Vision Research 155 (2019) 17–23

Contents lists available at ScienceDirect

Vision Research

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

Reading speed of patients with infantile nystagmus for text in different orientations

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ARTICLE INFO

Number of reviewer - 1

Keywords:
Infantile nystagmus
Reading
Orientation

ABSTRACT

Two case studies in the literature report on patients with infantile nystagmus (IN) who preferred to read text that is oriented vertically rather than horizontally. The current study systematically evaluated the effect of text orientation (−60 to +90 deg with respect to horizontal) on reading speed in nine individuals with IN associated with albinism at Hadassah Academic College (HAC), seven individuals with IN at the University of Houston (UH), and a total of 17 normal control observers. Observers at HAC read 40-character passages of Hebrew text from standardized 2nd grade level reading material and observers at UH read MNRead acuity chart sentences. Letter size was two to six lines larger than each observer's measured visual acuity. In both individuals with IN and normal observers reading speed was fastest for horizontally oriented text and decreased for other orientations. However, reading speed decreased significantly more for non-horizontally orientated text in the observers with IN, compared to controls. In general, it is recommended that to achieve best reading performance patients with IN read horizontally oriented text.

1. Introduction

Nystagmus is an involuntary oscillation of one or both eyes that is characterized clinically by the degree of conjugacy, plane(s) of oscillation, directions of gaze in which it is present or most prominent, waveform, amplitude, and frequency (Abadi, 2002). Infantile nystagmus (IN) appears in the first six months of life (Papageorgiou, McLean, & Gottlob, 2014) and is commonly associated with various disorders including albinism, optic nerve hypoplasia and congenital cataracts, but also can occur without any associated visual-system abnormalities, i.e., idiopathic IN (Fresina, Benedetti, Marinelli, Versura, & Campos, 2013). The prevalence of nystagmus is 24 per 10,000 people, whereas idiopathic IN occurs in 14 per 10,000 people (Sarvananthan et al., 2009).

One form of IN is associated with albinism, an inherited disorder in the melanin biosynthesis pathway (Gronskov, Ek, & Brondum-Nielsen, 2007; Omar, Idris, Meng, & Knight, 2012) that is characterized by reduced or absent pigmentation in the eyes, skin, and/or hair (Kruijt, Franssen, Prick, van Vliet, & van den Berg, 2011). Aside from IN, ocular manifestations include hypopigmentation of the iris and retinal pigment epithelium, iris transillumination, foveal dysplasia, ametropia (Gronskov et al., 2007; Yahalom et al., 2012) that frequently includes with-the-rule astigmatism (Fresina et al., 2013), strabismus (Omar et al., 2012), photophobia (Summers, 1996; Summers, 2009), sensitivity to glare (Gronskov et al., 2007), and a reduction in visual acuity (Hertle, 2000). In many individuals with albinism, the visual dysfunction is so severe that they are classified as having low vision (Neveu, Holder, Sloper, & Jeffery, 2005; Wildsoet, Oswald, & Clark, 2000). The prevalence of all forms of albinism varies considerably worldwide and has been estimated to occur in one of every 17,000 people (Gronskov et al., 2007).

The eye movements associated with IN are involuntary, conjugate, and primarily horizontal (Abadi & Bjerre, 2002), comprising either oscillations with fast phases (saccades) in one or both directions combined with slower phases in the opposite direction or slow, pendular movements in both directions (Abadi, 2002).

Individuals with IN are reported to read at normal (Dysli & Abegg, 2016) or near-normal speeds (Barot, McLean, Gottlob, & Proudlock, 2013; Thomas et al., 2011; Woo & Bedell, 2006). Typically, individuals with IN adopt an eye-movement strategy to facilitate reading, such as a suppression of quick phases or the utilization of quick phases to modify the characteristics of slow phases (Thomas et al., 2011). These strategies enable longer foveation periods over a wider range of visual angles (Papageorgiou et al., 2014; Thomas et al., 2011). Although reading is possible during non-foveating periods of the nystagmus eye movement, reading accuracy is best during the foveation periods (Woo & Bedell,

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https://doi.org/10.1016/j.visres.2018.12.004
Received 23 April 2018; Received in revised form 2 December 2018; Accepted 12 December 2018
0042-6989/

Table 1
Characteristics of the study participants with IN at HAC and font sizes used for testing.

