Toker *et al.*
The Egyptian Journal of Otolaryngology (2023) 39:140
https://doi.org/10.1186/s43163-023-00506-z

The Egyptian Journal of Otolaryngology

ORIGINAL ARTICLE Open Access

Effect of digital screen usage on the visual-vestibular system interaction

Özge Gedik Toker[1*], Nida Tas Elibol[1], Özlem Erentürk[1], Songül Erdem[1], Meliha Başöz Behmen[1] and Nilüfer Bal[1,2]

Abstract

Background/aim This research aims to develop an original understanding of the subject by examining how digital screen usage correlates with visual-vestibular system interaction and the vestibuloocular reflex mechanism using vestibular test parameters.

Materials and methods The study included 59 healthy participants. Participants were divided into two groups according to their screen usage time 3–6 h (Group 1) and over 6 h (Group 2). Participants were asked questions about complaints after screen use. After that, Video Head Impulse, Dynamic Visual Acuity, Videonystagmography test was applied to the participants.

Results DVA was significantly poor in group 2. In vHIT and Videonystagmography test, a significant difference was not observed between the groups.

Conclusion There is no conclusive evidence that digital screen usage directly affects the peripheral or central vestibular systems. However, the decrease in DVA in individuals who use digital screens for more than 6 h may be related to the effects of digital screen exposure on the visual-vestibular system.

Keywords Computer vision syndrome, Digital screen, Dynamic visual acuity, Visual-vestibular interaction, Oculomotor system

Background

Digital devices such as smartphones, tablets, and laptops are a large part of human life. According to the research conducted by Pew Research Center, the rate of owning a smartphone use from 35% in 2011 to 85% in 2023. While the rate of smartphone use is 96% in individuals aged 18-29, it is 95% between the ages of 30-49 and 83% between the ages of 50- 64 [1, 2]. There is a relationship between the rapid development of technology and the earlier onset of digital screen exposure [3]. In later years, digital devices become an essential part of daily life, so much so that children aged 7-16 spend an average of 3.3 hours online [4]. According to the literature, excessive screen exposure has adverse effects such as physical and mental health problems, stress, sleep disturbance, and poor academic performance in infants, children, and adolescents [5, 6]. Excessive screen use can cause physical problems such as neck stiffness, blurred vision, dry eyes, and back pain. Asthenopia, which occurs due to excessive exposure to the screen, is defined as computer vision syndrome and manifests with visual, ocular, and musculoskeletal symptoms, especially in the neck and shoulder region [7–9]. Additionally, the accommodation mechanism is impaired with excessive screen exposure, resulting in blurred vision, double vision, presbyopia, myopia, and a slowdown in focus shift [9].

*Correspondence:
Özge Gedik Toker
ogediktoker@bezmialem.edu.tr
[1] Department of Audiology, Faculty of Health Sciences, Bezmialem Vakıf University, Eyüpsultan, Silahtarağa Street, No:189, Istanbul, Turkey
[2] Department of Audiology, Faculty of Medicine, Marmara University, Istanbul, Turkey

The vestibulo-ocular reflex (VOR) is an effective mechanism in the control of eye movements. It is reported that the VOR mechanism must be intact to maintain a fixed gaze in a moving person [10]. Head movements activate visual and vestibular receptors, resulting in various visual-vestibular interactions [11]. Interacting with digital screens continuously requires the eye to be in harmony at all times; if this situation continues for a long time, the visual motor system gets tired and causes eye strain and headaches. Due to this situation, blurred vision and double vision can be explained by eye fatigue, dry eye symptoms, lack of accommodation, and focus problems at different distances [7, 12]. To detect the beneficial and harmful effects of technology use on people, it has become critical for health professionals to determine how technology is used. Despite studies examining the effects of digital screen use on physical and mental health, no study has examined the visual- vestibular system interaction due to methodological difficulties.

This study aims to research how digital screen exposure correlates with visual-vestibular system interaction and VOR mechanism in individuals by using vestibular test parameters.

