Published in final edited form as:

Ophthalmic Physiol Opt. 2020 November ; 40(6): 801–814. doi:10.1111/opo.12735.

Validation of the Clouclip and Utility in Measuring Viewing Distance in Adults

Khob Bhandari^a, Lisa A Ostrin^{a,1}

^aUniversity of Houston College of Optometry, 4901 Calhoun Rd, Houston, TX, 77204 USA.

Abstract

Purpose: To validate the Clouclip, a continuously measuring objective rangefinder, and examine viewing behaviours during various near tasks in non-myopic and myopic adults.

Methods: In experiment 1, five Clouclip devices were utilised. An infrared camera was used to visualise and measure infrared beam size and angle. Repeatability for distance tracking was assessed from 5 to 120 cm in 5 cm increments. Accuracy of distance tracking was investigated for paper and iPad targets, spatial integration was calculated, effects of target tilt were determined and light measurements were compared to a lux meter. In experiment 2, viewing behaviour was assessed in 41 subjects (21 non-myopic, 20 myopic) during four 15-minute near tasks; a) passive reading of printed material, b) active writing on printed material, c) passive viewing on an electronic device and d) active engagement on an electronic device. Working distance was compared between tasks and refractive error groups.

Results: Clouclip distance tracking showed good repeatability, with a mean difference of 0.34 cm and limits of agreement of ± 2.0 cm. Clouclip-measured and actual distances were highly correlated for paper and electronic targets from 5 to 120 cm, with mean differences and limits of agreement of 3.96 ± 13.78 cm and 4.48 ± 8.92 cm, respectively; variability increased for distances > 100 cm. Tracking ability increased with larger target sizes; tracking was accurate when the target occupied 1.5–20.3% of tracking beam area, depending on distance and with target tilt up to ± 60 degrees. Clouclip- and lux meter-measured ambient illumination were highly correlated for a wide range of intensities ($r = 0.96$, $p < 0.001$), but with greater variability for intensities $> 20,000$ lux. The Clouclip infrared beam had a diameter of $25.6 \pm 2.2^\circ$ and a downward angle of $10.3 \pm 0.5^\circ$. For subject testing, viewing distance was significantly closer for active and passive printed tasks (29.5 ± 6.7 cm and 33.2 ± 8.8 cm, respectively) than for active and passive electronic tasks (35.4 ± 8.0 cm and 40.8 ± 10.4 cm, respectively), with no differences between refractive error groups ($p = 0.88$).

Conclusions: The Clouclip performed well in measuring near and intermediate distances and could distinguish between indoor (< 1000 lux) and outdoor (> 1000 lux) illumination. A closer working distance was observed for printed tasks compared to those on an iPad, with no difference in viewing distance between non-myopic and myopic adults.

¹corresponding author: Lisa A Ostrin (lostrin@central.uh.edu).

Disclosures: Author LO holds provisional patent No. 62/608,755, RangeLife: Continuous objective assessment of near work. The authors report no conflicts of interest and have no proprietary interest in any of the materials mentioned in this article.

Keywords

myopia; refractive error; near work; sensor technology; range finder

Introduction

Myopia, or nearsightedness, is a growing epidemic affecting an estimated 22.9% of the world population.¹ The prevalence is projected to increase twofold by 2050, with the prevalence of high myopia projected to increase from 2 to 10%. Urbanised East Asian nations, such as Hong Kong, Singapore and Taiwan, have the greatest prevalence.² The socio-economic burden associated with myopia accounts for a loss of approximately \$220 billion global gross domestic product.³ Myopia is associated with increased risks of sight threatening ocular morbidities, such as retinal detachment, choroidal neovascularisation, myopic macular degeneration, cataracts and glaucoma.⁴ More than 23% of all cases of retinal detachment occurs in eyes with high myopia.⁵ There is growing interest in elucidating the regulatory mechanisms underlying myopic eye growth to address potentially blinding complications associated with excessive axial elongation.

Refractive development is the result of a complex interaction between genetics^{6–8} and environmental and behavioural factors, such as light exposure and time spent performing near work.^{9, 10} The Sydney Myopia Study reported that the odds ratio for myopia was highest in children who spend the least time outdoors and the most time on near work.^{11, 12} Accumulating evidence confers that increased time spent outdoors is protective against myopia in children.^{13–15} However, the role of near work in refractive error development is not well understood, with conflicting findings across studies.^{16, 17}

Near work may influence eye growth because of factors related to accommodation.¹⁸ When the accommodative response is less than the accommodative demand of the near target, it is referred to as accommodative lag.¹⁹ Some studies have reported that myopic children have a higher accommodative lag compared to emmetropic children;²⁰ this lag of accommodation further induces hyperopic defocus on the peripheral and central retina, which may be a cue for the eye to grow. Increased near activities have been reported to be a risk factor for a higher prevalence and incidence of myopia.^{21, 22} A three-year study in school children showed increased near work load was associated with more myopic refractive changes.²³ Near work has been associated with myopia in university level students,²⁴ and myopia and higher education were related in a large sample study in the U.S.²⁵ However, the evidence regarding the influence of near work in myopia causation is controversial, with some studies reporting no influence of near work on myopia onset and progression.^{16, 17, 26–31}

The intensity of near work, rather than total duration, may have a role in myopia pathogenesis. In Australian school children, myopia was found to be significantly associated not only with greater duration of near work, but also closer reading distances.¹⁰ A shorter working distance was found to be significantly associated with faster progressive myopia in school children.³² Head posture, gaze angle and viewing distance have been shown to vary based on the task, and may be important factors to quantify when assessing near work behaviours. Additionally, the number of viewing breaks during near work might also be

relevant in myopia development. Advancement and implementation of devices to continuously and objectively track working distance during near work are required to assess these aspects of viewing behaviour.

Recently, investigators have utilised validated sensor technology to precisely record and monitor environmental and behavioural factors related to myopia, including light exposure, working distance, activity and sleep patterns.^{33–37} Here, we investigate the utility of the Clouclip, a small, battery-powered clip-on sensor device capable of continuous measures of near viewing distance and ambient light level.³⁸ The Clouclip has been used in myopia related behavioural studies in children,^{39–44} as well as in interventional studies, in which the device sends proximity alerts to the wearer when the reading distance is too close;^{45, 46} however, validation of the device has not yet been published. The goals of this study were to validate the range finding and light sensing capabilities of the Clouclip, and to assess the utility of the device for distance tracking during various near tasks in non-myopic and myopic adult subjects.

Methods

Five second generation Clouclip devices (Hangzhou JingZhiJing Technology Co. Ltd, www.clouclip.com) were provided by Aier Eye Hospital Group, China, and used in this study. The Clouclip is a $45.3 \times 13.4 \times 8.0$ mm device that is designed to attach to the temple of a spectacle frame via a rubber sleeve. The anterior most portion of the device emits an infrared range finding beam every five seconds and has an ambient light sensor that records illumination every two minutes. The device is Bluetooth capable and consists of a magnetic USB charger for syncing the device to an app and uploading data to the cloud. Once synchronised to the app, the stored data in the Clouclip device were uploaded to the cloud platform, from where using provided login credentials, raw data consisting of date and time-tagged viewing distances and light levels were downloaded as an Excel (Microsoft, www.microsoft.com) spreadsheet. Reported range of the second generation Clouclip for distance tracking is 5 to 120 cm, with a 25° beam diameter and a 10° inferiorly directed beam angle, and 1 to 655,336 lux for ambient illumination measurement.^{47, 48}

Experiment 1: Validation

To examine the validity and capabilities of the Clouclip, five devices were tested under a variety of conditions. First, beam diameter and measurement angle were measured for distances of 5–120 cm. Then, repeatability, accuracy, spatial integration and effects of target tilt on distance tracking were assessed. Finally, ambient illumination measurements were compared to a lux meter under different indoor and outdoor environments.

