CLINICAL AND EXPERIMENTAL
OPTOMETRY

RESEARCH

Near visual function measured with a novel tablet application in patients with astigmatism

Ananya Datta* PhD MPhil BOptom
Kathryn Richdale* PhD OD FAAO
Erin S Tomiyama* OD MS FAAO
Chuan Hu* OD MD
Anna-Kaye M Logan* OD FAAO
Kelsea Skidmore* OD MS FAAO
Moriah A Chandler OD FAAO
Eric R Ritchey* PhD OD FAAO
James S Wolffsohn† BSOptom PhD FAAO

*The Ocular Surface Institute, University of Houston College of Optometry, Houston, Texas, USA
†Optometry and Vision Science Research Group, Aston University, Birmingham, UK
E-mail: j.s.w.wolffsohn@aston.ac.uk

Clinical relevance: While the clinical focus of performance metrics is traditionally based on visual acuity, research from the field of visual impairment has demonstrated that metrics such as reading speed and critical print size correlate much more strongly with subjective patient reported outcomes and assessed ability in real-world tasks.

Background: More recently, digital device use has increasingly replaced many paper-based tasks. Therefore, this study aimed to assess the correlation between standard acuity/contrast metrics and functional reading ability compared to real-world performance on an iPad-based reading task with astigmatic patients corrected wearing toric and mean spherical equivalent contact lenses.

Methods: Thirty-four adult participants, with −0.75 to −1.50 D of refractive astigmatism, were enrolled in a double-masked cross-over study and fitted with toric and spherical equivalent contact lenses, in random order. A digital application was developed to assess zoom, contrast modifications, the distance at which the tablet was held, blink rate, and time to complete the reading task. High and low contrast near logMAR visual acuity were measured along with reading performance (critical print size and optimal reading speed).

Results: The amount participants chose to increase tablet font size (zoom) was correlated with their high-contrast visual acuity with toric correction (r = 0.434, p = 0.010). With best sphere correction, zoom was associated with reading speed (r = −0.450, p = 0.008) and working distance (r = 0.522, p = 0.002). Text zoom was also associated with horizontal (toric: r = 0.898, p < 0.001; sphere: r = 0.880, p < 0.001) and vertical scrolling (toric: r = 0.857, p < 0.001; sphere: r = 0.846, p < 0.001). There was a significant negative association between the selection of text contrast and zoom (toric: r = −0.417, p = 0.0141; sphere: r = −0.385, p = 0.025).

Conclusion: Real-world task performance allows more robust assessment of visual function than standard visual metrics alone. Digital technology offers the opportunity to better understand the impact of different vision correction options on real-world task performance.

Measuring visual function has always been a challenge considering the various visual components that can affect task performance such as size, contrast, spacing, and presentation speed. The assessment of visual acuity with traditional vision charts is the most commonly performed vision test in the clinical set-up. However, measuring visual acuity alone may not provide sufficient information about visual function, as has been acknowledged by vision science researchers.[1] Measurement of contrast sensitivity along with high-contrast visual acuity could be a better approach to characterise visual function than measuring visual acuity alone.[2,3] But contrast still does not fully capture all the elements of visual function in the real world. Metrics based visual function assessments such as mean reading speed (MRS) and critical print size (CPS) correlate more strongly with subjective outcomes in real-world tasks.[4–6] It seems evident that the evaluation of reading speed and reading acuity, or even better, of reading speed based upon reading acuity, is clinically a better measure of near visual performance than standard acuity measures alone.[7] Radner Reading Charts were developed in order to equate the reading requirements at each print size, with the same number of words for each print size, word length, number of syllables, position of words, lexical difficulty, and syntax complexity.[8,9] This allows a standard comparable visual function assessment technique in accordance with international standards developed from interdisciplinary co-operation by psychologists, linguists, statisticians and ophthalmologists in order to minimise the variations between test items.[8,10]

Digital technology offers the ability to present visual stimuli in a more controlled form and can use on-board sensors to assess real-world elements of task performance such as working distance and screen changes. Research has shown comparable, reliable,[1] and repeatable[11,12] results in regard to assessment of contrast sensitivity function on an iPad device (Apple, Cupertino, CA, USA) versus traditional paper-based assessment. Wolffsohn et al. developed an

iPad-based application that can quantify reading performance on digital devices while the user performs everyday reading tasks.[13] The digital system utilises a front-facing camera to capture real-time performance and allows working distance and blinks to be tracked. Changes in magnification, and the time to complete the task are also recorded.