Observer	Gender	Age	VA LogMAR	Font Size- Points (LogMAR)	Diagnosis
HACIN-1	M	25	0.80	36 (1.00)	IN + oculocutaneous albinism
HACIN-2	M	21	0.70	36 (1.00)	IN + oculocutaneous albinism
HACIN-3	M	22	0.80	36 (1.00)	IN + oculocutaneous albinism
HACIN-4	M	27	0.30	20 (0.70)	IN + albinism
HACIN-5	M	18	0.40	20 (0.70)	IN + oculocutaneous albinism
HACIN-6	F	25	1.10	75 (1.30)	IN + albinism
HACIN-7	F	15	0.50	20 (0.70)	IN + albinism
HACIN-8	M	25	0.50	20 (0.70)	IN + albinism
HACIN-9	M	14	0.80	36 (1.00)	IN + albinism
Mean ± SD		21.3 ± 4.7	0.66 ± 0.25	33.2 ± 17.6 (0.90 ± 0.21)	

2006).

Dimmer (1907) reported that reading in a patient with idiopathic IN was facilitated by holding printed text vertically as opposed to horizontally. Later, Schmidt (1937) described another patient with IN and albinism who preferred to read by holding text vertically rather than horizontally. However, to the best knowledge of the authors, the orientation of text and reading speed in IN has not been systematically investigated.

Several researchers showed that English readers are faster when reading horizontal vs. non-horizontal text orientations (Byrne, 2002; Firth, Machin, & Watkins, 2007; Yu, Park, Gerold, & Legge, 2010). This horizontal advantage appears to be dependent on experience, as native Chinese students at a United States university read vertically oriented Chinese text faster than when it was oriented horizontally (Miles & Shen, 1925). However, Chinese (Sun, Morita, & Stark, 1985) as well as Japanese readers (Oda, Fujita, Mansfield, & Legge, 1999) who were experienced with both horizontal and vertical text orientation demonstrated similar reading speeds for both orientations. Moreover, reading speed in the non-preferred text orientation can improve with practice (Liu & Blaylock, 2015; Tinker, 1955). Although reading speed in the peripheral visual field also increases with practice (Chung, Legge, & Cheung, 2004; Subramanian, Legge, Wagoner, & Yu, 2014), training does not improve the reading speed of established readers, either those with normal vision or individuals with IN, when the text is presented in its customary orientation in the central visual field (Huurneman, Boonstra, & Goossens, 2016).

Two competing hypotheses can be advanced regarding the relative reading speed for vertically vs. horizontally oriented text in individuals with IN. First, horizontal nystagmus would be expected to smear the retinal images of adjacent letters and words together more for horizontally compared to vertically oriented text (Dimmer, 1907), which suggests that reading speed should be slower for horizontal text. Second, the observation that normal observers read fastest when text is presented in its customary orientation (Huurneman et al., 2016; Miles & Shen, 1925; Oda et al., 1999; Sun et al., 1985) suggests that individuals with IN, whose native language is written left to right or right to left, should read horizontal text faster than vertical text.

This study examined the influence of text orientation on reading speed in a total cohort of 16 observers with IN, tested in two institutions in countries where the native languages are read from left to right (English) and from right to left (Hebrew). As detailed in the next section, the experimental procedures used at the two institutions differed in a number of ways based, to some extent, on the available resources. Nevertheless, the similarity of the results obtained encourages us as to their generalizability.

2. Methods

2.1. Observers

Observers with a prior diagnosis of oculocutaneous albinism, ocular albinism or idiopathic IN, as well as groups of normal control observers, were recruited for this prospective study at the Hadassah Academic College Department of Optometry (HAC, Jerusalem, Israel) and the University of Houston College of Optometry (UH, Texas, USA). Observers with IN who had conditions commonly associated with IN, such as infantile cataract, retinal dystrophy, and optic nerve hypoplasia (Abadi & Bjerre, 2002; Papageorgiou et al., 2014), were considered to be eligible to participate. However, individuals with other ocular or systemic diseases, who were taking medications that may affect vision, or who had self-reported learning disabilities were excluded.