Diameter and Angle of Distance Tracking Beam—Beam diameter and angle were determined for the five devices by viewing the incident infrared beam in a dark room (< 1 lux) on a calibrated target that consisted of printed concentric circles on white paper (Figure 1). An infrared camera (DSP B/W CCD, Supercircuits, www.supercircuits.com) and monitor (HLT71, Haier, www.haier.com) were used to capture an image of the beam, and these images were examined frame-by-frame to visualise and measure the size of the incident beam on the target. The distance between the Clouclip and the target was increased from 5 to

85 cm in 5 cm incremental steps; 85 cm was the farthest distance that the incident beam could reliably be visualised using the infrared camera. Additionally, the angle of the beam from the horizontal line of sight was determined. The beam angle was measured for 5 different distances, from 10 to 50 cm in 10 cm incremental steps. The midpoint of the target was aligned along the horizontal line passing through the middle axis of the device. Visualising the image from the infrared camera, the displacement of the emitted infrared beam from the centre of the target was determined. The tangent of the angle subtended by the displacement was calculated as the beam angle.

Repeatability of Distance Tracking—To assess the repeatability of distance tracking, five devices were each tested on two different days for distances of 5–120 cm in 5 cm incremental steps against a white wall. Measurements were performed in standard indoor room illumination (300–400 lux). The devices were mounted to the right temple of a spectacle frame and placed on a mannequin head on a height adjustable lab table with wheels. The devices were directed straight ahead towards the wall. A millimetre scale was taped on the floor to guide the distance increment. For each distance tested, the device was maintained at that position for 30 seconds. The device goes into “sleep” mode if no motion is detected for 40 seconds, and moving the device along the path was not sufficient to activate the built-in triaxial accelerometer. We found that in order to prevent the device from going into sleep mode, it was necessary to tilt the mannequin head from side to side before continuing with each subsequent distance measurement.

Accuracy of Distance Tracking—To assess the accuracy of distance tracking for commonly viewed targets, each of five Clouclip devices was tested against two different types of targets, a paper target and an iPad (iPad Air 2, Apple, www.apple.com), for distances of 5–120 cm in 5 cm incremental steps. The paper target consisted of black text printed on a white sheet of A4 paper in portrait orientation. The iPad had a 9.7-inch screen size and was set to play a movie in portrait orientation during testing to simulate what a Clouclip wearer may be viewing. Each device was individually positioned on the mannequin head, as described above, and held at each distance for 30 seconds, tilting the device before moving to the next increment.

Spatial Integration of Tracking Beam—To model the spatial integration of the tracking beam, i.e., how much area of the tracking beam must be filled with the target for the device to capture an accurate distance measurement, five devices were tested for seven target sizes at distances of 5–120 cm in 5 cm increments. As described above, the devices were positioned on the mannequin head, and held at each distance for 30 seconds, tilting the device before moving to the next increment. Seven targets were cut from cardboard, 2×2 cm, 4×4 cm, 6×10 cm, 8×8 cm, 8×16 cm, 14×16 cm, and 16.5×24 cm. These target sizes included the average sizes of an Apple iPhone (8×16 cm) and a 9.7 inch screen size iPad Air 2 (16.5×24 cm), as well as other sizes of potential small targets that a wearer may view, such as books (Figure 2A). The infrared camera was used during testing to ensure that the beam was centred over the target. The maximum distance that the target was accurately tracked was determined for each target size.

Effects of Target Tilt—When the Clouclip is mounted to a child's spectacles, it is likely that the tracking beam will not be incident with the target at an exactly perpendicular angle. Therefore, to assess the effects of target tilt, a letter sized paper target (22 × 28 cm) was placed at 30 cm from each device, and Clouclip-measured distances were determined with the target oriented at a perpendicular angle to the incident beam (i.e. 0° tilt), with the target tilted away from the device at 30, 60 and 90°, and tilted towards the device at −30, −60, and −90° (Figure 2B). Note that at 0° tilt, the target was in a vertical position (perpendicular to the beam angle), and at ± 90°, the target was in a horizontal position (along the same axis as the beam).

Ambient Illumination—To assess ambient illumination measurements by the Clouclip, devices were mounted to a spectacle frame and placed in various indoor and outdoor locations, including optometry building classrooms, hallways and common areas, and outdoors in shade and full illumination. For each location, Clouclip-measured light levels were compared to those from a lux meter (Dr. Meter LX1330B, www.drmeter.com). The sensor of the lux meter was oriented along the line of sight at the same level as the Clouclip. Each light level was maintained for at least four minutes, and at least two measurements, two minutes apart, were recorded with the lux meter.

Analysis—Following each measurement session, Clouclip devices were synchronised to the app installed on a smart phone via Bluetooth and uploaded to the cloud created by the developer. Correlation and scatter plots were used to visualise the relationship between actual and measured values, and a linear regression was fitted for the 5–120 cm distance range. For light level measurements, regression analysis was performed to compare lux meter-measured and Clouclip-measured ambient illumination for the range of indoor and outdoor environments tested. Bland-Altman analyses were used to assess the repeatability and accuracy of distance tracking and ambient illumination measurements, and mean and 95% limits of agreement were determined.

Experiment 2: Viewing Behaviours

For assessing viewing behaviours in non-myopic and myopic young adults, 41 healthy young adult subjects aged 26.57 ± 5.05 years (range 18–39 years) participated. Ethical approval was obtained from the Committee for Protection of Human Subjects at the University of Houston, and all procedures adhered to the tenets of the Declaration of Helsinki. All subjects provided written informed consent after learning about the study and before participating.

Self-reported ocular and systemic health details were recorded. Subjects' height and Harmon distance were measured in the lab. Harmon distance was measured as the distance from the elbow to the middle knuckle while placing their hand on a table and making a fist. All subjects had visual acuity of 6/7.5 or better with habitual refractive corrections. Unilateral and alternating cover tests were performed to rule out excessive phoria or a tropia. Non-cycloplegic refraction was measured (WAM-5000 autorefractor, Grand Seiko, www.grandseiko.com) and biometry performed (LenStar LS900 optical biometer, Haag-Streit, www.haag-streit.com). Five measurements were taken in each eye and

averaged. Subjects were grouped by spherical equivalent refractive error, with non-myopes > −0.5 D and myopes ≤ −0.5 D.

Of the five Clouclip devices that were validated and calibrated in experiment 1, we used four of them for subject testing in experiment 2. Specifically, we did not use “device 4,” which was shown to be less reliable for distances beyond 80 cm. The Clouclip was mounted on the right temple of the subject’s habitual spectacle frame (for myopes) or a provided frame with plano lenses (for non-myopes) with an additional 10 degree downward tilt. The infrared beam from the Clouclip device has a 10 degree downward tilt built in to track the target. However, based on in-lab observations using the infrared camera, it was found that when subjects held a book or iPad in a chair, an additional 10 degree downward tilt was necessary for the beam to reliably capture the viewing targets used in this experiment. During downward gaze, the additional tilt helped to align the centre of the tracking beam to the centre of the reading materials. Subjects were instructed to wear the glasses throughout the test period, which included four different 15-minute near tasks; a) passive reading of printed material, b) active writing of printed material, c) passive viewing on an electronic device and d) active engagement on an electronic device. The order of the four tasks was randomised, and subjects were given a five minute break between tasks.

