A novel instrument for logging nearwork distance.

(Short Title: Instrument for measuring nearwork)

[1] Tsz-wing Leung, B.Sc.(Hons) Optometry

[2] Daniel Ian Flitcroft, D.Phil., FRCOphth.

[3] Josh Wallman, Ph.D.

[4] Tat Hing Lee, M.Sc.

[4] Yongping Zheng, Ph.D.

[1] Carly Siu-yin Lam, B.Sc. (Hons) Optometry, M.Sc., Ph.D., MCOptom., FAAO

[1] Chea-su Kee, B.Sc. (Hons) Optometry, M.A., Ph.D.

[1] Centre for Myopia Research, School of Optometry, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong SAR.

[2] Department of Ophthalmology, Children's University Hospital, Temple Street, Dublin.

[3] Department of Biology, City College, City University of New York, New York, NY 10031, U.S.A.

[4] Department of Health Technology and Informatics, The Hong Kong Polytechnic University, Kowloon, Hong Kong SAR.

Word Count: Number of Figures: Number of Tables:

Keywords: Myopia, Refractive errors, Humans, Reading habits

Corresponding author:
Chea-su Kee, B.Sc.(Hons.) Optometry, M.A., Ph.D.
Voice: (852) 2766-7941; Fax: (852) 2764-6051; Email: sokee@inet.polyu.edu.hk

Proprietary interest: Nil.
Supported by: The Hong Kong Polytechnic University Niche Myopia Funding J-BB7P

Abstract

Purpose: To validate a novel ultrasonic sensor for logging reading distances. In addition, this device was used to compare the habitual reading distances between low and high myopes.

Methods: First, the stability and sensitivity of the ultrasonic device were determined by repeated measures using artificial targets. Then, thirty Hong Kong Chinese (20-30 yrs) were recruited, of whom fifteen were considered to be high myopes (mean±SD= –8.7±0.5D) and 15 to be low to non-myopes (mean±SD= –2.0±0.2D). Each subject read a newspaper with habitual visual aid continuously for 10 minutes in two sessions at their preferred working distances. The reading distances were recorded continuously using a novel nearwork analyzer. The modal working distance was considered as the 'habitual' reading distance. In addition, habitual reading distance was reported orally by each subject.

Results: The nearwork analyzer gave accurate and repeatable measurements over a range of distances and angles. Using this instrument, high myopes were found to have a significantly shorter reading distance than low myopes or non-myopes (mean±SD= 35.9±9.8 cm vs. 50.9±24.8 cm; two-sample t-test, $p= 0.04$, DF=18). The reading distances reported orally by the subjects were not correlated with those recorded by the nearwork analyzer.

Conclusions: The nearwork analyzer was found to be an effective tool for measuring nearwork reading distance in a small group of emmetropic and myopic adults over a 10 minute interval. Differences between the reading distance between high myopes and low/non-myopes was detected by the device. Further study is needed to determine if a closer working distance is the cause or effect of myopia development.

Introduction

It has been conjectured for centuries that large amounts of nearwork lead to myopia. In recent years, epidemiological studies have provided some supporting evidence, but studies differ greatly in how much of an association is found between nearwork and the incidence or rate of progression of myopia. Studies that compare populations show a clear association between the amount of time spent on nearwork (e.g., schoolwork and reading) and the prevalence and degree of myopia.{Saw, 2002 #18;Williams, 2008 #24;Wong, 1993 #25} However, studies comparing individuals within a population find nearwork to be only weakly correlated with myopia.{Ip, 2008 #8;Mutti, 2002 #14;Jones, 2007 #9} Although this discrepancy might be due to the “ecological fallacy” (the statistical situation in which comparing the means of two populations yields a misleading conclusion about the individuals in the two populations), the weak correlations may also reflect the fact that commonly used metrics of nearwork, such as the “diopter hour” {Mutti, 2002 #14;Saw, 2002 #18;Zadnik, 1994 #47} or the number of books read per week, do not take into consideration the details of how long the periods of nearwork are, how frequently they are interrupted by distant vision, etc. In this respect, evidence from experiments on chicks,{Napper, 1995 #39;Napper, 1997 #40;Schmid, 1996 #34} tree shrews,{Norton, 2006 #32;Shaikh, 1999 #35} and rhesus monkeys{Kee, 2007 #30;Smith III, 2002 #44} show that when defocused vision is presented for different time periods, the amount of myopia depends more on the temporal pattern of presentation than on the total amount of defocused vision experienced. Thus, whether myopia in children shows a similar dependence on the temporal pattern of nearwork is an issue of great concern in high-risk populations. Clarifying this issue would give a scientific basis for programs directed toward preventing myopia in schoolchildren.

