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Symptoms associated with reading from a smartphone in conditions of light and dark

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ABSTRACT

Asthenopia symptoms were investigated in visually-normal subjects without computer-related vision symptoms after prolonged reading from: smartphone versus hardcopy under photopic conditions, and smartphone in conditions of ambient versus dark room illumination. After reading from the smartphone, total symptom scores and nine out of ten questionnaire symptoms were significantly worse than for the hardcopy ("blurred vision while viewing the text, "blurred distance vision after the task", "difficulty in refocusing from one distance to another", "irritated or burning eyes", "dry eyes", "eyestrain", "tired eyes", "sensitivity to bright lights" and "eye discomfort"). Mean total symptom scores and scores for "irritated or burning eyes" and "dry eyes" were significantly higher for the dark versus photopic conditions. In conclusion, prolonged smartphone reading could cause worse asthenopic symptoms than reading from a hardcopy under similar conditions. Symptoms could be even worse when reading from a smartphone in the dark.

1. Introduction

The use of computers and other digital screen devices for both professional and non-professional activities is practically universal in the developed world. In Forrester Research's largest annual survey of Americans' technology adoption, 73 percent of 37,000 respondents claimed that mobile phones were the electronic devices they most used (Schadler et al., 2013). Although the use of smartphones has recently increased among individuals of all age groups, young people continue to be the main users of mobile phones and 95% of these devices are smartphones. According to current estimates, at least one half of all users are connected to the Internet for a period exceeding half an hour per day and one user in ten connects to the Internet over more than 4 h a day (Ditrendia, 2015). Further, a recent survey reports that mobile device users spend more than 20 h a week emailing, text messaging and using social network services, indicating their heavy reliance on smartphones to connect and communicate with others (Lee et al., 2015).

Intensive use of the smartphone has been linked to musculoskeletal problems such as pain affecting the neck and shoulders, the severity of these symptoms increasing with the total time spent using a mobile device (Berolo et al., 2011; Kim, 2015; Lee et al., 2015). Although the use of electronic devices is also known to produce visual symptoms, relatively few studies have addressed the vision effects associated with the use of a smartphone. The relatively small screen and font size of these devices may necessitate close working distances, increasing visual demands (on both accommodation and vergence) over those needed for printed texts (Bababekova et al., 2011).

Digital displays emit light directly resulting in more stress to the human eye (Chen and Cranton, 2012). Young adults and children spend increasingly more time viewing electronic devices, and a rise in sleep deficiency in adolescents is today a major public health concern (Hysing et al., 2015). About 90% of young people sleep with their smartphones in or right next to their beds (Nick, 2012) and often wake up in the middle of the night to use their smartphone, during which they experience discomforting glare and strain to their eyes. Currently, most smartphones have a self adjusting brightness control, which adjusts the brightness of the display according to ambient lighting. However, this function is mainly designed for operation during the day and the display is usually too bright when working in a dark room since it is not possible to reach a sufficiently low level of illumination for comfortable reading without glare (Berolo et al., 2011). Besides, many users will not bother to adjust display brightness when using the smartphone in the dark.

Several studies have assessed symptoms produced in response to reading from a computer or electronic book (Chu et al., 2011; Mangen

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et al., 2013; Noyes and Garland, 2008; Hue et al., 2014; Lee et al., 2008, 2011; Siegenthaler et al., 2012; Gowrisankaran and Sheedy, 2015). Chu et al. when comparing a computer screen with paper reported significantly worse blurred near vision and mean total symptom scores following sustained computer use than those reported after hardcopy fixation under similar viewing conditions (Chu et al., 2011). In a comparison between the ebook or Ipad and hardcopy reading, Hue et al. observed no significant differences in total symptom scores, though scores indicating tired eyes and eye discomfort were significantly higher for the ebook than hardcopy. However, when comparing the Ipad with hardcopy, no significant differences in symptom scores were found (Hue et al., 2014). Eye symptoms are the most common health problems among users of digital screen devices (Blehm et al., 2005). These symptoms may include eyestrain, eye discomfort, dry eye, double vision, and blurred vision either at near or when looking into the distance after prolonged use (Rossignol et al., 1987), and coincide with the symptoms of the condition known as computer vision syndrome (CVS) (Gowrisankaran and Sheedy, 2015; Hayes et al., 2007). However, conditions when reading from a smartphone differ from those when reading from a computer (e.g., reading position, size screen, scrolling text) and we would expect differences in symptoms. This issue was addressed in this study.

As far as we know, no study has examined possible asthenopia symptoms associated with prolonged reading from a smartphone compared with hardcopy reading and neither have visual symptoms been assessed arising from prolonged reading from a smartphone in the dark.

Despite the recent rise in the use of smartphones in everyday life, possible visual symptoms associated with their prolonged use or use under non recommended conditions have not yet been explored in detail. The purpose of this study was to identify possible asthenopia symptoms associated with reading from a smartphone versus reading from a hardcopy. A further objective was to compare symptoms after reading from a smartphone in conditions of adequate ambient illumination versus in the dark. Reading speeds for the different sources and lighting conditions were also compared.

