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

LU MA,[1,2] Xi Yu,[3] Ling Gong,[3] Lili Wei,[3] Zisu Peng,[1,2] Kai Wang ,[1,2] Yan Li,[1] Jiawei Zhou,[3] Mingwei Zhao[1,2]

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LM and XY are joint first authors.

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For numbered affiliations see end of article.

Correspondence to
Dr Kai Wang; wang_kai@bjmu.edu.cn

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; $F_{(4840)}$, 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.

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.

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 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.

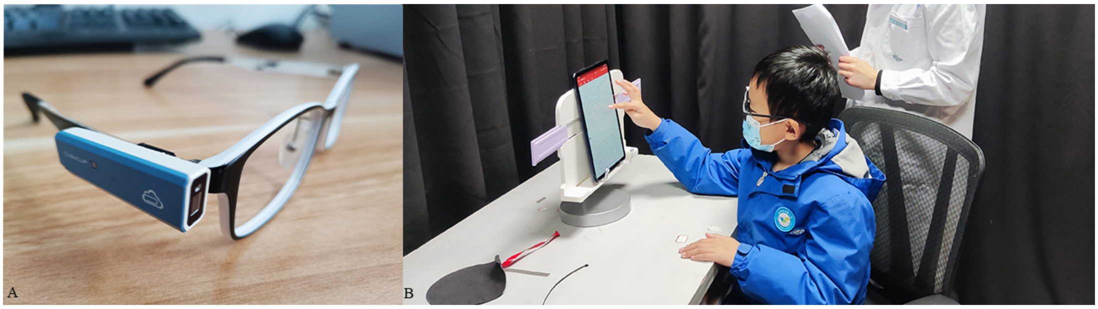

Figure 1 (A) The Clouclip can be attached to the temple of a spectacle frame with its anterior panel parallel to the spectacle plane. (B) The experimental conditions of the workplace. Digital devices were placed on the reading bracket with a background board to extend the viewing plane. The reading bracket 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=(pixels/degree)= $2 \times D \times R \times \tan 0.5°$ formula 1.

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

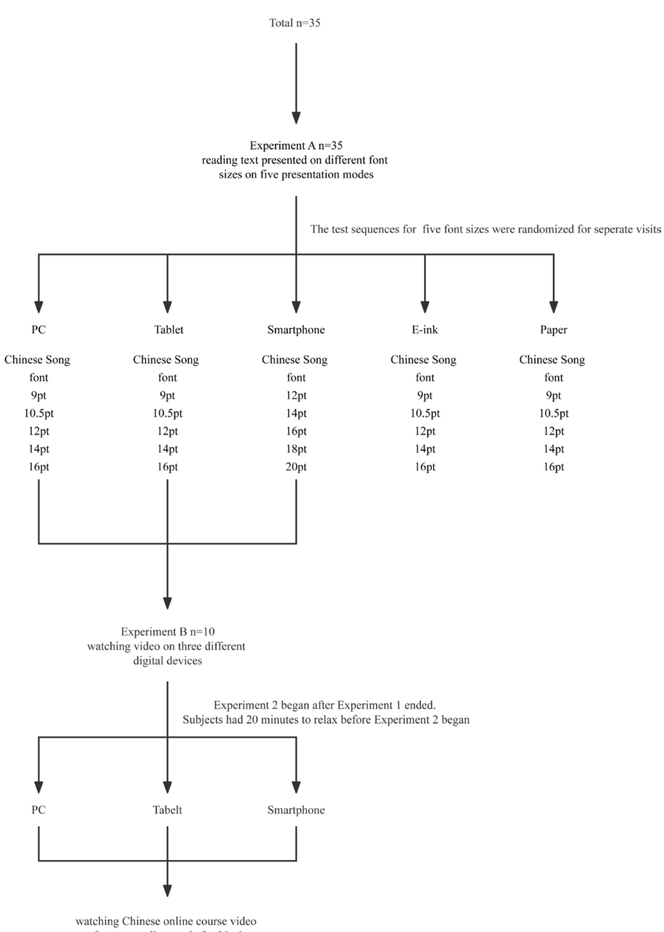

Figure 2 The flow of experimental procedures.

