

Evaluating the optimised font size and viewing time of online learning in young children: a multicentre cross-sectional study

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ABSTRACT

Objectives Near viewing distance (VD) and longer viewing times are associated with myopia. This study aimed to identify the font size and viewing time that guarantee the appropriate VD and pixels per degree (PPD) for children's online learning.

Design This cross-sectional study comprised two experiments. In experiment A, participants read text in five font sizes on three backlit displays (a personal computer, a smartphone and a tablet), an E-ink display and paper for 5 min per font size. In experiment B, participants watched videos for 30 min on three backlit displays.

Setting The Peking University People's Hospital in Beijing (China) and the School of Ophthalmology and Optometry, Wenzhou Medical University (Zhejiang Province, China).

Participants Thirty-five participants completed experiment A. Ten of them participated in experiment B.

Primary and secondary outcome measures VDs were measured by Clouclip. The corresponding PPD was calculated.

Results In experiment A, font size and display type significantly affected VD ($F_{(4840)}=149.44$, $p<0.001$, ES (Effect size)=0.77; $F_{(4840)}=149.44$, $p<0.001$, ES=0.37). VDs were >33 cm for all five font sizes on the PC, the tablet and paper and for 18-pt on the smartphone and 16-pt on E-ink. PPD for 16-pt on the PC, 14-pt on the tablet and all five font sizes on the phone were >60. In experiment B, VD increased over the four previous 5 min periods but decreased slightly on tablets and PCs in the fifth 5 min period. PPD was >60.

Conclusion Children demonstrated different VDs and PPDs based on font size and display type. To ensure a 33 cm VD and 60 PPD, the minimum font size for online reading should be 18-pt on smartphones, 16-pt on PCs and E-ink, 10.5-pt on tablets and 9-pt on paper. More attention should be given to children's VD with continuous video viewing of more than 25 min.

Trial registration number ChiCTR2100049584.

INTRODUCTION

People's lives have been deeply affected by COVID-19.^{1 2} To prevent the spread of COVID-19, traditional teaching modes have been replaced by online teaching at nearly

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ Online teaching has widespread applications during COVID-19 and may continue to flourish.
- ⇒ Increased digital screen time and near viewing distance (VD) were associated with the onset and progression of myopia in young children.
- ⇒ Clouclip allowed for an objective VD measurement.

WHAT THIS STUDY ADDS

- ⇒ We explored the optimised font size and acceptable viewing time from the perspective of myopia prevention.
- ⇒ Children demonstrated different VDs and pixels per degree based on font size, viewing time and display type.
- ⇒ The minimum font size for text should be 18-pt on smartphones, 16-pt on PCs and E-ink, 10.5-pt on tablets and 9-pt on paper. Continuous video watching time should be less than 25 min.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ This study may provide recommendations for interface design for young children.

all education levels, and this situation may continue during the postpandemic era.³

The daily online course time is 1 hour for grades 1 and 2 and 2.5 hours for grades 3–6.⁴ Children aged 8–12 years in the USA were found to spend 4–6 hours a day watching or using screens.⁵ One study revealed that the prevalence of myopia after COVID-19 was approximately three times higher than in other years for children aged 6 years, 2 times higher for children aged 7 years and 1.4 times higher for children aged 8 years.⁶ Although the increased prevalence of myopia precedes the advent of smart devices, it has been suggested that these devices could exacerbate the myopia epidemic.

Shorter reading distance is widely considered a significant environmental risk factor

for myopia incidence and progression.^{7 8} The Chinese Ministry of Education proposed 33 cm as a 'watershed' between fast and slow myopia progression^{7 9 10} and the appropriate distance from the eye to the viewing panel when children are reading or writing.¹¹ For backlit displays, relatively small screens may necessitate close viewing distance (VD) and small text sizes, increasing the accommodation and vergence demand and thus accelerating myopia progression.^{12 13} Another display parameter, pixels per degree (PPD), referring to the average number of pixels in every 1° field angle, should also be considered. A lower PPD leads to the screen door effect, which describes the visible gaps between actual pixels. This effect is induced by shorter distances and resolved by increasing resolution. PPD should be at least 60 to avoid the screen door effect.^{14 15}