Assessing potential benefits of toric contact lenses in low and moderate astigmatic refractive error has been a challenge since traditional visual acuity assessment may not fully capture the reading challenges these patients experience. Therefore, this study aimed to evaluate how standard, clinical visual metrics and digital performance tests characterised real-world performance of common visual tasks utilising a data set of moderate astigmatic subjects fitted with toric and mean spherical equivalent contact lenses.

Methods

Assessment of the real-world performance app was conducted as part of a randomised controlled trial. Details of the study methods and primary outcomes of that study have

been published elsewhere.[14] In brief, eligible subjects had a refractive error between +0.50 to +4.00 or −0.50 to −6.00 D of spherical error and between 0.75 and 1.50 D of astigmatic refractive error, when referenced to the corneal plane. Subjects were free of ocular disease and could not have had corneal surgery or have worn hard or gas-permeable contact lenses in the past six months. A double-masked blinded crossover study was conducted with subjects randomised to begin with either Dailies Aqua Comfort Plus Sphere or Toric (Alcon, Fort Worth, TX, USA) contact lenses. There were five visits; at baseline, measurements were taken to determine contact lens fitting parameters. Lens fit assessment and over-refraction (spherical or sphero-cylindrical, depending on the type of lenses) was performed, and lenses were adjusted if they improved high-contrast logMAR acuity by at least three letters with over-refraction. Visits 2 and 4 were standard contact lens follow-up visits and visits 3 (Day 10 ± 2) and 5 (Day 20 ± 2) were outcome visits for the two lens types. All testing was conducted in the same examination room with standard illumination (226 ± 5 Lux).

Tablet application

READING ARTICLE PERFORMANCE APPLICATION

The functional reading performance test was created using Apple's X-code Starkit Developer extension in the Objective-C programming language for the iPad 3. Figure 1 shows the typical set-up. The screen luminance was set to 200 cd/m^2, which is a typical setting for an iPad used in normal room illumination. Subjects read different on-line Wikipedia articles, matched for length and layout, at each visit. The articles were all at an average Flesh-Kincaid reading level (range 8.4–12.0). Initially, the text contrast was set to 10 per cent Michelson contrast. Subjects were instructed to adjust the contrast to the minimum level where they could read the text comfortably, before starting the reading performance test. The zoom was initially displayed at 10 per cent. Subjects were also instructed that they could pinch or spread to zoom and scroll, as needed to read the whole article effectively during the reading task. The distance the subject held the iPad (assessed by the front-facing camera image using a facial recognition algorithm), the blinks, scrolling, zoom and contrast changes, were measured continuously during testing. The average blink rate (total number of blinks divided by total time), total scrolling (number of pixels), and the average distance the iPad was held, zoom and contrast were calculated for the duration of each test.

