Journal of Optometry 19 (2026) 100584

Contents lists available at ScienceDirect

Journal of Optometry

journal homepage: www.journalofoptometry.org

Original Article

Characterization of eye blink parameters during high and low-dynamic scenes in different video game genres

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A R T I C L E   I N F O

Keywords:
Videogame
Blink rate
Blink amplitude
Blink regularity
Cognitive factors

Purpose: Playing videogames involves prolonged screen exposure, potentially leading to ocular discomfort and altered eye blink behavior. However, until date, only action video game genres have been considered for their effects on blink rate and amplitude, compared to non-action video games. This study explored blink rate, amplitude, and regularity across video game genres and the influence of specific in-game scenes on blinking.

Methods: Twenty casual gamers (mean age 26.2 ± 4.6 years) were enrolled in the study. Blink parameters were recorded using the Pupil Core eye tracker while watching and playing three video games in random order: Call of Duty (Action), Sackboy (Adventure), and FIFA 19 (Sports). Blink rate, amplitude and regularity were analyzed during baseline, gameplay viewing and active play sessions. Blink parameters during high- and low-dynamic in-game scenes were examined.

Results: Blink rate significantly decreased during both gameplay viewing and active play compared to baseline ($p < 0.001$). The lowest blink rate was observed in action video games, but differences among genres did not reach statistical significance. No significant differences were found in incomplete blinks across conditions. Blink regularity was significantly different between game genres, with sports games showing the highest irregularity. Participants blinked less frequently during high-dynamic scenes across all genres ($p = 0.007$).

Conclusions: Blink rate was similarly reduced in all gameplay situations, although action games had the largest impact on blink irregularity. Incomplete blinks did not differ between genres. Blinks tended to occur less during high-dynamic in-game scenes across videogame genres, with potential implications on ocular discomfort and dryness.

Introduction

Playing videogames is one of the most popular spare time entertainments nowadays. According to Statista, the average daily time spent playing videogames is 1 hour (h),[1] although some gamers may devote up to 4 h a day to play.[2] In addition, athletes competing in e-sports can increase this time up to 8 h.[3] Multiple reviews have documented that the amount of time spent in front of the computer or other types of displays has a direct influence on a variety of symptoms related to visual disturbance, ocular discomfort and dryness, commonly described with the term computer vision syndrome (CVS).[4,5] Video gaming is often accompanied by long, uninterrupted periods of screen use. Thus, the potential for exacerbating visual symptoms in gamers is a critical issue to address, especially considering the growing popularity of gaming as both a recreational and competitive activity.

In addition to the duration of screen exposure, the type of video game genre may play a role in determining the degree to which these symptoms manifest. Video games span a wide range of genres, including Action, Role-Playing Games (RPG), Multiplayer Online Battle Arenas (MOBA), Sports, Adventure, and many others, each with its own unique gameplay mechanics and objectives.[6] These genres differ not only in their visual demands, but also in the cognitive and motor functions they engage in, which can influence how players interact with the game. For instance, action video games (AVG), known for their fast-paced, dynamic nature, have been shown to impact certain aspects of visual function, including enhancing visual attention,[7,8] dynamic visual acuity,[9] and visuo-motor coordination,[10] as well as improving other cognitive functions.[11,12]

Despite positive effects on cognitive and visual functions, there is evidence to suggest that playing AVG can also lead to a decrease in blinking rate, measured in blinks per minute (bpm), and to an increase in the occurrence of incomplete blinking.[13] The relationship between visual attention and blink rate is well-documented in the literature, noting that, as visual attention is heightened, blink rate tends to decrease.[14,15] In the context of AVG, the fast-paced, high-stakes nature of the gameplay requires players to maintain intense focus and attention, which may

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https://doi.org/10.1016/j.optom.2025.100584
Received 8 May 2025; Accepted 11 September 2025
Available online 16 October 2025

inhibit their tendency to blink as frequently as during less exacting activities. Reduced blink rate, as well as incomplete blinking and blink irregularity, have been shown to disrupt tear film production and distribution on the ocular surface, which is essential for eye comfort and health.[13,16,17] Non-action video games (NAVG), which typically involve slower-paced, more deliberate gameplay, may not place the same intense demands on visual attention, and thus may not result in the same alterations in blink parameters, although the differences in blink behavior across game genres remains largely unexplored. Indeed, each genre is likely to place distinct demands on visual processing, attention, and cognitive resources, which may influence blinking patterns in different ways. For example, in adventure or RPG games, which typically involve longer periods of exploration and interaction with the game world, players may exhibit different blinking patterns than when playing fast-paced action or MOBA games that require rapid decision-making and coordination.