The VD of most studies was acquired by questionnaires or by using rulers and a continuous shooting system, or the participants' heads were fixed using a chin-support tripod without regard to how people actually read in daily life. This study used a Clouclip device (JingZhiJing Technology, Hangzhou, China), which is attached to the spectacle arm and can measure both light intensity and distance. The collected data reflect the experience of the eye itself.¹⁶

This study aims to explore the optimal font sizes and acceptable viewing time during children's online learning to guarantee a suitable VD and PPD for backlit devices.

METHODS

Study design

This is a cross-sectional multicentre-based study, mainly conducted in the Peking University People's Hospital and the School of Ophthalmology and Optometry, Wenzhou Medical University. The study protocol is available in online supplemental appendix.

Participants

All children completed a form with details of their basic information. Then, cycloplegia was induced via the administration of four drops of Mydrin-P (tropicamide (0.5%) phenylephrine (0.5%) eye-drops; Santen Pharmaceuticals, Japan) at an interval of 5 min in both eyes. The refraction was first examined using a desk-mounted autorefractor (KR-8900; Topcon, Tokyo, Japan). Subjective refraction was performed on another day. Refractive errors were corrected with full-correction lenses. The inclusion criteria were as follows: (1) the best-corrected visual acuity of both eyes was ≤ 0.00 logMAR or better; (2) spherical equivalent refractive errors ranging from -1.00 to -5.50 D; (3) without anisometropia >1.00 D or astigmatism >1.50 DC. All participants were in good health without ocular diseases or any other systemic conditions affecting ocular health.

Table 1 Details of the materials used in the study

Backlit displays	
Smartphone	Huawei P30
Screen size (inch)	2.56 (W)×5.55 (H)
Screen resolution (ppi)	422
Tablets	Huawei Matepad BAH1-W09
Screen size (inch)	6.10 (W)×9.65 (H)
Screen resolution (ppi)	224
Laptop	Lenovo Thinkpad L480
Screen size (inch)	12.20(W)×6.89(H)
Screen resolution (ppi)	157
E-ink display	
E-ink	Kindle PaperWhite4
Screen size (inch)	4.49 (W)×6.54(H)
Screen resolution (dpi)	226
Paper material	
Excerpt from 'The Thousand and One Nights'	A4 paper
Paper size (inch)	8.27 (W)×11.69 (H)

dpi, dots per inch; H, height; ppi, pixels per inch; W, width.

Apparatus

The devices used in our study are listed in [table 1](#). All displays were tested in experiment A. Three backlit devices were tested in experiment B.

A Clouclip device was attached to the temple of a spectacle frame by a rubber sleeve with its anterior panel parallel to the spectacle plane ([figure 1A](#)). It measured working distances every 5 s and environmental luminance every 120 s; therefore, the time-tagged perpendicular distance from the participants' eyes to the display plane and light levels were recorded.

Experimental work conditions

Devices were placed on a reading bracket with a background board to extend the viewing plane. The reading bracket was placed on an 800 mm high test table, and the participants sat on swivel chairs. The reading bracket angle and height, the swivel chair height and the VD could be adjusted according to the participants' preferences during the experimental process ([figure 1B](#)). The participants needed to touch the screen or turn the page by themselves when finishing the current page.

This study maintained a constant ambient illumination of 300 lx. The screen luminance was environmentally dependent, as all devices were set to automatic adjustment mode. No reflection appeared on the screen of the digital devices during the experimental process.

