

Teleoptometry and smartphone-associated visual habits across the lifespan

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Summary. — The spread of smartphones has seen an extraordinary growth in recent years, a condition that asks for detailed studies to identify visual habits and visual health associated with their use. In the present study, we measured viewing distance and character size across different age groups while participants read a simple text message. We also assessed the precision of a specific teleoptometry application in estimating smartphone usage distance. Our results showed that both reading distance and character size differed across age with non-presbyopes using closer distances and smaller character sizes as compared to presbyopes. We also found that a teleoptometry smartphone application exploiting the built-in front camera reliably assessed device usage distance with an average error lying below the value usually considered critical in clinical practice. In summary, our data reveal that visual habits in the use of smartphones can substantially vary across age, and suggest interesting future scenarios for teleoptometry to reliably predict visual health status.

1. – Introduction

During the last decade, the use of smartphones has seen an extraordinary growth in terms of spread and time of use. It is estimated that almost 75% of adults in Italy spend more than 3 hours a day using their smartphone and 25% spend more than 7 hours a day [1]. Although the use of smartphones can be of great help in the optimization of our time, their worldwide distribution has dramatically changed our visual habits to the point that a great attention is paid to determine long-term effects on ocular and physical health [2-5].

Concurrently, we are assisting to a significant growth in the field of telemedicine as digital devices can be extremely valuable tools to assess and monitor our habits in order to predict our health status. In this view, smartphones can soon turn their role from

cause to prevention of ocular distress and the advent of the Covid-19 pandemic has surely speeded up this process [6].

In the present study, we aimed at shedding light on visual habits adopted by smartphone users of different ages while also assessing the precision of a specific teleoptometry smartphone application in monitoring device usage distance.

2. – Visual habits across smartphone users

We recruited 217 participants with no self-reported history of ocular pathologies which were split into a group of non-presbyopes (*NP*; age < 40; $n = 157$) and a group of presbyopes (*P*; age > 40; $n = 60$). Visual habits were defined as the working distance and character size used while participants read a text message on their personal smartphones and wore their usual refractive correction (spectacles or contact lenses). The reading distance was defined using a tape measure with an approximation to the nearest millimeter and its inverse provided us with the extent of accommodative demand expressed in diopters (D). The character size was obtained by evaluating the height of lower-case letters that did not contain ascenders and descenders (*e.g.*, m, o, e) and transforming pixels in millimeters with the following eq. (1):

$$(1) \quad h = h_{pxl} \frac{\text{diag}_{mm}}{\text{diag}_{pxl}},$$

where h_{pxl} is the character dimension in pixels, while diag_{mm} and diag_{pxl} are the measurements of the diagonal of the screen in millimeters and pixels respectively. Measurements of the diagonal (in millimeters and pixels) were obtained as the hypotenuse of the triangle built on screen height and width reported on smartphones data sheets.

The combination of reading distance and character dimension produced a measure of what we here defined the natural angle of resolution (NAR), which was calculated with the following eq. (2):

$$(2) \quad NAR = \tan^{-1} \left(\frac{h}{5d} \right) \cdot 60,$$

where h is the character dimension and d is the reading distance with both measurements reported in millimeters and with distance multiplied by a factor of five to obtain the NAR corresponding to the smallest stimulus detail.

Presbyopes also completed the Italian version of the Near Activity Visual Questionnaire (NAVQ) which provided us with an assessment of individual difficulties in near vision to be related with visual habits [7, 8].

Our results showed a difference in the usual reading distance adopted by the two groups as *NP* were found to use closer working distances (mean = 33.4 cm; std = 7.6 cm) as compared to *P* (mean = 39.7 cm; std = 6.3 cm) and this difference was significant to statistical analysis ($t_{(215)} = -5.59$; $p < 0.001$; $d = -0.85$). Consequently, accommodative demand was found to be higher for *NP* (3.17 D) than *P* (2.59 D).

Character sizes used by *NP* were smaller (Md = 1.59 mm; IQR = 0.19) as compared to those used by *P* (Md = 1.72 mm; IQR = 0.49) with this difference being statistically significant as well ($U = 3121$; $p < 0.001$; $r = -0.337$).

Reading angular size showed no difference between the two groups ($NP = 0.53 \text{ LogNAR}$, $P = 0.5 \text{ LogNAR}$; $t_{(215)} = 1.83$; $p = 0.07$; fig. 1).