READING SENTENCE PERFORMANCE APPLICATION

The reading speed test was based on the Radner reading test and included 11 sentences, each consisting of 14 words with a standardised structure from a text size of 0.9 logMAR (6/48 Snellen equivalent) to 0.0 logMAR (6/6 Snellen equivalent).[10] Subjects were positioned 40 cm from the iPad screen in the field of view of the iPad computer's front-facing camera. The pupillary distance of the subject was tracked by an in-app algorithm to ensure a constant 40 cm distance between the subject and the device for this test (Figure 1A). Subjects were instructed to read the sentences, one at a time, aloud as quickly and accurately as possible and proceeded further by selecting the 'READ' button. When the sentence was too difficult to read, the subject selected the 'CANNOT READ' button (Figure 1C). The test was automatically timed to measure test duration. After completion of the test, the
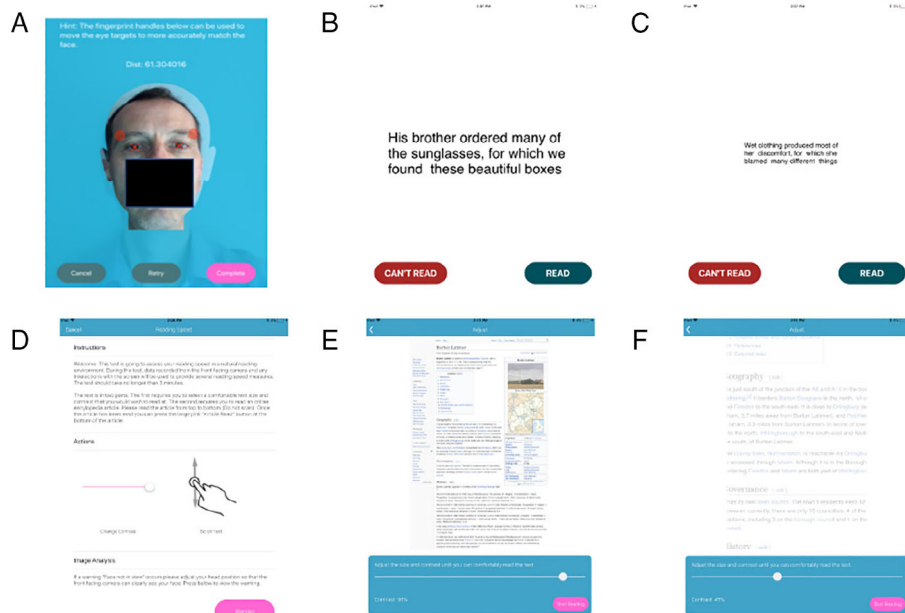