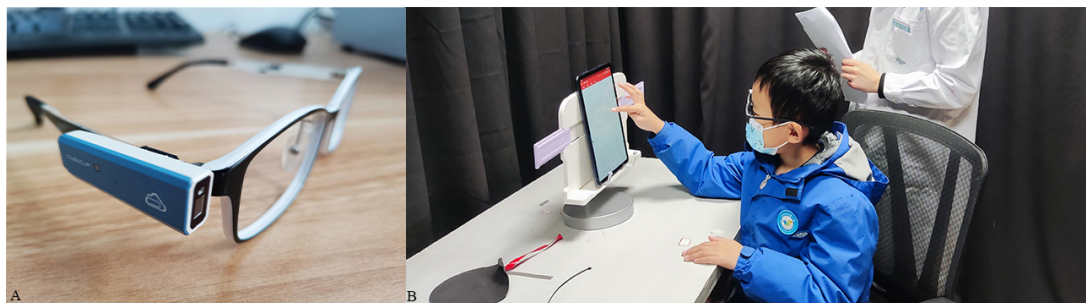


Figure 1 (A) The Clouclip can be attached to the temple of a spectacle frame with its anterior panel parallel to the spectacle plane. (B) The experimental conditions of the workplace. Digital devices were placed on the reading bracket with a background board to extend the viewing plane. The reading bracket was placed on an 800 mm high test table, and the participants sat on swivel chairs. The reading bracket angle and height, the swivel chair height and the viewing distance could be adjusted according to the participants' preferences during the experimental process.

Experiments and procedures

Figure 2 shows the flow chart of the experimental procedures. The study comprised two experiments during which the VDs of the participants were measured (experiment A, reading text presented in different font sizes; experiment B, watching video on various digital devices). For the backlit displays, the PPD was also calculated by formula 1.¹⁷

$$PPD = (\text{pixels/degree}) = 2 \times D \times R \times \tan 0.5^\circ \text{ formula 1.}$$

D: the distance from the participants' eyes to the display plane in inches.

R: screen resolution in pixels per inch.

Experiment A

This task evaluated the following two independent variables:

1. Text display type: smartphone, tablet, personal computer (PC), E-ink and paper.
2. Font size: five Chinese 'song' font sizes, 9-pt, 10.5-pt, 12-pt, 14-pt and 16-pt for paper, tablet, PC and E-ink and 12-pt, 14-pt, 16-pt, 18-pt and 20-pt for smartphones since text displayed in 9-pt and 10.5-pt font is difficult to read on phone screens. 'Song' font was used due to its popularity for Chinese text presentations, especially in children's books.

The text display type and font size were considered within-subject factors. Each participant read text presented in five font sizes (5 min per font size) on one display type at each visit. A 10 min distance viewing was allowed after reading one kind of font size to avoid possible biases resulting from the visual fatigue effect. The test sequences for the five text display types and five font sizes were randomised.

Experiment B

This task evaluated the following two independent variables:

1. Video display type: smartphone, tablet and PC.
2. Time: the middle 25 min of a continuous 30 min period was segmented into five 5 min periods, and the mean reading distance in each 5 min period was calculated.

Video display type and time were considered within-subject factors. Ten participants who completed experiment A were further invited to participate in experiment B. To avoid possible biases resulting from the visual fatigue, a 20min rest was given. Then, they watched a high-definition Chinese online course video corresponding to their grade on the screen for 30 continuous minutes. The test sequences for the three backlit display types corresponded with those in experiment A.

All visits were completed between 9:00 and 12:00 hours within a period of 10 days to avoid any influence of diurnal variations on ocular status.