The research protocol was approved by each institution's ethics committee and conformed to the tenets of the declaration of Helsinki. Each observer, or his/her parent or guardian, signed a statement of informed consent prior to his or her participation.

All of the observers with IN at both institutions had horizontal nystagmus. The participants with IN at HAC (N = 9, 7 male) had nystagmus associated with albinism and were native Hebrew (right to left direction of reading) speakers. They were not paid for their participation, but received vision services at cost as partial compensation for their participation.

Of the observers with IN from UH (N = 7, 2 male), two had IN associated with albinism, one had IN associated with bilateral optic nerve hypoplasia, one had IN with bilateral optic atrophy, and three had idiopathic IN. All UH participants were native English (left to right direction of reading) speakers and were paid for their participation in the study. Summaries of the characteristics of the observers with IN at the two institutions are provided in Tables 1 and 2. The parameters of nystagmus are included only for the observers at UH (Table 2) because no equipment for recording eye movements was available at HAC.

Control subjects at HAC (N = 9, 7 male) had a mean age of 29 ± 7 (Range: 13–27), whereas control subjects at UH (N = 8, 4 male) had a mean age of 37 ± 18 (Range: 17–67).

After verification of inclusion criteria, near visual acuity was determined using a Rosenblum chart at 40 cm for the observers at HAC with their habitual refractive correction. The visual acuities of the observers from UH were based on a recent eye examination, as recorded in their clinical records. Each value in Table 2 is the best-corrected distance visual acuity of the tested eye, as measured using a standard clinical chart.

2.2. Experimental procedures

2.2.1. HAC

Eighteen second-grade level Hebrew passages, each containing 40 characters, were extracted from official standardized Ministry of Education materials (http://cms.education.gov.il/EducationCMS/Units/Rama/AarachaBeitSifrit/Mivdak_Hebrew.htm). The eighteen passages were taken from three different stories, and consecutive passages from the same story were not used. The passages were printed in black Arial font on white paper, and were presented to all observers in the same examination lane at a viewing distance of 40 cm. Measured

Table 2
Characteristics of the study participants with IN at UH and font sizes used for testing.

Observer	Gender	Age	VA LogMAR	Font Size- Points (LogMAR)	Diagnosis	Nystagmus Type	Average Amplitude (deg)	Frequency (Hz)
UHIN-1	F	47	0.14	32 (0.78)	IN	Jerk left	8.7	4.6
UHIN-2	F	18	0.70	54 (1.01)	Ocular albinism + INs	Bi-directional jerk	3.8	2.7
UHIN-3	F	33	0.30	22 (0.62)	IN	Bi-directional jerk	2.2	4.0
UHIN-4	M	57	0.18	28 (0.72)	IN	Jerk left	2.0	2.4
UHIN-5	F	40	0.18	28 (0.72)	Bilateral optic atrophy + IN	Alternating	2.9	2.0
UHIN-6	M	57	0.00	22 (0.62)	IN	Jerk left	0.8	3.8
UHIN-7	F	41	0.43	32 (0.78)	Ocular albinism + IN	Jerk left	1.6	4.4
Mean ± SD		41.9 ± 13.8	0.28 ± 0.23	26.9 ± 4.3 (0.75 ± 0.13)			3.1 ± 2.6	3.4 ± 1.0

Fig. 1. Examples of Hebrew passages read (from right to left) by observers at HAC, Font size 46, spanning two lines. Text orientation is 0 deg in panel (a) and +30 deg in panel (b). In this clockwise rotation, the text is read from the bottom right to the top left. The English translations of the two passages are: (a) One day my mother called me and said "Noa, in a month we are moving away" (b) They took the sandwiches, fruits and sweets out from their bags. "Bon Appetite" she said.