Methods

This study was conducted in accordance with the ethical principle stated in the Declaration of Helsinki, and written consent was obtained from all the participants. Registered names are kept confidential to protect personal data. The research examined the effect of digital screen usage time on the test results used to evaluate visual-vestibular system interaction and VOR mechanism in healthy young adults. The study included fifty-nine volunteer healthy young adults (9 males, 50 females) between 18–40 who did not have metabolic and psychiatric diseases, hearing loss, or vestibular complaints and could cooperate with the tests.

Participants were asked the average daily hours they were exposed to digital screens such as smartphones, computers, and tablets. Participants were divided into two groups according to their daily digital screen usage times. Group 1 had 3 to 6 h of digital screen use, and Group 2 had more than 6 h of digital screen use. 0 to 2 h of screen exposure could not be included in the study due to the absence of individuals using digital screens for 0 to 2 h a day. Participants did not know how the groups were separated and which group they included. Likewise, the researcher who applied the vestibular tests did not know which group the participants were in. Firstly, participants were directed to 6 questions about subjective complaints after screen exposure prepared by the researcher. Video Head Impulse Test (vHIT), Dynamic Visual Acuity test (DVA), and Videonystagmography (VNG)-oculomotor tests were performed on all participants. VOR gains and asymmetry values of six semicircular canals were obtained by performing Video Head Impulse Test (vHIT) with Synapsys vHIT Ulmer II (Marseilles, France) device. During the test, the participants were asked to focus on the target points at 0^0, 20^0 to the right, and 20^0 to the left. For horizontal canal stimulation, the clinician moved the participants' heads 10 -20 degrees to the right and left at a velocity of 120–150 ^{0} /sec while their heads were in the 30-degree flexion position. For vertical canal stimulation, the clinician moved the participants' heads up and down shortly and quickly for a minimum of 120–150^0/sec when their heads were positioned 30–40 degrees to the left for the right anterior left posterior (RALP) stimulation. For the left anterior right posterior (LARP) stimulation, the head was moved up and down shortly and quickly for a minimum of 120–150 ^{0} /sec when their heads were positioned 30–40 degrees to the right.

The Dynamic Visual Acuity test was performed using the Snellen Eye Chart. The person was seated at the distance where they could read the second line from the bottom of the chart and then the lowest line that they could read with three or fewer errors during horizontal nodding at a frequency of approximately 2 Hz and an angle of 20 degrees [13]. To avoid familiarity with the letters in the graph, two different Snellen graphs were used in the test with the head still and nodding. The line difference score is determined by subtracting two values that can be read with a maximum of three errors [14]. Oculomotor tests consisting of saccade, pursuit, and optokinetic tests were performed using Interacoustic Micromedical VisualEyes Videonystagmography (Chatham, IL, USA) device. The results were recorded and analyzed using the VisualEyes 4 Channel Spectrum 9.2 software. Calibrations were performed in the horizontal and vertical planes before starting the test, and the patients were asked to focus on the target without moving their heads during the test. The parameters of the VNG test were determined as 20 seconds when the target was at 20 degrees for the horizontal test, 20 seconds when the target was at 15 degrees for the vertical test, and a total of 20 saccades at the target range between 7-24 degrees for the saccade test, 15 seconds at the target frequency of 0.1Hz, 0.2 Hz and 0.4 Hz for the smooth pursuit test, and 15 seconds at a target velocity of 30 degrees/second for right and left directions in the optokinetic test.

