

# Comparing Binocular Vision Suppression on an e-Reader versus a Smartphone

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## Abstract

**Purpose:** Normal binocular vision is an important factor that influences visual performance. Hence, this study aims to determine the differences in binocular vision suppression when using common handheld devices compared with a hard copy control.

**Methods:** In this experimental study, 11 subjects were asked to read the same text on a backlit smartphone, non-backlit display e-reader, and hard copy (black text on white paper). Suppression was determined by subjective reporting using anaglyphic bar readers and glasses. The viewing distance was measured with a millimeter rule.

**Results:** The incidence of suppression was 72.7% for the e-reader, 27.2% for the hard copy, and 18.1% for the smartphone. There were significant differences between the e-reader and hard copy by repeated measurement ANOVA for each reading condition. The working distance was farthest with the hard copy and closest with the smartphone. The mean working distances were significantly different by repeated measurement ANOVA with all three devices, with hard copy being read at  $32.9 \pm 3.0$  cm, the e-reader at  $29.9 \pm 5.3$  cm, and the smartphone at  $28.6 \pm 5.8$  cm.

**Conclusions:** Suppression of binocular vision is more likely on an e-reader and hard copy. This occurs despite a farther working distance than the smartphone and a closer working distance on an e-reader than a hard copy.

## Key Words

binocular suppression, educational technology, e-reader, smartphone, vergence anomalies

## Introduction

Handheld electronic devices, most notably smartphones and e-readers, are rapidly increasing in use in classrooms among both college students and educators. The portability, decreasing cost, and searchability of these devices offer distinct advantages over their hard copy predecessors and has made their adoption in the classroom increasingly inevitable.<sup>1</sup> Among eye care professionals, smartphones are an invaluable and portable tool in clinical testing, diagnosis, treatment, and billing and coding.<sup>2</sup>

Despite the smaller size of the video display, many find it easier to read for extended periods on a handheld device like a smartphone or e-reader compared with reading on a desktop or laptop display. It has been postulated that proprioception may play some role in the apparent greater comfort when using a handheld device.<sup>3</sup> However, this does not explain the extraordinarily short working distance used by many when texting or reading e-mail on a smartphone, for example.

As shown in previous studies, working distance with handheld electronic devices depends on the size of the display as well as interaction with it.<sup>3</sup> Passive interaction, such as watch-

ing a video, may be done as far away as about 50 cm despite the very small screen size on the typical handheld device. Devices that required typing or other user input were held at about the standard working distance of around 40 cm. By comparison, handheld videogames were held at the closest working distance of about 35 cm or less. Note that all three of these activities may occur on the same smartphone, so they are clearly device-independent. Yet, decreasing working distance means logarithmically increasing demands on accommodation and convergence of the eyes. The former is unavoidable without reading glasses, but the latter can be circumvented by binocular suppression.

The purpose of this study is to examine the vergence response for suppression of an eye while reading on a handheld device. Previous studies by the Vision Performance Institute have examined working distance using handheld devices<sup>3</sup> and the accommodative response to the display of these devices compared with that of a desktop computer.<sup>4</sup> This handheld study will examine, for the first time, the vergence or pointing response of the eyes when using the same devices. It is postulated that users may be avoiding the excessive convergence demand required to avoid double vision or blur by simply

suppressing one eye. To the authors' knowledge, such a study has not been undertaken previously.

## Methods

In this study, 11 (age range of 18 to 40 years) subjects who met inclusion criteria and consented were entered into the study after Institutional Review Board approval.

Inclusion criteria were: at least six months of experience in handheld device usage, best-corrected visual acuity of 20/20 or better in each eye at distance, the absence of manifest strabismic deviation at distance with cover test, no ocular pathology, no history of photosensitive epilepsy, and an average of two hours per day spent using a handheld video display, usually a smartphone. Small-angle strabismus was ruled out by monitoring participants for consistent suppression throughout the study. One subject was eliminated before statistical analysis due to constant monocular suppression.

Since the participants were optometry students whose refractive error and best-corrected acuity were familiar to them, these qualifications were self-reported. The Hirschberg test was used to determine the presence or absence of strabismus.

For the experiment, participants were asked to read a short (4000-word) story on hard copy and electronically ("The Monkey's Paw") on an iPhone 4 and a first-generation Amazon Kindle while wearing red-green anaglyphic filters and with a red-green bar reader over each video display. These three reading conditions were presented in a randomized order to each participant (Figure 1).