For passive reading of printed material, subjects were instructed to read a printed novel (22.5 cm × 14.5 cm) at their preferred habitual reading distance. Font size was approximately 8.5–10 point. For the active task on printed material, subjects were provided with colouring sheets, word puzzles, and Sudoku, printed on white A4 paper. For the passive electronic task, subjects watched a movie on an iPad (9.7-inch screen). For the active electronic task, subjects played a video game (Angry Birds, Rovio, www.rovio.com) on an iPad.

Analysis—Following the completion of all four near tasks, the Clouclip was synced to the app and the raw data were downloaded from the cloud. The time-tagged data were separated by task. During each 15-minute task, the mean viewing distance, excluding breaks where it was evident that the subject looked away from the near target, was determined. Statistical analysis was performed in SPSS (IBM, www.ibm.com). A repeated measures ANOVA was used to assess the mean viewing distance by task (within-subjects factor) and refractive error group and gender (between-subjects factors). Gender was included as it has been shown to influence viewing distance in a previous study.⁴⁹ To assess if viewing distances vary over time and differ between non-myopes and myopes, the viewing distances recorded over 15 minutes were binned into three time periods, 0 to < 5 minutes, 5 to < 10 minutes, and 10 to 15 minutes, and compared using a repeated measure ANOVA. Bonferroni corrected post-hoc comparisons were performed when indicated.

Results

Experiment 1: Validation

Diameter and Angle of Distance Tracking Beam—The infrared beam emitted by the Clouclip was measured to be $25.63 \pm 2.22^\circ$ (range 22.95–32.43°). The beam diameter demonstrated a linear relationship with distances from 5 to 85 cm (Figure 3); beyond 85 cm, the beam could not be consistently viewed using the infrared camera. The infrared beam size

can be obtained with a linear regression equation $y = 0.40x + 1.8$. For a distance of 15 cm, mean beam diameter was 7.30 ± 0.44 cm ($27.16 \pm 1.43^\circ$), and for a distance of 60 cm, the beam diameter was 26.10 ± 0.74 cm ($24.62 \pm 0.62^\circ$). The beam angle was measured to be $10.3 \pm 0.52^\circ$ downwards (range 9.52 – 10.97°).

Repeatability of Distance Tracking—For distances measured on two separate days for the range of 5–120 cm, all five devices demonstrated good repeatability. The mean difference for each device ranged from -1.0 to $+0.6$ cm, with the limits of agreement ranging from -4.5 to $+4.5$ cm (Table 1). For all devices, mean difference was -0.3 cm between measurement days and the limits of agreement was ± 2.0 cm (Figure 4).

Accuracy of Distance Tracking—Distance tracking was assessed for the reported operational range of the Clouclip (5–120 cm), as well as for a limited range of 15–60 cm, which is the typical range of near to intermediate viewing distances for children.

We found that 4 of the 5 devices tested measured reliably up to 120 cm. The fifth device measured reliably up to 80 cm. Beyond these distances, the Clouclip data indicated an “out of range” measurement. Clouclip-measured distances were highly correlated with actual distances for the paper target ($R^2 = 0.98$, $p < 0.001$, Figure 5A) and the iPad ($R^2 = 0.96$, $p < 0.001$, Figure 5B). For this full range of 5–120 cm, Bland-Altman analysis of actual distances versus Clouclip-measured distances showed a mean difference of 4.0 cm (limits of agreement ± 13.8 cm) for the printed target (Figure 5C) and mean difference of 4.5 cm (limits of agreement ± 9.0 cm) for the electronic target (Figure 5D). As observed in Figure 5, differences between Clouclip-measured and actual distances were primarily driven by distances > 100 cm.

Considering just near to intermediate distances of 15–60 cm, tracking was more accurate. The mean difference in measurements between two days was -0.4 ± 1.3 cm with limits of agreement ± 2.5 cm. For both the paper and iPad targets, measured distances were highly correlated with actual distances: paper target ($R^2 = 0.99$, $p < 0.0001$) and iPad target ($R^2 = 0.99$, $p < 0.0001$). The mean difference between the actual and measured distances for the paper and iPad targets were -0.4 ± 0.8 cm (limits of agreement ± 1.5 cm) and $+0.5 \pm 0.8$ cm (limits of agreement ± 1.5 cm), respectively.

Spatial Integration of Tracking Beam—The maximum distance that each target size could be accurately tracked (by at least one device) is shown in Table 2. All Clouclip devices were able to track the smallest target (2×2 cm) up to 20 cm, with some devices tracking up to 40 cm. The maximum tracking distance increased with increased target size, as it enabled more of the tracking beam to fall on the target. For each target size, the area of the target was divided by the area of the tracking beam at the maximum tracking distance which provided the percentage of the beam that was occupied by the target. Results showed that the target had to occupy the central 1.5–20.3% of the beam in order to be tracked. These findings suggest that the Clouclip device has the ability to track relatively small targets, such as an iPhone.

Effects of Target Tilt—All Clouclip-recorded distances for baseline straight ahead positions were within ± 1 cm from the actual test distance (30 cm). For 90 degree positioning of the target in either direction (target was horizontal), the devices did not capture the distance, and they were shown as out of range. All measured values were lower than the test distance for oblique target positions. Figure 6 shows the recorded distances for different target orientations. Paired sample t-test was done to compare measured distances at baseline condition to measured distances at four different oblique positions. There was no significant difference between baseline distances and distances recorded for oblique target positions for all angles except for +60 degrees, for which a closer reading was seen (mean difference = -4.4 ± 2.0 cm; $p = 0.007$).

Ambient Illumination—Light intensities measured for indoor and outdoor conditions showed that the lux meter and Clouclip were highly correlated for a wide range of intensities ($r = 0.96$, $p < 0.001$, Figure 6A). The mean difference in light levels measured with a lux meter and the Clouclip was 1670.4 ± 4060.91 lux with limits of agreement of ± 7959.38 lux. Figure 7A shows the light levels recorded with Clouclip devices in various indoor and outdoor conditions. Bland-Altman analysis showed that variability was greater for $> 20,000$ lux (Figure 7B). While the Clouclip tended to underestimate illumination compared to the lux meter, the Clouclip reliably detected “outdoor” illumination, i.e. > 1000 lux, when tested outdoors.

Experiment 2: Viewing Behaviours

Subject demographics are presented in Table 3. Forty-one subjects, ages 26.57 ± 5.05 years, participated (26 male, 15 female) in the study. The spherical equivalent refractive error in non-myopes ($N = 21$) was $+0.09 \pm 0.39$ D (range -0.01 to $+1.0$ D), and in myopes was -2.88 ± 1.49 D (range -1.0 to -4.75 D). Myopes had significantly longer axial lengths compared to non-myopes ($p = 0.0006$). Interestingly, the myopic group was significantly shorter in height than the non-myopic group in this population ($p = 0.01$). Subjects’ height and Harmon distances showed a significant positive correlation ($R^2 = 0.55$, $p < 0.0001$).