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 20 min 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.

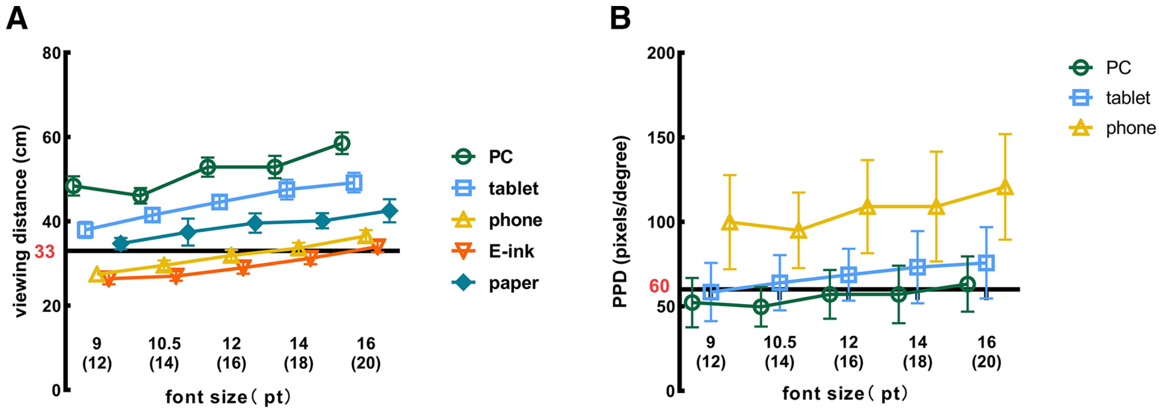

Figure 3 (A) The mean viewing distances for the five font sizes on the different text display types. (B) The PPD for three backlit displays. PPD, pixels per degree.
PC, personal computer.

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 ($F_{(4840)}$=149.44, p<0.001, effect size (ES)=0.77; $F_{(4840)=}$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.

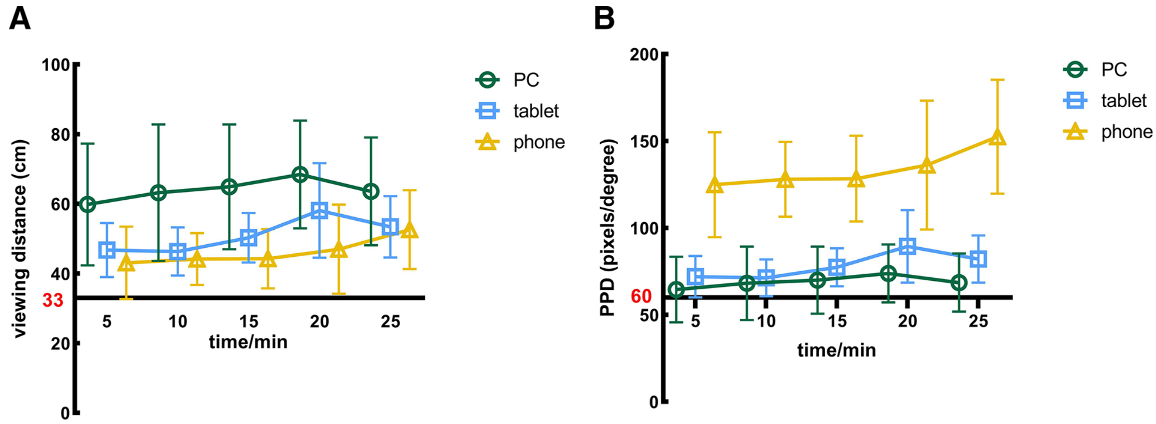

Figure 4 (A) The viewing distances for video watching on the backlit displays. (B) The PPD for three backlit displays. PPD, pixels per degree. PC, personal computer.

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 10 743 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.