Although they generally provide better contrast sensitivity, polarized bar readers and glasses were initially not used in this study because Liquid Crystal Displays (LCD) are plane polarized as well. However, it was discovered by experimentation that this objection was not entirely justified. In fact, research participants could see the backlit smartphone display equally well through either set of filters, while the non-backlit e-reader display was equally difficult to see for some subjects. Thus, polarized bar readers and the appropriate polaroid glasses were substituted when a research subject could not see the displays through the anaglyphic equivalent; this was done for four of the participants. These subject, used the polaroids throughout the study for consistency (Figure 2).

Participants were seated and asked to read the story on either the hard copy, smartphone, or the Amazon Kindle. The distance from the glasses to the display was measured once the participant began reading. At the beginning, middle, and end of a five-minute interval, the participant was asked if either the red, green, or gray bars appeared black (indicating which eye was being suppressed, if any).

After each reading condition (five minutes), a one-minute break was given before the next condition started. The entire study lasted about 20 minutes. After data collection, data were analyzed in SPSS.17 software using the Independent-Samples T test (or Mann-Whitney U test) and the Repeated measurement ANOVA. In analysis, the significance level was considered to be 0.05.

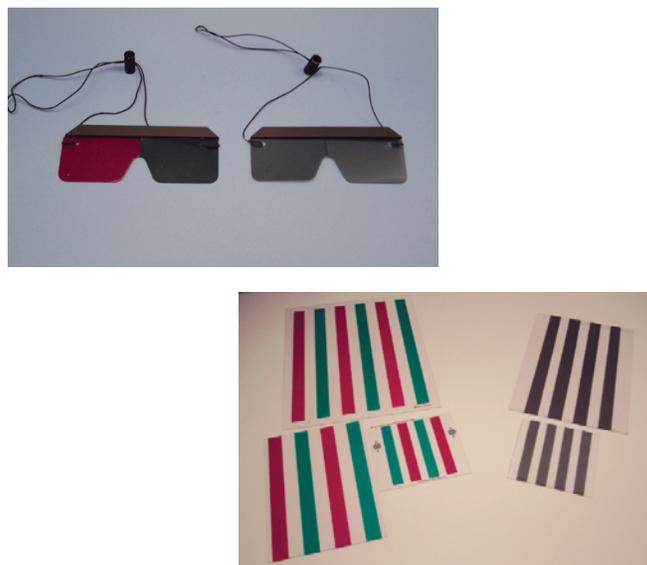
## Results

Among the 11 subjects under study, 45% were female and 55% were male. The mean age of all subjects was 26.7 years, being slightly younger (25.4 years) for females and slightly older (28.3 years) in males. The Independent-Samples T test

Figure 1: iPhone 4 and Amazon Kindle I



Figure 2: Anaglyphic (left) and Polaroid bar readers (left) and spectacles (right). Used with permission of Bernell Inc.



(or Mann-Whitney U test) did not show significant difference in the mean age between the two groups. ( $P=0.05$ ).

The Repeated measurement ANOVA showed significant differences in the mean working distance between the three groups ( $P=0.05$ ). The Bonferroni test was used for the multiple comparisons. The test results are shown in Table 1.

Table 1. Working distance comparisons in the three reading conditions

Condition	Working distance (cm)	Multiple comparisons result
	Mean $\pm$ SD	
Hard copy (group1)	32.9 $\pm$ 3.0	$P<0.05$ only with group 3
Kindle (group2)	29.9 $\pm$ 5.3	$P>0.05$ with all groups
iPhone (group3)	28.6 $\pm$ 5.8	$P<0.05$ only with group 1

There was small difference between each reading condition in working distance. This difference was significant when comparing the iPhone to hard copy (Figure 3). The working distance was farthest for hard copy (33± SD cm), followed by the Kindle (Mean±SD cm) and closest for the smartphone (28.5±SD cm).

There was considerable statistical difference in the probability of suppression between both the hard copy and iPhone with the Kindle. No difference in the possibility of suppression between the hard copy and iPhone was noted (Table 2).

**Table 2. Comparisons of suppression with the three devices**

Conditions	Probability of suppression (%)	Multiple comparisons result
	Mean ± SD	
Hard copy (group1)	27.2 ± 46.7	P<0.05 only with group 2
Kindle (group2)	72.7 ± 46.7	P<0.05 with groups 1 & 3
iPhone (group3)	18.1 ± 40.4	P<0.05 only with group 2

The highest percentage of the likelihood of binocular suppression among these reading conditions was related to the Kindle (~70 %). The iPhone had the lowest percentage (<20%) with hard copy coming in between (~30%). There was considerable difference in the amount of suppression by repeated measurement ANOVA with each reading condition (Figure 4).

