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Visual consequences of electronic reader use: a pilot study

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Abstract

Background—With the increasing prevalence of electronic readers (e-readers) for vocational and professional uses, it is important to discover if there are visual consequences in the use of these products. There are no studies in the literature quantifying the incidence or severity of eyestrain, nor are there clinical characteristics that may predispose to these symptoms with e-reader use.

Purpose—The primary objective of this pilot study was to assess the degree of *eyestrain* associated with e-reader use compared to traditional paper format. The secondary outcomes of this study were to assess the rate of *eyestrain* associated with e-reader use and identify any clinical characteristics that may be associated with the development of *eyestrain*.

Methods—Forty-four students were randomly assigned to study (e-reader iPAD) and control (print) groups. Participant posture, luminosity of the room, and reading distance from reading device were measured during a 1-h session for both groups. At the end of the session, questionnaires were administered to determine symptoms.

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Marlon M. Maducdoc and Asghar Haider are contributed equally.

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Results—Significantly higher rates of *eyestrain* ($p = 0.008$) and *irritation* ($p = 0.011$) were found among the iPAD study group as compared to the print 'control' group. The study group was also 4.9 times more likely to report severe *eyestrain* (95 % CI [1.4, 16.9]). No clinical characteristics predisposing to *eyestrain* could be identified.

Conclusions—These findings conclude that reading on e-readers may induce increased levels of *irritation* and *eyestrain*. Predisposing factors, etiology, and potential remedial interventions remain to be determined.

Keywords

Eyestrain; Asthenopia; Computer vision syndrome; Ocular complaints; Electronic readers and tablets

Introduction

The use of electronic devices for both vocational and personal uses is rising. In 2012, a survey conducted by the Vision Council demonstrated that an average adult reported spending 4–6 h a day with electronic or digital media [1]. Since the introduction of the first personal computers, clinicians have observed eye complaints related to use of computer monitors. A study by Agarwal et al. discovered that there is a high prevalence of *eyestrain*, headache, diminution of distance vision, and eye watering among computer users [2]. Itching, redness, burning, tearing of the eyes, headache, double vision, eye strain, and blurred vision were grouped into a condition termed computer visual syndrome (CVS) [3]. Studies have shown CVS occurring with greater frequency and severity with increasing computer monitor use [4, 5]. Indeed, a study found that 2 hours of visually demanding computer work could significantly increase eye-related pain, tiredness, blurred vision, and other symptoms [6]. In addition, Abdelaziz et al. showed that there might be a decrease in visual acuity and color vision after prolonged computer use [7].

Similarly, electronic reader (e-reader) use is increasing. In May 2010, the Pew Research Center reported the US ownership of e-readers at 3 %. By August 2010, their survey showed that the ownership had grown to 10 %. As of January 2014, e-reader use among American adults has risen to 42 % of the population [1]. Despite the similarities between computer monitors and portable electronic devices, e-readers are neither simply portable computers nor are they equivalent to book reading. Their use is often very different from either format [8]. The visual consequences associated with e-reader use have not been previously described.

The primary objective of this pilot study was to assess the symptoms associated with e-reader use compared to traditional paper format. The secondary outcomes were to assess the rate of *eyestrain* associated with e-reader use and identify parameters of dry eye and refractive error that might be associated with the development of *eyestrain*.

Methods

Participants

This randomized study was conducted from July 2011 to May 2013 at the University of California, Irvine School of Medicine, approved by the Institutional Review Board. Informed consent was obtained from all individual participants who were included in the study. This study was conducted in accordance with the Declaration of Helsinki. First year medical students were recruited through email using the LISTSERVs for incoming students. Medical students were selected as the subject population due to their extensive use of e-readers and traditional books. All study participants underwent an eye examination to determine their eligibility for inclusion in the study and to gather baseline data for further analyses. The evaluation included ophthalmologic and past medical histories, medications, assessment of visual acuity, manifest refraction, cycloplegic refraction, pupil function, ocular motility, confrontation visual field testing, external ocular examination, slit-lamp examination, intraocular pressure measurement, retinal examination, and Schirmer’s test. Inclusion and exclusion criteria are listed in Table 1.