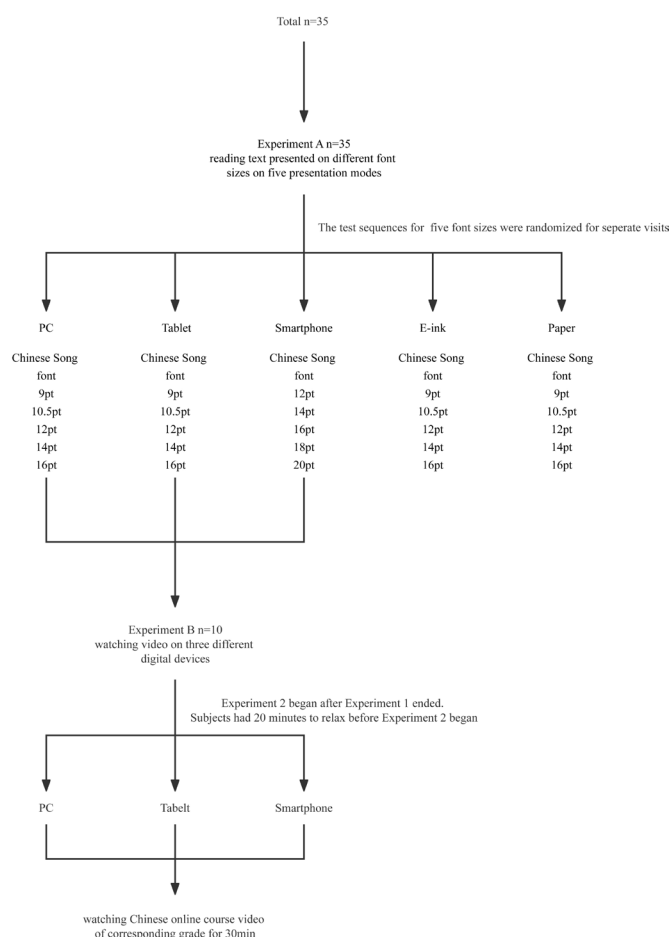


Figure 2 The flow of experimental procedures.

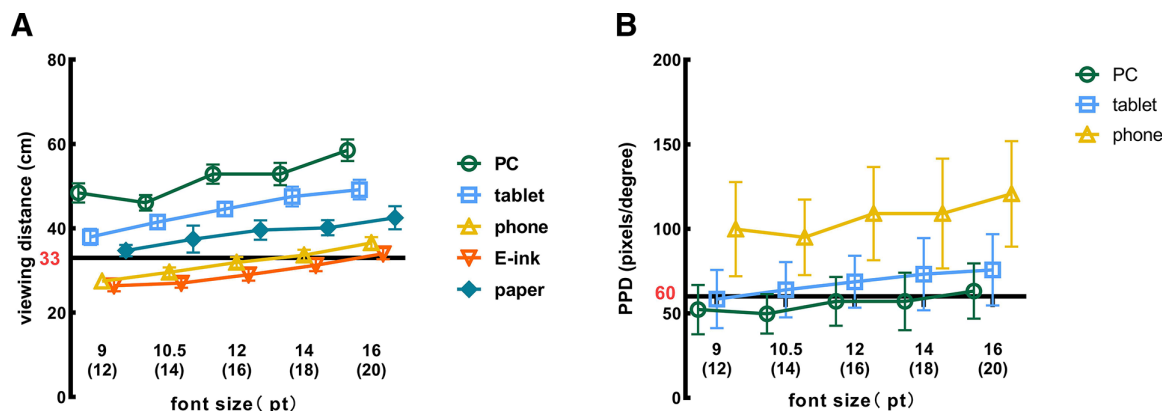


Figure 3 (A) The mean viewing distances for the five font sizes on the different text display types. (B) The PPD for three backlit displays. PPD, pixels per degree.

PC, personal computer.

Dependent measures and data analysis

The dependent variables in our study were the VD and PPD for the backlit devices. After excluding evident outliers,¹⁶ the mean VD during each 5 min task was considered, and the PPD was calculated. Statistical analyses were performed using IBM SPSS V.25.0 (IBM). A three-level multilevel linear model (MLM) was used to account for the multilevel data structure with the measurement data nested within display type and font size. We modelled the independent variables (display type and font size) as fixed effects. Pairwise comparisons were completed with Bonferroni correction. Spearman correlation analysis was conducted to obtain the correlation coefficients between the independent variables and within-subject factors. Statistical significance was set at $p < 0.05$.

Patient and public involvement

Patients and/or the public were not involved in the design, conduct, reporting or dissemination plans of this research.

RESULTS

Average VDs and PPD for text reading

A total of 35 young children (8.97 ± 1.12 years old; 138.51 ± 7.50 cm tall; 10 females) participated in experiment A. The mean VDs for the five font sizes on five display types are shown in figure 3A. The average VDs for 18-pt on the phone, 16-pt on E-ink and all five font sizes on the other display types were more than 33 cm.