illuminance was 41.2 lx. The text size was at least two-lines (i.e., 0.2 logMAR) larger than the measured near visual acuity (see Table 1). Depending upon the required font size, each passage spanned either one (font sizes 10 to 20, LogMAR 0.50–0.70), two (font sizes 31 to 46, LogMAR 0.9 to 1.09), or three (font size 60 and font size 75, LogMAR 1.19–1.30) lines. The vertical spacing was set to 1.15 lines in Microsoft Word, and was measured to be 1.4 times the letter size. From trial to trial, six different text orientations were presented (−60, −30, 0, 30, 60, 90 deg) in a pseudo-random order. An orientation of 0 deg refers to horizontally oriented text and 90 deg indicates that the text started at the bottom and ended at the top. Negative orientations correspond to text that was rotated anti-clockwise from horizontal, i.e., the beginning of each Hebrew sentence was at the upper right and the sentence ended at the lower left, and positive orientations correspond to clockwise text rotation (Fig. 1). The different orientations were obtained by placing the printed text passages over larger sheets of paper that included a sketched template for each tested angle. The different passages were secured to the sketched templates prior to the start of the experiment and were presented in a random order that was determined separately for each observer. Observers were asked to read each passage out loud while the reading speed was measured using a stop-watch. After providing instructions to read the passage as quickly and accurately as possible, the examiners placed the sketched template with the attached passage backwards in front of the observer. The stopwatch was set to initiate only when the sketched template with attached passage was flipped over and the observer read the passage out loud. Three measurements were taken for each text orientation, each time for a different sentence, from which the mean and median reading speeds were computed in words per minute (wpm).

The observers at HAC made no mistakes during reading, possibly because the passages contained only short words at a 2nd grade level of difficulty. Reading accuracy also may have been fostered by the slower speed of reading aloud, compared to silent reading (Ashby, Yang, Evans, & Rayner, 2012; Ramulu, Swenor, Jefferys, & Rubin, 2013).

2.2.2. UH

English Minnesota Low-Vision Reading (MNRead) (Legge, Ross, Luebker, & LaMay, 1989) sentences, each comprising 55 characters, were displayed on a 21-inch monochromatic computer monitor (Image Systems, Hopkins MN, USA). The display resolution was 576 × 320 pixels and the frame rate was 160 Hz, non-interlaced. The background luminance was 140 cd/m^2, and text was presented with −97% Weber contrast. Each sentence was presented at a distance of 1 m in double-spaced Helvetica font, formatted to appear in 4 lines. The font size was between 3 and 6 lines (average = 0.44 LogMAR) larger than each observer's measured visual acuity (see Table 2). In each block of trials, the text was presented in random order in each of 6 orientations (horizontal, i.e., 0 deg, and rotated by −60, −30, 30, 60 and 90 deg with respect to horizontal). At UH, negative orientations signified clockwise rotation of the text, such that the direction of reading was from top left to bottom right, and positive orientations indicated anti-clockwise rotations. For the 90 deg orientation, the text ran from bottom to top. Different text orientations were obtained by having the observer view the monitor through a Dove prism. Because of the limited, 17.5-deg field of view provided by the Dove prism, the observers at UH viewed the text monocularly with the preferred eye while the non-viewing eye was occluded by an opaque patch. The reading speed for each text orientation was determined using a staircase procedure in which the duration was reduced if all the words on the preceding trial were read correctly, and increased if an error was made. In particular, each word in the sentence had to be read verbatim and in the correct sequence for the trial to be scored as correct. Initially, the duration of successively presented sentences was reduced by 50% until the first staircase reversal, and increased or decreased by 25% on all subsequently presented sentences until a total of four reversals were obtained, as described by Woo and Bedell (2006). Mean and median reading speeds were determined for each observer from between four and five estimates of the reading speed at each text orientation.

2.3. Analyses

The observers' median reading speeds in words per minute (wpm) for the different text orientations were compared using two-way mixed-model ANOVAs and repeated-measures ANOVAs (SuperANOVA software, Abacus Concepts, Berkeley, CA, USA). Because of the