Furthermore, the specific in-game scenes and the types of visual stimuli they present, such as intense visual action sequences, high-speed motion, or static environments, could also play a role in determining blink occurrence and completeness during gameplay. For instance, blink analysis of viewers of a short film revealed that blinking tended to coincide with moments in which the amount visual information appearing on screen was low or consisted in repeated scenes, resulting in an increased blink irregularity.[18−20]

Given these considerations, the present study was aimed at exploring eye blink parameters, including blink rate, blink amplitude, and blink regularity, across different video game genres (AVG, adventure and sports). In addition, the interaction between game genre and specific in-game scenes was investigated, with the purpose of gaining a deeper understanding of the mechanisms governing how the dynamic nature of video game environments impacts ocular health and visual comfort. Finally, blinking parameters during actual gameplay were compared with those recorded while participants viewed videos of gameplay to determine the influence of cognitive engagement on blinking.

Methods

Study participants

Participants were recruited through social media posts, friends, and acquaintances to take part in this research, which was conducted in university settings. Inclusion criteria were age between 18 and 35 years, and casual video game playing experience, with average weekly playing time of more than 1 h, but <5 h. All participants were required to have a monocular best-corrected visual acuity of ≥20/20 (Bailey-Lovie chart) with their habitual refractive correction, stereoacuity of ≤70 arcseconds (Random Dot Test), and no signs of strabismus (Cover-Uncover test). To avoid potential inference of contact lens wear with blink dynamics, all participants wore their glasses for the duration of the study, regardless of whether their habitual correction was glasses or contact lenses. None of the participants had high refractive errors (e.g., moderate or high myopia or astigmatism) that could alter visual demands. Exclusion criteria were amblyopia and color vision anomalies (Ishihara test). The validated and translated Ocular Surface Disease Index (OSDI) questionnaire was administered to all participants. Only participants with a score of <13 were included in the study, i.e., normal ocular surface conditions with minimal or no dry eye symptoms.[21] Participants were informed of the nature of the study and signed a written informed consent before participation. The study was approved by an institutional review board at the Universitat Politècnica de Catalunya (UPC).

Videogames and measurements

Three games of different genres were selected for this study: the commercial video game *Call of Duty: Modern Warfare*® (Activision Publishing Inc., Santa Monica, CA, US) as an AVG, *Sackboy: A Big Adventure*® (Sony Interactive Entertainment Inc., San Mateo, CA, US) as an adventure game (ADV), and *FIFA 19*® (Electronic Arts Inc., Redwood City, CA, US) as a sports video game (SPO). *Call of Duty* is a first-person shooter videogame franchise known for its fast-paced combat, realistic military settings, and multiplayer gameplay. It includes a zombie-mode, which was used for this study. *Sackboy* is a platforming game series, emphasizing creative level design, cooperative multiplayer, and puzzle-solving. *FIFA 19* is a soccer simulation game featuring realistic gameplay, official team and player licenses, and various game modes. A PlayStation 4 (Sony Interactive Entertainment Inc., San Mateo, CA, US) and a wireless gamepad were used for playing. All participants needed to be familiarized with the gamepad to prevent the need to look at it while playing.

Eye blinks were recorded using the eye tracker Pupil Core (Pupil Labs, Berlin, Germany) at 200 Hz. This device registers eye movements using two cameras and simultaneously captures the view the participants are looking at with an additional camera. After verifying the inclusion criteria, participants were seated, and the eye-tracker calibration was performed. A standard nine-point calibration procedure was performed, where participants fixated on predefined points displayed on a screen. The system recorded gaze positions and adjusted for individual variations in pupil size and eye position. After calibration, a validation step was carried out to assess accuracy, and recalibration was performed if necessary.

During baseline viewing conditions, participants sat 2 m away from a television screen (TD Systems, 50″, Ultra HD 4 K, 3840 × 2160 pixels) and watched a naturalistic image (a green forest) in silence for 2 min. Then, participants viewed three 2-min gameplay video excerpts on the same television at 2 m, one for each game, presented in random order. These gameplays were pre-recorded by the authors and corresponded to the same games used in the study. The gameplay sequences started at the same scenes in *Call of Duty* and *Sackboy* that the participants would later play. However, for *FIFA 19*, this was not strictly controlled, although it may be assumed that in this type of game, gameplay maintains similar characteristics throughout the match. Finally, participants played each of the three games for 5 min in random order on the same television and also at a distance of 2 m. To avoid potential triggers for eye blinking, all conditions, including viewing gameplays and playing, were conducted in silence.[22] The Pupil Core software was used to capture video recordings from both eyes at baseline and while participants viewed gameplay videos or actively played video games. These recordings were used to characterize blinking during a posterior analysis, as described below.

To examine the specific scenes in which participants blinked, gameplay scenarios were categorized as containing "high dynamic" or "low dynamic" scenes, as seen in Table 1.

All measurements were conducted in the same room under consistent illumination (500 lx), with participants wearing their habitual refractive correction.