A representative example of the raw Clouclip data for one 15-minute near task is shown in Figure 8. Mean Clouclip-measured viewing distances for each of the near tasks are presented in Figure 9 and Table 4. On average, we obtained 14.54 ± 1.5 minutes of valid data for each 15-minute task. Data were lost when the subjects were so still that the device went into sleep mode while they were wearing it. Additionally, some data points were recorded as “out of range,” which was most likely due to the subject’s taking viewing breaks. However, we speculate that some “out of range” data points occurred when the infrared beam did not capture the target because the viewing angle was lower than the angle of the Clouclip.

The average viewing distance for all subjects for passive printed, active printed, passive electronic and active electronic tasks were 33.2 ± 8.8 cm (accommodative demand 3.0 D), 29.5 ± 6.7 cm (accommodative demand 3.4 D), 40.8 ± 10.4 cm (accommodative demand 2.5 D) and 35.4 ± 8.0 cm (accommodative demand 2.8 D), respectively. Repeated measures ANOVA showed that mean viewing distance was significantly different among the four tasks ($p < 0.001$), but not between refractive error groups ($p = 0.88$) or by gender ($p = 0.1$). Post-

hoc pairwise comparisons revealed that viewing distance for the active printed task was significantly closer than for the passive printed ($p = 0.002$), passive electronic ($p < 0.001$) and active electronic ($p < 0.001$) tasks. Viewing distance for the active electronic task was significantly closer than for the passive electronic task ($p < 0.001$). Viewing distance for the passive printed task was closer than for the passive electronic task ($p < 0.001$). Viewing distances for four near tasks were not significantly correlated with the spherical equivalent distance refraction. A significant correlation between Harmon distance and viewing distance was seen only for the passive electronic task ($R^2 = 0.01$, $p = 0.04$). Multiple regression analysis incorporating subjects' heights along with Harmon distances showed that there were no significant correlations between viewing distance and height for all tasks, and viewing distance and Harmon distance were significantly correlated only for passive electronic task (adjusted $p = 0.03$).

If the Clouclip does not detect movement for 40 seconds, then the device goes into sleep mode. The number of occasions the device goes to sleep may depend on how intently subjects look at the near material. Therefore, we counted the duration and the number of occasions Clouclip devices went to sleep for each subject and task. On average, for 4 different near tasks and for all 41 subjects, the devices stopped tracking on 0.25 ± 0.49 occasions. Each time the device went to sleep, about two minutes of data were lost. The average number of occasions the device went to sleep in non-myopes was 0.29 ± 0.37 (range: 0–5), and in myopes was 0.21 ± 0.59 (range: 0–5). The number of occurrences was similar between non-myopes and myopes ($p = 0.60$), and between the four tasks ($p = 0.75$, repeated measures ANOVA).

Viewing distances binned into three time periods (0 to < 5 minutes, 5 to < 10 minutes and 10–15 minutes) were similar across the three time periods for all near tasks and were similar between non-myopes and myopes ($p > 0.05$ for all, repeated measure ANOVA).

To further analyse the results based on the level of the subject's engagement and the modality of task presentation, viewing distances were compared between passive versus active tasks, and printed paper- versus electronic-based near tasks. The averaged viewing distance for passive and active tasks were 37.0 ± 8.5 cm (2.7 D) and 32.4 ± 6.5 cm (3.08 D) respectively. Active tasks were performed at significantly closer distances (on average 4.6 ± 5.3 cm closer) than passive near tasks ($p < 0.0001$, paired t-test). However, the viewing distances did not differ by gender or the type of refraction between active and passive tasks. Similarly, the viewing distances for paper-based and iPad-based near tasks were 31.3 ± 7.3 cm (3.20 D) and 38.1 ± 8.2 cm (2.62 D) respectively. Paper-based tasks were performed at significantly closer distance (average: 6.7 ± 6.3 cm closer) than iPad-based near tasks ($p < 0.0001$, paired t-test). However, the viewing distances did not differ by gender or the type of refraction for both modalities of task presentation. Table 5 summarises the p values for two-way ANOVA comparison between non-myopes and myopes for near viewing distances.

Discussion

Precise quantification of visual activity is important in understanding the role of near work and light exposure in eye growth and myopia development. Quantification of these

behaviours is challenging. Traditionally used subjective methods to assess near work and time outdoors are prone to poor memory recall, biases and over- or under-estimation.^{50, 51} With the use of continuous and objectively measuring range finding and light sensing devices, visual activity can be more precisely assessed in real time under a variety of conditions. The results of this study demonstrate that the Clouclip showed good repeatability and accuracy for near and intermediate distance tracking; however, results for far intermediate distances and beyond should be taken cautiously. The Clouclip was capable of tracking eye level illumination, with the ability to distinguish between indoor and outdoor light levels. Additionally, the Clouclip demonstrated utility in assessing near viewing behaviours in adult subjects performing paper- and electronic-based tasks. The light weight of the Clouclip, long battery life, and frequent sampling rate make the Clouclip a useful tool to assess behaviours known to be risk factors for myopia. These results provide rationale for conducting similar studies in children to investigate near viewing behaviours with regard to myopia. With real time objective data, information regarding the temporal pattern of myopiagenic stimuli can provide further insight into the role of near work in myopia pathogenesis.

The Clouclip has been specified by the developers to be reliable for near and intermediate distances ranging from 5 to 120 cm, with a beam size of 25° and downward angle of 10°. For validation, we assessed five Clouclip devices that were provided by the manufacturer. We found that the devices were repeatable and reliable for near and intermediate distances. However, one of the five devices could not reliably track distances greater than 80 cm. Williams *et al.* provide a classification of near viewing distances that are relevant for myopia-related studies, ranging from extremely near (10–20 cm) to far intermediate (90–100 cm), and showed that most near work activities are performed indoors, i.e., illuminance < 1000 lux.³⁷ Our findings suggest that overall, the Clouclip is able to quantify this range of viewing distances. Because some differences were noted between devices with respect to the range of accurate distance tracking beyond 80 cm, it is suggested that investigators calibrate each Clouclip device before utilising them in studies. However, it is unlikely that a child would hold reading material or hand-held electronic devices, or view a computer, beyond 80 cm; therefore, our findings suggest that the Clouclip can be a valuable tool to objectively quantify near viewing.

In this study, measurements of beam size and angle were similar to those reported by the manufacturer. Beam size is an important metric, because it provides information on the size of a target that can be reliably captured by the device. For example, we found that at a distance of 15 cm, the beam diameter is approximately 7 cm. Therefore, it would be expected that the device is capable of detecting a small target, such as a hand-held smartphone. The beam angle emitted from the Clouclip is downward 10°. Generally, near work is performed in downward gaze. The Clouclip is attached to the spectacle frame, and therefore aligned with head angle and not necessarily viewing angle. The additional 10° downward angle of the Clouclip beam is designed to account for the discrepancy between head angle and viewing angle. However, we found that 10° was not always sufficient to capture the target, and it was necessary to mount the Clouclip on the spectacle frame with an additional 10° downward tilt for the tasks in this study.