The most common approach to nearwork assessment is by means of questionnaires, interviews or diaries.{Adams, 1992 #1;Ip, 2008 #8;Saw, 1999 #19;Wong, 1993 #25} These techniques rely on recall and subjective assessments of working distance and provide only crude information relating to the temporal pattern of nearwork. Recently, the application of the experience-sampling method in adults for nearwork assessment{Rah, 2001 #16} is an improvement, but still requires subjective estimation by the subject and only provides information related to the proportion of each day for different tasks, not how tasks are broken up and interspersed. There is therefore a pressing need for a method of assessing nearwork activities with high temporal resolution. It is important that such measurements interfere as little as possible with the normal nearwork activity. This study tested the functionality of a novel nearwork analyzer and compared data collected from two groups of myopic adults.

Methods

Specifications of the Novel Nearwork Analyzer

The first generation nearwork analyzer was designed by one of the coauthors (D.I.F.) and further developed at the Hong Kong Polytechnic University. Specifically, as shown in Figure 1 (A & B), the nearwork analyzer uses a battery-powered ultrasonic transceiver to log the distances of nearby objects within its field and stores 6.3 hours of data with an adjustable sampling rate set at 1.04 second. The data are stored in an EEPROM memory device and later retrieved for analyses using a custom-written algorithm (Visual Basics, Visual Studio 2005, Microsoft). The algorithm extracts the stored data from the memory device and saved them in a separate Excel worksheet. The nearwork analyzer is attached to a head band and has an adjustable vertical angle.

Experiment 1: Determination of the stability and sensitivity of the nearwork analyzer.

(i) Stability

The stability of the nearwork analyzer was determined by recording data when a target was placed along the device's longitudinal axis at five preset working distances (25, 40, 60, 100, and 200 cm) for one hour. The device was mounted on a stand and adjusted to align with the center of a fixed target (21 cm x 30 cm).

(ii) Sensitivity ("Directionality")

The sensitivity of the nearwork analyzer to objects located away from the measuring beam was tested by pointing it at angles up to 40 deg away from the edge of a large card (size = 20.5 cm x 47.5 cm) held perpendicular to the measuring beam in a large, indoor open space. At each of 5 distances (25, 40, 60, 100, and 200cm) and at each of 5 eccentric angles (from 0 deg, when the measuring beam was pointed at the edge of the card, to 40 deg away from the edge in 10 deg intervals, *i.e.*, 0°, 10°, 20°, 30°, and 40°), the nearwork analyzer was rotated around its longitudinal axis to 8 orientations (0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315°). In each position, data were recorded for 5 minutes and the 'hit ratio' was calculated, in which a measurement was considered a 'hit' if the recorded distance was within 5% range of the preset testing distance, and the 'hit ratio' was calculated as the ratio of the number of hits to the total number of measured distances at each position. Thus, these measures reflect the sensitivity of nearwork analyzer when the edge of a target is approaching the measuring beam from different directions.

Experiment 2: Determination of the preferred reading distance in high myopes and low myopes/emmetropes.

Thirty young adults were recruited from students and staff of the School of Optometry at The Hong Kong Polytechnic University (Age: mean±SD= 23.7±3.1 years; range: 20 to 30 years; Gender: 19 males, 11 females). After informed consent had been given, comprehensive eye examinations were conducted by a registered optometrist to exclude subjects with poor general and ocular health, or those with history of ocular diseases and surgery. Non-cycloplegic subjective refractions were measured, using the maximum plus addition for best visual acuity as an endpoint; only subjects with best corrected visual acuity of at least 6/6 in both eyes and habitual prescription within 0.50D of the subjective refraction's end point were included in this study. A cover test and a measurement of accommodative facility were carried out to exclude any subject with binocular or accommodative anomalies according to criteria employed in the primary care optometry clinic.{Grosvenor, 2007 #46} All procedures followed the Declaration of Helsinki and the protocol was reviewed and approved by the Ethics Committee of The Hong Kong Polytechnic University.

Subjects

Our 30 subjects had a mean (±SD) age of 23.7±3.1 years old (range: 20 to 30 years), with no significant difference between low/non-myopes and high myopes (two-sample t-test, p= 0.13, DF=27). Because there were no significant differences between right and left eyes in the magnitudes of spherical equivalent (SE, paired t-test, p= 0.12, DF=29) and astigmatism (Cyl, paired t-test, p= 0.55, DF=29), only the right eyes' data were used for statistical analyses. Of the 30 subjects, fifteen were considered as high myopes (Spherical Equivalent Refractive Error, SE: mean±SD= –8.5±2.7 D, range: –5.0 to –13.3 D) and 15 as low to non-myopes (SE: mean±SD= –2.0±1.2 D, range: 0.0 to –4.0 D). The high-myopic group had significantly greater SE (p<0.001, DF=19, two-sample t-test) and astigmatism (1.7±1.1 D vs. 0.8±0.7 D, two-sample t-test, $p=0.01$, DF=23) than did the low/non-myopic group.