A roster of eligible participants was created. The subjects were invited to participate in 1-h reading sessions using an iPad 1 (Apple Inc., Cupertino, CA) (iPAD group—study group) as an e-Reader (tablet computer) or a medical textbook (print group—‘control group’). Subjects in both groups read the same book. The dimensions of the iPAD 1 used in the study were 9.56″ by 7.47″ (1024 × 768, 132 ppi), multi-touch “glossy” LED-backlit lPS display. The font size of the hardcopy book was approximated for the iPad 1 tablet computer, and subjects in the iPAD study group were instructed not to adjust the brightness or font size on the iPad 1 (*Times New Roman, 12 font size*). The reading sessions were conducted in a basement room without windows to ensure constant ambient lighting. Luminance was measured using a LS-110 Luminance Meter (Konica Minolta, Inc., Marunouchi, Chiyoda, Tokyo). A comprehension pretest on the presented material was administered before each reading session. Instructions were given to both groups. Subjects were seated around a table and allowed to read in any position. Subjects were also free to take breaks during the reading sessions.

Outcome measures

Outcome measures included assessing luminosity, reading distance, and posture every 5 min for the entire reading session. A comprehension posttest was administered at the end of the 1-h reading session to ensure active participation.

Questionnaires

A symptoms questionnaire, developed using descriptors from the computer device-related *eyestrain* literature, was also administered at the end of the reading session. The following descriptors were selected: *burning, dryness, eye pain, irritation, eyestrain,* and *blurring*. The symptoms questionnaire utilized a Likert scale (1–5) to measure to what extent participants experienced the above descriptors. Participants were also asked to provide their definition of eye strain and tired eyes using fill-in text format. A headache questionnaire was also included for those participants who may have experienced a headache, and checked the location, severity, quality, and associated symptoms.

Statistical analysis

Statistical analysis was completed using the Fisher's exact test, two-sample *t* test, and ordinal logistic regression. A *p* value of <0.05 was considered statistically significant.

Results

A total of 53 participants completed initial evaluation, and 44 (13 males and 31 females) were randomly assigned to the iPAD study group (n = 24) or print 'control' group (n = 20). One of the male subjects had an ophthalmologic condition and was excluded from the study, and eight participants did not schedule the reading session. The mean age of included subjects was 24.71 years, range of 21–31 years. The mean ages of the two groups were equivalent ($p = 0.1884$). All had normal uncorrected or distance corrected vision, no strabismus, and no prior history of any ophthalmic disease.

The reported symptoms experienced during testing by the print 'control' and iPAD study groups are listed in Table 2. Fisher's exact test was applied to evaluate any association between the print 'control' group and severity reported for each symptom. Significant differences between the groups were detected for *eyestrain* ($p = 0.0008$) and *irritation* ($p = 0.0107$). All subjects in the print 'control' group reported mild or no *eyestrain* (severity rating of 1 or 2), while 50 % of the iPAD study group reported moderate or higher *eyestrain* (severity rating of 3 or 4). Similarly, for reported *irritation*, 95 % of the print 'control' group reported no *irritation*, while 42 % of the iPAD study group reported *irritation* in the mild to moderate range.

The differences between the two groups for average distance from reading material, luminosity of room, and visual acuity of participants are summarized in Table 3. The combined average spherical equivalent to report the refractive error was used. This number was calculated by taking the average of the spherical equivalent of each eye [i.e., (OD spherical equivalent + OS spherical equivalent)/2]. The manifest spherical equivalent of each eye was used to compute this number. No significant difference between the groups was found on any measure using the two-sample *t*-test.

We compared the baseline abnormality in participant's eye dryness between the two groups: (a) for baseline eye dryness, "abnormal" was defined as any value less than 15 mm in either eye on Schirmer testing and (b) "normal" was defined as any value greater than or equal to 15 mm on Schirmer testing. No significant difference in baseline eye dryness was detected between the groups, with 50 % of the print 'control' group and 33 % of the iPAD study group found to have "abnormal" eye dryness ($p = 0.21$).

To evaluate if any of the above factors (*reading distance, luminosity, visual acuity, and eye dryness*) had an effect on reported *eyestrain*, the ordinal logistic regression was applied separately for each factor. None of the factors were found to affect reported eyestrain ratings with *reading distance* (p = 0.88), *luminance* (p = 0.32), *visual acuity* (p = 0.57), and *eye dryness* (p = 0.85).

An additional ordinal logistic model was performed to evaluate the print ‘control’ group effect on reported *eyestrain* while controlling for both visual acuity and eye dryness. The reading group remained as a significant factor for reported *eyestrain* (p = 0.012), with the iPAD study group estimated to be 4.9 times (95 % CI [1.4, 16.9]) more likely than the print ‘control’ group to report more severe *eyestrain*. Neither *visual acuity* (p = 0.58) nor *eye dryness* (p = 0.34) had a significant effect on reported *eyestrain*. In addition, the comprehension tests’ results given after each session for the two conditions were equivalent.