Descriptive statistics of the parameters were made in the IBM SPSS Statistics 22.0 program. The sample size was determined at least 20 to obtain 80% power at a95% confidence level. Statistical significance was set at $p<0.05$. The distribution of the data was analyzed by using the Shapiro-Wilk test. The analysis of normally distributed data was done with the t- test, and the analysis of the

Table 1 Answers to questions directed to participants

Questions	Group 1	Group 2
How do you see the objects around you after using the screen	6.8% (blurry vision)	20% (blurry vision) 3.3% (double vision)
Do you have balance problems after using the screen?	6.8%	10%
Do you experience the feeling of being pulled somewhere after using the screen?	3.4%	6.6%
Do you experience the feeling of being off-balance after using the screen?	3.4%	6.6%
Do you experience the feeling of rocking dizziness after using the screen?	3.4%	3.3%
What are the complaints you experience after using the screen?	headache, eye redness, burning and dryness in the eyes, difficulty in visual fixation, blurred vision, and neck/shoulder/back pain	headache, eye redness, burning and dryness in the eyes, difficulty in visual fixation, blurred vision, and neck/shoulder/back pain

Table 2 Semicircular canal (SCC) vestibulo-ocular reflex gains and asymmetry values of the groups

Test	SCC Gains and Asymmetry Values	Group 1 $\bar{x} \pm SD$	Group 2 $\bar{x} \pm SD$	*p*-value
Video Head Impulse Test	**Right Anterior SCC Gains**	1.05 ± 0.05	1.02 ± 0.06	0.086
	Left Anterior SCC Gains	1.04 ± 0.07	1.02 ± 0.05	0.216
	Anterior SCC Asymmetry Values	0.01 ± 0.01	0.01 ± 0.01	0.554
	Right Posterior SCC Gains	1.02 ± 0.05	1.00 ± 0.06	0.335
	Left Posterior SCC Gains	1.01 ± 0.05	1.00 ± 0.05	0.704
	Posterior SCC Asymmetry Values	0.01 ± 0.01	0.01 ± 0.01	0.636
	Right Lateral SCC Gains	1.00 ± 0.02	1.00 ± 0.03	0.737
	Left Lateral SCC Gains	0.99 ± 0.02	0.99 ± 0.04	0.106
	Lateral SCC Asymmetry Values	0.01 ± 0.01	0.01 ± 0.008	0.356

non-normally distributed data was done with the Mann-Whitney U test.

Results

Fifty-nine (9 males, 50 females) volunteer healthy participants were divided into groups: those with a daily digital screen usage of 3 to 6 h (Group 1) and more than 6 h (Group 2). The group with 3 to 6 h of digital screen use consisted of 29 people (27 women and 2 men), whereas the group with more than 6 h of digital screen use consisted of 30 people (23 women and 7 men). The mean ages of the groups were 21.24 ± 1.78 and 21.46 ± 1.56, respectively. All participants were people exposed to digital screens such as tablets, smartphones, and computers for at least ten years.

The answers to the questions directed to the participants are given in Table 1. According to the answers obtained from the participants, there are more participants with visual and vestibular complaints in Group 2. Participants in both groups stated that they experienced headaches, eye redness, burning and dryness in the eyes, difficulty in visual fixation, blurred vision, and neck/shoulder/back pain after screen use.

Table 3 Dynamic visual acuity scores of the groups

Group	DVA Scores	SD	*p*-value
Group 1	0.6897	1.25762	**0.043***
Group 2	1.2667	1.25762	

Mann–Whitney U test, *$p < 0.05$. *SD* Standard Deviation

In vHIT results, there was no significant difference in VOR gains or asymmetries between the two groups ($p > 0.05$) (Table 2).

In the Dynamic Visual Acuity test performed with the Snellen Eye Chart, DVA was significantly poor in the second group compared to the line difference values ($p < 0.05$) (Table 3).

In the videonystagmography test battery, there was no significant difference between the groups in saccade, pursuit, and optokinetic test results ($p > 0.05$). Table 4 shows