Procedure

Subjects were instructed to read an assigned newspaper (size: 28.5cm width X 36.5cm high) with their habitual visual aids (spectacle, n=26; contact lenses, n=2; none, n=2) at their preferred reading distances while wearing the nearwork analyzer. To cover conditions in which the device's measuring axis was not aligned with the eye's fixating axis, data were collected at two separate inclination angles of the sensor. These two inclination angles were chosen to align with eye's fixating directions when the subject was looking straight ahead or reading. As illustrated in Figure 1C & D, the two inclination angles were determined by replacing the ultrasound sensor with a headlamp and aligning the beam with the subject's fixating axes for targets placed at two distances. Specifically, when a subject was instructed to fixate at a letter "X", placed at either 3m away (letter size= 9mm) or at the subject's habitual working distance (letter size= 1mm), the inclination angle of the headband's mount (see arrow head in Fig. 1B) was adjusted until the light projected from a headlamp illuminated the letter. After the two inclination angles had been determined, the headlamp was replaced by the nearwork analyzer to record habitual reading distances for ten minutes when the subject was reading the newspaper. Similar oral instructions and the same newspaper materials were given to all our subjects. The two ten-minute sessions, one for each inclination angle, were separated by less than 5 minutes. Figures 1E & F illustrate frequency distribution of working distances measured during the two sessions (white area: 1st session; grey area: 2nd session) for two subjects, the dark areas represent intersections of the two sessions. As illustrated, because the distributions cluster at more than one working distances in most subjects (data not shown), the modal reading distances—that is, the distances most frequently recorded in each logging period—were used to represent the objectively measured working distances. Since significant differences in objective measures of reading distances was found between low/non-myopes and high myopes (see below), we were interested to know if subjective measures of reading distances would produce similar results. To compare the data with subjective estimation of reading distance, each subject was contacted again by the same investigator (TWL) through phone call after at least six months to answer the following question, "Without using any measuring device, please estimate your habitual working distance in centimeter when reading newspaper?" This subjective estimation procedure closely resembles the methods employed in previous studies; the six-month interval between the two measures may have minimized the likelihood of immediate recall from objective measures.

Results

Experiment 1: Stability and Sensitivity of the nearwork analyzer

Stability

The histograms in Figure 2 show the distributions of recorded distances as percentages at the five preset working distances; all distributions were leptokurtic (kurtosis: 18.4 at 25cm; 2.4 at 40cm; 5.3 at 60cm; 2.2 at 1m; 6.1 at 2m), and all recorded working distances were within 2 cm of the tested distances 100% of the time.

Sensitivity

The nearwork analyzer retained much of its sensitivity even when the target (in this case, a large card) was located quite far from the device and at a substantial angle away from the measuring beam. In Figure 3, the center of each graph represents the case where the beam is aimed at the edge of the target; the outer ring in each figure represents the measuring beam being aimed 40 deg away from the edge of the target. As expected, the sensitivity of the nearwork analyzer was highest when pointed at the edge of the target (red area), and it decreased as the instrument was aimed progressively further from the target. The region of maximal sensitivity (the red-orange areas signifying ratios of 0.8 to 1.0) were about 30° for working distances from 40cm to 100cm, but smaller at the closest and furthest distance.

Experiment 2: Reading behavior in high vs. low or non-myopes.

In general, we found that the high myopes had shorter working distances than the low myopes and emmetropes. Because the modal reading distances of all subjects were not significantly different between the two inclination angles tested (paired t-test, p=0.19, DF=29), the average of the two modal working distances was used for data analyses. Figure 4 plots the average modal working distances as a function of spherical-equivalent refractive errors in the right eyes for all subjects, with the two bars representing the mean distance and refractive error for each group of subjects. The average modal working distances (±S.D.) of low/non-myopes and high myopes were, respectively, 50.9 ± 24.8 cm (range: 26.5 to 99.5cm) and 35.9 ± 9.8cm (range: 29.0 to 69.5cm), a statistically significant difference (two-sample t-test, p=0.04, DF=18). Furthermore, the low/non-myopia group had a greater scatter of working distances compared to the high myopia group.

The subjective working distances reported orally by the subjects were not significantly correlated with the working distances measured by the nearwork analyzer, in large part because all subjects reported rather similar working distances. Figure 5 shows a scatter plot of objective and subjective reading distances for low/non-myopes (open symbols) and high myopes (filled symbols). As can be seen, there were no significant correlations found between the two measures (Pearson's r: low/non-myope=0, high myope=0.12; all p≥0.68). In addition, although one third (10 out of the 30 subjects, 33.3%) of our subjects provided oral estimations accurate to within 4 cm of the modal working distance, nearly half (14 out of 30 subjects, 46.7%) had discrepancies between the two measures of at least 10 cm, and almost a quarter of our subjects (7 out of 30 subjects, 23.3%) had discrepancies greater than 25cm (range: 27.5 to 68 cm). Most importantly, in contrast to the significant difference in working distances between low/non-myopes and high myopes as detected by the nearwork analyzer (see above), no significant difference in orally reported distances was found between the two groups (mean±SD= 36.9±8.5cm vs 39.0±11.2cm, two-sampled t-test, $p = 0.56$, DF=26).

