Vision Research 86 (2013) 43–51

Contents lists available at SciVerse ScienceDirect

Vision Research

journal homepage: www.elsevier.com/locate/visres

Reading behavior of emmetropic schoolchildren in China

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ARTICLE INFO

Article history:
Received 5 April 2012
Received in revised form 11 March 2013
Available online 18 April 2013

Keywords:
Reading behavior
Reading distance
Ergonomics
Children
Chinese children

ABSTRACT

Knowing the actual behavior of readers will help us understand how near work influences a reader's eyes, comfort, reading efficiency, pleasure, and the ability to learn to read. We designed a methodology for reading behavior research, and investigated the reading behavior of emmetropic schoolchildren in China and factors that influence their reading. Children from grades 2 through 5 read text in an armchair, at a desk, and when reading and writing at the desk with three different font sizes. Their preferred reading distance was very near to the eyes, averaging 28.5 ± 6.4 cm in the armchair, 25.4 ± 6.6 cm at the desk and 20.6 ± 6.5 cm in the reading/writing task, and was always slightly closer for the smallest font. Second grade children averaged just a 16.3 ± 4.1 cm reading distance in the reading/writing task. Head tilt and angle of gaze were altered by reading condition and font size. Reading speed was fastest at the desk and for those with longer reading distances and, surprisingly, for the smallest font size. Reading behavior is not a fixed entity but differs with grade level and reading condition. This suggests that reading behavior can be altered through better ergonomics and text design which may reduce myopia, aesthenopia, and binocular anomalies and help children read better.

1. Introduction

Reading posture can affect the pleasure and effectiveness of reading as well as retinal image quality, convergence and accommodation demands, and binocular comfort during reading (Scheiman & Wick, 2008; Schor & Cuifredda, 1983). Through these factors, it may also influence how readily a child learns to read. Some investigators also consider reading behavior an important factor in the development of myopia (Gwiazda, Thorn, & Held, 2005; Gwiazda et al., 1995; Ip et al., 2008) and in promoting dry eye (Miljanović et al., 2007; Sheedy, Hayes, & Engle, 2003). Eye care practitioners ascribe several other patient problems to excessive or inappropriate near work and have numerous sensory and motor tests to quantify different aspects of near vision (Scheiman & Wick, 2008). Yet some of the most basic parameters in these tests have no empirical support.

The parameters most relevant to a child's near work clinical examination should reflect how children actually look at a page of text while they are reading. There is almost no ophthalmic literature addressing this problem other than a few abstracts from recent meetings. Researchers have demonstrated that the near working distance is shorter than is normally assumed by eye care practitioners (Chiu, Rosenfield, & Solan, 1994; Drobe et al., 2008). Young adults read at about the optometric near distance (40 cm) when reading in an armchair but when reading at a desk they read at a much closer distance of about 30 cm (Hartwig et al., 2011a, 2011b; Hill, Han, & Thorn, 2005). In both settings, these subjects assume a wide variety of head postures and gaze angles. Harb, Thorn, and Troilo (2006) showed that young adults have highly variable accommodative lags when reading and often glance away from near text. Children's reading distances have been shown to be even closer (Haro, Poulain, & Drobe, 2000; Sampedro, Montalt, & Alemany, 1997). When Japanese adolescents read and write at a desk their reading distance is less than 30 cm and accompanied by a sharp downward head turn (Marumoto et al., 1998). Yet near work testing is performed clinically at standard reading distances and angle (straight ahead with head upright at either a 33 cm or 40 cm distance) without regard to how people actually read in daily life. Knowing the actual behavior of readers may be crucial to understanding how near work influences a reader's eyes, comfort, reading efficiency, and pleasure.

The present study is designed to examine the reading ergonomics of emmetropic Chinese schoolchildren from the 2nd to 5th grades under different reading conditions to establish a methodology for reading behavior research and to understand how children behave when they are reading. We hope this work will have immediate educational and public health benefits and that it will lead to a redesign of ophthalmic tests where appropriate.

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http://dx.doi.org/10.1016/j.visres.2013.03.007

2. Methods

2.1. Subjects

A total of 59 children, 31 boys and 28 girls (age range, 7–12 yrs; mean age, 9.05 yrs) participated in the study. Each child was emmetropic with a spherical equivalent refractive error between +0.50 D and −0.50 D in both eyes, and astigmatism ⩽−0.50 D as measured by noncycloplegic subjective refraction. Monocular uncorrected distance visual acuity was ⩾20/20 in each case. Children were in grades 2, 3, 4 and 5 at two elementary schools in Wenzhou, China. The two schools have equivalent curricula and teaching styles at each grade. Informed consent was obtained from all subjects and their accompanying parents or guardians after the nature and possible consequences of the study had been fully explained. The study was approved by the ethics committee of the Wenzhou Medical College and followed the tenets of the Declaration of Helsinki. Eligibility criteria included: no strabismus and no history of ocular pathology, trauma, or surgery.