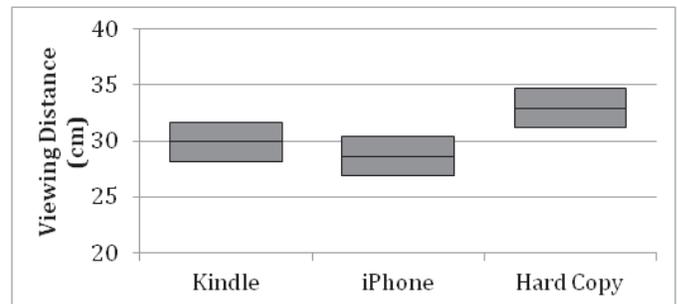
## Discussion

The working distance differences seen with these three devices are inversely proportional to the size of the reading material displayed. These results coincide with those from the Handheld I study conducted by the Vision Performance Institute in 2008.<sup>3</sup> Of more interest is the role of suppression in the use of these handheld devices. While it may seem detrimental at first, suppression is a solution to diplopia when using a small-font and small-diameter display at very close working distances over extended periods of time.

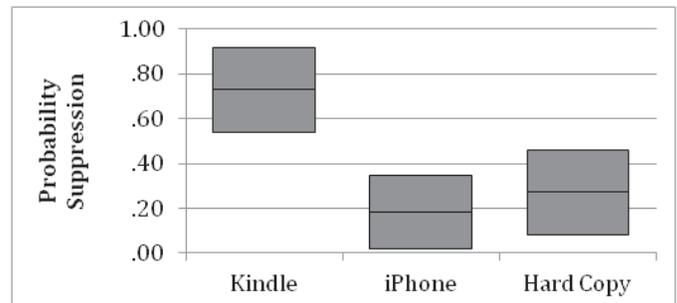
The current study found a greater amount of suppression on the moderately sized e-reader display compared with hard copy and the touchscreen smartphone. There are several possible reasons for this. One may be the closer working distance combined with the level of tactile of interaction with the devices. Specifically, it may not be surprising that there was little suppression of binocular vision when reading hard copy, as it was held at the farthest working distance of the three conditions. The reason for the lack of apparent suppression on the smartphone is less clear, as it was held closer than either of the other conditions. The difference may be because of backlighting on the smartphone.

When using a bar reader, the non-backlit e-reader display was darker than the backlit smartphone display. However, this does not explain why the non-backlit hard copy would have been less difficult than the Kindle, unless it is the photometric mismatch between the transmittance of the red and green filters.

*Figure 3. Working distance for three reading conditions*



*Figure 4. Likelihood of suppression for three reading conditions*



There is also a proprioceptive difference between the three reading conditions. While all three were handheld, the e-reader involved minimal use of peripheral buttons to allow paging forward and, if necessary, back. These buttons were not in primary gaze in space. The smartphone had a touchscreen display that needed to be “swiped” to turn pages, often near the center of the page, right where the fixation point would be. Although the link between proprioception and fixation is well known, it is unknown whether these subtle factors make a difference in suppression.

Looking beyond this study, proprioception and working distance may matter less when using television screens. It has become commonplace for so-called “multi-screen viewing,” often a TV and a handheld device like an e-reader or smartphone. This behavior is increasingly seen among our patients, optometry students and educators alike. Alternating between the near and more distant screens also provides relief for accommodation and convergence. It has also been observed that it gives the user something to do during digital downtime, such as when files are uploading.<sup>5</sup>

Like our patients, optometric physicians are subject to potential eyestrain when using these handheld displays for patient care. They are increasingly benefiting from the use of tablets and smartphones in their practices. Applications (apps) like EyeHandbook can be used for mobile testing of visual acuity, contrast sensitivity, color vision, OKN, and other mostly subjective findings. These sorts of apps can also be used for their extensive disease databases targeted at ophthalmology.<sup>2</sup> Other extremely useful optometric apps like Eyedock can be used for contact lens, topical medication, and coding searches. It is important for the optometric physician to know that close working distances with these ubiquitous digital devices can spare vergence by use of suppression, especially if used on a non-backlit display.

## Conclusions

This small study would benefit from a larger number of subjects to verify whether or not these intriguing results can

be replicated. Other methods of suppression control would be worth exploring as well. For instance, the present study initially avoided using polarized bar readers because of polarization of the LCD smartphone display. Later experimentation showed that this was less of a concern than previously thought, perhaps due to compatible polarization angles. A polarized bar reader would allow for a better photometric balance and color-correct neutral-density filtering. Simple changes like this one would be beneficial to determine whether suppression plays a positive role in allowing the human organism to adapt to the “socially compelled, biologically unacceptable” digital near task of the modern world.

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