Discussion

We have shown that: 1) the nearwork analyzer produced repeatable data in logging nearwork distances; 2) high myopes had shorter habitual reading distances than low/non-myopes; and 3) there was a poor correlation of subjective and objective measurements of working distance.

Application of the novel nearwork analyzer

The nearwork analyzer logged distances accurate to 2 cm within the tested range of 25 cm to 200 cm. Although the nearwork analyzer decreased in sensitivity from the central field and the sensitive zone was relatively smaller for the 200 cm working distance, the central 20° field, which had hit ratio ≥0.8 for tested distances from 25 cm to 100 cm, would be sensitive enough to log objects falling within the central annular areas of about 8.8cm diameter (for 25 cm distance) and 35.3 cm diameter (for 100 cm distance). Thus, for most nearwork activities including reading, the nearwork analyzer should be able to provide an objective measure of working distances over time.

Ideally the longitudinal axis of the analyzer should be aligned with the subject's visual axis at all times to reflect nearwork activities. Our results showed that, whether the analyzer's longitudinal axis was aligned with our subject's visual axes fixating at targets placed at 3m or at the habitual reading distance, the recorded modal working distances were not significantly different between the two conditions, indicating that either of the two alignments of the instrument would capture the near working distances most frequently used by the subject. This similarity probably was due to the fact that most of the change in gazes from distant to near targets was accomplished largely by head movements. Indeed, although not measured, only minimal adjustment was needed to realign the analyzer's longitudinal axis between distant and near fixating targets. Furthermore, the frequency distributions of raw data (e.g., Fig.1E & F) between the two conditions were not obviously different.

Variation of working distance with refraction

As revealed in Fig.4, a few subjects with low myopia had as short reading distances as high myopes, but it was obvious that low myopes had a more variable and wider range of reading distances. In this respect, it should be noted that the range of habitual reading distances measured by the nearwork analyzer, 26.5 cm to 99.5 cm (Fig. 4), were all within the functional range of the device (Fig. 3). Thus, the greater variability in the low/non-myopic group, as well as the significant difference in reading distance between the two groups of subjects, are not a result of instrument errors. By observation, a few subjects who had longer reading distance, including the subject with 99.5 cm reading distance, preferred to read newspaper by laying the material down on a desk, while those who had shorter reading distance usually held newspaper in hand. Nevertheless, because the Pearson's correlations between the reading distance and the degree of refractive errors (SE and astigmatism) were weak and non-significant for both subjective ($r=-0.08$ and 0.11) and objective measures ($r=-0.26$ and 0.26), one cannot conclude that reading distance is directly related to the degree of manifest myopia at the age of these subjects. However, the pattern we found of shorter reading distances being associated with high myopia (except in one subject) should be further investigated to determine the relationship between working distance and myopia development.

Objective vs. Subjective measures of nearwork activities.

As shown in Figure 5, subjective estimations of habitual reading distance showed significant discrepancies from the objective measures provided by the nearwork analyzer. It is interesting to note that subjects with closer working distances tended to overestimate their reading distance orally whereas those with longer working distances tended to underestimate their reading distances (Fig.5), suggesting a bias towards a perceived normal average value. Indeed, nearly half (46.7%) of the subjects mis-estimated their habitual reading distances by at least 10 cm compared to the readings measured by the nearwork analyzer. Although it is possible that some subjects might have changed their habitual working distances during the six months period after the objective measure, our results argue for caution in the use of subjective recall of habitual reading distance, especially in children, because of the potential of masking the role of nearwork activities in refractive error development.

Possible relation of habitual reading distance to myopia

Environmental factors such as nearwork activities have long been speculated to promote myopia development. Numerous studies, although not always in agreement, have linked the incidence of myopia with visually demanding occupations,{Goldschmidt, 1968 #734} duration/frequency of close work,{Saw, 2001 #794} and reading habits.{Zylbermann, 1993 #720} A long-standing speculation is that the accommodative blur associated with close working distances leads to myopia, a speculation compatible with our findings that high myopes frequently exhibited closer working distances. Alternatively, myopes have been found to interrupt fixation during reading less frequently than emmetropes,{Harb, 2006 #6} a relationship we plan to use the nearwork analyzer to explore in the future. Clearly, however, our studies of 10 min of reading newspaper cannot predict the effects of much longer periods of nearwork on myopia development. There is ample evidence from animal models that shows that visual error signals that influence refractive development are integrated non-linearly over time.{Kee, 2007 #895;Napper, 1995 #708;Norton, 2006 #806;Schmid, 1996 #184;Shaikh, 1999 #183;Winawer, 2002 #367} Furthermore, while the frequency distribution of reading distances were repeatable between the two sessions for individual subjects, it was common to find subjects who switched between two reading distances (Figure 1E). Consequently, the modal working distances collected within a short interval do not describe the variety of behaviors that could have influential effects on myopia development.