The MLM results indicated that font size and display type had significant effects on VD ($F_{(48,40)} = 149.44$, $p < 0.001$, effect size (ES)=0.77; $F_{(48,40)} = 26.22$, $p < 0.001$, ES=0.37), with no significant interaction between font size and display type ($F_{(16,840)} = 1.25$, $p = 0.223$). Significant differences in VD existed among the five display types, except between the smartphone and E-reader ($p = 0.151$). Furthermore, there were significant differences among font sizes (all $p < 0.05$) but not between 9-pt and 10.5-pt fonts ($p = 1.00$) or between 12-pt and 14-pt fonts ($p = 1.00$). PCs, paper and tablets were associated with the longest,

second-longest and third-longest VDs, respectively. The shortest VD was recorded when the children read on E-ink.

Figure 3B shows the PPD of the three backlit displays. The PPD of 16-pt on the PC, 14-pt on the tablet and all five font sizes on the phone were more than 60. Font size and display type had significant effects on PPD ($F_{(4139,356)} = 12.36$, $p < 0.001$, ES=0.48; $F_{(2339,098)} = 225.17$, $p < 0.001$, ES=0.94). The results of the Bonferroni method indicated that PPD differed significantly among the three backlit displays (all $p < 0.05$). The PPD of the smartphone was the largest under all five font sizes. Non-significant differences were found between the 9-pt and 10.5-pt fonts and among the 12-pt, 14-pt and 16-pt fonts (12-pt and 14-pt fonts and 16-pt, 18-pt and 20-pt fonts on the phone), PPD differed significantly among other font sizes (all $p < 0.05$).

VD was significantly correlated with screen size ($r = 0.54$, $p < 0.001$), font size ($r = 0.068$, $p = 0.01$) and height ($r = 0.084$, $p = 0.012$). PPD was correlated with font size ($r = 0.509$, $p < 0.001$), screen size ($r = -0.609$, $p < 0.001$), age ($r = -0.137$, $p = 0.002$), grade ($r = -0.114$, $p = 0.001$) and height ($r = -0.115$, $p = 0.008$). This finding indicates that a relatively larger screen size and larger font size tended to induce a longer VD, while a smaller screen size and a larger font size tended to induce larger PPD when the children read text.

Average VDs and PPD for video watching

Ten of the participants (8.3 ± 1.16 years old; 3 females) further participated in experiment B. Figure 4A shows the VD of the three backlit displays. The average VDs during the 30 min experimental process were all more than 33 cm.

Display type significantly affected VD ($F_{(271,456)} = 21.783$, $p < 0.001$, ES=0.58). The effect of time was non-significant ($F_{(438,537)} = 2.277$, $p = 0.079$, ES=0.15). VD increased slightly with increasing viewing time. However, in the fifth 5 min period, VD decreased slightly when the children used the PC and the tablet.