In an effort to understand the spatial integration characteristics of the Clouclip tracking beam, we measured tracking ability for seven different-sized targets. These measurements were important to undertake to understand if small targets can be captured by the tracking beam. For example, an iPhone (approximately 8×16 cm) held at 30 cm in portrait orientation subtends a horizontal angle of 15.2° , and the reported diameter of the Clouclip infrared tracking beam is 25° ; therefore, we were interested to know if the tracking beam would capture the distance of the iPhone or the distance of the objects behind the iPhone. Our findings show that targets as small as 4×4 cm are tracked properly up to 55 cm, and the tracking capability increases with larger targets. Additionally, the Clouclip was robust in measuring tilted targets ($\pm 60^\circ$); therefore, material that is tilted with respect to the Clouclip beam, such as paper on a desk or an iPad in a lap, will likely be accurately tracked.

Viewing behaviours are complex and diverse, with factors including duration, number of viewing breaks taken and absolute viewing distance.⁵² Animal studies show that experimental myopia is dependent upon the temporal pattern of imposed form deprivation or defocus, rather than the total time period of myopiagenic stimuli.^{15, 53} In chicks, brief interruptions of form deprivation with normal viewing breaks resulted in reduced magnitude of myopia.⁵³ This supports the hypothesis that reading breaks or intermittent periods of fixation changes, rather than sustained near work, might be beneficial in reducing myopiagenic stimuli. Li *et al.* showed that, in humans, continuous reading and a closer reading distance were significantly associated with myopia.⁵⁴ Questionnaires and diaries⁵⁵ are not capable of capturing absolute viewing distance or viewing breaks.^{50, 51} Other studies have utilised the experience sampling method, which requires the subject to record activities at discrete time points during the day.^{56, 57} While this method minimises limitations of recall error, only a limited number of time points are captured each day, results depend upon a subjective response and similar to questionnaires and diaries, absolute viewing distance and viewing breaks cannot be captured. In order to fully quantify the complex nature of viewing behaviour relevant to myopia, objective continuously measuring devices must be used.

In this study, we evaluated viewing behaviour during four different 15-minute near tasks. The specific tasks evaluated were those that are likely to be performed by children and adolescents, specifically reading books, writing on paper and watching and actively engaging with electronic devices. We found that subjects demonstrated shorter working distances for tasks on paper compared to those on an iPad, with no differences between non-myopes and myopes. From the continuous data recorded, which were binned into three time periods, we found no significant variation in viewing distances over 15 minutes between non-myopic and myopic subjects. In a previous study, Hartwig *et al.* assessed eye and head movements during three different near tasks using a helmet-mounted eye tracker and motion sensor in non-myopes and myopes.⁴⁹ Tasks included reading on a screen, reading a printed book, and writing on paper. The authors found that there were no differences in working distance, eye movements or head movements between non-myopes and myopes. However, they reported a positive correlation between mean spherical equivalent and working distance for reading a book and more myopic refractive error was associated with closer working distances. In their study, each reading task lasted for only one minute, which may not have been sufficient time for participants to adopt their habitual position. Leung *et al.* compared viewing distances as measured with a novel head-mounted ultrasonic device during 10

minute reading tasks in young adults with high myopia, low myopia or emmetropia.⁵⁸ A closer working distance was reported for high myopes, whereas more variable and a wider range of working distances were observed for low myopes and emmetropes.

There are several factors that may have influenced the subject's working distance in our study. Subjects were somewhat limited in position based on the experimental set up in the lab, which included a freestanding chair for reading and electronic tasks, and a fixed desk and chair for the active printed task. Future studies taking place in the subjects' habitual environments would be informative. For tasks on electronic media, we utilised a full-size iPad, which is one of the larger forms of hand-held electronic device. Smart phones, for example, are significantly smaller and may be held at a closer working distance than a full-size iPad. A study from 2010 showed that 75% of children aged 12–17 years in the U.S. have their own cell phone,⁵⁹ and a recent study showed smartphone ownership was 84% among 13 to 18 year olds.⁶⁰ Thus, assessing viewing behaviours with a variety of electronic media, including smartphones, may help to better understand visual activity.

Time outdoors has been shown to be protective for myopia.^{13, 61–64} To better understand the role of time outdoors in myopia onset and progression, it is essential to quantify duration of time spent outdoors, as well as absolute light level. Light intensities greater than 1000 lux are commonly used as a proxy method to define outdoor environment,^{35, 65} which ranges from 1000 lux to greater than 150,000 lux.^{35, 65, 66} Here, we compared ambient illumination as measured with the Clouclip to that measured with a commercially available lux meter. We found that while the Clouclip measured slightly lower illumination than the light meter, the Clouclip and lux meter were well correlated, and the Clouclip was generally able to distinguish between indoor (< 1000 lux) and outdoor (≥ 1000 lux) environments. We speculate that differences between the Clouclip and lux meter may be due to differences in the size and orientation of the detector. The light sensor of the Clouclip is an integrated chip with an exposure area of approximately 2 × 2 mm. On the other hand, the lux meter consists of an integrating sphere with a diameter of approximately 28 mm. The Clouclip light sensor has an advantage over other commonly used light sensors in myopia research, in that it is positioned at eye level, and therefore may better represent ambient illumination reaching the eye compared to a sensor mounted on the arm or around the neck, such as the Hobo light monitor, or wrist worn, such as the Actiwatch.^{33, 36, 67–69} However, we did not assess ambient illumination with the Clouclip oriented in different directions, which may affect measurements.

One limitation in this study was that a cycloplegic agent was not instilled prior to autorefraction. All subjects were young adults, and an open-field auto refractor was used to measure refractive error. While it is possible that subjects may have been accommodating during the measurement leading to misclassification into the myopic refractive error group, we were also able to confirm the classification through unaided visual acuity and habitual correction. Additional limitations were noted with the Clouclip. The device goes into “sleep” mode if no movement is detected for 40 seconds. We found that for subjects who were particularly still during the near tasks, the device went into sleep mode, resulting in a loss of a few minutes of data for one or more tasks. For data collection in children in our lab (unpublished), we have not yet had any subjects who were so still that the device went into

sleep mode, so this may not be a concern with a younger population. Furthermore, the Clouclip is fixed to the temple of the spectacle frame and does not necessarily coincide with the line of sight. We found that the infrared beam occasionally missed the target during the passive printed task because the beam was not angled downward enough to capture the book; subjects tended to position the book in their lap. Because of these limitations, we were unable to accurately quantify viewing breaks in this study because “out of range” measures from missing the target versus true viewing breaks could not be distinguished. However, these limitations will be addressed in future studies by increasing the downward beam angle by mounting the device with additional tilt on the spectacle frame, and confirming that the infrared beam is directed at the target using the infrared camera during subject testing. The development of devices that include eye trackers would allow a more accurate tracking of the viewing angle, as well as vergence. However, this technology would not be as small and portable as the Clouclip, which is a necessary feature for continuous measurement of behaviours in children. The sampling rate of the Clouclip is five seconds; therefore, rapid viewing breaks may be missed. An increased sampling frequency may provide a more precise measure of viewing breaks. Another limitation in this study is that we did not measure head or viewing angle while subjects performed near tasks. This information would be useful to more fully describe viewing behaviours and will be collected in future studies.

In conclusion, the Clouclip was shown to provide reliable measurements of ambient illumination and viewing distance during near work. We found that viewing behaviours differed with the type of near work performed. There were no differences observed in viewing distance between non-myopic and myopic adults. Further studies utilising the Clouclip and including a large sample of children performing a variety of tasks will provide a better understanding of the role of environmental and behavioural factors in myopia onset and progression.

Acknowledgements:

The authors thank Weizhong Lan for kindly providing the Clouclip devices. This study was funded by NIH P30 EY007551.

