20 min of device use[36] and that there is a greater tendency for phoria to shift toward greater exophoria after using a computer for as little as 20 min.[36,37] Nevertheless, despite these findings, other research found no changes in these parameters with computer visualization, which could be due to differences in methodology.[39–41].

In the present study, following the 20-20-20 rule significantly improved binocular accommodative facility compared to before (i.e., visits 1 and 2). Iribarren et al.[42] found that the cumulative duration of near work over months showed a significant negative correlation with binocular accommodative facility. Accordingly, the 20-20-20 rule may improve accommodative facility in regular computer users by reducing screen time, thus preventing cumulative effects of prolonged near work, although more research is required to confirm these findings.

Conversely, the 20-20-20 rule had no significant effect on any other visual, accommodative or vergence parameter. Based on the available evidence, the impact of computer use on accommodation and vergence is inconclusive and has yet to be clarified. Participants in the present study were young and took, on average, a considerable number of natural breaks per day. Overall, there may not have been alterations in accommodation and vergence consequent to computer use in the first place, which would have prevented observing any benefit associated with the 20-20-20 rule. Future research is required to assess the benefits of the 20-20-20 rule in computer users with a tendency to stare at the screen for long periods and/or with binocular disorders arising from computer use.

4.3. Symptoms and dry eye

Digital device use has been implicated as a contributing factor to dry eye disease.[43] Substantial research points to an increased prevalence

Table 4
Dry eye signs and symptoms obtained before (visits 1 and 2) and after two weeks of compliance with the 20-20-20 rule reminders (visit 3) and symptoms reported one week after the interruption of the management strategy (visit 4) and statistical results of the comparison. Data are presented as mean ± SD (min – max).

Parameter		Visit 1 (Baseline) (n = 29)	Visit 2 (n = 29)	Visit 3 (20-20-20 rule) (n = 29)	Visit 4 (Online Follow-up) (n = 29)	p-value	Statistically significant post-hoc differences (p-value)
CVS-Q		10 ± 4 (6 – 20)	11 ± 4 (6 – 25)	8 ± 4 (3 – 22)	9 ± 4 (4 – 21)	p = 0.001‡	Visit 1 – Visit 3 (0.008) Visit 2 – Visit 3 (0.008)
OSDI		22.88 ± 12.49 (0.00 – 45.45)	24.64 ± 16.09 (0.00 – 62.50)	18.95 ± 13.58 (0.00 – 60.42)	19.96 ± 13.80 (0.00 – 50.00)	p = 0.015‡	Visit 2 – Visit 3 (0.019)
DEQ-5		10 ± 4 (3 – 17)	/	/	/	/	
SANDE I	Frequency	40 ± 26 (4 – 90)	37 ± 23 (4 – 90)	31 ± 21 (0 – 85)	37 ± 24 (0 – 80)	p = 0.124‡	—
	Severity	33 ± 22 (4 – 81)	32 ± 20 (4 – 90)	26 ± 19 (0 – 73)	33 ± 23 (0 – 90)	p = 0.045*‡	Visit 1 – Visit 3 (0.045)
	Total score	35 ± 21 (4 – 75)	34 ± 20 (4 – 90)	28 ± 19 (0 – 78)	34 ± 22 (0 – 80)	p = 0.022*†	Visit 2 – Visit 3 (0.043)
SANDE II[a]	Frequency	/	1 ± 6 (-15 – 14); p = 0.358¥	−11 ± 10 (-40 – 12); p < 0.005*§	8 ± 13 (-10 – 40); p = 0.005*¥	/	
	Severity	/	0 ± 6 (-17 – 16); p = 0.904¥	−12 ± 12 (-37 – 10); p < 0.005*§	4 ± 17 (-40 – 40); p = 0.222¥	/	
TMH (mm)		0.23 ± 0.13 (0.11 – 0.73)	0.23 ± 0.11 (0.09 – 0.64)	0.24 ± 0.10 (0.11 – 0.51)	/	p = 0.538†	—
Conjunctival redness	Bulbar - Temporal	0.8 ± 0.4 (0.2 – 1.8)	0.8 ± 0.5 (0.2 – 1.9)	0.8 ± 0.4 (0.2 – 1.8)	/	p = 0.677†	—
	Bulbar - Nasal	1.1 ± 0.6 (0.2 – 2.7)	1.1 ± 0.6 (0.1 – 2.9)	1.1 ± 0.7 (0.3 – 2.5)	/	p = 0.972†	—
	Limbal - Temporal	0.4 ± 0.4 (0.0 – 1.6)	0.4 ± 0.4 (0.0 – 1.7)	0.4 ± 0.3 (0.1 – 1.3)	/	p = 0.810 ‡	—
	Limbal - Nasal	0.6 ± 0.5 (0.1 – 1.8)	0.6 ± 0.5 (0.0 – 1.7)	0.7 ± 0.5 (0.1 – 2.2)	/	p = 0.504 ‡	—
Blink rate (blinks / min)		23 ± 14 (0 – 64)	22 ± 16 (4 – 64)	17 ± 12 (1 – 54)	/	p = 0.034*‡	Visit 1 – Visit 3 (0.040)
Incomplete blinking (%)		56 ± 31 (0 – 100)	53 ± 31 (0 – 100)	49 ± 31 (0 – 100)	/	p = 0.089‡	—
Lipid layer thickness[b]		3 ± 1 (1 – 5)	3 ± 1 (1 – 5)	3 ± 1 (1 – 5)	/	p = 0.180‡	—
NIKBUT		10.98 ± 6.19 (4.25 – 24.16)	10.83 ± 5.85 (3.51 – 23.39)	10.79 ± 6.22 (3.70 – 23.55)	/	p = 0.991‡	—
Corneal staining		1 ± 1 (0 – 3)	1 ± 1 (0 – 4)	1 ± 1 (0 – 3)	/	p = 0.924‡	—
Conjunctival staining		1 ± 1 (0 – 4)	1 ± 1 (0 – 3)	1 ± 1 (0 – 4)	/	p = 0.685‡	—
LWE	Horizontal length	1 ± 1 (0 – 3)	1 ± 1 (0 – 3)	1 ± 1 (0 – 3)	/	p = 0.584‡	—
	Sagittal width	0 ± 1 (0 – 4)	0 ± 1 (0 – 3)	0 ± 1 (0 – 3)	/	p = 0.360‡	—
MGD (%)	Upper eyelid	23.8 ± 14.0 (2.7 – 69.0)	/	/	/	/	
	Lower eyelid	41.2 ± 18.2 (10.3 – 69.9)	/	/	/	/	