Table 4 Pursuit and optokinetic test results of the groups

Test	Frequency and Motion Direction	Group 1 $\bar{x} \pm SD$	Group 2 $\bar{x} \pm SD$	*p*-value
Pursuit Test	0.1 Hz Right Moving	0.96 ± 0.04	0.97 ± 0.03	0.653
	0.1 Hz Left Moving	0.96 ± 0.04	0.98 ± 0.03	0.087
	0.2 Hz Right Moving	0.98 ± 0.05	1.00 ± 0.03	0.474
	0.2 Hz Left Moving	0.98 ± 0.04	1.00 ± 0.03	0.245
	0.4 Hz Right Moving	0.97 ± 0.04	0.98 ± 0.04	0.885
	0.4 Hz Left Moving	0.98 ± 0.02	0.98 ± 0.03	0.608
Optokinetic Test	Right Moving	0.92 ± 0.07	0.94 ± 0.10	0.379
	Left Moving	0.94 ± 0.07	0.93 ± 0.09	0.672

Table 5 Saccade test results of the groups

Analysis Parameters	Group 1 $\bar{x} \pm SD$	Group 2 $\bar{x} \pm SD$	*p*-value
Right Moving Velocity	285.77 ± 21.58	276.93 ± 20.62	0.113
Left Moving Velocity	335.02 ± 26.55	334.05 ± 27.16	0.890
Right Moving Latency	220.56 ± 27.78	216.32 ± 22.74	0.523
Left Moving Latency	216.62 ± 23.29	217.09 ± 27.57	0.856
Right Moving Accuracy	99.69 ± 6.89	97.31 ± 5.04	0.203
Left Moving Accuracy	96.14 ± 3.01	97.81 ± 7.67	0.885

the pursuit and optokinetic test results, and Table 5 shows the saccade test results of participants.

Discussion

The condition "digital eye fatigue" or "computer vision syndrome" consists of three pathophysiologies: extraocular, accommodative, and ocular surface mechanism. Extraocular mechanisms include musculoskeletal symptoms such as head and neck pain [14]. Problems in accommodative mechanisms cause blurred vision, diplopia, presbyopia, myopia, and a slowdown in focus shift, while ocular surface mechanisms cause dryness, redness, and burning [15, 16]. In our research, participants in both groups stated that they experienced redness, burning, dryness, blurred vision, and difficulty in visual fixation after digital screen use.

Head movements may cause dizziness or visual blurring in a unilateral or bilateral vestibular hypofunction patient. When the head is in motion, this perception of objects is called oscillopsia. It can be attributed to a defect in the VOR mechanism [17]. Although the effect of digital screen use on the vestibular system research is limited, Wang et al. (2022) performed vHIT and caloric tests to evaluate the vestibular system in individuals who had played video games for over ten years and less than ten years. In both groups, vHIT and caloric test results were within normal limits [18]. We did not run the caloric test in our study; therefore, we do not have comparison data.

Although it is thought that eye muscle fatigue and possible vestibular involvement due to digital screen use may affect VOR, in our research, channel gains and asymmetry ratios in both groups were within normal limits in the vHIT test. The obtained findings support the study by Wang et al. (2022). Specifically, it was found that close follow-up caused dry eye by increasing saccadic eye movements. A study examining the number of saccades according to the distance to the computer monitor observed that a reading distance of 20 inches caused the least number of saccades, resulting in a decrease in eye fatigue and an increase in reading speed [19].

Participants' screen-to-eye distance during screen exposure is unknown, so a comparison could not be made between the groups according to the distance. In addition, eye fatigue due to computer use is explained by the decrease in blinks-related cognitive changes [16].

The primary function of the VOR is to maintain the retina fixed on the target while the head is moving. This process allows the person to maintain visual acuity with head movement. It is a reflexive response and is known as dynamic visual acuity. The VOR mechanism is susceptible, resulting in reduced visual acuity and oscillopsia if VOR is impaired [1]. The ability of a stationary person to distinguish a static object is called static visual acuity (SVA), and the ability to distinguish a moving object is called dynamic visual acuity (DVA). While static visual acuity is related to ocular resolution, dynamic visual acuity is related to the oculomotor system. The function of the oculomotor system is evaluated by examining the difference between DVA and SVA [20]. In the presence of abnormality in DVA, the underlying vestibular problem should be determined. The DVA test is also known as the "oscillopsia test." It measures the person's visual acuity with and without a head swing. Visual acuity deteriorates during head movements when VOR damage occurs. The orbit also moves when the head moves during the DVA test however, to provide a clear image of the target in the fovea, the neural firings of hair cells in the lateral SCC should be sufficient, as well as the contraction and relaxation of the appropriate oculomotor muscles and the proper functioning of the VOR mechanism [1].