Author affiliations
[1]Department of Ophthalmology & Clinical Centre of Optometry, Eye Disease and Optometry Institute, Peking University People's Hospital, Beijing Key Laboratory of the Diagnosis and Therapy of Retinal and Choroid Diseases, Beijing, China
[2]Institute of Medical Technology, Peking University Health Science Centre, Beijing, China
[3]School of Ophthalmology and Optometry, Affiliated Eye Hospital, State Key Laboratory of Ophthalmology, Optometry and Vision Science, Wenzhou Medical University, Wenzhou, Zhejiang, China

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

ORCID iD
Kai Wang http://orcid.org/0000-0002-4171-825X

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Myopia induced by digital devices usage: A multicenter cross-sectional study

1. Research background

The start and development of myopia are influenced by two major factors: heredity and environment (Saw et al., 2000). Myopia is highly related to education level. One study reported that the higher the education level, the higher degree of myopia (Rosner and Belkin, 1987). Potential risks may be the reduction of outdoor activity time, the increase of near-work time, continuous reading and the increase of reading intensity. And it was reported that near-work is highly associated with axial length elongation (Ip et al., 2008). Reading distance <30cm will induce faster myopia progression. It was reported that the average reading distance of Chinese emmetropic pupils was less than 30cm (Wang et al., 2013).Jin et. al. focused on the reading posture and myopia in primary school students, and they found that closer reading distance, head tilt angle and eye tilt angle were significantly related. Eyelid pressure during near work can change the shape of cornea, and extraocular muscles can change the tension and pressure of eyeball, and then influence the development of myopia. Continuous near-work requires more accommodation to maintain the sharpness of the target, increasing hyperopic defocus. Excessive accommodation can lead to the spasm of the ciliary muscle, which can accelerate the myopia progression. The distances for reading, writing and playing PlayStation games of primary school students were significantly different, which were 27.2cm, 24.9cm and 21.3cm respectively. It seemed that playing PlayStation games was a more dangerous factor for myopia.

With social development, electronic products are widely popularized, and various learning APPs are constantly being explored. Electronic products are used not only for daily entertainment, but also as important learning tools for children and adolescents. It can be speculated that the increasing rate of teenagers myopia may be related to increasing "reading tasks" added to students by smart phones. In addition, it was reported that the cerebral cortex of children who heavily used (>7 hours) intelligent products to play video games showed signs of premature thinning, according to the preliminary research data of the National Institutes of Health (NIH). Excessive use of smart phones can also cause a series of problems such as eye acid, visual fatigue, accommodative dysfunction, and even acute concomitant strabismus (Long et al., 2017). 23% school aged children and 64-90% computer users have symptoms such as visual fatigue and visual dysfunction (Bhanderi et al., 2008). Based on the binocular examination data of Wenzhou Medical College in 2017, 72.4% college students have binocular visual dysfunction, which is far greater than that in the United States. The main reason is that Chinese children has and a longer near-work time and a higher myopia rate. Previous studies have shown that poor illumination may cause a series of eye discomfort, while appropriate illumination and screen brightness can reduce the discomfort caused by flickering during the viewing process (Benedetto et al., 2014).

"Internet plus education" is the inevitable trend of future education. Major issues that the medical and educational circles are concerned about are how the use of electronic products will affect the occurrence and development of myopia and children's eye health, and how to standardize the use of electronic products to prevent and control the development of myopia in children and adolescents.

2.Aim

We aim to clarify the conditions of electronic products usage, the occurrence and development of myopia and visual fatigue of children and adolescents through two years of research, and solve problems including whether use of electronic products influences the development of students' vision, how to choose electronic screens, brightness level, font size and other parameters to help children and adolescents prevent and control myopia. We are able to obtain basic eye health data and the new occurrence and development of myopia in the past two years of young children, and form a standardized process and feasibility report for establishing eye health archives through these studies. Simultaneously, we can obtain scientific evidence about the use of electronic products in children's and adolescents' learning and life, as well as its exact relationship with the occurrence and development of visual fatigue and myopia. What's more, the most suitable brightness and font size for teenagers were obtained, and then the brightness specifications for display panels and the standards for text font size were formulated.

3. Study design

3.1 Study type

This is a large sample, multi-center, interventional study.

3.2 Study participants

3.2.1 Inclusive criteria

School-aged children (9-11 years old) with myopia full-corrected; 2) Best corrected visual acuity of both eyes was 20/20 or better; 3) no presence of any ocular diseases or injuries or surgeries.

