African Vision and Eye Health
ISSN: (Online) 2410-1516, (Print) 2413-3183

Device-dependent variations in accommodation response during printed and digital reading

Authors:
Noor H. Buari[1,2]
Fatin A. Ahmad[3]
Firdaus Yusof[4,5]

Affiliations:
[1]Centre for Optometry Studies, Faculty of Health Science, Universiti Teknologi MARA, Selangor, Malaysia

[2]Ocular Wellness and Neuro-Opthalmic research Group (OWNeR), Faculty of Health Science, Universiti Teknologi MARA, Selangor, Malaysia

[3]Focus Point, Selangor, Malaysia

[4]Department of Optometry and Visual Science, Kulliyyah of Allied Health Sciences, International Islamic University Malaysia, Pahang, Malaysia

[5]Integrated Omics Research Group, Kulliyyah of Allied Health Sciences, International Islamic University Malaysia, Pahang, Malaysia

Corresponding author:
Noor Buari,
noorhalilah@uitm.edu.my

Dates:
Received: 18 Jan. 2026
Accepted: 26 May 2026
Published: 03 July 2026

How to cite this article:
Buari NH, Ahmad FA, Yusof F. Device-dependent variations in accommodation response during printed and digital reading. Afr Vision Eye Health. 2026;85(1), a1164. https://doi.org/10.4102/aveh.v85i1.1164

Read online:
Scan this QR code with your smart phone or mobile device to read online.

Background: The increasing reliance on digital devices for reading and academic activities has raised concerns about how different screen types influence the accommodative system during prolonged near work.

Aim: This study aimed to compare the accommodation response of young adults when reading printed text and digital text displayed on a smartphone, tablet and computer.

Setting: This study was conducted at Universiti Teknologi MARA among 32 young adults aged 20–25 years with normal visual function.

Methods: Reading passages were presented under four conditions, namely printed text, smartphone, tablet and computer, in randomised order. Accommodation response was measured using the monocular estimation method (MEM) dynamic retinoscopy.

Results: A lead of accommodation was observed in all conditions, with significant variation across devices (Friedman test: χ^2 [3] = 15.932, P = 0.001). Smartphone reading produced the greatest accommodative lead and differed significantly from printed text (P = 0.029), tablet (P = 0.005) and computer (P < 0.001). Reading with printed text, tablet and computer produced similar accommodation responses.

Conclusion: Smartphones reading induces a greater accommodative lead than printed text and larger digital displays, suggesting that smaller digital screens impose a disproportionately higher accommodative demand.

Contribution: Accommodation response during reading is influenced by both device type and screen size. These findings provide clinically relevant evidence to support ergonomic guidance on device choice, viewing distance and screen use habits aimed at reducing visual stress and digital eye strain among young adults.

Keywords: accommodation response; electronic device; digital screen; screen size; smartphone; tablet; computer; reading.

Introduction

The rapid expansion of digital technology has transformed how people work, study, read and access information. University students and working adults spend a substantial amount of time using computers, tablets and smartphones for reading and other visually demanding near tasks, with daily screen time often exceeding several hours and, in many cases, reaching levels considered excessive.[1] This shift has raised concerns about the impact of prolonged near work on visual function, especially on the accommodative system, which maintains clear retinal images during close viewing.[2] Prolonged digital near work has been associated with visual discomfort, headaches, difficulty refocusing and other symptoms of digital eye strain.[3,4] Understanding how different reading media influence accommodation is therefore essential for both visual comfort and long-term ocular health.

Accommodation does not always precisely match the dioptric demand of a near target, as young adults may exhibit either a lag (under-accommodation) or a lead (over-accommodation) depending on task characteristics, attentiveness and viewing conditions.[5,6,7] Previous studies comparing printed and digital reading have produced mixed findings.[5,8,9] Some reported comparable accommodative responses when viewing distance and stimulus parameters were matched and well controlled,[5,8] while others found that certain digital conditions,

Copyright: © 2026. The Author(s). Licensee: AOSIS. This work is licensed under the Creative Commons Attribution 4.0 International (CC BY 4.0) license (https://creativecommons.org/licenses/by/4.0/).

such as high-resolution smartphone screens, may alter accommodative behaviour.[9] These inconsistent findings suggest that device type alone may not explain accommodative behaviour and that methodological differences across studies play a significant role.