Figure 1. Example screen shots from functional Vision Testing System. A: Reading Speed Sentences calibration step for accurate working distance assessment. B: Larger Reading Speed Sentences text size. C: Smaller Reading Speed Sentences text size. D: Reading Article's instructions including zoom/contrast. E: Reading Article's original zoom with increased contrast. F: Reading Article with increased zoom and less contrast.
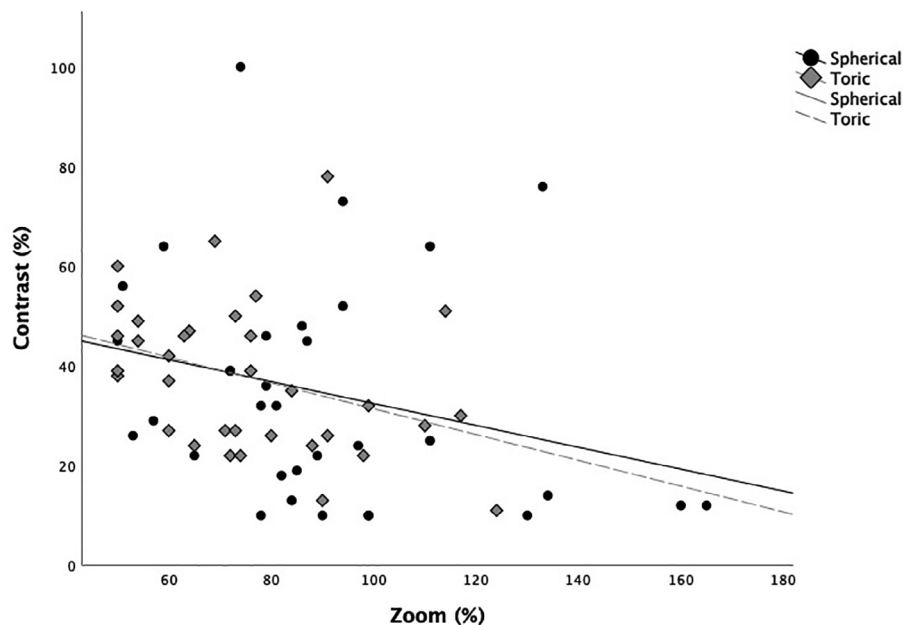
Figure 2. The relationship between zoom and high-contrast acuity for subjects fitted with toric (r = 0.434, p = 0.010), and spherical equivalent lenses (r = 0.247, p = 0.159) reading webpage articles
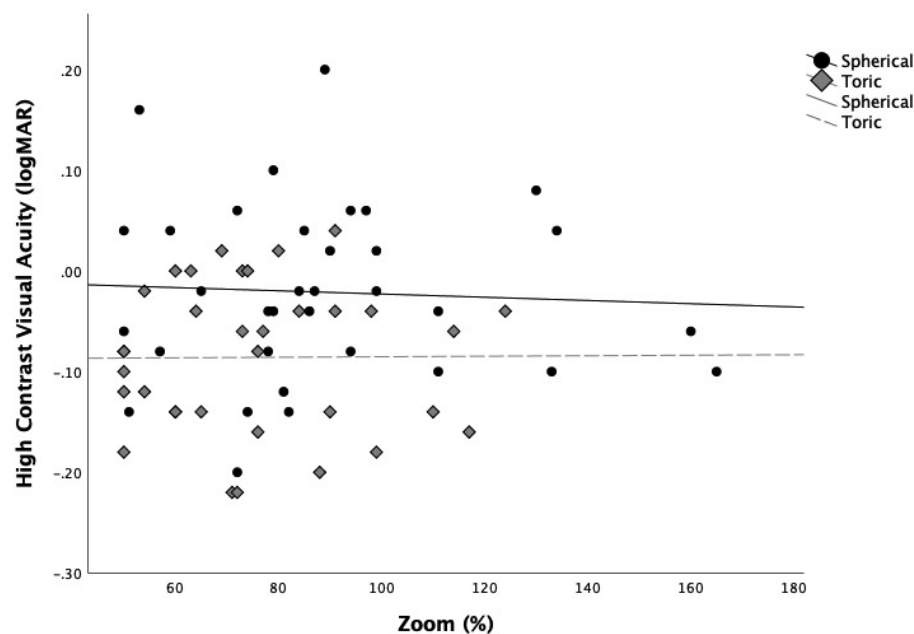

Figure 3. The relationship between zoom and contrast for subjects fitted with toric (r = −0.417, p = 0.014) and spherical equivalent lenses (r = −0.385, p = 0.025) reading webpage articles

masked examiner replayed the audio and manually marked the incorrectly read words for each sentence. Optimal reading speed (ORS) was calculated as the average reading speed of all lines above the CPS and was reported in words per minute (WPM). CPS was measured as the last print size read before the reading speed reduced more than the 95 per cent confidence interval of the preceding paragraphs reading speed.

Threshold reading acuity was taken as the last sentence size the subject could read. The application was previously shown to have good (ORS) or better (CPS) repeatability than the paper-based test.[13]

LogMAR high and low contrast near visual acuity

To compare with standardised acuity testing, binocular high and low contrast logMAR visual acuity was assessed at 40 cm using the electronic M&S Clinical Trial Suite system (Niles, IL, USA). The text contrast was 100 per cent (high contrast) and 10 per cent (low contrast). The system was calibrated according to the manufacturer's directions every day, prior to use. The test started at the smallest line where patients could read all five letters and continued until three or more letters were missed on a line.

Statistical analysis

Digital app metrics of task duration, reading distance, zoom and contrast as well as high-contrast acuity and maximum reading speed were not significantly different from a normal distribution (Kolmogorov–Smirnov test p > 0.05); however, blink frequency, scrolling, low contrast visual acuity, CPS and threshold reading acuity were not normally distributed so median and interquartile ranges were calculated. Spearman correlations and linear regressions were performed to determine the association between app generated metrics (zoom, contrast, scrolling, working distance and blinking) and more traditional visual assessment (visual acuity, contrast and reading speed). Correlations and regressions were performed individually for when subjects wore spherical equivalent and toric correction. Stepwise linear regression was used to determine the variance in-app task zoom and task duration that could be predicted from standard visual function tests. The cut-off level for statistical significance was set at p < 0.05.