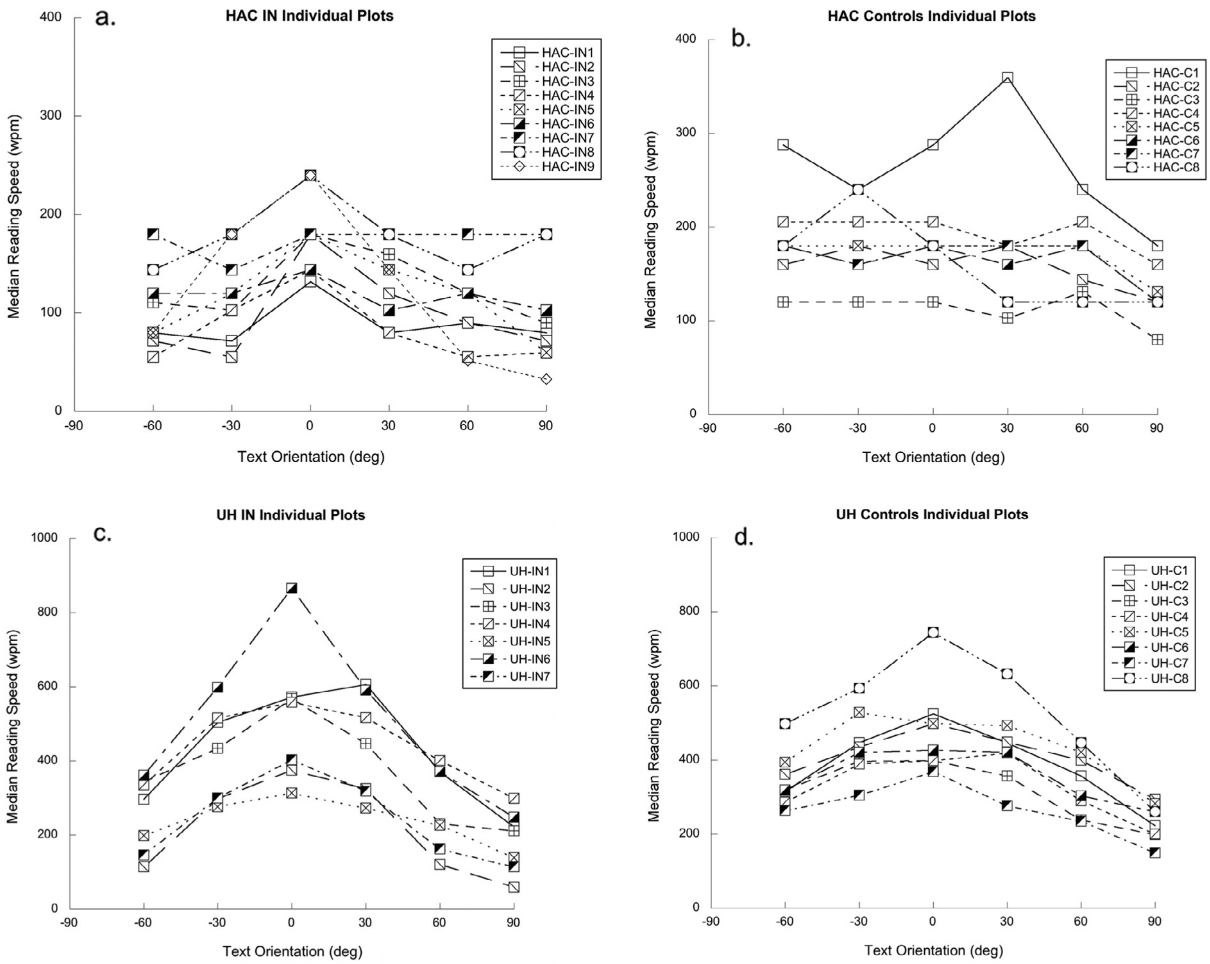

Fig. 2. Individual plots of median reading speed (in words per minute, wpm) as a function of text orientation for the cohorts of observers with IN (a) and normal control observers (b) at HAC and IN (c) and normal control observers (d) at UH. In each panel, each data point represents the median of between three and five measurements of reading speed, and the different symbols and line types represent the results of different observers. Please note that the y-axis scales differ in the panels for HAC and UH.

methodological differences between the experimental protocols at HAC and UH, separate analyses were used to evaluate the data collected at each institution. Each mixed-model ANOVA included two factors: experimental group (IN or normal) and text orientation. Each repeated-measures ANOVA assessed the influence of text orientation for a single experimental group at one of the two institutions. The significance level adopted was 95% and all reported significance levels include a Huynh-Feldt correction for departures from sphericity. No appreciable differences in the outcome of the analyses or the obtained significance levels were found if ANOVAs were performed using the mean reading speeds or the logarithms of the median reading speeds.