Viewing distance is one of the main factors differentiating digital devices.[10,11] Young adults typically hold smartphones at shorter distances than printed materials or computer screens, often at 30 cm–35 cm or less, whereas computers are commonly viewed at 50 cm–70 cm.[10,12] Both accommodative and vergence demands are increased at closer viewing distance, which may contribute to eyestrain and visual fatigue more than extended, ergonomically suggested distances.[7,13,14] Research has also shown that sustained digital screen use may alter accommodative parameters such as facility, amplitude and microfluctuations.[15,16,17,18]

The accommodative response can also be influenced by screen size and visual ergonomics in addition to distance.[14] Compared to bigger displays like tablets and computers, smaller devices, like smartphones, frequently demand viewing smaller text on a compact, self-luminous display, potentially increasing accommodative and vergence effort.[9,14,15] Larger devices, on the other hand, are usually viewed from farther away with larger text and a more steady posture, which may lessen the overall accommodative load.[5] Reviews on digital eye strain emphasise that accommodative and vergence problems are often driven by demanding near work and suboptimal ergonomics rather than screen exposure alone.[4,19]

Despite growing interest in the visual effects of digital device use, several gaps remain in the existing literature. Many studies have focused on symptom-based assessment of digital eye strain and relied on self-reported discomfort, rather than direct physiological measurement.[20,21] Few studies have directly compared accommodative responses across multiple screen sizes within the same group of participants, but have been limited to one or two types of digital devices.[5,15,22,23] As a result, it remains unclear how commonly used reading media influence the accommodative system when key visual parameters are standardised. Accommodation response measurements, such as the monocular estimation method (MEM) dynamic retinoscopy, can offer a more accurate assessment of device-related visual demands by providing clinically relevant insight into accommodative behaviour during active near activities.[24] These measurements are essential for guiding ergonomic recommendations, providing clinical advice and interventions aimed at reducing accommodative stress caused by digital reading. Therefore, the present study aimed to compare accommodation responses during reading printed text and digital text presented on a smartphone, tablet and computer among young adults. The findings provide insight into how device type and screen size influence accommodative behaviour during everyday reading tasks.

Research methods and design

Study design and participants

This within-subject, repeated-measures study design was conducted to compare accommodation responses across different reading trials. The required sample size was calculated using a web-based sample size calculator[25] based on a continuous outcome, incorporating a standard deviation of accommodative response during digital device use ($\sigma = 0.42$) obtained from previous study.[15] As this calculation was not based on a finite population, a population size was not specified. Therefore, 32 young adults aged 20–25 years were recruited.

Participants with mild refractive error (spherical within ± 3.00 D) and low astigmatism (< 1.00 DC) were recruited. All participants underwent visual acuity screening and were required to achieve best-corrected distance and near visual acuity of 0.18LogMAR or better (equivalent to 6/9) and N6 or better, respectively, using their habitual correction. Participants who did not meet the visual acuity criteria were excluded and referred for further optometric assessment. All eligible participants performed the reading tasks wearing their habitual optical correction. Participants were required to demonstrate normal binocular vision, assessed using near point of convergence (NPC) and amplitude of accommodation (AA) with a Royal Air Force (RAF) rule, with findings within age-appropriate normative ranges. A cover test at distance and near was conducted to exclude manifest strabismus. Participants with abnormal binocular vision findings, ocular pathology identified during ocular health assessment or a known history of ocular disease were excluded.