Blinking analysis

The Pupil Core system software (Pupil Player) was used to open and view recorded files. For the purposes of blinking analysis, the complete 2-minute video recordings obtained at baseline and during gameplay viewing conditions were used, while only the central 2 min (minutes 2 to 4) of active play were considered. The number of complete blinks during each of the 2-minute video segments was counted to obtain mean blink rates (in bpm). To determine blink amplitude, complete blinks were defined as the upper eyelid covering more than three-quarters of the eye during closure; otherwise, blinks were classified as incomplete. The Pupil Player slow-motion functionality was used to improve the accuracy of the blink amplitude analysis while counting incomplete blinks per minute for each experimental condition.

To assess blink regularity, mean interblink intervals (IBI) were calculated for each 2-minute video segment by recording the time (in seconds) at which each complete blink occurred within each minute.[23]

Table 1
High or low dynamic scenes for each game under analysis.

	High dynamic scenes	Low dynamic scenes
Call of Duty	Enemies appear on screen, gun reloads, aiming and shooting at enemies	Scenes without enemies, death of player
Sackboy	Enemies are present, collecting items, traversing enemy populated areas, jumping between objects	Walking without encountering enemies, and without jumping
FIFA 19	Opponents approach the goalkeeper, carrying the ball, passing and shooting	Play pauses due to offside, fouls (yellow/red cards), or when the ball moves out of bounds.

Blink regularity was defined as the coefficient of variation of the inter-blink interval (i.e., the standard deviation of IBI divided by its mean: values under 100 % may be considered to denote low variance or moderate to high regularity, whereas values over 100 % correspond to low regularity, or a wider dispersion of blinks within the explored time-frame).[24]

In addition, the particular scenes at which participants conducted each blink were identified. For this purpose, the Pupil Core provides synchronous recordings of the eyes of the participants and the scenes they are observing.

Color and luminance levels between videogames

The color and luminance (brightness) of the three video games was analyzed, as these properties can influence overall visual comfort.[4,5] An OHSP-350-F Portable Spectral irradiance colorimeter from HOPOO-COLOR (Hopoo Light&Color Technology Co.,Ltd., Hangzhou, China) was employed for this purpose. A 2-minute gameplay of each game was displayed on a laptop screen (Lenovo ThinkPad E16 Gen 1, 16″, 1920 × 1200 pp, set up at high contrast), and an equivalent number of still frames was selected for each videogame (every 0.66 s).

The spectral colorimeter was positioned at a fixed distance from the screen (40 cm), reproducing a viewing angle of 38°. All additional lighting in the laboratory was switched off so that the spectroradiometer received the impinging light from the laptop screen alone. For every single frame, five consecutive measures were taken, including the illuminance in lux, correlated color temperature (CCT) in Kelvin, and x and y chromaticity parameters derived from the tristimulus values X, Y, Z of the CIE 1931 color space. Mean values were computed.

Statistical analysis

Statistical analysis was conducted using the SPSS version 28 for Windows (Armonk, NY: IBM Corp). Blink parameters were first examined for data distribution with the Kolmogorov-Smirnov test. A repeated measures ANOVA was conducted to analyze differences in blink parameters (blink rate, number of incomplete blinks, blink regularity) across the seven conditions (baseline, three gameplay viewing sessions, and three playing sessions). The Greenhouse-Geisser correction was applied in those instances in which sphericity could not be assumed (Mauchly's test $p < 0.05$) and the corresponding post-hoc corrections (Tukey's test) were considered to reduce the probability of Type I error. A p-value <0.05 denoted statistical significance.

The free software G*Power,[25,26] was employed for *a priori* sample size calculation, based on a previous study comparing blink rates between action and non-action video games,[13] assuming an alpha risk of 0.05, a beta risk of 0.20, a bilateral contrast model, three groups, and a repeated measures ANOVA. This calculation determined that a sample size of 20 participants would achieve >90 % statistical power.

Results

Twenty participants (12 females) were included in the study, with a mean age and standard deviation (±SD) of 26.2 ± 4.6 years, and a range from 21 to 35 year.

Blink rate, incomplete blinks, and regularity

Table 2 presents a summary of blink parameters for each condition (Fig. 1). Overall, mean blink rate was 12.79 ± 8.42 bpm, with 4.34 ± 5.52 incomplete bpm, and 62.93 ± 11.23 % of regularity. The ANOVA of repeated measures for the 7 factors (baseline, 3x gameplay viewing, 3x active playing) showed a significant effect for blink rate, ($F(2.37,45.07) = 16.01$, $p < 0.001$, $\eta_p^2 = 0.459$). Post-hoc pair-wise analysis revealed a statistically significant difference in blink rate between baseline and all gameplay viewing conditions (AVG mean differences of

Table 2
Descriptive data for blink rate, incomplete blinks and blink regularity (as a coefficient of variation, in percentage) for all experimental conditions. Results are shown as mean ± standard deviation (SD), 95 % confidence interval (CI) and range (min to max). AVG = *Call of Duty*, ADV = *Sackboy*, SPO = *FIFA 19*.