Results

Thirty-seven subjects were screened, 35 were enrolled and randomised, and one participant was withdrawn due to an adverse event at visit 2 (corneal staining greater than grade II), leaving 34 available for analysis. The majority were habitual soft lens wearers (94 per cent), female (76 per cent) and Caucasian (53 per cent), and the average age of subjects was
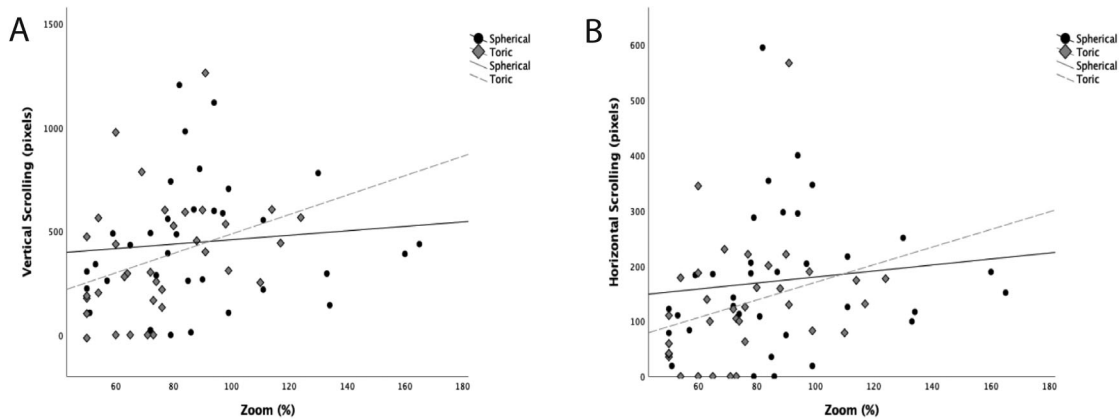
Figure 4. The relationship between zoom and horizontal (A: toric: r = −0.898, p < 0.001, spherical equivalent lenses: r = 0.880, p < 0.001) and vertical scrolling (B: toric: r = 0.857, p < 0.001, spherical equivalent lenses: r = 0.846, p < 0.001) for subjects fitted with toric and spherical equivalent lenses reading webpage articles
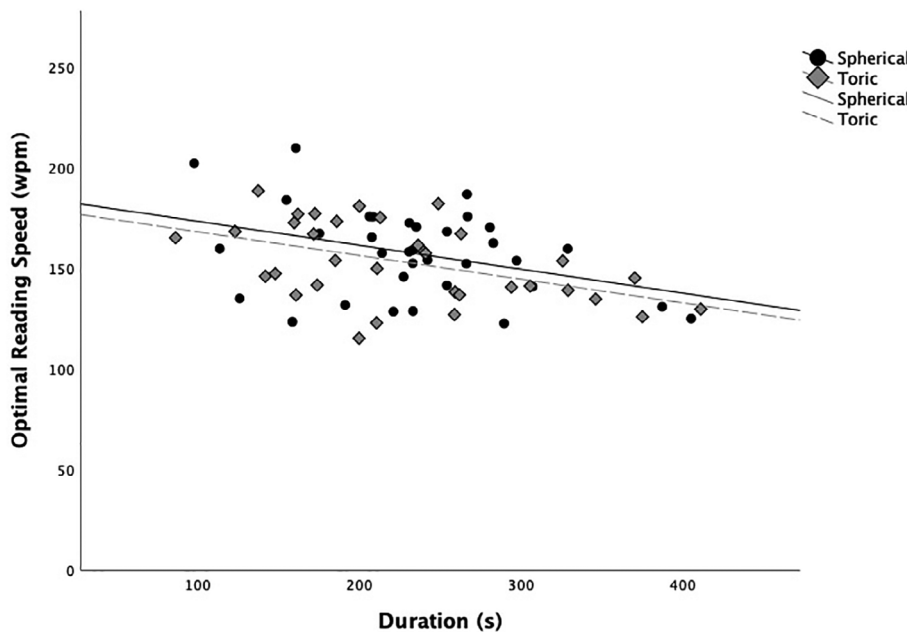