Reading devices

Four types of reading materials were used in this study to represent printed and digital formats with varying screen sizes. For the printed condition, participants read from a standard A4 white sheet (100 g/m²; dimensions 210 mm × 297 mm). The small-screen digital condition was represented by an iPhone X (Apple Inc., United States), featuring a 5.8-inch diagonal display with a Super Retina HD panel (1125 × 2436-pixel resolution) and a maximum luminance rating of 625 nits. The medium-sized digital display was an Apple iPad (10.2-inch diagonal; 2160 × 1620-pixel resolution; 500 nits brightness), while the large-screen condition was presented on a 13.3-inch MacBook Air laptop (2560 × 1600-pixel resolution; peak brightness 400 nits).

The general room illumination during testing was maintained at 320 cd/m². During printed text reading trials, the luminance was set at 85 cd/m². The brightness of the digital screen was manually adjusted and calibrated using a luminance meter (Konica Minolta, Japan) to standardise luminance at 300 cd/m² across all electronic reading trials.

Reading trials and assessment procedures

Participants first underwent visual screening and eligibility assessment. Eligible participants were then seated in a

controlled environment. Each participant completed four reading trials (printed, smartphone, tablet and computer) in a randomised order. Malay reading passages used were carefully matched for font size, content difficulty and reading duration and standardised across all reading trials.[26] Participants were asked to read aloud continuously while keeping their usual reading posture. During each trial, accommodative response was measured using MEM dynamic retinoscopy while participants read continuously.

To minimise the confounding effect related to viewing distance and posture, reading distances were standardised across devices. The viewing distance for printed text, smartphone and tablet reading was standardised at 40 cm to minimise variability and enable direct comparison across conditions, consistent with previous accommodation studies.[15,22] The computer viewing distance was set at 50 cm to reflect typical ergonomic usage. These settings are consistent with ergonomic recommendations for near and intermediate tasks. The purpose of this setting was to separate the effect of screen size on accommodative response than habitual viewing behaviour. All reading trials were carried out in a room with consistent illumination. To mitigate fatigue, participants were given 10-min break between reading trials, which they were instructed to look at distant objects or relax without engaging in near work.

Accommodation response measurement

The MEM dynamic retinoscopy was used in this study due to its reliable estimation in accommodative response and shows good agreement with objective autorefractor-based techniques.[24,27] Furthermore, MEM was chosen for its ability to measure accommodative behaviour during a naturalistic reading task. A streak retinoscope was used to conduct MEM measurements in a fully illuminated room. The retinoscope was maintained at a fixed working distance of 40 cm for all measurements, in accordance with standard MEM procedure.[24] While printed text, smartphone and tablet stimuli were presented at 40 cm, the computer display was positioned at 50 cm, with accommodative response assessed relative to the fixed retinoscope position. A string attached to the retinoscope was aligned to the participant's right or left eye to ensure constant measurement distance across all trials.

Participants continued reading the corresponding Malay passage, while the examiner observed the reflex in the participant's right eye and neutralised it using loose, wide-aperture trial lenses. Wide-aperture loose trial lenses were used to minimise visual disruption and maintain continuous fixation during the MEM procedure.[28] The lens power that produced the first neutrality was recorded as the accommodative response. Positive values indicate a lag of accommodation, whereas negative values indicate a lead. The same procedure was repeated for the left eye. All measurements were performed by a single examiner to minimise inter-examiner variability. Accommodation response measurements were repeated twice, and the average values were used for analysis.

Data analysis

Data was analysed using International Business Machines (IBM) Statistical Package for the Social Sciences (IBM SPSS) Statistics for Mac, version 26.0 (IBM Corp., Armonk, New York, USA). No statistically significant differences were found between the right and left eye accommodation responses (Wilcoxon signed-rank, $P > 0.05$). Therefore, only right-eye responses were used for subsequent analysis, consistent with standard practice in accommodative research.[29] Normality testing indicated a violation of the parametric assumption; hence, nonparametric statistical tests were employed. The Friedman test was chosen to compare accommodative responses across the four reading trials, followed by Wilcoxon signed-rank post hoc comparisons with Bonferroni-adjusted significance levels. Statistical significance was set at $P < 0.05$.