3.2.2 Exclusive criteria

Not meeting the above requirements.

3.2.3 Exit criteria

Participants withdraw voluntarily from the experiment, or behavioral data showed that they did not complete the task according to the task illustration.

3.3 Study design

(1) The effect of font size on reading distance and eye health in adolescents and children

The effect of font size of mobile phones on reading distance and eye health.

The effect of font size of on tablets on reading distance and eye health.

The effect of font size of personal computers on reading distance and eye health.

The effect of font size of electronic books on reading distance and eye health.

(2) The effect of viewing time on reading distance and eye health in adolescents and children

The effect of viewing time of mobile phones on reading distance and eye health.

The effect of viewing time of tablets on reading distance and eye health.

The effect of viewing time of electronic books on reading distance and eye health.

3.4 Study steps

(1) Complete the collection of visual function (uncorrected visual acuity, corrected visual acuity and refractive error) every three months in three regional schools, including rural schools, urban schools, and provincial schools. We also used electronic questionnaires (electronic product usage rating scale, visual fatigue rating scale) to understand the electronic products usage frequency and visual fatigue of children and adolescents. After the data of the scales being uploaded to the cloud platform, eye health archives of these participants are established.

(2) The screening of myopic children and basic indicators such as visual acuity, refractive error and axial length were collected with routine ophthalmic clinical examination.

A Clouclip device was used to measure the working distances when the subjects read the text and watched the video. The Clouclip device can be attached to the temple of a spectacle frame by a rubber sleeve, with its anterior panel parallel to the spectacle plane as shown in Figure 1A. The Clouclip device measured working distances every 5 s and environmental luminance every 120 s; therefore, the time-tagged perpendicular distance from the eyes of the participants to the display plane and light levels were recorded.

4. Main outcome measures

Uncorrected visual acuity, corrected visual acuity and refractive error, axial length, slit lamp examination, scores of the electronic product usage rating scale scores, viewing distance.

5. Sample size determination basis

It is estimated that 1000 pieces of data will be collected from 1000 subjects' eye health data and corresponding visual fatigue scale and electronic product usage rating scale.

During the viewing distance measurement, 360 valid data points can be collected by each measurement, and then 2520 valid data points in total of each subject.

5. Schedule of Research progress

September 2020: determine research topics and improve the experimental program

October 2020 to May 2021: Collect cases

May 2021 to June 2021: Data analysis

June 2021 to December 2021: Write and contribute papers

6. Statistical analysis

Quantitative results: parametric and nonparametric tests. The indicators that can be tested by parametric tests include uncorrected visual acuity, best-corrected visual acuity, refractive error, axial length and viewing distance. To study the correlation between various indicators, the main methods include t-test/paired t-test, repeated measurement ANOVA, correlation, regression, etc. The indicators that can be tested by nonparametric tests including the health status classification of eye surface. The main statistical methods include ANOVA, Kruskal Wallis test, chi square test Mann Whitney test.

Qualitative results: Corresponding grades will be generated according to the scores of the visual fatigue scale and the electronic product usage rating scale. Kruskal-Wallis test have been used.

7. Right protection of the subject

The results of this research may be published in medical journals, but we will keep the patient's information confidential according to the legal requirements. Unless required by relevant laws, the patient's personal information will not be disclosed. When necessary, the government management department, the hospital ethics committee and their relevant personnel can consult the patient's data according to the regulations.

8. Participating units of multi-center research

The responsible unit of the project is the School of Optometry, Peking University Health Science Center. The clinical teaching hospital of the School of Optometry of Peking University Health Science Center is composed of the People's Hospital of Peking University, the Third Hospital of Peking University and the Peking University Hospital. In this research project, 500 participants in the first part of the experiment and 25 subjects in the second part of the experiment are needed to be recruited in this research center.

The project participants are the School of Ophthalmology and Optometry, Affiliated Eye Hospital, Wenzhou Medical University. The research center has undertaken the construction of the State Key Laboratory of Ophthalmology, the National Optometry Engineering Technology Research Center, the Guo Jian Clinical Research Center and so on. In this research project, 500 participants in the first part of the experiment and 25 subjects in the second part of the experiment are needed to be recruited in this research center.

9. References

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