We thought that the effect of digital screen use on ocular or vestibular structures could reduce DVA, and our results supported our hypothesis. DVA scores showed a statistically significant increase in the group with a digital screen use of more than six hours. In other words, DVA was significantly poor in Group 2. However, in the vHIT

test, SCC gains were within normal limits. This suggests that the increase in DVA scores is related to the effect of digital screen fatigue on the accommodative mechanisms rather than the vestibular system. As indicated by the answers given to the questionnaire, most of the participants in Group 2 had complaints such as headache, eye redness, burning and dryness in the eyes, difficulty in visual fixation, and blurred vision after screen usage, which supports the decrease in DVA and digital screen fatigue.

The information about the mobility of the image on the digital screen was not included in the research because the probability of getting a reliable response is very low. However, it is thought that the VOR effect may change depending on whether the screen's image is moving. In the literature, it has been reported that the moving visual environment can increase sensory mismatch in people with underlying vestibular problems and cause symptoms such as nausea, vomiting, and imbalance [21, 22]. There are different results on this subject in the literature. To examine the relationship between the complaints of dizziness observed after video games and the otolith function, Wang et al. (2022) divided the participants into two groups: those playing video games for less and more than ten years [18]. They analyzed the c-VEMP (cervical vestibular evoked myogenic potentials) and o- VEMP (ocular vestibular evoked myogenic potentials) test results. The research showed no significant difference between the groups before and after the game in the o-VEMP test. However, there was a significant decrease in the post-game response amplitudes in the group that played games for more than ten years in the c- VEMP test. The researchers thought neck tilt, which occurs due to long-term exposure to video games, stimulated otolith organs and caused a blockage in the sacculo- colic reflex system, which may cause a decrease in c-VEMP responses. Chang et al. (2020) investigated the frequency of motion sickness during video games and reported that post-game motion sickness was widespread in women [23]. Our research showed no significant difference between the groups in the oculomotor test battery's pursuit, optokinetic, and saccade test results. According to the normalization study of optokinetic and pursuit gain values, the saccade velocity and accuracy values of our participants were within normal limits, while a prolongation in saccade latency values was observed in our study [24]. It is known that the prolongation of latency in the saccade test is associated with age, attention deficit, degenerative disorders, and visual disturbances. According to the American Optometric Association, continuous use of digital devices for two hours a day is sufficient to cause vision-related problems, expressed as digital eyestrain [25]. Bali et al. (2007), in their study investigating computer vision syndrome in ophthalmologists, determined this period as 4 h [26]. Based on the literature, it was thought that ocular problems that may occur in both groups with 3 to 6 h and more than 6 h of daily use of digital screens might cause prolongation in saccade test latency. This result opens up a new field of discussion in the literature that the long-term use of digital screens may affect central vestibular test findings.

Our research employed the self-report to obtain information about the participants' screen exposure duration. This is the main limitation of our research. Self-report may cause problems such as inaccurate statements or incorrect recall. Nevertheless, self-report is the most preferred method because they are easy to apply [27]. Since our study includes many different digital screens such as computers, phones, tablets, and television, we did not ask for screen distance. This is another limitation of our study. Additionally, the characteristics of the screen the participants were exposed to, the posture during exposure, and the sedentary life caused by exposure could not be examined. Therefore, statistical comparisons could not be made about these topics.

Conclusion

As a result of the analyses, the decrease in DVA in individuals with more than six hours of digital screen usage can be attributed to the effects of digital screen exposure on the visual-vestibular system. In this direction, it is predicted that the deterioration in the visual-vestibular system mechanism due to screen exposure may increase in future generations due to the increase in the duration of digital screen usage and the decrease in the age of exposure. Therefore, the influence of this mechanism should be investigated and discussed in a more comprehensive framework and wide vestibular test batteries by controlling it in a laboratory environment, taking into account variables such as the degree of exposure and the characteristics of the screen.