Ethical considerations

All participants provided written informed consent prior to the study, and this study adhered to the Declaration of Helsinki and was approved by the Universiti Teknologi MARA Research Ethics Committee (FERC/FSK/MR/2022/0066). Participants were anonymised and coded to ensure confidentiality.

Results

A total of 32 university students (mean age 22.75 ± 1.30 years) completed the reading trials. The majority were women (87.5%), and all demonstrated normal or near-normal distance visual acuity (mean VA = –0.01 to –0.02 LogMAR). Most participants had low-to-moderate refractive correction, with spherical values averaging approximately –0.50 D in both eyes and small amounts of astigmatism (≤ –0.25 DC). Baseline accommodative and vergence measures were within age-expected clinical ranges. The mean amplitude of accommodation was 10.4 D – 10.5 D, and the mean near point of convergence (break) was 5.69 cm ± 1.28 cm. No manifest strabismus was detected on cover tests.

Figure 1 illustrates accommodative responses across all reading conditions. The median (Mdn) accommodative

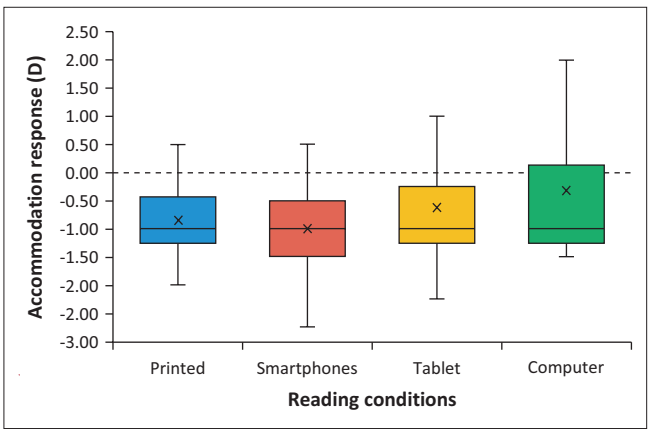

FIGURE 1: Accommodation responses during reading across four conditions: (1) printed text, (2) smartphone, (3) tablet and (4) computer.

TABLE 1: Post hoc pairwise comparisons (Wilcoxon signed-rank test) of accommodation response between reading trials.

Reading trial I	Reading trial II	Accommodation response reading trial I		Accommodation response reading trial II		*Z*-value	*p*-value
		Median	IQR	Median	IQR		
Smartphone	Printed	-1.00	1.00	-1.00	0.94	2.179	0.029*
Smartphone	Tablet	-1.00	1.00	-1.00	1.00	-2.808	0.005*
Smartphone	Computer	-1.00	1.00	-1.00	1.63	-3.534	< 0.001*
Printed	Tablet	-1.00	0.94	-1.00	1.00	-0.629	0.529
Printed	Computer	-1.00	0.94	-1.00	1.63	-1.356	0.175
Tablet	Computer	-1.00	1.00	-1.00	1.63	-0.726	0.468

IQR, interquartile range.
*Significant, $P < 0.05$.

response was found at the same central tendency across printed (Mdn = −1.00 D, interquartile range [IQR] = 0.81), smartphone (Mdn = −1.00 D, IQR = 1.00), tablet (Mdn = −1.00 D, IQR = 1.00) and computer (Mdn = −1.00 D, IQR = 1.38) reading conditions. The boxplots represent the median, interquartile range and overall variability of accommodative response for each reading condition, with mean values indicated by (×).

Comparison of accommodation response between printed and digital screen reading

A Friedman test revealed significant differences in accommodation responses across the four reading conditions, (χ^2 [3] = 15.932, P = 0.001). Mean rank values from the statistical test indicated a trend towards greater accommodative lead during smartphone reading (mean rank = 1.81), followed by printed (2.52), tablet (2.72) and computer conditions (2.95).

As tabulated in Table 1, post hoc Wilcoxon signed-rank tests with Bonferroni adjustment indicated that accommodative responses during smartphone reading differed significantly from printed text (P = 0.029), tablet (P = 0.005) and computer conditions ($P < 0.001$). This indicates smartphones imposed the greatest accommodative demand among all conditions. However, no significant differences were found between printed and tablet or between tablet and computer conditions ($P > 0.05$).