We excluded the children in grade 1 because their reading ability is very limited and their books are very different. Their books are in Chinese characters below which is a phonetic language using a western alphabet called Pinyin. They first learn to read phonetically and then are shifted to Chinese characters so the reading task in 1st grade is totally different from older students. We also did not include the children in grade 6 because reading ability is starting to asymptote and the proportion of myopic children is increasing rapidly as emmetropic children are being turned into myopes.

2.2. Procedures

Two experienced optometrists performed the eye examinations which included case history, visual acuity, cover test, subjective refraction, slit-lamp examination, and near phoria testing using the modified Thorington test (Lyon, Goss, & Horner, 2005) on each subject. And the test was performed at a closer distance of 33 cm. Since working distance may depend on the size of the child, we measured height and the Harmon distance (distance from the elbow to the hand) of each child. Basic epidemiological and biometric characteristics are described in Table 1. As expected, height and Harmon's distance increased significantly with grade ($P < 0.001$). There were no significant gender differences for age, height, Harmon distance, or near phoria ($P > 0.1$). Therefore, the data for boys and girls are combined in the results. The percentage of near exophoria, orthophoria and esophoria were 47.50%, 37.20% and 15.30%, respectively.

Prior to reading, each child had an 8 mm strip of stiff cloth attached vertically to the left side of the face while the child held the head upright and looked straight ahead. The purpose of the strip is to easily calibrate the upright head position as a baseline for measurements of reading distance and angle.

The child then read under three different reading conditions in the following sequence:

a. A relaxed setting in a comfortable armchair without a desk or table.
b. A school reading setting in a chair at a desk like those used in regular school classes.
c. A school reading/writing condition in a chair at a desk like that in the above condition. But the child was also instructed to mark three Chinese characters, "的, 地, 得" which appeared at random in the text.

We will refer to these conditions as "read in armchair," "read at desk," and "read/write at desk" throughout the text. The desk and chair heights (73.2 and 43.7 cm, respectively) were held constant for all grades and were very similar to those used for students across grades in the local elementary schools.

In each reading condition, children were asked to silently read grade-appropriate Chinese stories using three different font sizes (9, 12 and 14 pt) in the Chinese Song font. The texts with different font sizes were provided in a random sequence. Children read each assignment for 3 min. After the first 30 s of reading, they were photographed from the left side with a digital camera at 10-s sampling intervals. Each sample was imported into ImageJ software where reading distances and head tilt angles were determined using macros written for this project. Ten photographs were randomly chosen, and the mean value of each parameter was used for data analysis. Reading parameters were as follows:

1. Reading distance: distance from the left eye to the midpoint of the page (Fig. 1: line *AB*).
2. Head tilt angle: forward downward angle of the head relative to a vertical upright position of the head (Fig. 1: angle α).
3. Eye gaze angle: vertical eye gaze angle of the eyes relative to the head (Fig. 1: angle β).

Reading was silent in our study. Children read each assignment for 3 min. The first character and the last character read were marked, and then the number of characters read in 3 min was counted and recorded. Reading speed was calculated as characters read per minute.

Table 1
Relationship of school grade and gender to epidemiological and biometric measures.

Grade	Gender	Number	Age (yrs)	Height (cm)	Harmon (cm)	Phoria Δ[a]
2	Boys	9	7.3 ± 0.5	125.8 ± 4.8	18.2 ± 1.4	−0.9 ± 3.9
	Girls	7	7.6 ± 0.5	128.0 ± 11.0	19.1 ± 1.8	−2.0 ± 3.9
	Total	16	7.4 ± 0.5	126.8 ± 7.9	18.6 ± 1.6	−1.4 ± 3.8
3	Boys	7	8.4 ± 0.5	133.1 ± 5.1	20.4 ± 1.5	−2.1 ± 2.3
	Girls	7	8.3 ± 0.8	130.7 ± 4.4	19.9 ± 1.8	−2.1 ± 2.3
	Total	14	8.4 ± 0.6	131.9 ± 4.7	20.2 ± 1.6	−2.1 ± 2.2
4	Boys	7	10.0 ± 0.6	138.7 ± 5.3	21.1 ± 1.4	−1.0 ± 3.1
	Girls	8	9.8 ± 0.7	137.9 ± 5.7	20.8 ± 1.2	−1.4 ± 4.3
	Total	15	9.9 ± 0.6	138.3 ± 5.4	20.9 ± 1.3	−1.2 ± 3.7
5	Boys	7	10.9 ± 0.7	143.0 ± 10.1	21.6 ± 3.0	−3.0 ± 3.1
	Girls	7	10.6 ± 0.5	149.8 ± 6.3	22.0 ± 1.4	−1.1 ± 4.9
	Total	14	10.7 ± 0.6	146.4 ± 8.8	21.8 ± 2.3	−2.1 ± 4.0

[a] A positive phoria is "eso" and a negative phoria is "exo."