3. Results

As indicated by a significant main effect of text orientation, the participants with IN in both the HAC and UH cohorts achieved the fastest reading speed for horizontally oriented text (0 deg orientation) and slower speeds for other orientations (HAC: $F_{(df=2.7,21.5)} = 10.37$, $p = 0.0003$; UH $F_{(df=2.4,14.5)} = 33.99$, $p < 0.0001$, see individual results in Fig. 2 and average values in Fig. 3). On average, the normal observers in the UH cohort also achieved the fastest reading speed for horizontally oriented text, and reading speed decreased significantly for non-horizontal text orientations ($F_{(df=2.6,18.1)} = 40.94$, $p < 0.0001$). Bonferonni-corrected post-hoc contrasts indicated that reading speed for horizontally oriented text was significantly faster than for text oriented at ± 60 deg or at + 90 deg in both IN cohorts and for the normal observers at UH (all p values < 0.0003). Although the normal observers in the HAC cohort exhibited less change in reading speed with text orientation, the influence of orientation was still significant ($F_{(df=1.7,11.8)} = 5.92$, $p = 0.020$). In this group, reading speed for horizontally oriented text was significantly faster only compared to text at + 90 deg ($p = 0.008$). Overall, a significant effect of text orientation was identified in the mixed-model ANOVAs performed on both the HAC ($F_{(df=3.6,56.8)} = 12.73$, $p = 0.0001$) and UH samples ($F_{(df=2.4,31.8)} = 72.53$, $p = 0.0001$). As can be seen in Figs. 2 and 3, the slowest reading speed in both the HAC and UH observers was for vertically (90 deg) oriented text.

Rotating the text from horizontal to vertical reduced reading speed by approximately 20% (HAC) and 13% more (UH) in observers with IN than in normal controls, as confirmed by a significant interaction between text orientation and observer group (HAC: $F_{(df=3.6,56.8)} = 5.08$, $p = 0.002$; UH: $F_{(df=2.4,31.8)} = 3.33$, $p = 0.04$).

In the HAC sample, ANOVA indicated a significant effect on reading speed of experimental group (IN vs. normal control: $F_{(df=1,16)} = 7.07$, $p = 0.017$), which results from the lower reading speeds achieved among the observers with IN when reading non-horizontal text (Fig. 3a). The UH data did not exhibit a significant main effect of experimental group ($F_{(df=1,13)} = 0.35$, $p = 0.56$). However, the three observers in the UH cohort with non-idiopathic IN read more slowly than the observers with idiopathic IN, which might reflect primarily the

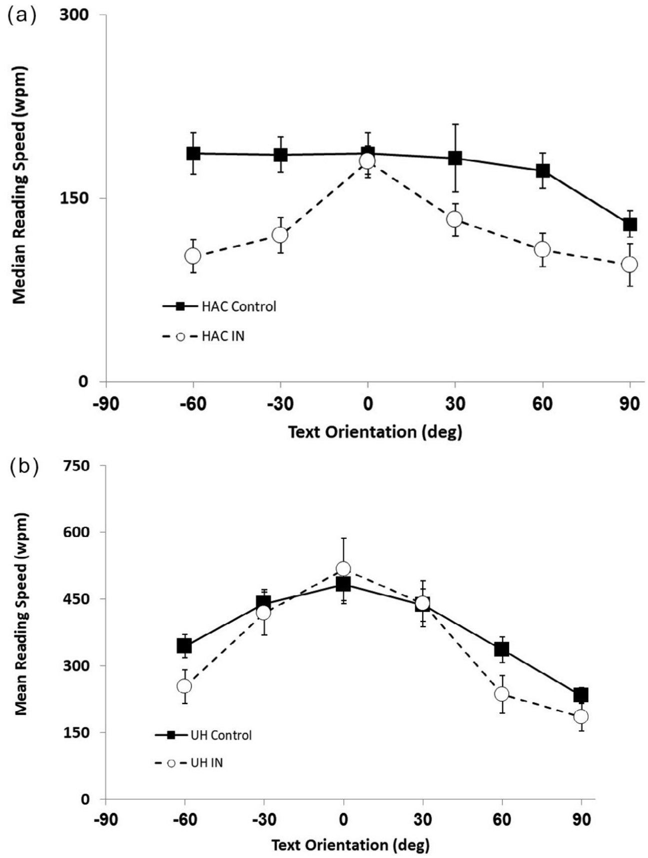

Fig. 3. Mean reading speed (in words per minute, wpm) as a function of text orientation for the cohorts of normal control observers (filled squares) and observers with IN (unfilled circles) at HAC (a) and UH (b). Each plotted mean value is the average of the median reading speeds of the observers in the designated cohort. Error bars represent ± 1 SE of the mean. Please note that the y-axis scales differ in the two panels.

tendency for reading speed to be slower in individuals with poorer visual acuity (Barot et al., 2013).