Discussion

This study examined how accommodation responses vary when young adults read printed text and digital text on a smartphone, tablet and computer screen. A lead in accommodation across was observed in all four reading trials, with the largest lead during smartphone reading and the smallest during computer use. This pattern suggests a device-dependent modulation of accommodative behaviour rather than a uniform response to near work alone. The presence of an accommodative lead aligns with what is typically expected in young, non-presbyopic individuals who frequently demonstrate strong tonic accommodation, proximal cues and highly responsive accommodative systems during sustained near task.[7,14,23,30] These individuals often demonstrate a tendency to over-accommodate during near tasks, especially when visual or cognitive demands increase.[6,31] Importantly, accommodative lead may occur even in the presence of visual discomfort and does not necessarily indicate visual dysfunction. This distinction is critical because some research on digital eye strain relies mostly on symptom-based evaluations that do not always correspond directly to objective accommodative measurements.[3,19] Thus, the accommodative lead observed in the present study reflects physiological accommodative behaviour under cognitively demanding reading conditions.

Computer reading produced the least accommodative response**,** which is probably due to larger screen size and longer viewing distances typically used with of computers**.** Ergonomics standards generally recommend a viewing distance of 50 cm–70 cm for computer tasks.[11] At these distances, both vergence and accommodative demands are reduced, resulting in less strain on the accommodation–vergence system.[32] This pattern is in line with studies that indicate using a computer reduces accommodative stress as compared to tasks carried out at shorter viewing distances.[4,7,13] The relatively less accommodative response while reading with a computer in this study supports existing ergonomic guidelines and suggests that a larger screen display may offer a more visually sustainable option for prolonged near work.[13,19]

Reading on a smartphone resulted in a significantly greater accommodation response than reading printed text, a computer or a tablet. This result emphasises the disproportionate visual demand imposed by handheld and smaller digital devices.[14,15] Young adults typically hold smartphones closer, often between 25 and 33 cm, which substantially increases the accommodative stimulus.[15] Short viewing distances also raise vergence demand, and because accommodation and vergence are closely linked, the combined effort intensifies activation of the near triad.[16,17,33,34] Studies have also supported that larger accommodative lead during smartphone reading not only increased dioptric demand, but also heightened neural drive associated with sustained attention during near work.[35,36]

Another key finding was that printed text, tablet and computer reading produced similar accommodative responses, with no statistically significant difference between them. This finding suggests that tablets may function similar to traditional printed materials than to smartphones with respect to accommodative demand, particularly when viewing distance and luminance are controlled.[5,14,22,37] A previous study has also reported comparable findings under controlled stimulus conditions.[5] In typical use, tablets and

printed text are about the same size and are usually held at distances around 30 cm–40 cm.[10] Tablets may therefore offer an intermediate option between smartphone and computer, balancing between portability and less accommodative stress.

Several factors may contribute to the increased accommodative response observed with smartphones. Using a smaller screen often results in reduced character size and higher visual density, which potentially could lead to more frequent and prolonged fixation, and greater cognitive load during reading.[38] These visual behaviour changes may place additional strain on the visual system, thereby indirectly increasing accommodative effort.[15] Digital eye strain literature consistently identifies accommodative and vergence stress as key contributors to symptoms such as eyestrain and headaches during screen use.[1,4,13] Taken together, our findings reinforce important implications. Young adults with borderline accommodative or binocular function may be particularly vulnerable to accommodative stress during prolonged smartphone reading. The results corroborate clinical recommendations that promote the use of larger screens, longer viewing distances and frequent breaks to mitigate accommodative overload associated with handheld digital devices.[4,19]

The findings also have broader relevance to discussions about near work and myopia. Short viewing distances and intensive near tasks have been identified as environmental risk factors for myopia development and progression.[39,40] Although this study did not investigate a direct relationship between accommodative response and myopia, the higher accommodative demand associated with smartphone use corresponds with behavioural patterns implicated in increased near-work load.[14,35] The finding highlights the importance of device selection and viewing habits in discussions of visual health, especially among young adults who engage heavily with digital screens.