Figure 5. The relationship between reading duration on the webpage article and optimal reading speed with the Radner reading chart (toric: r = −0.956, p < 0.001; spherical equivalent lenses: r = −0.993, p < 0.001) for subjects fitted with toric and spherical equivalent lenses

zoom was associated with reading speed (r = −0.450, p = 0.008) and working distance (r = 0.522, p = 0.002, data not shown). There was a significant negative correlation between the selection of text contrast and zoom for both corrections (toric: r = −0.417, p = 0.014; sphere: r = −0.385, p = 0.025; Figure 3), such that with low contrast more zoom was required to complete the reading task. Text zoom was positively correlated with horizontal scrolling (toric: r = 0.898, p < 0.001; sphere: r = 0.880, p < 0.001) and vertical scrolling (toric: r = 0.857, p < 0.001; sphere: r = 0.846, p < 0.001; Figure 4). Simple linear regression analysis showed that only 34.5 per cent of the text zoom variance could be predicted from high and low contrast visual acuity and reading speed with toric correction, and 38.1 per cent from reading speed and distance with the best sphere (p < 0.001).

Reading duration to complete the webpage article was highly correlated with ORS from the Radner chart (r = −0.956, p < 0.001; Figure 5). CPS was also associated with webpage reading duration when subjects were corrected with the best sphere (r = 0.374, p = 0.030), but not with toric correction (r = −0.089, p = 0.618, data not shown). The distance adopted for reading the webpage was also inversely related to reading speed (r = −0.343, p = 0.047, data not shown).

Discussion

This study assessed both standard, clinical visual metrics, and real-world performance of a common digital task and how this was impacted by visual correction.

26.2 ± 5.3 years. Mean spherical refractive error was −2.93 ± 1.52 D sphere and −1.14 ± 0.27 D cylinder.

The primary results showed a significant difference in the total duration to complete the reading article with spherical equivalent contact lenses compared to toric lenses (toric: 234.78 ± 67 s, sphere: 229 ± 79 s; p = 0.047). Zoom (r = 0.926, p < 0.001), contrast (r = 0.879, p < 0.001) and working distance

(r = 0.905, p < 0.001) set/adopted by the subject at the initial set-up stage, and averaged over the whole task duration, were highly correlated. Thus, only the initial set-up data for these measures were further analysed. Preferences for text zoom were positively associated with high-contrast acuity with toric correction (r = 0.434, p = 0.010), but not with the best sphere (r = 0.247, p = 0.159; Figure 2). With best sphere correction,

Subjects' preferred tablet zoom settings were highly related to other metrics. The tasks were relatively short in duration, but the print size in the website varied from Arial 9–18 point font, thus the visual acuity demand was over a wide range. The findings suggest that even the simple task of holding the digital screen at the preferred distance, and pinching the screen to optimise the task magnification (as this was inversely correlated with contrast which is not always adjustable) provides useful additional information about the visual quality achieved by a visual correction. Only about one-third of the variance in zoom could be accounted for by traditional clinical visual metrics, and reading speed charts are rarely used in clinical practice. In this study, when the vision of the astigmatic subjects were optimally corrected with a toric contact lens, better high-contrast acuity was associated with less zoom, whereas when the vision was suboptimally corrected with the best sphere,[14] this relationship was more variable as subjects more randomly attempted to improve their ability to function. With spherical correction, the zoom was better associated with reading speed and working distance. However, the selection of text zoom and contrast did not show any correlation with the blink rate during reading performance. Similarly, horizontal and vertical scrolling did not demonstrate any increased rate of blinks.