			Blink Rate (blinks/minute)	Incomplete Blinks (blinks/minute)	Regularity (%)
Baseline		Mean and SD	12.79 ± 8.42	4.34 ± 5.52	62.93 ± 11.23
		95 % CI	(8.84, 11.62)	(1.75, 6.92)	(57.67, 68.19)
		min to max	1.50, 33.00	0.00, 21.00	47.40, 86.60
Gameplay viewing	AVG	Mean and SD	8.15 ± 7.42	3.28 ± 3.20	64.51 ± 14.32
		95 % CI	(4.67, 11.62)	(1.77, 4.77)	(57.81, 71.21)
		min to max	0.50, 24.00	0.00, 14.50	35.36, 86.30
	ADV	Mean and SD	8.10 ± 6.38	4.43 ± 4.94	73.90 ± 12.62
		95 % CI	(5.11, 11.08)	(2.11, 6.73)	(68.00, 79.81)
		min to max	1.50, 19.50	0.00, 18.00	55.52, 91.44
	SPO	Mean and SD	7.64 ± 6.95	3.55 ± 3.66	40.46 ± 14.48
		95 % CI	(4.38, 10.89)	(1.83, 5.26)	(33.68, 47.24)
		min to max	0.50, 20.50	0.00, 11.50	22.48, 68.59
Playing	AVG	Mean and SD	3.70 ± 3.45	2.74 ± 2.22	63.62 ± 26.89
		95 % CI	(2.08, 5.32)	(1.69, 3.77)	(51.03, 76.20)
		min to max	0.00, 15.00	0.00, 8.00	0.00, 95.18
	ADV	Mean and SD	3.88 ± 2.57	3.68 ± 3.70	54.09 ± 24.05
		95 % CI	(2.68, 5.09)	(1.94, 5.40)	(42.83, 65.34)
		min to max	0.00, 11.00	0.00, 11.50	0.00, 82.44
	SPO	Mean and SD	4.26 ± 3.86	2.87 ± 2.49	58.04 ± 28.82
		95 % CI	(2.45, 6.06)	(1.70, 4.04)	(44.56, 71.53)
		min to max	0.00, 15.00	0.00, 8.00	0.00, 93.90

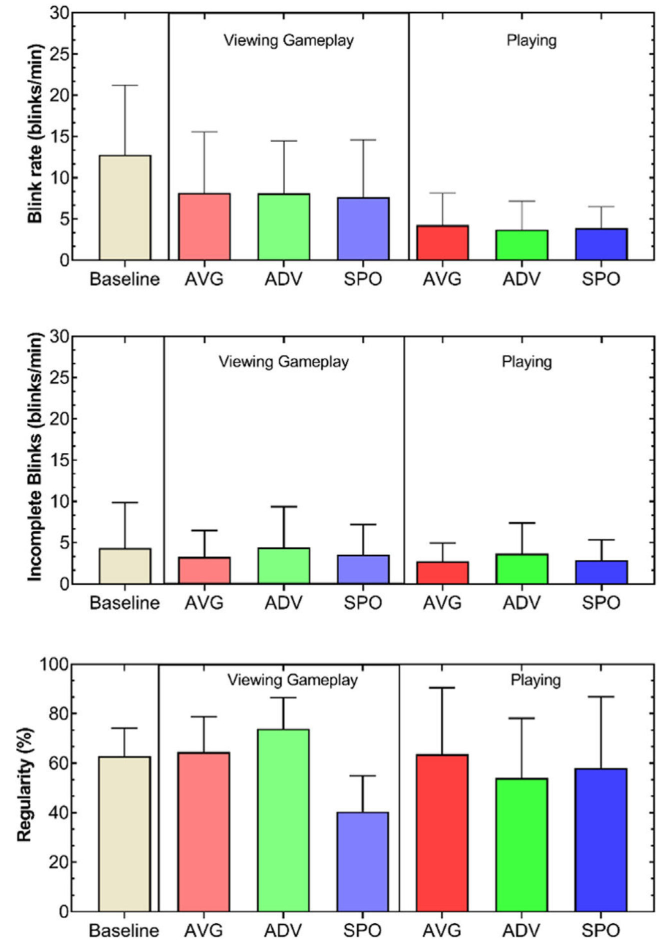

Fig. 1. Bar plots showing mean and standard deviation values for blink rate (blinks/minute), incomplete blinks (blinks/minute) and regularity (coefficient of variation in percentage) for baseline, gameplay viewing and active playing (AVG = *Call of Duty*, ADV = *Sackboy*, SPO = *FIFA 19*).

4.64 bpm for AVG, $p = 0.014$; 4.68 bpm for ADV, $p = 0.012$; 5.15 bpm for SPO, $p = 0.019$), and all playing conditions (9.08 bpm for AVG, $p < 0.001$; 8.90 bpm for ADV, $p < 0.001$; 8.52 bpm for SPO, $p < 0.001$). Statistically significant differences were found in blink rates when comparing viewing vs. playing the same game for AVG ($p = 0.012$) and ADV ($p = 0.016$), but not for SPO ($p = 0.169$).