CVS-Q = Computer vision syndrome questionnaire; OSDI = Ocular surface disease index; DEQ-5 = 5-item dry eye questionnaire; SANDE I = Symptom assessment in dry eye questionnaire, version 1; SANDE II = Symptom assessment in dry eye questionnaire, version 2; TMH = Tear meniscus height; NIKBUT = Non-invasive keratograph break-up time; LWE = Lid wiper epitheliopathy; MGD = Meibomian gland dysfunction. [a] Statistical comparison with value of 0 (no change). [b] Graded as: 1 = open meshwork; 2 = closed meshwork; 3 = wave; 4 = amorphous; 5 = 1st order colours; 6 = 2nd order colours. Asterisks denote statistically significant values ($p < 0.05$). † Repeated-measures ANOVA. ‡ Friedman. § One-sample *t*-test. ¥ One-sample Wilcoxon signed rank test.

of dry eye signs and symptoms amongst digital display users.[9] Ocular surface and tear film abnormalities, including reduced tear stability, alterations in tear volume and tear composition, increased oxidative stress, ocular surface inflammation and even meibomian gland dysfunction have been found in computer users and tend to exacerbate with longer durations of device use.[44–47] Alterations in the pattern of blinking, mainly a reduction in the blink rate and blink amplitude (i.e., increase in incomplete blinking), have been identified as one of the main mechanisms behind the harmful effects of digital screens on the ocular surface.[48,49].

According to the results of the present study, participants exhibited a noticeable reduction in the blink rate while using the computer (8 – 9 blinks/min when using the computer vs 16 – 22 blinks/min when looking in primary gaze). This is closely in line with previous research on contemporary digital device usage.[48] Most importantly, following the 20-20-20 rule had no effects on the blink rate and blink duration of participants while using the computer. Therefore, the 20-20-20 rule reminders are likely to have no beneficial effect on the blinking pattern during device use.