Abbreviations

VOR	Vestibulo-ocular reflex
vHIT	Video Head Impulse Test
DVA	Dynamic Visual Acuity Test
VNG	Videonystagmography
RALP	Right Anterior Left Posterior
LARP	Left Anterior Right Posterior
SD	Standard Deviation
SVA	Static Visual Acuity
SCC	Semicircular Canal
c-VEMP	Cervical Vestibular Evoked Myogenic Potentials
o-VEMP	Ocular Vestibular Evoked Myogenic Potentials

Acknowledgements

Not applicable.

Authors' contributions

ÖGT conception, design of study, collecting and analyzing the data, writing the manuscript. NTE collecting and analyzing the data, writing the manuscript.

ÖE collecting data. SE collecting data. MBB collecting and analyzing the data NB collecting and analyzing the data.

Authors' information
ÖGT: Assistant Professor
NTE: Research Assistant
ÖE: Audiologist
SE: Audiologist
MBB: Lecturer
NB: Assistant Professor

Funding
This research did not receive any specific grant from public, commercial, or not-for-profit funding agencies.

Availability of data and materials
The data supporting this study's findings are available on request from the corresponding author. The data are not publicly available due to privacy.

Declarations

Ethics approval and consent to participate
This research was conducted in the Audiology Clinic of Bezmialem Vakıf University. Bezmialem Vakıf University Non-Interventional Research Ethics Committee approved the study on 28 December 2021 (decision number: 2021/403). It was conducted in accordance with the ethical principle stated in the Declaration of Helsinki, and written consent was obtained from all the participants.

Consent for publication
The participants gave written informed consent for the publication of the data and materials contained within this study.

Competing interests
The authors reported no potential conflict of interest.

Received: 6 July 2023 Accepted: 25 August 2023
Published online: 07 September 2023