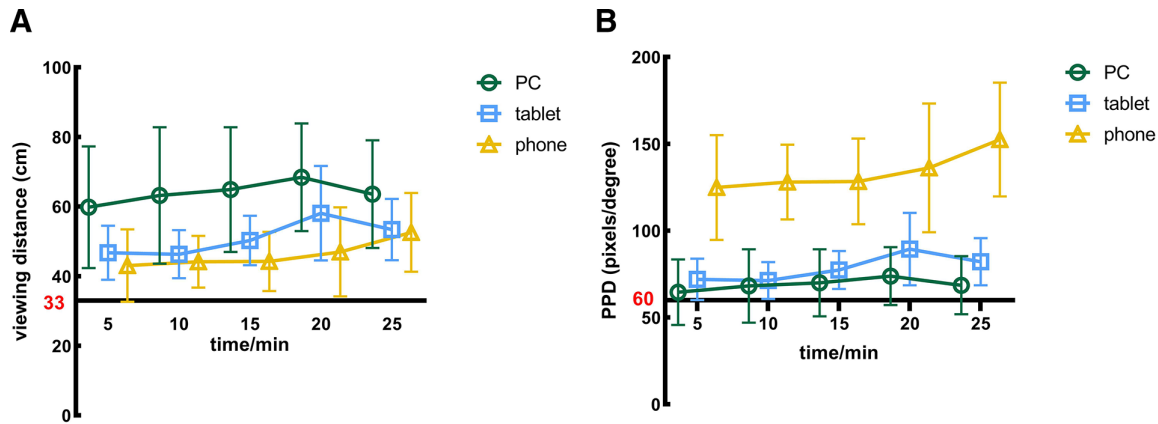


Figure 4 (A) The viewing distances for video watching on the backlit displays. (B) The PPD for three backlit displays. PPD, pixels per degree. PC, personal computer.

Figure 4B shows the PPD of the three backlit displays. The average PPDs during the 30 min task were all more than 60. Display type and time had significant effects on PPD ($F_{(2103.699)}=100.037$, $p<0.001$, $ES=0.87$; $F_{(437.167)}=2.622$, $p=0.05$, $ES=0.11$). The PPD of the phone was the largest and that of the PC was the smallest. The results of the Bonferroni method indicated that PPD differed only between the second and fifth 5 min periods ($p=0.037$).

VD was significantly correlated with screen size ($r=0.467$, $p<0.001$), time ($r=0.221$, $p=0.007$) and height ($r=0.189$, $p=0.02$). PPD was significantly correlated with screen size ($r=-0.744$, $p<0.001$). A relatively larger screen size tended to induce a longer VD, while smaller PPD was observed when the children watched videos.

DISCUSSION

The major goal of our study was to identify the optimal font size and video viewing time in children and to guarantee the appropriate VD and PPD for online learning. Questionnaire-based studies have reported that shorter reading distance is a major environmental risk factor for myopia incidence and progression.^{18 19} However, subjective evaluations of VD seem less persuasive. The preferred VD among Chinese children has been found to be 20.6 ± 6.5 cm.²⁰ A study of Japanese adolescents also found that reading distance <30 cm was accompanied by a steep downwards angle during reading and writing.²¹ In both studies, a camera was used to take photographs when the children were performing visual tasks. Measurements of the video images were taken by frame analysis and only provided a series of time point data. In our study, a Clouclip device, capable of continuously measuring near-VD,^{16 22} was used for data collection. Except for the E-reader, the mean VDs of the five font sizes were >33 cm. Our findings differ from those of previous studies, possibly due to the different measurement methods.

According to the ANSI/HFS-100 standard, the minimum character height for computer workstations should be 16', with a preferred range of 20–22' for

legibility.²³ Lee *et al*²⁴ suggested that the recommended English character size for E-books should be approximately 22'. However, these findings were based on the English alphabet and mainly obtained from adults, and most digital devices tested were developed more than a decade ago. In our study, font size, the different physical sizes on the varied display types, was considered a within-subject factor because people usually adjust the font size directly when they intend to vary the text size on a display panel. Therefore, font size functions as a direct indicator.

For adults, adopted VDs are suggested to be 30 cm for phones and electronic books, 60 cm for desktop computers and 3 m for televisions for comfortable viewing.²⁵ The key concern of children may be different from that of adults. In addition to readability and comfort, near-work-induced myopia should also be considered. The findings of a 2-year prospective study of 10743 children showed that a longer work distance (>30 cm) and the discontinuation of near work every 30 min had a strong protective effect against myopia progression.²⁶ The Ministry of Education of the Chinese government has suggested that 33 cm is the appropriate distance from the eye to the viewing panel when children are reading or writing.¹¹ Considering these effects, tablets, PC and paper are recommended, and the mean VDs for all test conditions should be more than 33 cm.