Furthermore, there was a significant improvement in dry eye symptoms after the management period. Following the 20-20-20 rule led to a lower OSDI compared to previous visits, although this was not enough to prevent a positive symptom score (OSDI ≥ 13). Likewise, the severity of dry eye symptoms reported in SANDE I was lower after the management period compared to before, leading to a lower total SANDE I score, although no change in the frequency of dry eye symptoms was observed between visits. In parallel, the SANDE II scores after the management period were significantly smaller than 0, meaning that both the severity and frequency of symptoms reported by the participants were lower compared to the previous visit (visit 2).

Symptoms of dryness (OSDI and SANDE I) reported one week after the discontinuation of the 20-20-20 rule (visit 4) were not different from those reported before the management strategy (visits 1 and 2), yet they were not greater than those observed at visit 3, thus some of the improvement was maintained one week after discontinuation. Similarly, the frequency score in SANDE II obtained one week after the discontinuation of the rule reminders was significantly greater than zero, although the severity score revealed no difference. Consequently, the frequency of dry eye symptoms increased one week after the interruption of the strategy, yet the perceived severity of dry eye was maintained.

Conversely, no differences in dry eye signs were observed between visits for any of the parameters, except for the blink rate which was significantly lower after the management period with the 20-20-20 rule compared to baseline (visit 1). One of the main factors responsible for normal spontaneous blinks is the imminent break-up of the tear film which is sensed by the cornea.[50] Consequently, excessive blinking has been associated with reduced tear stability and may occur as a wetting process.[51] The reduction in the spontaneous blink rate observed in the present study after the management period might reveal an improvement in tear function, though this was not accompanied by an improvement in any tear film parameter.

As aforementioned, participants naturally looked away from the screen or moved away from their workstation frequently even before the activation of the rule reminders. Therefore, although the 20-20-20 rule prevented exposure times higher than 20 min, it did not request a considerable number of rule breaks for most individuals, which may explain why, despite an improvement in symptoms, most parameters remained unvaried.

Finally, the CVS-Q score was significantly lower after the management period compared to before, thus DES significantly decreased as a result of the 20-20-20 rule reminders. Particularly, the CVS-Q score of some participants fell below 6 (positive CVS-Q score) after two-weeks compliance with the 20-20-20 rule, thus excluding them from a positive DES diagnosis after the management period. Nevertheless, no difference with pre-management values was observed one week after the discontinuation of the reminders, although, as with dry eye symptoms, DES was not greater than at visit 3 and therefore some improvement was maintained at the follow-up visit. These results are in accordance with previous research.[14,52] Anggrainy et al.[52] found a significant difference in the incidence of DES between a treatment group taking breaks every 20 min during 5 working days and a control group. Similarly, Alghamdi et al.[14] found a reduction in DES in a group of symptomatic individuals 20 days after they were given a structured advice booklet with instructions on the 20-20-20 rule. Nevertheless, despite the improvement observed in the present study, the 20-20-20 rule did not prevent DES (CVS-Q $\geq$ 6).

The present study had some limitations to consider. Due to the subjective evaluation of symptoms, a placebo effect on the results cannot be completely ruled out. However, this can be considered as intrinsic to any study assessing symptoms after a management strategy. Additionally, the developed software was downloaded onto the participants' laptops only, and therefore did not take into account the use of other digital devices. Finally, due to the large volume of tests performed, fatigue effects may have influenced binocular vision measurements to some extent. Nevertheless, as aforementioned, rest periods were left between repeated measurements and between test procedures. Additionally, the order of the measurements was chosen to minimize the effects of fatigue on the results.

Overall, following the 20-20-20 rule significantly changed the way the participants used their computers by increasing the total number of breaks taken per day, and by reducing the duration of breaks and the time spent looking at the computer screen without rest. However, the blinking pattern exhibited during device use was not different and the blink rate remained low. The 20-20-20 rule improved binocular accommodative facility, although it had no effects on any other accommodative or vergence parameters. Furthermore, the 20-20-20 rule was effective in reducing DES and dry eye symptoms, although it was not sufficient to prevent DES or a positive OSDI score. Moreover, the improvement in symptoms was barely sustained one week after discontinuation, with the frequency of dry eye symptoms receding more to previous levels than the severity. Conversely, no improvement in dry eye signs was observed during the study period. Further reducing the time interval between breaks or offering personalized rule breaks, based on the natural habits of computer users, may prove more beneficial. Future research in larger samples is required to confirm these findings. Also, specific research on the matter is needed to assess and compare the effectiveness of the 20-20-20 rule in different population groups, especially in individuals with different durations of computer usage.