2. Materials and methods

This study was conducted at the Faculty of Optics and Optometry, Universidad Complutense de Madrid, Madrid, Spain. Measurements were obtained in 54 visually-normal subjects of mean age 23.7 ± 2.6 years (19–35 years). Subjects with under average visual acuity, gross accommodative dysfunction and disorders of binocular vision were excluded. The Computer Vision Symptom Scale (CVSS17), a new, validated questionnaire designed to assess computer-related visual and ocular symptoms associated with video display terminal usage (Gonzalez-Perez et al., 2014), was used to select subjects without symptoms related to habitual computer use. Inclusion criteria were a binocular distance and near corrected visual acuity of 0.1 logMAR (ETDRS) or better, less than 0.1 logMAR difference between the two eyes, no strabismus, no clinical diagnosis of dry eye, and no reported eye disease. Further inclusion criteria were at least 5.00 D accommodative amplitude to rule out early presbyopia, near point convergence of 6.0 cm or less, near horizontal heterophoria (modified Thorington test) no greater than two esophoria or eight exophoria and a CVSS17 score lower than 36 points (see Table 1). The study protocol adhered to the tenets of the Declaration of Helsinki. All participants gave written informed consent prior to participation.

We performed two experiments, so the sample was divided randomly into two groups of subjects to avoid repeated sessions affecting symptom scores: Group 1 (N = 27) and Group 2 (N = 27) for Experiment 1 and 2 respectively. In both experiments, each participant was required to read two different texts at a viewing distance of 40 cm each for a continuous 20 min period in two different conditions. We maintained the same working distance and tilt angle for the reading tasks to ensure the same accommodative and convergence demands and be able to identify other possible sources of asthenopic symptoms. In Experiment 1, we compared reading from a smartphone versus printed hardcopy, both in ambient photopic conditions. In Experiment 2, we compared reading from a smartphone under photopic illumination versus reading from the same smartphone in the dark.

In both experiments and for each subject, the order of the reading conditions was counterbalanced. Every subject was tested between 9 a.m. and 11 a.m. The two texts were randomly presented in each of the formats and had similar characteristics related to difficulty of comprehension and topic ("koalas" or "sharks"). We provided enough reading material for 20 min of reading without repetition. When using the smartphone, the subject scrolled through the text as required whereas when reading from paper, the subject turned the pages. To maximize compliance, participants were informed that after reading each text they would have to answer a few comprehension questions. This variable was not examined in the study. We also informed them that they would have to complete a short questionnaire describing their symptoms after reading.

In Experiment 1, the hardcopy text font and size was Arial 7 point and the same font was selected for the smartphones. For both formats, the angle subtended by the letters at 40 cm was approximately 13 min of arc (capital letter height 1.5 mm). This height is within the recommended limits for letters displayed on a video display terminal, which range from 12 to 26 min of arc (mean 18) (Hennings and Nong, 1996). This letter size was selected so that reading would be somewhat demanding, although still in line with Grundy's recommendation that the visual acuity for a task should be at least twice that required to see the task (Grundy, 1981). The hardcopy text was presented in two columns 4.8 cm wide x 11.5 tall printed horizontally on A4 paper. Interline distances were < 0.2 cm.

In Experiments 1 and 2, to not restrict the study to a single brand, two smartphones (*Iphone 4* and *Motorola Moto-G)* with similar characteristics (see Table 2) were randomly used when reading in the smartphone format. In Experiment 2, the subjects used the same smartphone for the two readings. On the smartphones, the texts were presented within the WhatsApp application since letter size is standard across smartphones and this was the application most used by the

Table 1
Characteristics of the sample (N = 54; 29 female).

Variable	Mean ± SD
Distance VA RE	−0.04 ± 0.08 logMAR
Distance VA LE	−0.04 ± 0.10 logMAR
Distance refraction RE	−1.16 ± 1.21 D
Distance refraction LE	−1.09 ± 1.36 D
Near point of convergence	2.5 ± 1.7 cm
Accommodative amplitude	7.86 ± 1.42 D
Near horizontal heterophoria	1.71 ± 2.37 Δ
CVSS17	26.06 ± 4.33

VA: visual acuity. RE: Right eye. LE: Left eye. Distance refraction: Spherical equivalent (Sphere + Cylinder/2) of the habitual distance refraction. CVSS17: Computer Vision Symptom Scale.

Table 2
Technical characteristics of the smartphones used in the study.

Smartphone	Display technology	Display size	Display resolution
IPhone 4	IPS Touchscreen LCD	4.8 × 7.4 cm 3.5 inches	640 × 960 pixels
Motorola Moto G	LCD TFT Touchscreen Capacitive	5.8 × 9.8 cm 4.5 inches	720 × 1280 pixels

IPS: in-plane switching. LCD: liquid crystal display. TFT: thin film transistor.