4. Discussion

Participants with IN in both the HAC and UH cohorts achieved the fastest reading speed for horizontal text (0 deg orientation) and had reduced reading speeds for other orientations. This was observed also for the normal control observers in the UH cohort, but less so in the HAC cohort, in which the reading speed was approximately constant for all except the vertical orientation. The latter observation is consistent with a report by Koriat and Norman (1985) that the response speed of normal Hebrew readers to identify single 4 and 5 letter words decreases approximately symmetrically only for word orientations larger than ± 60 degrees.

As noted in the Introduction, two competing hypotheses can be advanced concerning the influence of text orientation on reading speed in individuals with IN. One hypothesis is that the eye movements during IN should produce horizontal motion smear, which would preferentially reduce the reading speed for horizontal text. However, our results provide no support for the prediction that individuals with IN read horizontally oriented text more slowly than text in other orientations. In the presence of eye-movement-induced retinal image motion, individuals with IN report substantially less motion smear than normal observers (Bedell & Bollenbacher, 1996; Bedell & Tong, 2009), which may explain in part why we found no disadvantage in individuals with IN for reading horizontal text.

The other hypothesis is that because both English- and Hebrew-speaking observers have substantial experience reading horizontally oriented text, reading in this orientation is quicker than in other, less familiar orientations. This hypothesis is consistent with the findings of Miles and Shen (1925), Schmidt, Ullrich, and Rossner (1993), Oda et al. (1999) and Yu et al. (2010), who reported that the reading speed for horizontally and vertically oriented text depends on the observers' familiarity and experience in reading in each orientation. In addition, several investigators found that, following practice, reading speed improves in normal English speaking observers for vertical, but not for horizontal, text (Liu & Blaylock, 2015; Subramanian et al., 2014; Tinker, 1955). The results of our study are in agreement with the hypothesis that reading speed depends primarily on familiarity with text orientation.

Previous studies reported that reading speed in individuals with IN is either the same or slightly reduced compared to normal observers (Barot et al., 2013; Barot, McLean, Gottlob, & Proudlock, 2014; Dysli & Abegg, 2016; Huurneman et al., 2016; Thomas et al., 2011; Woo & Bedell, 2006). Further, reading speeds are similar in individuals whose nystagmus is associated with albinism and in those with idiopathic IN (Barot et al., 2013; Barot et al., 2014; Huurneman et al., 2016; Thomas et al., 2011). For horizontally oriented text, our results indicate no significant difference in reading speed between individuals with IN and normally sighted observers. Thus, the slower reading speeds shown in Figs. 2 and 3 for the observers with albinism at HAC compared to the observers with IN at UH are most likely attributable to differences between the experimental protocols used at the two institutions, rather than to differences in the etiology of IN.

Our results indicate that reading speed is reduced significantly more for vertically oriented text in the observers with IN than in normal observers. Woo and Bedell (2006) reported that observers with IN can read words presented during the non-foveating periods of the IN waveform, although less accurately than during the foveation periods. It is possible that the greater-than-normal reduction of reading speed for non-horizontally oriented text in individuals with IN occurs because their horizontal nystagmus displaces the fovea away from, rather than along, each line of text, thereby reducing the opportunity to read during the non-foveating periods.

Proudlock, Barot, McLean, and Gottlob (2012) reported that both the speed and accuracy of reading numeric lists is better in observers with IN when the numbers are arrayed vertically, in "marquee" format, compared to horizontally. However, unlike text, numbers contain neither 'word-shape' nor contextual information and presumably have to be processed one at a time, in contrast to the way that fluent readers scan and process text (Fisher, 1975; Pelli & Tillman, 2007; Woo & Bedell, 2006). The observation, replicated here, that text is read fastest when presented in a familiar orientation is consistent with a contribution of word-shape information to normal reading. In the absence of word-shape and contextual information, horizontal retinal image smear and/or the dispersion of successive foveation periods (Bedell, White, & Abplanalp, 1989; Cesarelli, Bifulco, Loffredo, & Bracale, 2000) may limit the reading speed for sequences of digits in individuals with IN.