Funding

This work was supported by the Spanish Ministry of Education [grant number FPU17/03665]; and the "Conselleria d'Educació, Investigació, Cultura i Esport de la Generalitat Valenciana" [grant number GV/2018/059].

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] American Optometric Association. Computer vision syndrome. AOA; 2018. Available at: https://www.aoa.org/patients-and-public/caring-for-your-vision/protecting-your-vision/computer-vision-syndrome?sso=y. Accessed January 20, 2022.
[2] Sheppard AL, Wolffsohn JS. Digital eye strain: prevalence, measurement and amelioration. BMJ Open Ophthalmol 2018;3(1):e000146. https://doi.org/10.1136/bmjophth-2018-000146.
[3] Sánchez-Brau M, Domenech-Amigot B, Brocal-Fernández F, Quesada-Rico JA, Seguí-Crespo M. Prevalence of Computer Vision Syndrome and Its Relationship with Ergonomic and Individual Factors in Presbyopic VDT Workers Using Progressive Addition Lenses. Int J Environ Res Public Health 2020;17(3):1003. https://doi.org/10.3390/ijerph17031003.
[4] Cantó-Sancho N, Sánchez-Brau M, Ivorra-Soler B, Seguí-Crespo M. Computer vision syndrome prevalence according to individual and video display terminal exposure characteristics in Spanish university students. Int J Clin Pract 2021;75(3):e13681. https://doi.org/10.1111/ijcp.13681.
[5] Ganne P, Najeeb S, Chaitanya G, Sharma A, Krishnappa NC. Digital Eye Strain Epidemic amid COVID-19 Pandemic - A Cross-sectional Survey. Ophthalmic Epidemiol 2021;28(4):285–92. https://doi.org/10.1080/09286586.2020.1862243.
[6] Sheedy JE, Hayes JN, Engle J. Is all asthenopia the same? Optom Vis Sci 2003;80:732–9. https://doi.org/10.1097/00006324-200311000-00008.
[7] Portello JK, Rosenfield M, Bababekova Y, Estrada JM, Leon A. Computer-related visual symptoms in office workers. Opthalmic Physiol Opt 2012;32(5):375–82. https://doi.org/10.1111/j.1475-1313.2012.00925.x.
[8] Rosenfield M. Computer vision syndrome: a review of ocular causes and potential treatments. Ophthalmic Physiol Opt 2011;31(5):502–15. https://doi.org/10.1111/j.1475-1313.2011.00834.x.
[9] Talens-Estarelles C, García-Marqués JV, Cervino A, García-Lázaro S. Use of digital displays and ocular surface alterations: A review. Ocul Surf 2021;19:252–65. https://doi.org/10.1016/j.jtos.2020.10.001.
[10] Jaiswal S, Asper L, Long J, Lee A, Harrison K, Golebiowski B. Ocular and visual discomfort associated with smartphones, tablets and computers: what we do and do not know. Clin Exp Optom 2019;102(5):463–77. https://doi.org/10.1111/cxo.12851.
[11] Coles-Brennan C, Sulley A, Young G. Management of digital eye strain. Clin Exp Optom 2019;102:18–29. https://doi.org/10.1111/cxo.12798.
[12] Tribley J, McClain S, Karbasi A, Kaldenberg J. Tips for computer vision syndrome relief and prevention. Work 2011;39(1):85–7. https://doi.org/10.3233/WOR-2011-1183.
[13] Anshel J, editor. Visual Ergonomics Handbook. New York: Taylor and Francis; 2005.
[14] Alghamdi WM, Alrasheed SH. Impact of an educational intervention using the 20/20/20 rule on Computer Vision Syndrome. African Vis Eye Health J 2020;79(1).
[15] Fogelton A, Benesova W. Eye blink detection based on motion vectors analysis. Comput Vis Image Underst 2016;148:23–33. https://doi.org/10.1016/j.cviu.2016.03.011.
[16] Seguí Mdel M, Cabrero-García J, Crespo A, Verdú J, Ronda E. A reliable and valid questionnaire was developed to measure computer vision syndrome at the workplace. J Clin Epidemiol 2015;68(6):662–73. https://doi.org/10.1016/j.jclinepi.2015.01.015.
[17] Schiffman RM, Christianson MD, Jacobsen G, Hirsch JD, Reis BL. Reliability and validity of the ocular surface disease index. Arch Ophthalmol 2000;118(5):615–21. https://doi.org/10.1001/archopht.118.5.615.