Limitations and future research

Several limitations should be considered when interpreting these findings. The study population consisted of healthy young adults with normal binocular function, limiting the generalisability to older adults, children or those with accommodative or vergence disorders. Additionally, MEM retinoscopy provides a single-point assessment of accommodative response and does not capture dynamic fluctuations that occur during sustained reading. This study also did not include subjective symptom assessment; therefore, the relationship between accommodative response and symptoms of visual discomfort or digital eye strain could not be explored. Future studies with larger and more diverse samples should incorporate objective measurements, longer reading tasks, eye-tracking measures and symptom correlation to provide further insight into device-related visual demands.

Conclusion

Accommodation response during reading varies according to device type and the size of the reading medium. Smartphones elicited the greatest accommodative response, indicating a higher accommodative demand compared with tablet, printed text and computer viewing, while computer use produced the lowest demand. These findings suggest that prolonged reading on handheld digital devices may place greater strain on the accommodative system.

From a clinical and ergonomic perspective, larger screens or printed materials should be preferred for extended reading tasks, particularly among young adults engaged in intensive near work. Collectively, the results underscore the importance of considering device type, ergonomic posture and viewing distance when advising students, educators and the public on safe and sustainable reading practices in increasingly digital learning environments.

Acknowledgements

The authors would like to thank all participants for their time and cooperation in this study. They also acknowledge the assistance of Muhammad Fikran Syahiran, Sharifah Aimi Ayuni and Siti Nur Athira for their support during the data collection phase. Their contributions are gratefully appreciated.

Competing interests

The authors, Noor H. Buari, Fatin A. Ahmad and Firdaus Yusof, declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

CRediT authorship contribution

Noor H. Buari: Conceptualisation, Data curation, Formal analysis, Methodology, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing. Fatin A. Ahmad: Data curation, Formal analysis, Investigation, Methodology. Firdaus Yusof: Conceptualisation, Writing – original draft, Writing – review & editing. All authors reviewed the article, contributed to the discussion of results, approved the final version for submission and publication and take responsibility for the integrity of its findings.

Funding information

The authors received no financial support for the research, authorship and/or publication of this article.

Data availability

The data that support the findings of this study are not openly available due to confidentiality and ethical restrictions related to

human participant data and are available from the corresponding author, Noor H. Buari, upon reasonable request.

Disclaimer

The views and opinions expressed in this article are those of the authors and are the product of professional research. They do not necessarily reflect the official policy or position of any affiliated institution, funder, agency or that of the publisher. The authors are responsible for this article's results, findings and content.