No significant effect was found for incomplete blinks (F(2.97,56.54) = 1.09, $p = 0.360$, $\eta_p^2 = 0.012$). In contrast, a statistically significant effect was found upon examining blink regularity (F(3.15,59.92) = 5.56, $p = 0.001$, $\eta_p^2 = 0.525$), with pair-wise analysis disclosing statistical differences between baseline and gameplay viewing conditions for ADV (mean difference of −10.97 %, $p = 0.008$) and SPO (22.47 %, $p < 0.001$), but not for AVG ($p = 0.999$). No differences were found between baseline and playing conditions (all $p > 0.700$). Blink regularity while viewing gameplay was different between AVG and SPO (mean difference 24.05 %, $p = 0.0049$), and between ADV and SPO (33.44 %, $p < 0.001$). No significant difference was found between viewing gameplay and playing conditions for any game (AVG, $p > 0.999$; ADV, $p = 0.096$; SPO, $p = 0.177$).

Blink occurrence

Blinking patterns in high- and low-dynamic scenes across the three-gameplay viewing and three active playing conditions were explored by identifying the scenes in which blinks occurred (Table 3). A significant effect was found in high-dynamic scenes and gameplay viewing conditions (F(2,38) = 5,65, $p = 0.007$, $\eta_p^2 = 0.229$), with pair-wise analysis revealing differences between AVG and SPO ($p = 0.038$), but not between AVG and ADV ($p = 0.203$), nor between ADV and SPO ($p = 0.973$). No significant effect was found in active playing conditions in high-dynamic scenes (F(2,38) = 3.77, $p = 0.689$, $\eta_p^2 = 0.019$).

Table 3
Mean ± standard deviation of blinks occurring at high- and low-dynamic scenes in gameplay viewing and active playing conditions for the three games (AVG = *Call of Duty*, ADV = *Sackboy*, SPO = *FIFA 19*). P-values correspond to the ANOVA of repeated measures analysis.

High Dynamic					
Viewing Gameplays			Playing		
AVG	ADV	SPO	AVG	ADV	SPO
1.95 ± 0.69	2.65 ± 0.88 $p = 0.007$	2.70 ± 0.57	0.55 ± 0.60	0.60 ± 0.68 $p = 0.689$	0.45 ± 0.51
Low Dynamic					
Viewing Gameplays			Playing		
AVG	ADV	SPO	AVG	ADV	SPO
3.15 ± 0.88	3.80 ± 0.83 $p = 0.093$	3.50 ± 0.76	3.90 ± 0.97	4.35 ± 0.75 $p = 0.025$	3.75 ± 0.91

Whereas no significant effect was found in low-dynamic scenes in gameplay viewing conditions (F(2,38) = 2,53 = 0.093, $\eta_p^2 = 0.118$), statistical significance was revealed in active playing conditions (F(2,38) = 4.09, $p = 0.025$, $\eta_p^2 = 0.177$). Pair-wise post-hoc analysis disclosed statistically significant differences between ADV and SPO ($p = 0.040$), but not between AVG and ADV ($p = 0.370$), nor between AVG and SPO ($p = 0.988$).

Considering scenes (high- and low-dynamics) and conditions (viewing gameplay and active playing) as between-subject factors, and the three videogames as within-subject factors, a significant effect was found between factors and conditions (F(1,76) = 10.39, $p = 0.002$, $\eta_p^2 = 0.120$), but not within factors and scenes (F(1,76) = 1.15, $p = 0.286$, $\eta_p^2 = 0.015$), nor factors, scenes, and conditions (F(1,76) = 0.69, $p = 0.406$, $\eta_p^2 = 0.009$).

Fig. 2 shows the scenes in which participants tended to blink more (in red) in the three videogames. In the case of *Call of Duty* (Fig. 2A), participants blinked more in scenes without enemies; for *Sackboy* (Fig. 2B), blinks occurred in most scenes without enemies and where the character was only walking; and for *FIFA 19* (Fig. 2C), participants blinked more in scenes passing the ball, or during offside.

Color and luminance analysis

Call of Duty exhibited the lowest illuminance (10.52 lx) and the highest CCT (9044 K), while *Sackboy* had the highest illuminance (38.80 lx) and a lower CCT (5031.66 K). *FIFA 19* displayed intermediate values, with an illuminance of 20.21 lx and a CCT of 6036.50 K. Chromaticity coordinates were lowest for *Call of Duty*, with x and y values ($x = 0.28$, $y = 0.29$), while *Sackboy* had ($x = 0.33$, $y = 0.37$), and *FIFA19* ($x = 0.31$, $y = 0.37$). The mean $x\,y$ chromaticity and color temperature components for the analyzed frames from all videogames are shown in Figure S1 (Supplemental Material). Data from $x\,y$ coordinates and color temperature are shown in Table S1 (Supplemental Material).