References

1. Holden BA, Fricke TR, Wilson DA, Jong M, Naidoo KS, Sankaridurg P, et al. Global Prevalence of Myopia and High Myopia and Temporal Trends from 2000 through 2050. *Ophthalmology*. 2016;123:1036–1042. [PubMed: 26875007]
2. Morgan IG, French AN, Ashby RS, Guo X, Ding X, He M, et al. The epidemics of myopia: Aetiology and prevention. *Prog Retin Eye Res*. 2018;62:134–149. [PubMed: 28951126]
3. Fricke TR, Holden BA, Wilson DA, Schlenther G, Naidoo KS, Resnikoff S, et al. Global cost of correcting vision impairment from uncorrected refractive error. *Bulletin of the World Health Organization*. 2012;90:728–738. [PubMed: 23109740]
4. Walline J, Smith M. Controlling myopia progression in children and adolescents. *Adolesc Health Med Ther*. 2015:133–140. [PubMed: 26316834]
5. Polkinghorne PJ, Craig JP. Northern New Zealand Rhegmatogenous Retinal Detachment Study: epidemiology and risk factors. *Clin Exp Ophthalmol*. 2004;32:159–163. [PubMed: 15068432]
6. Hammond CJ, Snieder H, Gilbert CE, Spector TD. Genes and environment in refractive error: The twin eye study. *Invest Ophthalmol Vis Sci*. 2001;42:1232–1236. [PubMed: 11328732]

7. Lyhne N, Sjlíe AK, Kyvik KO, Green A. The importance of genes and environment for ocular refraction and its determiners: A population based study among 20–45 year old twins. *Br J Ophthalmol*. 2001;85:1470–1476. [PubMed: 11734523]
8. Verhoeven VJM, Hysi PG, Wojciechowski R, Fan Q, Guggenheim JA, Hhn R, et al. Genome-wide meta-analyses of multiancestry cohorts identify multiple new susceptibility loci for refractive error and myopia. *Nature Genetics*. 2013;45:314–318. [PubMed: 23396134]
9. Ip JM, Rose KA, Morgan IG, Burlutsky G, Mitchell P. Myopia and the Urban Environment: Findings in a Sample of 12-Year-Old Australian School Children. *Invest Ophthalmol Vis Sci*. 2008;49:3858–3863. [PubMed: 18469186]
10. Ip JM, Saw S-M, Rose KA, Morgan IG, Kifley A, Wang JJ, et al. Role of Near Work in Myopia: Findings in a Sample of Australian School Children. *Invest Ophthalmol Vis Sci*. 2008;49:2903–2910. [PubMed: 18579757]
11. Huang HM, Chang DST, Wu PC. The association between near work activities and myopia in children - A systematic review and meta-analysis. *PLoS ONE*. 2015;10:e0140419. [PubMed: 26485393]
12. Rose KA, Morgan IG, Ip J, Kifley A, Huynh S, Smith W, et al. Outdoor Activity Reduces the Prevalence of Myopia in Children. *Ophthalmology*. 2008;115:1279–1285. [PubMed: 18294691]
13. Sherwin JC, Reacher MH, Keogh RH, Khawaja AP, MacKey DA, Foster PJ. The association between time spent outdoors and myopia in children and adolescents: A systematic review and meta-analysis. *Ophthalmology*. 2012;119:2141–2151. [PubMed: 22809757]
14. O'Donoghue L, Kapetanakis VV, McClelland JF, Logan NS, Owen CG, Saunders KJ, et al. Risk Factors for Childhood Myopia: Findings From the NICER Study. *Invest Ophthalmol Vis Sci*. 2015;56:1524–1530. [PubMed: 25655799]
15. Norton TT, Siegart JT, Amedo 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. [PubMed: 17065475]
16. Mutti DO, Zadnik K. Has near work's star fallen? *Optom Vis Sci*. 2009;86:76–78. [PubMed: 19156003]
17. Low W, Dirani M, Gazzard G, Chan YH, Zhou HJ, Selvaraj P, et al. Family history, near work, outdoor activity, and myopia in Singapore Chinese preschool children. *Br J Ophthalmol*. 2010;94:1012–1016. [PubMed: 20472747]
18. Saw S-M, Hong C-Y, Chia K-S, Stone RA, Tan D. Nearwork and myopia in young children. *The Lancet*. 2001;357:390.
19. Correction of Myopia Evaluation Trial 2 Study Group for the Pediatric Eye Disease Investigator G, Manny RE, Chandler DL, Scheiman MM, Gwiazda JE, Cotter SA, et al. Accommodative lag by autorefraction and two dynamic retinoscopy methods. *Optom Vis Sci*. 2009;86:233–243. [PubMed: 19214130]
20. Gwiazda J, Thorn F, Bauer J, Held R. Myopic children show insufficient accommodative response to blur. *Invest Ophthalmol Vis Sci*. 1993;34:690–694. [PubMed: 8449687]
21. French AN, Morgan IG, Mitchell P, Rose KA. Risk factors for incident myopia in Australian schoolchildren: The Sydney Adolescent Vascular and Eye Study. *Ophthalmology*. 2013;120:2100–2108. [PubMed: 23672971]
22. Da Ramamurthy. A review of environmental risk factors for myopia during early life, childhood and adolescence. *Clin Exp Optom*. 2015;98:497–506. [PubMed: 26497977]
23. Lin Z, Vasudevan B, Mao GY, Ciuffreda KJ, Jhanji V, Li XX, et al. The influence of near work on myopic refractive change in urban students in Beijing: a three-year follow-up report. *Graefes Arch Clin Exp Ophthalmol*. 2016;254:2247–2255. [PubMed: 27460281]
24. Kinge B, Midelfart A, Jacobsen G, Rystad J. The influence of near-work on development of myopia among university students. A three-year longitudinal study among engineering students in Norway. *Acta Ophthalmol Scand*. 2000;78:26–29. [PubMed: 10726783]
25. Nickels S, Hopf S, Pfeiffer N, Schuster AK. Myopia is associated with education: Results from NHANES 1999–2008. *PLoS ONE*. 2019;14:e0211196. [PubMed: 30695049]