The average time to complete the reading performance test was under two minutes hence it was at least as quick to perform as reading charts and reading speed tests,[9,15] and could provide information on other individual metrics such as preferred working distance and screen adjustments to inform the clinician as to appropriate optimisation strategies for visual performance and comfort. The test could also be used in the clinic to allow patients to get a more real-world understanding of different correction options and the best visual outcome. The subjects in this study had relatively low levels of astigmatism (average of about 1.00 D), yet performance on the iPad varied significantly with toric versus spherical equivalent correction.[14]

The limitation of this study was the visual performance app was only tested on a single platform (an Apple iPad due to the conformity between screens across devices) and not on a smartphone device as well as a tablet. However, the principal of the usefulness of real-world digital task performance has been established. In the future, it would be helpful to develop a global metric to provide summarised information from digital testing for a clinical setting.

Overall, this study has established that multiple factors are involved in successfully completing digital visual tasks. Real-work task performance is associated more strongly with visual function metrics than traditionally reported measures such as visual acuity. Digital technology offers the opportunity to better understand the impact of refractive correction on real-world task performance.

ACKNOWLEDGEMENTS

REFERENCES

1. Dorr M, Lesmes LA, Lu ZL et al. Rapid and reliable assessment of the contrast sensitivity function on an iPad. *Investig Ophthalmol Vis Sci* 2013; 54: 7266–7273.
2. Di LM, Caputo SG, Porciatti V. Nonselective loss of contrast sensitivity in visual system testing in early type I diabetes reversible retinal ganglion cell dysfunction in glaucoma view project retinal ganglion cell plasticity view project. *Diabetes Care* 1992; 15: 620–625.
3. Richman J, Lorenzana LL, Lankaranian D et al. Importance of visual acuity and contrast sensitivity in patients with glaucoma. *Arch Ophthalmol* 2010; 128: 1576–1582.
4. Aslam TM, Murray IJ, Lai MYT et al. An assessment of a modern touch-screen tablet computer with reference to core physical characteristics necessary for clinical vision testing. *J R Soc Interface* 2013; 10: 20130239.
5. Legge GE, Ross JA, Luebker A et al. Psychophysics of reading. VIII. The Minnesota low-vision Reading test. *Optom Vis Sci* 1989; 66: 843–853.
6. Black J, Jacobs R, Phillips G et al. An assessment of the iPad as a testing platform for distance visual acuity in adults. *Br J Ophthalmol* 2013; 3: e002730.
7. Woods J, Woods CA, Fonn D. Early symptomatic presbyopes-what correction modality works best? *Eye Contact Lens* 2009; 35: 221–226.
8. Radner W, Willinger U, Obermayer W et al. A new German Reading chart for the simultaneous evaluation of reading acuity and reading speed. *Klin Monbl Augenheilkd* 1998; 213: 174–181.
9. Stifter E, König F, Lang T et al. Reliability of a standardized reading chart system: variance component analysis, test-retest and inter-chart reliability. *Graefes Arch Clin Exp Ophthalmol* 2004; 242: 31–39.
10. Radner W, Diendorfer G. English sentence optotypes for measuring Reading acuity and speed - the English version of the Radner Reading charts. *Graefes Arch Clin Exp Ophthalmol* 2014; 252: 1297–1303.
11. Kollbaum PS, Jansen ME, Kollbaum EJ et al. Validation of an iPad test of letter. *Optom Vis Sci* 2014; 91: 291–296.
12. Kingsnorth A, Drew T, Grewal B et al. Mobile app Aston contrast sensitivity test. *Clin Exp Optom* 2016; 99: 350–355.
13. Kingsnorth A, Wolffsohn JS. Mobile app reading speed test. *Br J Ophthalmol* 2015; 99: 536–539.
14. Logan A, Datta A, Tomiyama E et al. Randomized clinical trial of near visual performance with digital devices using spherical and toric contact lenses. *Optom Vis Sci* 2020; 97: 518–525.
15. Dexl AK, Schlögel H, Wolfbauer M et al. Device for improving quantification of reading acuity and reading speed. *J Refract Surg* 2010; 26: 682–688.