E-ink is well known for its engineering design. Numerous studies have proven its readability without the induction of extensive visual fatigue. Our results conflict with these findings, as VD is a vital factor affecting visual fatigue.^{27 28} Although the E-ink display used in our study offered a reading experience under all lighting conditions, the brightness of the screen was softer than that of the other devices; hence, the VD may have been affected. In addition, users may believe that an E-reader is better and safer for the eyes compared with reading on Liquid crystal displays (LCDs), which may provide a psychological indication for neglecting the VD.^{28 29}

PPD is more frequently mentioned in 'near-eye' devices, such as head-mounted displays or virtual reality

glasses. Lower PPD leads to the screen door effect, and PPD should be at least 60 to avoid this effect.^{14 15} This parameter was introduced in our study as the screen resolution, field of view and VD, which should be considered in combination when children use backlit displays. Therefore, the font size should be up to 16-pt on PCs, 10.5-pt on tablets and 12-pt on phones.

In our study, the mean VD and PPD for continuous 30 min video watching on smartphones, tablets and PCs were all suitable (all distance >33 cm and all PPD >60). The VD tended to increase slightly with viewing time, whereas in the fifth 5 min period, the VD decreased slightly when the children used tablets and PCs. This implies that parents should pay more attention to children's VD with the extension of viewing time. A 1-year cohort study found that 30–40 min of viewing with fewer viewing breaks during near work was associated with a significantly increased risk of myopia.³⁰ Students are encouraged to rest their eyes for 10 min after 30–40 min of educational screen time, and the continuous use of digital devices for noneducation purposes should be limited to <15 min per day according to the Chinese Ministry of Education.¹¹ Thus, viewing time should be emphasised to maintain the appropriate VD.

CONCLUSION

The minimum font size for text should be 18-pt on a smartphone, 16-pt on a PC and E-ink, 10.5-pt on a tablet and 9-pt on paper to ensure a 33 cm VD and 60 PPD. Moreover, 25 min of video watching does not result in 'closer' viewing but rather 'further' viewing.

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Contributors KW and JZ researched the literature and conceived the study. LM, XY, LG, LW and ZP were involved in protocol development, obtaining ethical approval, patient recruitment and data analysis. LM wrote the first draft of the manuscript. KW and JZ revised it critically for important intellectual content. YL and MZ approved the version to be published. KW accepted full responsibility for the work and/or the conduct of the study, had access to the data, and controlled the decision to publish. All authors reviewed and edited the manuscript and approved the final version of the manuscript. KW is the guarantor.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Consent obtained directly from patient(s).

Ethics approval This study involves human participants and was approved by the ethics committee of Peking University People's Hospital and Eye Hospital and Wenzhou Medical University approved this study (REC number 2020PHB273-01). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data was available upon reasonable request. Availability of data and materials: DOI: 10.6084/m9.figshare.21510018

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REFERENCES

- Hu Y, Zhao F, Ding X, *et al.* Rates of myopia development in young Chinese schoolchildren during the outbreak of COVID-19. *JAMA Ophthalmol* 2021;139:1115.
- Singh S, Roy D, Sinha K, *et al.* Impact of COVID-19 and lockdown on mental health of children and adolescents: a narrative review with recommendations. *Psychiatry Research* 2020;293:113429.
- Ma M, Xiong S, Zhao S, *et al.* COVID-19 home quarantine accelerated the progression of myopia in children aged 7 to 12 years in China. *Invest Ophthalmol Vis Sci* 2021;62:37.
- Wang G, Zhang Y, Zhao J, *et al.* Mitigate the effects of home confinement on children during the COVID-19 outbreak. *The Lancet* 2020;395:945–7.
- American Academy of Child & Adolescent Psychiatry. Screen time and children. n.d. Available: <https://www.aacap.org/AACAP/FamiliesandYouth/FactsforFamilies/FFF-Guide/Children-And-Watching-TV054.asptextOnaveragechildrenagesusemayleadproblems>
- Wang J, Li Y, Musch DC, *et al.* Progression of myopia in school-aged children after COVID-19 home confinement. *JAMA Ophthalmol* 2021;139:293.
- Gong Y, Zhang X, Tian D, *et al.* Parental myopia, near work, hours of sleep and myopia in Chinese children. *Health* 2014;06:64–70.
- Ip JM, Saw S-M, Rose KA, *et al.* Role of near work in myopia: findings in a sample of Australian school children. *Invest Ophthalmol Vis Sci* 2008;49:2903.
- Bhandari KR, Ostrin LA. Objective measures of viewing behaviour in children during near tasks. *Clin Exp Optom* 2022;105:746–53.
- Wu L-J, Wang Y-X, You Q-S, *et al.* Risk factors of myopic shift among primary school children in Beijing, China: a prospective study. *Int J Med Sci* 2015;12:633–8.
- Ministry of Education People's Republic of China website. Notice by the ministry of education and other eight departments on the issuance of the "Implementation plan for the prevention and control of myopia in children and adolescents. n.d. Available: http://en.moe.gov.cn/news/press_releases/201811/t20181101_353402.html
- Tosha C, Borsting E, Ridder WH, *et al.* Accommodation response and visual discomfort. *Ophthalmic Physiol Opt* 2009;29:625–33.
- Logan NS, Radhakrishnan H, Cruickshank FE, *et al.* IMI accommodation and binocular vision in myopia development and progression. *Invest Ophthalmol Vis Sci* 2021;62:4:..
- Anthes C, Garcia-Hernandez RJ, Wiedemann M, *et al.* State of the art of virtual reality technology. In: 2016 IEEE Aerospace Conference.
- Aksit K, Chakravarthula P, Rathinavel K, *et al.* Manufacturing application-driven foveated near-eye displays. *IEEE Trans Vis Comput Graph* 2019;25:1928–39.
- Bhandari KR, Ostrin LA. Validation of the clouclip and utility in measuring viewing distance in adults. *Ophthalmic Physiol Opt* 2020;40:801–14.