In conclusion, a novel nearwork analyzer, which was shown to provide reliable measures, recorded shorter modal working distances when reading a newspaper for a short interval in high myopes than in low/non-myopes. Furthermore, the subjective (self-reported) estimates of working distance were found to be poorly correlated with the objective measurements from the nearwork analyzer. Future research on characterizing nearwork activities over longer interval may lead to effective measures for ameliorating myopic progression.

References

1. Saw SM, Chua WH, Hong CY et al. Nearwork in Early-Onset Myopia. *Investigative ophthalmology & visual science.* 2002; 43: 332.

2. Williams C, Miller L, Gazzard G & Saw SM. A comparison of measures of reading and intelligence as risk factors for the development of myopia in a UK cohort of children. *British medical journal.* 2008.

3. Wong L, Coggon D, Cruddas M & Hwang CH. Education, reading, and familial tendency as risk factors for myopia in Hong Kong fishermen. *Journal of Epidemiology & Community Health.* 1993; 47: 50.

4. Ip JM, Saw SM, Rose KA et al. Role of Near Work in Myopia: Findings in a Sample of Australian School Children. *Investigative ophthalmology & visual science.* 2008; 49: 2903.

5. Mutti DO, Mitchell GL, Moeschberger ML, Jones LA & Zadnik K. Parental Myopia, Near Work, School Achievement, and Children's Refractive Error. *Investigative ophthalmology & visual science.* 2002; 43: 3633.

6. Zadnik K, Satariano WA, Mutti DO, Sholtz RI & Adams AJ. The effect of parental history of myopia on children's eye size. *JAMA.* 1994; 271: 1323-1327.

7. Napper GA, Brennan NA, Barrington M et al. The duration of normal visual exposure necessary to prevent form deprivation myopia in chicks. *Vision Res.* 1995; 35: 1337-44.

8. Napper GA, Brennan NA, Barrington M et al. The effect of an interrupted daily period of normal visual stimulation on form deprivation myopia in chicks. *Vision Res.* 1997; 37: 1557-64.

9. Schmid KL & Wildsoet CF. Effects on the compensatory responses to positive and negative lenses of intermittent lens wear and ciliary nerve section in chicks. *Vision Res.* 1996; 36: 1023-1026.

10. Norton TT, Siegwart JT & Amedon AO. Effectiveness of hyperopic defocus, minimal defocus, or myopic defocus in competition with a myopiagenic stimulus in tree shrew eyes. *Invest Ophthalmol Vis Sci.* 2006; 47: 4687-4699.

11. Shaikh AW, Siegwart JT, Jr. & Norton TT. Effect of interrupted lens wear on compensation for a minus lens in tree shrews. *Optom Vis Sci.* 1999; 76: 308-315.

12. Kee C-s, Hung L-F, Qiao-Grider Y et al. Temporal Constraints on Experimental Emmetropization in Infant Monkeys. *Invest. Ophthalmol. Vis. Sci.* 2007; 48: 957-962.

13. Smith III EL, Hung LF, Kee C-s & Qiao Y. Effects of brief periods of unrestricted vision on the development of form-deprivation myopia in monkeys. *Invest Ophthalmol Vis Sci.* 2002; 43: 291-299.

14. Adams DW & McBrien NA. Prevalence of Myopia and Myopic Progression in a Population of Clinical Microscopists. *Optometry and Vision Science.* 1992; 69: 467.

15. Saw SM, Nieto FJ, Katz J & Chew SJ. Distance, Lighting, and Parental Beliefs: Understanding Near Work in Epidemiologic Studies of Myopia. *Optometry and Vision Science.* 1999; 76: 355.

16. Rah MJ, Mitchell GL, Bullimore MA, Mutti DO & Zadnik K. Prospective Quantification of Near Work Using the Experience Sampling Method. *Optometry and Vision Science.* 2001; 78: 496.

17. Grosvenor T. *Primary Care Optometry*, 5th Edition. Butterworth Heinemann Elsevier, Missouri, 2007.

18. Goldschmidt E. On the etiology of myopia: an epidemiological study. *Acta Ophthalmol (Copenh).* 1968; 1(Suppl): 1:172.

19. Saw SM, Hong RZ, Zhang MZ et al. Near-work activity and myopia in rural and urban schoolchildren in China. *J Pediatr Ophthalmol Strabismus.* 2001; 38: 149-55.