Discussion

Blinking parameters, such as blink rate, blink amplitude (the balance between complete and incomplete blinks), and blink regularity are crucial factors associated with dry eye symptoms. A reduced blink rate is directly correlated with increased ocular discomfort, as a result of prolonged exposure of the corneal surface, exacerbating dry eye

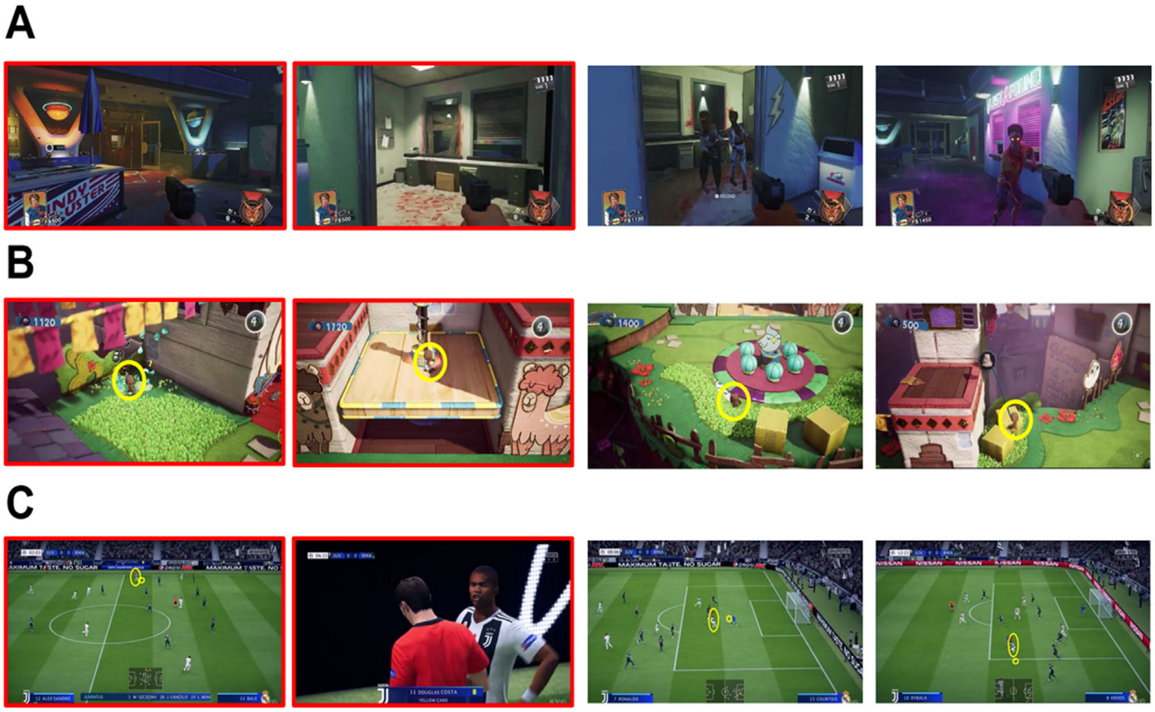

Fig. 2. Examples of scenes in which participants tended to blink more (left, red frames) or not blink (right frames). A) *Call of Duty*, B) *Sackboy*, and C) *FIFA 19*. In panels B and C, the yellow circles highlight where the 'avatar' in *Sackboy* is controlled (panel B) and where the player and the ball are on the field (panel C). Note that the scenes in which participants tended not to blink in *FIFA 19* (panel C) occurred when the ball approached the opposing goal. For *Call of Duty* and *Sackboy*, participants refrained from blinking when enemies appeared on screen.

symptoms.[13,16,17] Moreover, conditions that require higher visual attention have been found to decrease blink rate.[22,27] Incomplete blinks, a partial eyelid closure that fails to adequately spread the tear film across the ocular surface, have also been identified as a contributing factor to dry eye.[17,28–30] For instance, research has shown that reading on digital platforms, such as tablets, increases the occurrence of incomplete blinks,[16,17,31] while also higher levels of visual fatigue can further exacerbate this effect.[15,22] Additionally, blink regularity plays a key role in maintaining a stable tear film. Low blink regularity leads to inconsistent tear distribution over time, which can result in uneven ocular surface hydration and potential exposure-related discomfort.[13] All these altered blink parameters may increase ocular aberrations, ultimately affecting the optical quality of the image formed on the retina.[32,33] Besides, visual attention flow and blink occurrence have been shown to be interconnected. For instance, while watching a movie, eye blinks tend to occur during scenes that are less critical to the plot or when the protagonist is not present, i.e., the actual narrative of the scenes determines blink regularity and ultimately ocular health.[20]

In this study, the influence of playing different video games genres on various blink parameters was assessed. To date, only the AVG genre was shown to reduce blink rate,[13] although it may be assumed that other video game genres may also influence blink parameters, albeit differently, as each genre differs in terms of visual attention, perception, and motor demands. Thus, while AVG are characterized by their fast-paced nature, requiring continuous visual monitoring and precise motor coordination to progress in the game, other slower-paced game genres, e.g., puzzles or simulators, typically impose lower visual attention demands.