26. Jones-Jordan LA, Mitchell GL, Cotter SA, Kleinstein RN, Manny RE, Mutti DO, et al. Visual Activity before and after the Onset of Juvenile Myopia. *Invest Ophthalmol Vis Sci.* 2011;52:1841–1850. [PubMed: 20926821]
27. Jones LA, Sinnott LT, Mutti DO, Mitchell GL, Moeschberger ML, Zadnik K. Parental History of Myopia, Sports and Outdoor Activities, and Future Myopia. *Invest Ophthalmol Vis Sci.* 2007;48:3524–3532. [PubMed: 17652719]
28. Lin Z, Gao TY, Vasudevan B, Ciuffreda KJ, Liang YB, Jhanji V, et al. Near work, outdoor activity, and myopia in children in rural China: the Handan offspring myopia study. *BMC Ophthalmol.* 2017;17:203. [PubMed: 29149871]
29. Mutti DO, Mitchell GL, Moeschberger ML, Jones LA, Zadnik K. Parental myopia, near work, school achievement, and children's refractive error. *Invest Ophthalmol Vis Sci.* 2002;43:3633–3640. [PubMed: 12454029]
30. Saw SM, Nieto FJ, Katz J, Schein OD, Levy B, Chew SJ. Factors related to the progression of myopia in Singaporean children. *Optom Vis Sci.* 2000;77:549–554. [PubMed: 11100893]
31. Saw S-M, Shankar A, Tan S-B, Taylor H, Tan DTH, Stone RA, et al. A Cohort Study of Incident Myopia in Singaporean Children. *Invest Ophthalmol Vis Sci.* 2006;47:1839–1844. [PubMed: 16638989]
32. Hsu CC, Huang N, Lin PY, Tsai DC, Tsai CY, Woung LC, et al. Prevalence and risk factors for myopia in second-grade primary school children in Taipei: A population-based study. *J Chin Med Assoc.* 2016;79:625–632. [PubMed: 27349942]
33. Alvarez AA, Wildsoet CF. Quantifying light exposure patterns in young adult students. *J Mod Opt.* 2013;60:1200–1208. [PubMed: 25342873]
34. Figueiro MG, Hamner R, Bierman A, Rea MS. Comparisons of three practical field devices used to measure personal light exposures and activity levels. *Light Res Technol.* 2013;45:421–434. [PubMed: 24443644]
35. Ostrin LA. Objectively Measured Light Exposure in Emmetropic and Myopic Adults. *Optom Vis Sci.* 2017;94:229–238. [PubMed: 27811524]
36. Verkicharla PK, Ramamurthy D, Nguyen QD, Zhang X, Pu S-H, Malhotra R, et al. Development of the FitSight Fitness Tracker to Increase Time Outdoors to Prevent Myopia. *Transl Vis Sci Technol.* 2017;6:20. [PubMed: 28660095]
37. Williams R, Bakshi S, Ostrin EJ, Ostrin LA. Continuous Objective Assessment of Near Work. *Sci Rep.* 2019;9:6901. [PubMed: 31061427]
38. Wen L, Lan W, Huang Y, Wu Y, Li X, Yang Z. A novel device to record the behavior related to myopia development-preliminary results in the lab. *Invest Ophthalmol Vis Sci.* 2016;57:2491.
39. Lan W, Wen L, Li L, Li X, Zhu H, Yang Z. The correlation between an objective index summarizing individual environmental risk factors and the change of refractive error. *Invest Ophthalmol Vis Sci.* 2018;59:3393.
40. Li L, Zhu H, Wen L, Lan W. An objective environmental risk factor index related to the development of myopia. *Invest Ophthalmol Vis Sci.* 2018;59:3394. [PubMed: 30025070]
41. Li L, Zhu H, Wen L, Yang Z, Lan W. Association of myopia progression with visual behavior. *Invest Ophthalmol Vis Sci.* 2019;60:6454.
42. Wen L, Cao Y, Huang Y, Wu Y, Li X, Lan W, et al. Diverse visual behavior patterns in students in the same classroom. *Invest Ophthalmol Vis Sci.* 2017;58:2403.
43. Wen L, Lan W, Cao Y, Cheng Q, Li X, Wu Y, et al. Comparison of myopia-related behaviors between rural and urban schoolchildren in China based on Clouclip™. *Invest Ophthalmol Vis Sci.* 2019;60:3897. [PubMed: 31529121]
44. Zhuo Z, Wang Y, Yang X, Bao J, Toh YZ, Gabriel A, et al. Investigation of Time Duration Spent on Near Work and Outdoor Activities in Children: Perception versus Real-time Measurements. *Invest Ophthalmol Vis Sci.* 2018;59:3401.
45. Cao Y, Lan W, Wen L, Li X, Pan L, Wang X, et al. An effectiveness study of a wearable device (Clouclip) intervention in unhealthy visual behaviors among school-age children. *Medicine.* 2020;99:e17992. [PubMed: 31914011]

46. Wang Y, Zhuo Z, Yang X, Bao J, Toh YZ, Gabriel A, et al. Investigation of the Influence of Proximity Alert on near-work Behavior in Chinese Myopic Children. *Invest Ophthalmol Vis Sci*. 2018;59:3399.
47. Wen L, Cao Y, Cheng Q, Li X, Pan L, Li L, et al. Objectively measured near work, outdoor exposure and myopia in children. *Br J Ophthalmol*. 2020: doi: 10.1136/bjophthalmol-2019-315258.
48. Wen L, Cheng Q, Lan W, Cao Y, Li X, Lu Y, et al. An Objective Comparison of Light Intensity and Near-Visual Tasks Between Rural and Urban School Children in China by a Wearable Device Clouclip. *Transl Vis Sci Technol*. 2019;8:15.
49. Hartwig A, Gowen E, Charman WN, Radhakrishnan H. Working distance and eye and head movements during near work in myopes and non-myopes. *Clin Exp Optom*. 2011;94:536–5 [PubMed: 21762395]
50. Najman JM, Williams GM, Nikles J, Spence S, Bor W, O'Callaghan Ma. Bias influencing maternal reports of child behaviour and emotional state. *Soc Psychiatry Psychiatr Epidemiol*. 2001;36:186–194. [PubMed: 11518032]
51. Whiteman D, Green A. Wherein lies the truth? Assessment of agreement between parent proxy and child respondents. *Int J Epidemiol*. 1997;26:855–859. [PubMed: 9279619]
52. You QS, Wu LJ, Duan JL, Luo YX, Liu LJ, Li X, et al. Factors associated with myopia in school children in China: the Beijing childhood eye study. *PloS one*. 2012;7:e52668. [PubMed: 23300738]
53. Napper GA, Brennan NA, Barrington M, Squires MA, Vessey GA, Vingrys AJ. The effect of an interrupted daily period of normal visual stimulation on form deprivation myopia in chicks. *Vis Research*. 1997;37:1557–1564.
54. Li SM, Li SY, Kang MT, Zhou Y, Liu LR, Li H, et al. Near work related parameters and myopia in Chinese children: The anyang childhood eye study. *PLoS ONE*. 2015;10:e0134514. [PubMed: 26244865]
55. Saw SM, Nieto FJ, Katz J, Chew SJ. Estimating the magnitude of close-up work in school-age children: A comparison of questionnaire and diary instruments. *Ophthalmic Epidemiol*. 1999;6:291–301. [PubMed: 10544343]
56. Rah MJ, Mitchell GL, Zadnik K. Use of the Experience Sampling Method to Measure Nearwork. *Optom Vis Sci*. 2004;81:82–87. [PubMed: 15127926]
57. Rah MJ, Walline JJa. Comparison of the experience sampling method and questionnaires to assess visual activities in pre-teen and adolescent children. *Ophthal Physiol Optics*. 2006;26:483–489.
58. Wing Leung T, Flitcroft DI, Wallman J, Lee TH, Zheng Y, yin Lam CS, et al. A novel instrument for logging nearwork distance. *Ophthal Physiol Optics*. 2011;31:137–144.
59. Lenhart A, Ling R, Campbell S, Purcell K. Teens and Mobile Phones. *Pew Internet and American Life Project* 2010.
60. The Common Sense Census: Media Use by Tweens and Teens [database on the Internet]. Common Sense Media, San Francisco, CA 2019 Available from: <https://www.commonsensemedia.org/sites/default/files/uploads/research/2019-census-8-to-18-key-findings-updated.pdf> (Accessed on 4/6/2020).
61. Read SA, Collins MJ, Vincent SJ. Light Exposure and Eye Growth in Childhood. *Invest Ophthalmol Vis Sci*. 2015;56:6779–6787. [PubMed: 26567790]
62. Smith EL, Hung L-F, Huang J. Protective Effects of High Ambient Lighting on the Development of Form-Deprivation Myopia in Rhesus Monkeys. *Invest Ophthalmol Vis Sci*. 2012;53:421–428. [PubMed: 22169102]
63. Shah RL, Huang Y, Guggenheim JA, Williams C. Time Outdoors at Specific Ages During Early Childhood and the Risk of Incident Myopia. *Invest Ophthalmol Vis Sci*. 2017;58:1158. [PubMed: 28245296]
64. Ashby R, Ohlendorf A, Schaeffel F. The Effect of Ambient Illuminance on the Development of Deprivation Myopia in Chicks. *Invest Ophthalmol Vis Sci*. 2009;50:5348–5354. [PubMed: 19516016]
65. Read SA, Collins MJ, Vincent SJ. Light exposure and physical activity in myopic and emmetropic children. *Optom Vis Sci*. 2014;91:330–341. [PubMed: 24413273]