20. Zylbermann R, Landau D & Berson D. The influence of study habits on myopia in Jewish teenagers. *J Pediatr Ophthalmol Strabismus.* 1993; 30: 319-22.

21. Harb E, Thorn F & Troilo D. Characteristics of accommodative behavior during sustained reading in emmetropes and myopes. *Vision research.* 2006; 46: 2581.

22. Winawer J & Wallman J. Temporal constraints on lens compensation in chicks. *Vision Res.* 2002; 42: 2651-68.

Figures

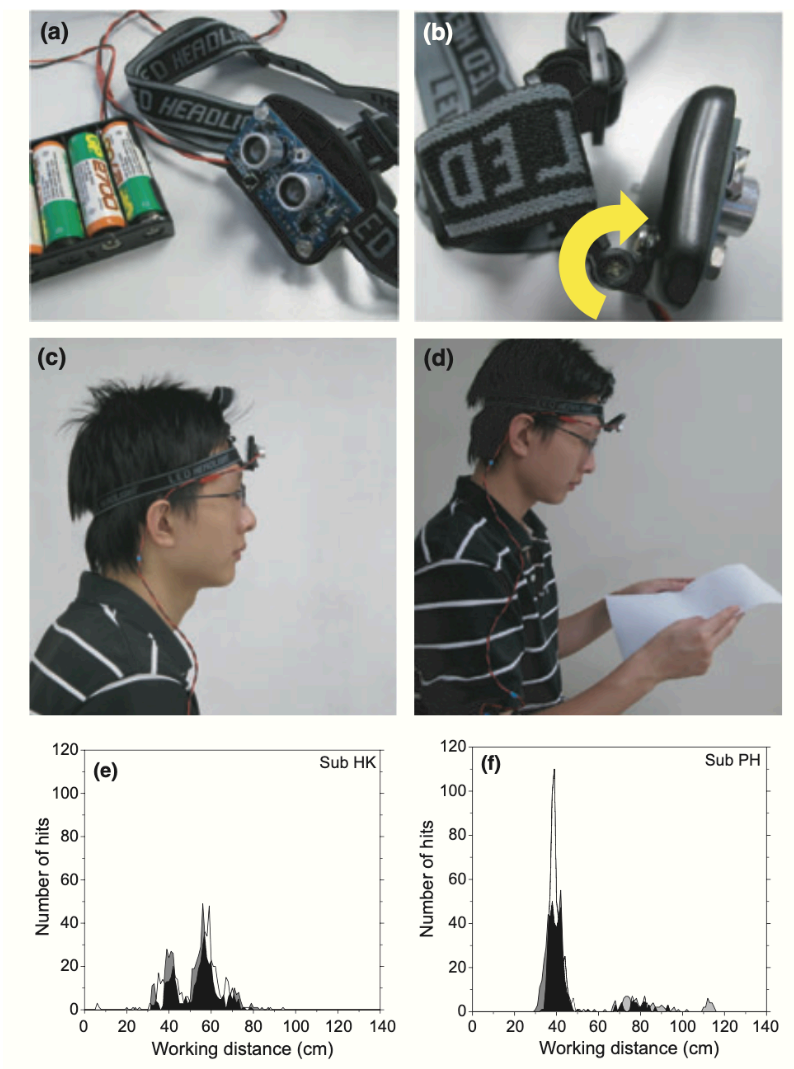


Figure 1. The nearwork analyzer. (A) Front view: The device was attached to a headband and powered by 4 AA-batteries. (B) Side view: The longitudinal axis of the device can be modified (yellow arrow) to align with the visual axis of a subject. (C) The longitudinal axis of the device is aligned with subject's fixating axis at straight ahead position (target is at 3m away). (D) The analyzer is adjusted to align the longitudinal axis of the device with subject's fixating axis at a letter "x" printed on an A4 paper. (E) & (F) Frequency distribution plots of working

distances collected during the two ten-minute sessions for two individual subjects (Subject HK: Objective=57.5cm, Subjective=30cm; Subject PH: Objective =40.50cm, Subjective=70cm). The first and second sessions were represented by white and grey areas, respectively; the intersections of the two sessions were highlighted by dark areas.