[18] Chalmers RL, Begley CG, Caffery B. Validation of the 5-Item Dry Eye Questionnaire (DEQ-5): Discrimination across self-assessed severity and aqueous tear deficient dry eye diagnoses. Cont Lens Anterior Eye 2010;33(2):55–60. https://doi.org/10.1016/j.clae.2009.12.010.

[19] Schaumberg DA, Gulati A, Mathers WD, Clinch T, Lemp MA, Nelson JD, et al. Development and validation of a short global dry eye symptom index. Ocul Surf 2007;5(1):50–7. https://doi.org/10.1016/s1542-0124(12)70053-8.

[20] Wolffsohn JS, Arita R, Chalmers R, Djalilian A, Dogru M, Dumbleton K, et al. TFOS DEWS II Diagnostic Methodology report. Ocul Surf 2017;15(3):539–74. https://doi.org/10.1016/j.jtos.2017.05.001.

[21] Mallett RF. The investigation of heterophoria at near and a new fixation disparity technique. Optician 1964;148:547–51.

[22] Pediatric Eye Disease Investigator Group. Interobserver reliability of the prism and alternate cover test in children with esotropia. *Arch Ophthalmol* 2009;127(1):59–65. doi:10.1001/archophthalmol.2008.548.

[23] Wesson MD. Normalization of prism bar vergences. Am J Optom Physiol Opt 1982;59(8):628–34. https://doi.org/10.1097/00006324-198208000-00002.

[24] Neely JC. The RAF near point rule. Br J Ophthal 1956;40:636–7.

[25] Abdelfattah NS, Dastiridou A, Sadda SR, Lee OL. Noninvasive imaging of tear film dynamics in eyes with ocular surface disease. Cornea 2015;34(10):48–52. https://doi.org/10.1097/ICO.0000000000000570.

[26] Wu S, Hong J, Tian L, Cui X, Sun X, Xu J. Assessment of bulbar redness with a newly developed keratograph. Optom Vis Sci 2015;92(8):892–9. https://doi.org/10.1097/OPX.0000000000000643.

[27] Ren Y, Chen J, Zheng Q, Chen W. Short-term effect of a developed warming moist chamber goggle for video display terminal-associated dry eye. BMC Ophthalmol 2018;18(1):33. https://doi.org/10.1186/s12886-018-0700-y.

[28] Guillon JP. Non-invasive Tearscope Plus routine for contact lens fitting. Cont Lens Anterior Eye 1998;1:S31–40. https://doi.org/10.1016/s1367-0484(98)80035-0.

[29] Hong J, Sun X, Wei A, Cui X, Li Y, Qian T, et al. Assessment of tear film stability in dry eye with a newly developed keratograph. Cornea 2013;32(5):716–21. https://doi.org/10.1097/ICO.0b013e3182714425.

[30] Bron AJ, Evans VE, Smith JA. Grading of corneal and conjunctival staining in the context of other dry eye tests. Cornea 2003;22(7):640–50. https://doi.org/10.1097/00003226-200310000-00008.

[31] Korb DR, Herman JP, Greiner JV, Scaffidi RC, Finnemore VM, Exford JM, et al. Lid wiper epitheliopathy and dry eye symptoms. Eye Contact Lens 2005;31(1):2–8. https://doi.org/10.1097/01.icl.0000140910.03095.fa.

[32] Ngo W, Srinivasan S, Schulze M, Jones L. Repeatability of grading meibomian gland dropout using two infrared systems. Optom Vis Sci 2014;91(6):658–67. https://doi.org/10.1097/OPX.0000000000000279.

[33] Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods 2007;39(2):175–91. https://doi.org/10.3758/bf03193146.

[34] Kwon K, Woo JY, Park M, Kim SR. The change of accommodative function by the direction of eye movements during computer game. J Korean Ophthalmic Opt Soc 2012;17:177–84.