Discussion

Ocular symptoms of *eyestrain* and *irritation* following 1 h of sustained e-reader use were significantly different from those reported after hard copy use under the same viewing conditions. *Eyestrain* and *irritation* were reported by the iPAD study group at a higher rate than the print ‘control’ group. In the iPAD study group, 18 subjects (75 %) reported eyestrain that ranged from mild to moderately severe. In contrast, 14 subjects (70 %) in the control group reported mild *eyestrain* only. *Irritation* was reported by ten subjects (41.7 %) in the mild to moderate range in the study group, while only one subject (5 %) reported moderate *irritation* in the book group. These findings suggest e-reader use is different from hard copy use.

The present pilot study did not observe significant differences in *burning*, *dryness*, *eye pain*, or *tired eyes* between the print ‘control’ and iPAD study groups. This is contrary to other published reports that have linked computer monitor use with these symptom descriptors [4, 9–11]. The difference may highlight how the use of e-readers is distinct from the use of computer monitors. For example, the average reading distance between the control (37.9 cm ± 5.1) and study groups (38.1 cm ± 5.6) is not statistically significant (p = 0.88). Based on previous studies, this reading distance is different from the 33–60 inches reported by computer monitor users [12]. Therefore, the ergonomics of using an e-reader are likely more similar to a book rather than a computer monitor.

Neither refractive error (p = 0.58) nor eye dryness (p = 0.34) had a significant effect on *eyestrain*. In our study, 4 out of 26 (15 %) subjects of the IPAD study group and 3 out of 20 (15 %) subjects of the print ‘control’ group had a spherical equivalent <-6.0D. Previous studies have shown refractive error to be associated with *eyestrain* in computer display users [12–14]. In a study by Nakaishi et al. (1999), dry eyes were found to be associated with *eyestrain* in computer users with an odds ratio of 4.61 ($p < 0.001$) compared with controls [13]. Of note, our pilot study used a 1-h reading session time, whereas studies that have found an association between refractive error and eye dryness surveyed subjects after longer periods of computer monitor use.

The iPAD study group was 4.9 (95 % CI [1.4, 16.9]) times more likely to report more severe *eyestrain* than the print ‘control’ group, after factoring in the differences in refractive error and baseline eye dryness. There was no statistical difference in baseline eye dryness between the two groups ($p = 0.21$), although a lower proportion of iPAD study group participants were classed as having abnormal *eye dryness*, 33 % versus 50 % in print ‘control’ group. This *eyestrain* could not be explained by luminance of the room, since no statistical difference in luminance was found ($p = 0.77$) between the print ‘control’ (271.3 lx ± 104.1) and iPAD study (263.2 lx ± 77.9) groups. The difference in reading surface likely explains this increased *eyestrain*. Siegenthaler et al. found the image quality of the electronic display rather than the technology itself was associated with the increased occurrence of fatigue and visual strain [14]. Although in our pilot study we did not adjust screen contrast and font size, individuals predisposed to experiencing *eyestrain* may benefit from electronic tablets easily adjustable to font size and contrast.

Limitations and conclusions

Our study has a few obvious limitations. The first limitation was the inability to perform a mask trial between our iPAD study and print ‘control’ groups. The subjects were clearly aware of whether they were performing the e-reader or hard copy task. Their responses to the questionnaire may have been influenced by format preference or bias based on preconceptions or prior experiences. The influence of preference of preconceptions is an inherent limitation of using the Likert scale, and this potential bias may account for the report of greater eyestrain and irritation for the study group. However, had that been the case, then one might have expected to find increased symptoms of sensitivity to screen brightness or tired eyes when reading with the e-reader. Furthermore an inherent bias against one format would not be expected to favor specific symptomotolgy as seen in our study. In addition, the respondents may interpret points on the scale differently (i.e., the difference between a “3” and a “4” may vary between two individuals) and thus the magnitude of an effect may not be well detected using the Likert scale. To minimize the potential impact of this, all study participants were provided instructions using identical instructions and all questionnaire items were unidirectional.

Our study did not have exclusion criteria for high myopia (spherical equivalent of −6.0D or less), which may have affected the results, given these subjects may experience symptoms differently from subjects without high myopia. Fortunately, both IPAD group and print ‘control’ group had approximately the same percentage of individuals with high myopia (15 %), although future studies should consider excluding these subjects.