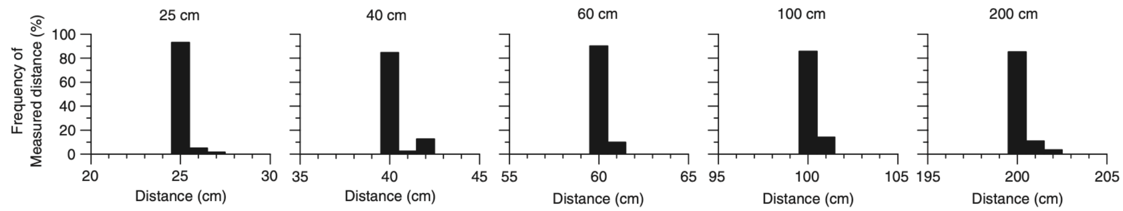
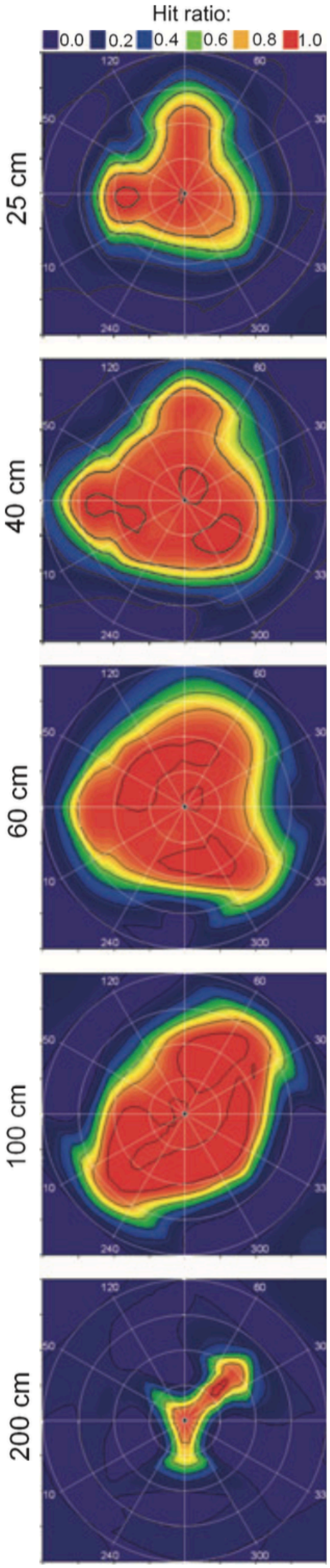


Figure 2. Frequency distributions of the measured working distances (in percentage) to a static target placed at individual tested distances over the one-hour period.



Hit ratio:
0.0
0.2
0.4
0.6
0.8
1.0
25 cm
40 cm
60 cm
100 cm
200 cm
120
60
240
300

Figure 3. Sensitivity of the nearwork analyzer to object placed at five distances (from top to bottom, 25, 40, 60, 100, 200cm). In each plot, sensitivity (‘hit ratio’) is represented by the color shown in the legend at the top of the figure, the contour lines represent areas with similar sensitivities. Each ring represents 10° of eccentric angle away from the edge of the target. The polar angles in each figure represent rotations of the nearwork analyzer around its measuring beam; the instrument is normally operated at the angle shown as 0° (horizontal line to the right). Hit ratio: 0.0 0.2 0.4 0.6 0.8 1.0