Each eye blink disrupts visual information processing for approximately 400 milliseconds.[34] Over 10 min of gameplay, with an average blink rate of 15 bpm, this disruption accumulates to a total loss of around 1 min of visual information. This effect is particularly critical in AVG, where rapid visual processing is essential. Notably, players of high-intensity games such as *Counter-Strike* or *Medal of Honor* often use the phrase, "blink and you'll die," highlighting the demanding visual requirements of these games. Eye blinks tend to be suppressed during high-attention scenes to avoid the loss of critical information flow.[20] Additionally, blinks are more suppressed during uninteresting or highly dynamic scenes when passively viewing video content.[18] This blink suppression helps prevent visual interruptions during moments that require heightened cognitive processing and situational awareness.[19]

Nevertheless, in the present study participants playing other genres, such as adventure (ADV) and sports (SPO), were also found to have a significant reduction in blink rate as compared to baseline conditions ($p < 0.001$), although no difference was found between genres. In addition, viewing pre-recorded gameplays of the same games also led to a reduced blink rate compared to baseline ($p < 0.020$ for all games), thus suggesting that gameplay viewing is also a highly demanding visual task accompanied with blink inhibition. Besides, a statistically significant difference was evidenced between viewing gameplays and actively playing the same games, with reduced eye blink rates while playing AVG and ADV games, but not when playing SPO. The games selected in the present study represent three distinct commercial game genres. However, they were chosen to offer a similar level of challenge and engagement to players in order to minimize confounding factors and better isolate the effects of game flow and dynamism on blink parameters. Although it must be acknowledged that difficulty and engagement are subjective and can vary from player to player, the design of our study controlled for this variability across video game genres, passive video viewing, and active gameplay for each participant. Notably, the sports game (*FIFA 19*) showed a less pronounced difference in blink parameters between viewing and playing conditions compared to the action video game (*Call of Duty*) and the adventure game (*Sackboy*). This may be attributed to the relatively consistent visual rhythm and lower narrative complexity in FIFA 19, which maintains similar attentional demands during both passive viewing and active gameplay. In contrast, *Call of Duty* and *Sackboy* involve more dynamic scene transitions, sudden stimuli, and higher variability in cognitive load between passive and active conditions, leading to more distinct blink suppression patterns.

These results highlight the fact that actually playing AVG and AVD games is a more visually demanding task than passively watching recorded gameplays of these game genres, a distinction that was not found for soccer games. These findings may be related to the dynamics of gameplay, which require different ocular movements across the screen. For example, the visual focus of AVG and ADV genres tends to be the center of the screen, commonly displaying the avatar of the player or the crosshair of the weapon being used. A relationship has been documented between eye blinks and eye saccades (the rapid switching between targets in the visual field), in which certain saccades trigger an eye blink.[35] This association is particularly dependent on the amplitude of the saccade, with blinks occurring more frequently for saccades of >30°, in order to stabilize the visual field during eye switching.[35] The current experimental settings required participants to be seated at 2 m from the television screen, which subtended 26° of visual angle. While this setting may not be considered sufficient for the induction of high amplitude saccadic eye movements, it may be hypothesized that different game dynamics and scenes could have impacted blink rates. Given the purpose of the present study, devoted to the analysis of blink parameters, the eye tracker was not employed to record eye movements. Future studies shall explore the relationship between eye movements and blinking behavior to gain a more comprehensive understanding of ocular dynamics during video game play.

The particular occurrence of blinks during certain scenes, with blink inhibition in scenes involving high-dynamic visual demands, gave support to the role of visual flow on blink behavior. No differences were found amongst games genres in this regard, suggesting that it is the visual complexity of the scene itself, rather than player interaction, which primarily modulates blink occurrence. Blinks tended to occur during low-dynamic scenes, primarily for AVG and SPO genres, a behavior that could be interpreted as a potential compensatory mechanism involving the triggering of blinks in moments of reduced attentional demand. In addition, the significant interaction between factors and conditions reinforces the impact of scene dynamics and viewing conditions, and suggests that visual processing demands differ between passive viewing and active engagement. However, the lack of significant interactions within factors and scenes implies that the effect of the type of scene content is not uniform across game genres.

The analysis of illuminance, correlated color temperature, and chromatic coordinates (x, y) in the CIE diagram for the video games revealed notable differences. These findings indicate that video games differ significantly in their luminance and color properties. However, despite the observed variations in illuminance and color properties, the present findings suggest that these parameters do not appear to influence blink rate or the occurrence of incomplete blinks. To the best of our knowledge, no prior study has specifically evaluated the potential differences in these components across video games and their potential impact on visual function.