Based on the findings of this study, patients with IN whose native language requires them to read horizontally arrayed text should be most efficient in reading horizontally oriented text. The question then arises why the patients in the case reports of Dimmer (1907) and Schmidt (1937) showed a preference for vertically oriented text. One possible explanation may have to do with the fact that many patients with IN have substantial *with-the-rule* astigmatism (Abadi & Bjerre, 2002; Bedell & Loshin, 1991; Sampath & Bedell, 2002; Wang et al., 2010; Wildsoet et al., 2000). Accordingly, Schmidt (1937) reported 5.00 DS of hyperopic with-the-rule astigmatism in both eyes of his adult patient with nystagmus and albinism. If the patient's ametropia was uncorrected, then his with-the-rule hyperopic astigmatism would have resulted in substantially more blur in the horizontal compared to the vertical retinal image direction. Indeed, even if the patient's refractive error were corrected, it is plausible that a meridional amblyopia would have existed if the correction had not been provided at a sufficiently young age (Freeman & Thibos, 1975; Mitchell, Freeman, Millodot, & Haegerstrom, 1973). Meridional amblyopia also can result from the retinal image motion produced by nystagmus eye movements (Abadi & King-Smith, 1979; Bedell & Ukwade, 1997). Meridional amblyopia resulting from a combination of hyperopic with-the-rule astigmatism and incessant horizontal retinal image motion would be expected to render vertically oriented image components unclear, mimicking the optical effect of uncorrected hyperopic with-the-rule astigmatism. In either of the above scenarios, better resolution could have been achieved if lines of text were viewed in a vertical rather than horizontal orientation (Little, Molloy, & Saunders, 2012). It is plausible that if the critical print size had been measured in the current experiment a different effect of text orientation would have been observed. However, the uniform results of the observers with IN, some with font sizes up to 0.6 LogMAR greater than the measured visual acuity, indicate that legibility is not likely to be an important contributing factor to their reduced reading speed for non-horizontal text.

The patient reported by Dimmer was a 9-year-old boy with idiopathic IN. Unfortunately, no information is provided about refractive status, except that the patient received a prescription for glasses from a different ophthalmologist one year before his examination by Dr. Dimmer, i.e., at approximately age 8.

The optimal reading speeds for the observers at HAC and UH differed by a factor of approximately 2.5. Reading English text has been reported to be faster than reading Hebrew (Shimron & Sivan, 1994). This difference in reading speed could be due to differences between English and Hebrew fonts, the uniformity of Hebrew block-like letters with horizontal and vertical strokes and the presence of fewer curves and diagonal strokes compared to English (Share & Levin, 1999, Shimron & Navon, 1981). Perhaps more importantly, the reading speed of the observers at HAC was determined by the time it took to complete reading each passage aloud, whereas the observers at UH were permitted to continue reporting words after the text disappeared.

A potential limitation of our study is that we did not measure reading speed for both 90-deg clockwise and anti-clockwise rotations of text from the habitual horizontal orientation. However, previous studies that compared reading for text orientations of ± 90 deg found similar reading speeds at these two orientations for English passages (Yu et al., 2010) and for individual Hebrew words (Koriat & Norman, 1985). The reading speeds of our observers were similar for the ± 60-deg orientations, suggesting that similar reading speeds also would have been obtained for text in the ± 90-deg orientations. With respect to the issue of clockwise vs. anti-clockwise text rotation, it may be noteworthy that Dimmer reported his patient read vertically oriented text from top to bottom, whereas Schmidt's patient read from bottom to top.

5. Conclusions

The findings of this study support the recommendation that patients with IN who live in countries where horizontal text is the norm be advised to read horizontally oriented text. However, based on the case reports presented in the Introduction, a small percentage of patients may prefer to read non-horizontally oriented text.

Acknowledgments

We thank Steve Mansfield and Gordon Legge for providing the MNRead sentences used in this study. This research was supported in part by Core Center grant, P30 EY 07551, from the National Eye Institute to the University of Houston College of Optometry.

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