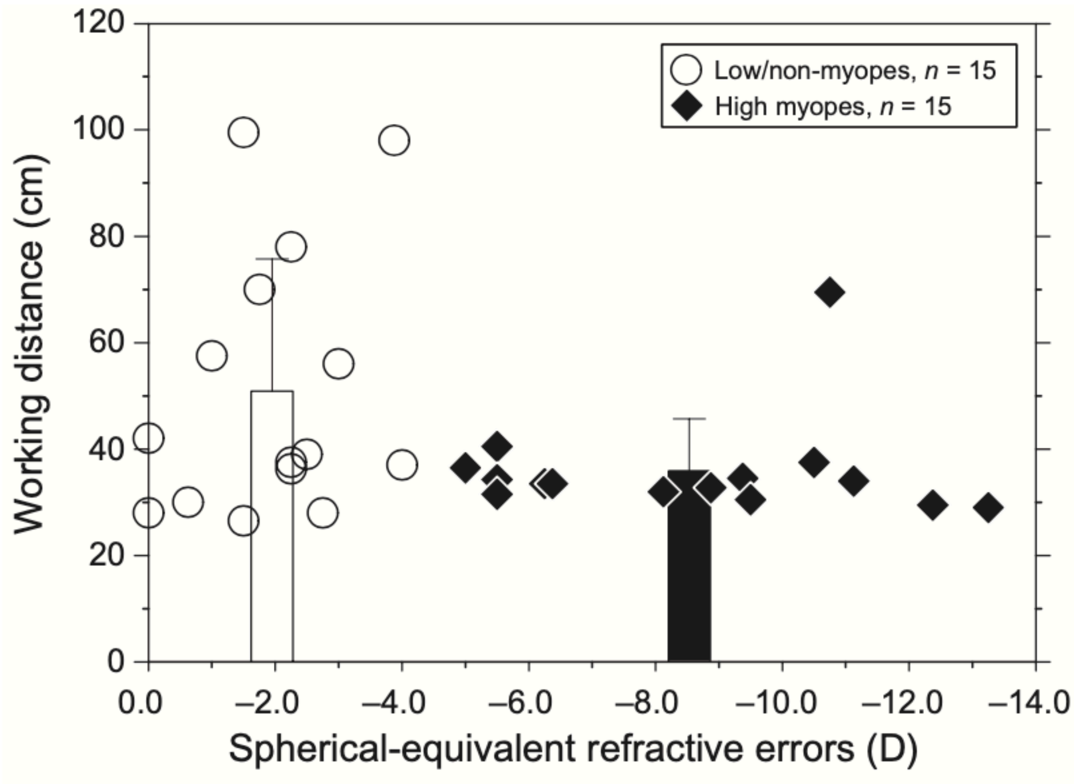


Figure 4. The modal working distances as a function of spherical-equivalent refractive errors for low/non-myopes (circles) and high myopes (diamonds). The two bars represent the means (±SEM) for the two groups of subjects.

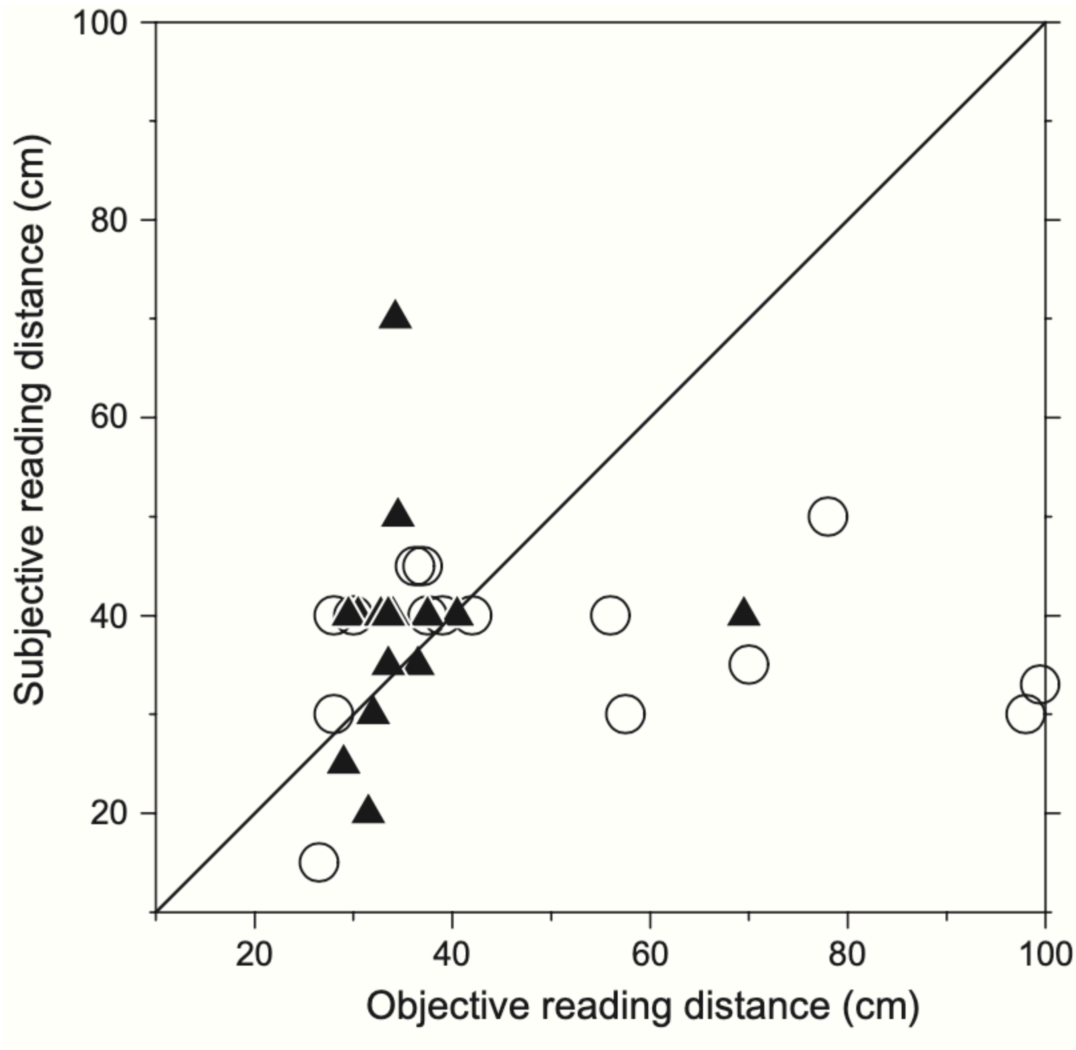


Figure 5. A scatter plot of the objective and subjective measures for low/non-myopes (open symbols) and high myopes (filled symbols). A straight line representing y=x is inserted for reference.