Another limitation of this pilot study was the homogenous population used, although selected due to their high risk of eyestrain. This makes our study’s findings more difficult to apply to the general public. Out of the 44 participants who completed the study, 34 were female. In addition, our pilot study’s 1-h reading time may be another possible limiting factor. Studies have reported longer periods of electronic monitor use associated with a higher prevalence of CVS [5]. Therefore, insufficient testing time may have been provided for more CVS symptoms to be observed. The screens of different e-readers are not uniform; therefore, the particular e-reader used in this study might have affected the results.

To reach more generalizable conclusions, larger studies should be conducted that include more heterogeneous groups. Our study was designed to determine if there is a difference in eye strain between electronic readers and conventional textbooks. Future studies should consider using multiple ophthalmic assessment tools to evaluate eye dryness, such as tear break-up time and fluorescein and Lissamine green staining. Future investigations can also use validated questionnaires for specific conditions like dry eye disease (Ocular Surface Disease Index) to improve validity and reliability of results. Predisposing factors, etiology, and potential remedial interventions remain to be determined. Larger studies should sample a broader population and investigate if patients who experience migraine or have photophobia are also likely to experience higher rates of *eyestrain*. Another issue not addressed in this young adult group is the role of *presbyopia* and *eyestrain*.

Another limitation in our study was not using the same individual to perform both tests (e-reader and print book) and have them collect this subjective information from the questionnaire. Randomizing the initial test would avoid the bias of favoring the first test in detriment to the second one. This will be taken into consideration in future studies.

With the increasing prevalence of e-readers in education and the professional world, it is important to discover if there are visual consequences in the use of these products. E-readers are changing the way we consume information. The effect of these devices on our eyesight is an unexplored area of study. The aim of this pilot study was not to vilify e-reader use, but to identify the presence of *eyestrain* associated with their use. The findings of the present investigation provide some evidence that prolonged viewing of e-readers is neither equivalent to the observation of printed text under similar viewing conditions nor is it equivalent to computer monitor use. Future studies are aimed at identifying predisposing characteristics so that clinicians can prescribe preventive measures for their electronic savvy patients and to spur device manufacturers to develop devices and/or software that are more suitable for at-risk individuals.

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Table 1

Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Medical Student	Historical
Corrected vision VA 20/20 or better	Preexisting eye condition
Normal Near vision	Any requiring large print
	Blepharitis
	Preexisting medical condition
	Chronic migraine
	Chronic headache
	Medications which may affect near vision
	Ophthalmic evaluation
	Presbyopia
	Underlying eye disease

Table 2

Percentage of ‘control’ (print) (n = 20) and ‘study’ (iPAD) groups (n = 24) responding to each symptom following testing session

Symptom	Group	Severity reported					Fisher’s exact test p-value
		1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	
Burning	Print	90.0	10.0	0.0	0.0	0.0	0.33
	iPAD	70.8	12.5	12.5	4.2	0.0	
Dryness	Print	50.0	35.0	15.0	0.0	0.0	0.21
	iPAD	37.5	20.8	25.0	16.7	0.0	
Eye pain	Print	85.0	10.0	5.0	0.0	0.0	0.23
	iPAD	58.3	29.2	8.3	4.2	0.0	
Eye strain	Print	30.0	70.0	0.0	0.0	0.0	0.0008
	iPAD	25.0	25.0	37.5	12.5	0.0	
Irritation	Print	95.0	0.0	5.0	0.0	0.0	0.0107
	iPAD	58.3	25.0	16.7	0.0	0.0	
Sensitivity to electronic reader screen brightness	iPAD	33.3	25.0	16.7	12.5	12.5	n/a
Sensitivity to ambient lighting	Print	95.0	5.0	0.0	0.0	0.0	0.33
	iPAD	70.8	8.3	12.5	4.2	4.2	
Tired eyes	Print	30.0	30.0	30.0	10.0	0.0	0.7
	iPAD	20.8	37.5	20.8	20.8	0.0	

Symptoms were reported on a scale from 1 (none) to 5 (severe)

Table 3

Summary of two-sample t-test for reading distance, luminosity, and visual acuity in control (print) and study (iPAD) groups

Factor	Group	N	Mean	SD	*p*-value
Reading distance	Print	20	37.9 cm	5.1	0.88
	iPAD	24	38.1 cm	5.6	
Luminance	Print	20	271.3 lx	104.1	0.77
	iPAD	24	263.2 lx	77.9	
Refractive error	Print	20	2.4[a]	2.3	0.26
	iPAD	24	3.3[a]	2.9	

[a]Combined averaged manifest refraction spherical equivalent was used to approximate visual acuity