66. Ostrin LA, Sajjadi A, Benoit JS. Objectively Measured Light Exposure During School and Summer in Children. *Optom Vis Sci.* 2018;95:332–342. [PubMed: 29554008]
67. Dharani R, Lee CF, Theng ZX, Drury VB, Ngo C, Sandar M, et al. Comparison of measurements of time outdoors and light levels as risk factors for myopia in young Singapore children. *Eye.* 2012;26:911–918. [PubMed: 22562184]
68. Read SA, Vincent SJ, Tan C-S, Ngo C, Collins MJ, Saw S-M. Patterns of Daily Outdoor Light Exposure in Australian and Singaporean Children. *Transl Vis Sci Technol.* 2018;7:8.
69. Schmid KL, Leyden K, Chiu Y-h, Lind S-R, Vos DJ, Kimlin M, et al. Assessment of Daily Light and Ultraviolet Exposure in Young Adults. *Optom Vis Sci.* 2013;90:148–155. [PubMed: 23314127]

Figure 1:

A) A Clouclip device (white arrow) is shown mounted to a spectacle frame and directed towards a target with calibrated rings to assess beam size and angle; **B)** image of the incident beam on the target as viewed with an infrared camera

A

B

Figure 2:

A) Clouclip measured distances from 5–120 cm were assessed for seven target sizes: 2×2 cm, 4×4 cm, 6×10 cm, 8×8 cm, 8×16 cm (iPhone size), 14×16 cm, and 16.5×24 cm.

B) Clouclip measured distances were assessed for a 22×18 cm target tilted from -90 to $+90^\circ$. The image shows the target at $+30^\circ$ tilt.

Figure 3. Infrared beam diameter with distance from the target, measured from 5 to 85 cm. Error bars represent the standard deviation for five devices tested. Dashed line shows a linear regression line.

Figure 4:

Bland-Altman analysis of repeatability for distance measurements 5–120 cm, collected on two days for five devices. The solid line represents the mean difference (−0.3 cm) and the dashed lines represent the limits of agreement (−2.3 to +1.7 cm)

Figure 5:

Clouclip-measured distances against actual distances from 5–120 cm for A) a printed target and B) an electronic target; Bland-Altman analyses for Clouclip-measured and actual distances for C) a paper target and D) an electronic target. The mean (solid line) $\pm$ limits of agreement (dashed lines) are shown. Shaded areas represents common near to intermediate distances of 15–60 cm.

Figure 6. Distances measured by five Clouclip devices before different amounts of target tilt at a test distance of 30 cm

Figure 7:

A) Ambient illumination recorded with Clouclip against a lux meter in variety of indoor and outdoor light conditions. Dashed line represents the 1:1 line, and red line indicates >1000 lux, i.e. outdoors. (B) Bland-Altman analysis for Clouclip-measured and lux meter-measured illumination. The mean (solid line) $\pm$ limits of agreement (dashed lines) are shown.

Figure 8: Representative raw data generated from the Clouclip for a subject performing the passive printed task for 15 minutes; the dashed line represents mean viewing distance excluding breaks; * = viewing breaks

Figure 9:
Mean viewing distance for each task by refractive error group (non-myopes: green; myopes: red); significant difference in post-hoc Bonferroni corrected comparisons at $*p < 0.01$ and $**p < 0.001$

Table 1:

Bland-Altman analysis for each of the five devices tested on two days. Mean difference and 95% limits of agreement for measurements for distances of 5–120 cm are shown

Device	Difference, Day 1- Day 2	Limits of Agreement
Clouclip 1	-0.6 ± 2.1 cm	± 4.1 cm
Clouclip 2	-0.1 ± 2.2 cm	± 4.3 cm
Clouclip 3	-1.0 ± 1.9 cm	± 3.8 cm
Clouclip 4	0.6 ± 1.4 cm	± 2.7 cm
Clouclip 5	-0.4 ± 2.3 cm	± 4.5 cm

Table 2:

Spatial integration of tracking beam. Target size is shown with maximum distance tracked, and beam area and percentage occupied by the target.

	Target Size						
	2 × 2 cm	4 × 4 cm	8 × 8 cm	6 × 10 cm	8 × 16 cm	14 × 16 cm	16.5 × 24 cm
Target Area	4 cm ²	16 cm ²	64 cm ²	60 cm ²	128 cm ²	224 cm ²	396 cm ²
Maximum distance tracked	40 cm	55 cm	80 cm	80 cm	100 cm	105 cm	120 cm
Beam area at maximum distance	267.5 cm ²	454.5 cm ²	835.0 cm ²	835.0 cm ²	1372.8 cm ²	1507.3 cm ²	1948.6 cm ²
Percentage of beam occupied by target	1.5%	3.5%	7.7%	7.2%	9.3%	14.9%	20.3%

Table 3:

Participant characteristics for non-myopic and myopic groups. *P* values are shown for unpaired t-test between groups; * < 0.05, ** < 0.001

Parameter	Non-Myopes (n=21)	Myopes (n=20)	<i>P</i> Value
Age (years)	26.07 ± 4.01	27.10 ± 6.01	0.52
Gender	14 M:7 F	12 M:8 F	0.66
Axial length (mm)	23.62 ± 0.97	24.83 ± 1.07	0.0006**
Spherical equivalent refractive error (D)	+0.09 ± 0.39	−2.88 ± 1.49	<0.0001**
Height (cm)	172.87 ± 9.09	165.31 ± 9.13	0.01*
Harmon distance (cm)	36.63 ± 3.78	35.57 ± 2.85	0.31

Table 4:

Viewing distances (cm) for different tasks for myopes and non-myopes; *P* value is shown for Bonferroni pairwise comparisons

Task	Non-Myopes (N = 21)	Myopes (N = 20)	<i>P</i> value
Passive Printed	33.5 ± 9.0 cm	32.9 ± 8.7 cm	0.94
Active Printed	29.9 ± 7.5 cm	29.0 ± 5.8 cm	0.79
Passive Electronic	40.7 ± 10.6 cm	40.9 ± 10.5 cm	0.84
Active Electronic	34.8 ± 8.2 cm	36.0 ± 7.9 cm	0.58

Table 5:

Two way ANOVA comparing effects of gender and type of refraction on viewing distances showing p-values for the factors and their interaction

Near Tasks	Gender	Refraction	Gender $\times$ Refraction
Passive	0.19	0.86	0.21
Active	0.12	0.69	0.12
Paper based	0.26	0.95	0.22
iPad based	0.19	0.59	0.15