[35] Seo E. Changes in accommodative function after VDT work. J Korean Ophthalmic Opt Soc 2012;17:285–91.

[36] Piccoli B, Braga M, Zambelli PL, Bergamaschi A. Viewing distance variation and related ophthalmological changes in office activities with and without VDUs. Ergonomics 1996;39:719–28. https://doi.org/10.1080/00140139608964493.

[37] Park K, Lee W, Lee N. Lee JY Changes in near lateral phoria and near point of convergence after viewing smartphones. J Korean Ophthalmic Opt Soc 2012;17:5.

[38] Hue JE, Rosenfield M, Saá G. Reading from electronic devices versus hardcopy text. Work 2014;47(3):303–7. https://doi.org/10.3233/WOR-131777.

[39] Rosenfield M, Gurevich R, Wickware E, Lay M. Computer Vision Syndrome: Accommodative & Vergence Facility. Invest Ophthalmol Vis Sci 2010;21:119–22.

[40] Collier JD, Rosenfield M. Accommodation and convergence during sustained computer work. Optometry 2011;82:434–40. https://doi.org/10.1016/j.optm.2010.10.013.

[41] Yammouni R, Evans BJW. Is reading rate in digital eyestrain influenced by binocular and accommodative anomalies? J Optom 2021;14(3):229–39. https://doi.org/10.1016/j.optom.2020.08.006.

[42] Iribarren R, Fornaciari A, Hung GK. Effect of cumulative nearwork on accommodative facility and asthenopia. Int Ophthalmol 2001;24:205–12. https://doi.org/10.1023/a:1022521228541.

[43] Stapleton F, Alves M, Bunya VY, Jalbert I, Lekhanont K, Malet F, et al. TFOS DEWS II Epidemiology Report. Ocul Surf 2017;15(3):334–65. https://doi.org/10.1016/j.jtos.2017.05.003.

[44] Talens-Estarelles C, Sanchis-Jurado V, Esteve-Taboada JJ, Pons ÁM, García-Lázaro S. How do different digital displays affect the ocular surface? Optom Vis Sci 2020;97(12):1070–9. https://doi.org/10.1097/OPX.0000000000001616.

[45] Choi JH, Li Y, Kim SH, Jin R, Kim YH, Choi W, et al. The influences of smartphone use on the status of the tear film and ocular surface. PLoS ONE 2018;13(10):e0206541. https://doi.org/10.1371/journal.pone.0206541.

[46] Yazici A, Sari ES, Sahin G, Kilic A, Cakmak H, Ayar O, et al. Change in tear film characteristics in visual display terminal users. Eur J Ophthalmol 2014;25(2):85–9. https://doi.org/10.5301/ejo.5000525.

[47] Wu H, Wang Y, Dong N, Yang F, Lin Z, Shang X, et al. Meibomian gland dysfunction determines the severity of the dry eye conditions in visual display terminal workers. PLoS ONE 2014;9(8):e105575. https://doi.org/10.1371/journal.pone.0105575.

[48] Talens-Estarelles C, Esteve-Taboada JJ, Sanchis-Jurado V, Pons ÁM, García-Lázaro S. Blinking kinematics characterization during digital displays use. Graefes Arch Clin Exp Ophthalmol 2021. https://doi.org/10.1007/s00417-021-05490-9.

[49] Chu C, Rosenfield M, Portello J. Computer vision syndrome: blink rate and dry eye during hard copy or computer viewing. Invest Opthalmol Vis Sci 2010;51:951.

[50] Collins M, Seeto R, Campbell L, Ross M. Blinking and corneal sensitivity. Acta Ophthalmol 1989;67(5):525–31. https://doi.org/10.1111/j.1755-3768.1989.tb04103.x.

[51] Rahman EZ, Lam PK, Chu CK, Moore Q, Pflugfelder SC. Corneal sensitivity in tear dysfunction and its correlation with clinical parameters and blink rate. Am J Ophthalmol 2015;160(5):858–866.e5. https://doi.org/10.1016/j.ajo.2015.08.005.

[52] Anggrainy P, Lubis RR, Ashar T. The effect of trick intervention 20-20-20 on computer vision syndrome incidence in computer workers. J Opthalmol (Ukraine) 2020:22–7. https://doi.org/10.31288/oftalmolzh202012227.