References

1. Kaewpradit K, Ngamchaliew P, Buathong N. Digital screen time usage, prevalence of excessive digital screen time, and its association with mental health, sleep quality, and academic performance among Southern University students. Front Psychiatry. 2025;16:1535631. https://doi.org/10.3389/fpsyt.2025.1535631
2. Darko-Takyi C, Mills TW, Boadi-Kusi SB, et al. Association between near visual display device usage and the eye's accommodation and vergence parameters: A cross-sectional study of high school children in Cape Coast, Ghana. BMJ Public Health. 2025;3(2):e003041. https://doi.org/10.1136/bmjph-2025-003041
3. Basur J, Saini H, Chanu KY. Digital eye strain: The current perspective. Haryana J Ophthalmol. 2024;XVI(2):123–126. https://doi.org/10.4103/HJOO.HJOO_7_24
4. Kaur K, Gurnani B, Nayak S, et al. Digital eye strain – A comprehensive review. Ophthalmol Ther. 2022;11(5):1655–1680. https://doi.org/10.1007/s40123-022-00540-9
5. Devenier M, Hansraj R, Rasengane T. The response of the accommodation system to digital and print images. Afr Vis Eye Health. 2021;80(1):1–6. https://doi.org/10.4102/aveh.v80i1.662
6. Fisher K, Mcbrien NA, Ciuffreda KJ. Accommodative hysteresis under static and dynamic stimulus conditions. Clin Exp Optom. 1997;80(4):139–144. https://doi.org/10.1111/j.1444-0938.1997.tb04869.x
7. Sigamani S, Majumder C, Sukumaran S. Changes in accommodation with visual fatigue among digital device users. Med Hypothesis Discov Innov Optom. 2022;3(1):63–69. https://doi.org/10.51329/mehdioptometry153
8. Nguyen J, Cisarik P. Accommodative responses to E-ink vs LCD vs ink on paper in young adults. Invest Ophthalmol Vis Sci. 2018;59(9):2952.
9. Hynes NJ, Cufflin MP, Hampson KM, Mallen EA. The effect of image resolution of display types on accommodative microfluctuations. Ophthalmic Physiol Opt. 2022;42(3):514–525. https://doi.org/10.1111/opo.12949
10. Swedish Agency for Work Environment Expertise. Guidelines for visual ergonomics – Lighting and vision in the workplace. 1st ed. Gävle: Myndigheten för arbetsmiljökunskap; 2025.
11. Ministry of Human Resources. Guidelines on occupational safety and health for working with display screen equipment 2024. Putrajaya: Department of Occupational Safety and Health Ministry of Human Resources; 2024.
12. Boccardo L. Viewing distance of smartphones in presbyopic and non-presbyopic age. J Optom. 2021;14(2):120–126. https://doi.org/10.1016/j.optom.2020.08.001
13. Barata MJ, Aguiar P, Grzybowski A, Moreira-Rosário A, Lança C. A review of digital eye strain: Binocular vision anomalies, ocular surface changes, and the need for objective assessment. J Eye Mov Res. 2025;18(5):39. https://doi.org/10.3390/jemr18050039
14. Long J, Cheung R, Duong S, Paynter R, Asper L. Viewing distance and eyestrain symptoms with prolonged viewing of smartphones. Clin Exp Optom. 2017;100(2):133–137. https://doi.org/10.1111/cxo.12453
15. Chellapan T, Narayanasamy S. Smartphone use patterns and the impact on accommodation and convergence system of the eyes among Malaysian teenagers. Int J Ophthalmol. 2024;17:2093–2099. https://doi.org/10.18240/ijo.2024.11.16
16. Mareena M, Kamath V, Rao D. Effect of smart phone on accommodation and vergence response in bright and dark illumination with different positions. Act Sci Oph. 2024;7(6):3–13. https://doi.org/10.31080/ASOP.2024.06.0626
17. Pachiyappan T, Srambikkal SA, Sushmitha. Changes in accommodation and vergence measurements after smartphone use in healthy young adults. RGUHS J Allied Health Sci. 2023;3(2):8–12. https://doi.org/10.26463/rjahs.3_2_3
18. Swetha M, Sumitra L, Sumitra G. Effect of screen time on visual accommodation and eye fatigue. Int J Acad Med Pharm. 2025;7(5):860–866.
19. Sheppard AL, Wolffsohn JS. Digital eye strain: Prevalence, measurement and amelioration. BMJ Open Ophth. 2018;3(1):e000146. https://doi.org/10.1136/bmjophth-2018-000146
20. 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