- 17 Degrees of visual angle. n.d. Available: http://en.wikipedia.org/wiki/Visual_angle
- 18 Hsu C-C, Huang N, Lin P-Y, *et al.* Risk factors for myopia progression in second-grade primary school children in Taipei: a population-based cohort study. *Br J Ophthalmol* 2017;101:1611–7.
- 19 Saw S-M, Carkeet A, Chia K-S, *et al.* Component dependent risk factors for ocular parameters in Singapore Chinese children. *Ophthalmology* 2002;109:2065–71.
- 20 Wang Y, Bao J, Ou L, *et al.* Reading behavior of emmetropic schoolchildren in china. *Vision Res* 2013;86:43–51.
- 21 Tokoro T. Myopia updates. Proceedings of the 6th International Conference on Myopia; Tokyo, 1998
- 22 Wen L, Cheng Q, Cao Y, *et al.* The clouclip, a wearable device for measuring near-work and outdoor time: validation and comparison of objective measures with questionnaire estimates. *Acta Ophthalmol* 2021;99:e1222–35.
- 23 Human Factors Society, Inc. American national standard for human factors engineering of visual display terminal workstations (ANSI/HFS standard no.100-1988) Santa Monica, CA,
- 24 Lee D-S, Shieh K-K, Jeng S-C, *et al.* Effect of character size and lighting on legibility of electronic papers. *Displays* 2008;29:10–7.
- 25 Bilton N. *I live in the future & here's how it works*. New York, NY: Crown Business, 2010.
- 26 Huang P-C, Hsiao Y-C, Tsai C-Y, *et al.* Protective behaviours of near work and time outdoors in myopia prevalence and progression in myopic children: a 2-year prospective population study. *Br J Ophthalmol* 2020;104:956–61.
- 27 Benedetto S, Drai-Zerbib V, Pedrotti M, *et al.* E-readers and visual fatigue. *PLoS One* 2013;8:e83676.
- 28 Siegenthaler E, Bochud Y, Bergamin P, *et al.* Reading on LCD vs e-ink displays: effects on fatigue and visual strain. *Ophthalmic Physiol Opt* 2012;32:367–74.
- 29 Siegenthaler E, Schmid L, Wyss M, *et al.* LCD vs. E-ink: an analysis of the reading behavior. *JEMR* 2012;5.
- 30 You X, Wang L, Tan H, *et al.* Near work related behaviors associated with myopic shifts among primary school students in the jiadong district of Shanghai: a school-based one-year cohort study. *PLoS One* 2016;11:e0154671.