This study has certain limitations inherent in research involving video games. Three specific commercial videogames were selected as representative of three popular genres. However, other videogames of the same genre may present different characteristics at a perceptual and cognitive level. While AVGs may be similar to each other in terms of gameplay, the scenes and type of engagement may vary, as in ADV and SPO games, thus limiting the generalization of the present findings. However, to date, the perceptual, cognitive, and motor characteristics of these game genres has not been thoroughly studied.[36] In addition, other game genres could be explored, such as RGP, sports other than soccer, racing, puzzle or party games, each with distinct dynamic scenes, and visual and motor attention demands. Besides, other gaming platforms may be the objective of future research, as many casual gamers nowadays used their laptops, mobile phones or tablets for gaming, with very different viewing distance and display characteristics. Another limitation comes for the number of minutes analyzed for blink-parameters. While the 2-minute segments may appear limited in duration, this choice was intentional to balance experimental control with participant engagement. Shorter exposure times reduce the risk of fatigue and learning effects, which can confound attentional or perceptual responses across conditions. Although longer sessions might capture more variability in game dynamics, particularly in genres like sports, gameplay duration was considered sufficient to elicit meaningful responses, while maintaining consistency across game types. Future research shall explore whether significant differences between game genres do require longer game playing times to manifest. Moreover, although scenes were classified as high- or low-dynamic based on clear in-game cues (see Table 1), the exact number or duration of these scenes per participant was not quantified. Scene classification was performed through frame-by-frame visual verification aligned with participant blinks, using the Pupil Core system. Consequently, the analysis relied on blink occurrences as an indirect proxy for dynamic scene frequency rather than precise temporal measurements. Although the selected clips included characteristic sequences of gameplay for each genre and scene type, future studies would benefit from more automated scene annotation methods to enhance the accuracy of dynamic content and allow for more detailed statistical analysis.

In addition, future research could explore blink parameters of expert video game players, such as e-sports athletes, to investigate potential adaptations in eye blinking while gaming. Interestingly, one study found that e-sports players of *Overwatch* (AVG genre) exhibited a lower tear film quality. However, no significant relationship was observed between hours of play and ocular findings.[2] This raises the question of whether, despite playing an average of 18 h per week without exhibiting dry eye symptoms, these players may have developed adaptations in their blinking behavior, such as strategically timing their blinks or regulating blink intervals, to optimize performance during gameplay. Although none of the participants in the study had high refractive errors and all achieved best-corrected visual acuity of 20/20 or better, blink analysis was not segmented according to type and magnitude of refractive error. Future research shall consider the possible influence of this factor on blink dynamics across game genres.

Finally, the results of this study allow for some recommendations related to videogame design and visual ergonomic aspects to improve ocular health and decrease dry eye symptoms. First, videogames should aim at presenting uniform, regular intervals of high- and low-dynamic scenes to ensure proper tear film distribution through eye blinks. This type of scene presentation is common in AVG and ADV games, in which enemies tend to appear in *waves*, but not so in SPO genres. Secondly, visual ergonomic strategies may be implemented to reduce eye strain and maintain ocular health during gameplay sessions, specially using computers. For instance, players should maintain an appropriate viewing distance of at least 50−70 cm from the screen to minimize eye fatigue.[5] Proper lighting is essential, with balanced ambient illumination to reduce glare and reflections,[37] while avoiding excessive contrast between the screen and surrounding environment. Regular breaks are important, following the 20−20−20 rule (i.e., looking at an object 20 feet away for 20 s every 20 min), as this can assist in relaxing the eye muscles and preventing strain.[38,39] Additionally, players should consciously blink more often and perform full, intentional blinks during breaks to keep the eyes hydrated and reduce the risk of dry eye symptoms.[39−41] Using artificial tears or a room humidifier may also help maintain tear film stability in prolonged gaming sessions.[42]

Conclusions

Playing action, adventure, and sports video games similarly reduced blink rate, suggesting that similar visual demands. Incomplete blinks were not different between genres. In addition, blinks tended to occur less in high-dynamic scenes during active playing, reinforcing the link between visual complexity and eye blinks. Game developers could incorporate structured transitions between high and low visual-demand scenes to promote uniform blink patterns and reduce the risk of dry eye symptoms.

Funding information

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data statement

The data that support the findings of this study are available from the corresponding author, M.A, upon reasonable request.

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.

CRediT authorship contribution statement

Marc Argilés: Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation, Validation, Methodology. **Genis Cardona:** Writing – review & editing, Validation, Methodology. **Maite Valentino:** Writing – review & editing, Resources.

Acknowledgments

This publication is part of the project PID2023−146101OB-I00. We thank Carmen Sastre, Amelie Sophie, and Nuria Garcia for the assistance during data collection.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.optom.2025.100584.

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