21. Halim SA, Feisal NAS, Cheah WY, et al. The impact of visual digital unit exposure on ocular symptoms of computer vision syndrome among Selangor Office Workers. J Health Sci Med Res. 2024;42(6):e20241106. https://doi.org/10.31584/jhsmr.20241106
22. Padavettan C, Nishanth S, Vidhyalakshmi S, Madhivanan N, Madhivanan N. Changes in vergence and accommodation parameters after smartphone use in healthy adults. Indian J Ophthalmol. 2021;69(6):1487–1490. https://doi.org/10.4103/ijo.IJO_2956_20
23. Kaliugavaradhan A, Ramamurthy D. Accommodative facility and response time before and after computer task of varying durations in young adults. Br Ir Orthopt J. 2023;19(1):85–95. https://doi.org/10.22599/bioj.295
24. Manny RE, Chandler DL, Scheiman, MM, et al. Accommodative lag by autorefraction and two dynamic retinoscopy methods. Optom Vis Sci. 2009;86(3):233–243. https://doi.org/10.1097/OPX.0b013e318197180c
25. Arifin WN. Sample size calculator (web) [homepage on the Internet]. 2024 [cited 2024 Mar 01]. Available from: http://wnarifin.github.io
26. Sharifah-Aimi SI, Saliman NH, Buari NH. Comparative analysis of blink rates during printed and on-screen reading across varying screen sizes. J Health Sci Med Res. 2024;42(6):20241097. https://doi.org/10.31584/jhsmr.20241097
27. Nguyen AT, Wayne JL, Ravikumar A, Manny RE, Anderson HA. Accommodative accuracy by retinoscopy versus autorefraction spherical equivalent or horizontal meridian power. Clin Exp Optom. 2018;101(6):778–785. https://doi.org/10.1111/cxo.12678
28. Scheiman M, Wick B. Clinical management of binocular vision: Heterophoric, accommodative, and eye movement disorders. 4th ed. Philadelphia: LWW; 2015.
29. Del Pilar Cacho M, García-Muñoz A, García-Bernabeu JR, López A. Comparison between MEM and Nott dynamic retinoscopy. Optom Vis Sci. 1999;76(9):650–655. https://doi.org/10.1097/00006324-199909000-00023
30. Hinkley S, Iverson-Hill S, Haack L. The correlation between accommodative lag and refractive error in minors under 18. Austin J Clin Ophthalmol. 2014;1(2):1–5.
31. Rosenfield M, Ciuffreda KJ, Ong E, Azimi A. Proximally induced accommodation and accommodative adaptation. Invest Ophthalmol Vis Sci. 1990;31(6):1162–1167.
32. Jun-we Z. Effects of different reading distances on the accommodation of children with myopia. Chin J Pract Ophthalmol. 2006;24(2):138–141.
33. Ellis SR, Menges BM. Judgments of the distance to nearby virtual objects: Interaction of viewing conditions and accommodative demand. Presence: Teleoperators Virtual Environ. 1997;6(4):452–460. https://doi.org/10.1162/pres.1997.6.4.452
34. Spiegel DP, Erkelens IM. Vergence-accommodation conflict increases time to focus in augmented reality. J Soc Inf Disp. 2024;32(5):194–205. https://doi.org/10.1002/jsid.1283
35. Chellapan T, Mat Daud N, Narayanasamy S. Smartphone use on accommodation and vergence parameters: A systematic review. Malays J Med Health Sci. 2023;19(3):325–333. https://doi.org/10.47836/mjmhs.19.3.42
36. Jalil S, Yaseen K. Effect of smartphone use on convergence among undergraduate students. J Clin Community Ophthalmol. 2025;3:28–32. https://doi.org/10.71177/jcco.v3i01.64
37. Cisarik P, Nguyen J. Comparison of accommodative responses to e-Ink vs. LCD vs. Standard ink on hard copy. Optom Vis Perform. 2019;7(5):269–281.
38. Buari NH, Md-Isa ANF. Eye movements behaviour in reading different text sizes among university students. Environ-Behav Proc J. 2019;4(12):12. https://doi.org/10.21834/e-bpj.v4i12.1916
39. Foreman J, Salim AT, Praveen A, et al. Association between digital smart device use and myopia: A systematic review and meta-analysis. Lancet Digit Health. 2021;3(12):e806–e818. https://doi.org/10.1016/S2589-7500(21)00135-7
40. Lanca C, Yam JC, Jiang WJ, et al. Near work, screen time, outdoor time and myopia in schoolchildren in the Sunflower Myopia AEEC consortium. Acta Ophthalmol. 2022;100(3):302–311. https://doi.org/10.1111/aos.14942