References

1. Center PR. Mobile Fact Sheet (2021) https://www.pewresearch.org/internet/fact-sheet/mobile/. Accessed 2023
2. Foster E, Preschoolers Don't Need Parents to Find Content (2021) https://kidscreen.com/2021/03/11/preschoolers-dont-need-parents-to-find-content/. Accessed 2023
3. Reid Chassiakos YL, Radesky J, Christakis D, Moreno MA, Cross C, Hill D, Ameenuddin N (2016) Children and adolescents and digitalmedia. Pediatrics 138(5):e1–e17. https://doi.org/10.1542/peds.2016-2593
4. Mohidin N, Ang C, Kah Meng C (2016) Reply to letter to the editor: wink glass, incomplete blink and computer vision syndrome. Curr Eye Research 41(4):579–580. https://doi.org/10.3109/02713683.2015.1034373
5. Hawi NS, Samaha M (2016) To excel or not to excel: Strong evidence on the adverse effect of smartphone addiction on academic performance. Comput Educ 98:81–89. https://doi.org/10.1016/j.compedu.2016.03.007
6. Thomée S, Härenstam A, Hagberg M (2011) Mobile phone use and stress, sleep disturbances, and symptoms of depression among young adults - A prospective cohort study. BMC Public Health 11:66
7. Bahkir FA, Grandee SS (2020) Impact of the COVID-19 lockdown on digital device-related ocularhealth. Indian J Ophthalmol 68(11):2378. https://doi.org/10.4103/ijo.IJO_2306_20
8. Kim DJ, Lim CY, Gu N, Park CY (2017) Visual fatigue induced by viewing a tablet computer with a high-resolution display. Korean J Ophthalmol 31(5):388–393. https://doi.org/10.3341/kjo.2016.0095
9. Rosenfield M (2011) Computer vision syndrome: A review of ocular causes and potential treatments. Ophthalmic Physiol Opt 31(5):502–515. https://doi.org/10.1111/j.1475-1313.2011.00834.x
10. Herman R, Maulucci JSR (1982) Development and Plasticity of Visual and Vestibular Generated EyeMovements. Exp Brain Res 47(1):69–78. https://doi.org/10.1007/BF00235888
11. Halmagyi GM, Gresty MA (1979) Clinical signs of visual-vestibular interaction. J Neurol Neurosurg Psychiatry 42(10):934–939. https://doi.org/10.1136/jnnp.42.10.934
12. Sheppard AL, Wolffsohn JS (2018) Digital eye strain: Prevalence, measurement and amelioration. BMJ Open Ophthalmol 3(1) https://doi.org/10.1136/bmjophth-2018-000146
13. Devin L, McCaslin J, Andrew Dundas GPJ (2016) Bedside Assessment of the Vestibular System. NTS. Gary P. Jacobson (ed) Balance Function Assessment and Management, 137–162
14. Hakala PT, Saarni LA, Punamäki RL, Wallenius MA, Nygård CH, Rimpelä AH (2012) Musculoskeletal symptoms and computer use among Finnish adolescents-pain intensity and inconvenience to everyday life: a cross-sectional study. BMC Musculoskelet Disord 13(41):1–7
15. Portello JK, Rosenfield M, Bababekova Y, Estrada JM, Leon A (2012) Computer-related visual symptoms in office workers. Ophthalmic Physiol Opt 32(5):375–382. https://doi.org/10.1111/j.1475-1313.2012.00925.x
16. Sheedy JE, Hayes J (2003) Is all asthenopia the same? Optom Vis Sci 80(11):732–739. https://doi.org/10.1097/00006324-200311000-00008
17. Lissak G (2018) Adverse physiological and psychological effects of screen time on children and adolescents: Literature review and case study. Environ Res 164:149–157. https://doi.org/10.1016/j.envres.2018.01.015
18. Wang CC, Young YH (2022) Effect of Video Games on the Otolithic Reflex System. Audiol Neurootol 27(1):40–47. https://doi.org/10.1159/000516252
19. Ciuffreda KJ, Kenyon RV, Stark L (1978) Increased saccadic latencies in amblyopic eyes. InvestigOphthalmol Vis Sci 17(7):697–702
20. Quevedo L, Aznar-Casanova JA, Silva JA (2018) Dynamic visual acuity Trends Psychol 26(3):1267–1281. https://doi.org/10.9788/TP2018.3-06Es
21. Pollak L, Osherov M, Berkovitz N, Beckerman I, Stryjer R, Tal S (2015) Magnetic resonance brain imaging in patients with visual vertigo. Brain and behavior 5(11):e00402
22. Guerraz M, Yardley L, Bertholon P, Pollak L, Rudge P, Gresty MA, Bronstein AM (2001) Visual vertigo: symptom assessment, spatial orientation and postural control. Brain 124(8):1646–1656
23. Chang Y (2020) Females Are More Likely to Get Motion Sickness While Playing Video Games:A Comparative Study Between PC Games and VR Games. MSc Dissertation, Northeastern University.
24. Kang S, Kim US (2015) Normative data of videonystagmography in young healthy adults under40years old. Korean J Ophthalmol 29(2):126–130. https://doi.org/10.3341/kjo.2015.29.2.126
25. AOA. Computer vision syndrome. 2001. https://www.aoa.org/healthyeyes/eye-and-vision-conditions/computer-vision-syndrome?/. Accessed 2023.
26. Bali J, Navin N, Thakur BR (2007) Computer vision syndrome: a study of the knowledge, attitudesand practices in Indian ophthalmologists. Indian J Ophthalmol 55(4):289–293. https://doi.org/10.4103/0301-4738.33042
27. Moreno MA, Binger K, Zhao Q, Eickhoff J (2021) Adolescents Digital Technology Interactions and Importance: Associations with Demographics and Social Media Frequency. J Pediatr 236:312–315. https://doi.org/10.1016/j.jpeds.2021.06.00

Publisher's Note