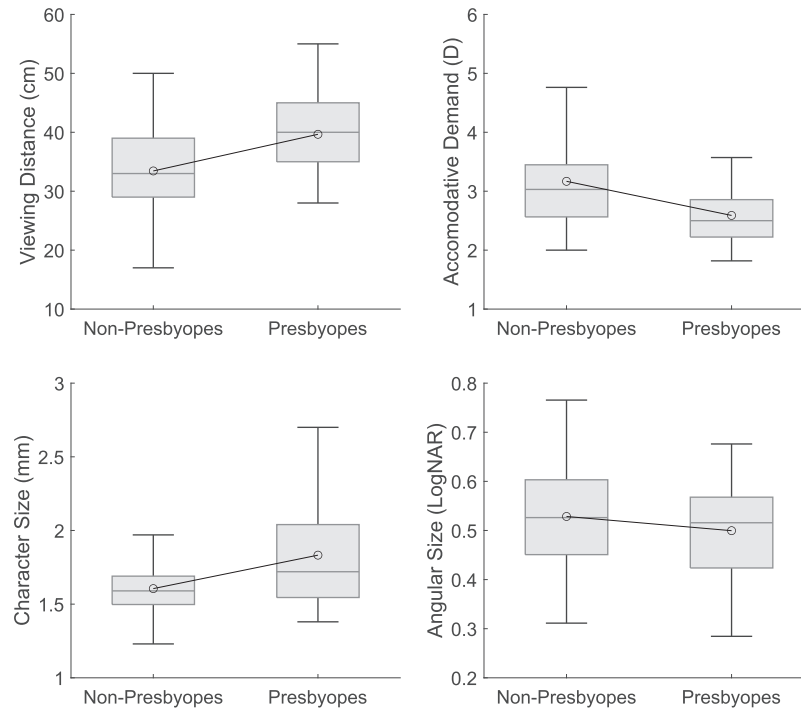


Fig. 1. – Boxplots depicting differences between Non-Presbyopes and Presbyopes in viewing distance, accommodative demand, character size and angular size while reading a text message on their smartphone. The line inside the plot is the sample median, the upper and lower edges represent the upper and lower quartiles respectively, while the orange dots depict mean values.

The analysis of NAVQ scores revealed that P reporting difficulties in near vision (*i.e.*, NAVQ score > 10) adopted larger character sizes (mean: 2.01 mm, std: 0.28 mm) as compared to P with subthreshold scores (mean: 1.76 mm, std: 0.38 mm; $t_{(58)} = -2.31$; $p = 0.024$). Conversely, the reading distance was found to be unrelated to NAVQ scores.

3. – Precision of a teleoptometry smartphone application

We assessed the precision of a teleoptometry application (Myopia app; Innovattic) to evaluate smartphone usage distance through the integrated front camera. The application is free, was developed by the company Innovattic (www.innovattic.com) and is available both in IOS and Android. It evaluates face-to-screen distance after a quick and easy calibration.

Two different measurements were adopted. First, in a group of 32 participants, we compared the reading distance obtained using tape measure with those reported by the Myopia app. Second, we arranged a smartphone in an optical table and assessed the precision of usage distance for two participants in two separate conditions: a first condition in which the smartphone was kept parallel to the face of the participant (Parallel Condition) and a second condition in which the smartphone was arranged to form an angle that simulated a typical viewing position (Angle Condition). Precision was defined as the deviation from either the distance obtained in the optical table or the hypotenuse

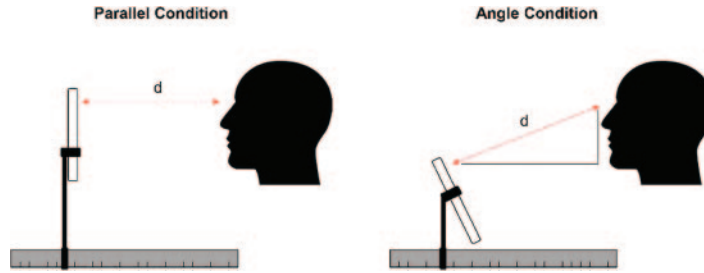


Fig. 2. – Schematic illustration of the paradigm used to investigate the reliability of usage distance measurements of the Myopia app. In the Parallel Condition, the smartphone was arranged to stay parallel to the face of the participants, while in the Angle Condition it was arranged to simulate a typical viewing position. Face-to-screen distance was varied in steps of 1 cm.

of the invisible triangle obtained from vertical and horizontal eye-to-camera distances (fig. 2).

Results revealed that distances obtained with tape measure and distances obtained with the Myopia app were highly correlated, suggesting a good reliability of the application (Pearson; $r_{(30)} = 0.60$; $p < 0.001$).

Similarly, measurements of the deviation from the values obtained in the optical table were reasonably low. In particular, in the Parallel Condition, both error and across measurements variability were low for all the tested distances (mean error: 0.51 cm). In the Angle Condition, the error was larger (mean error: 1.16 cm) and increased with distance (fig. 3). However, the maximal error was evident at 48 cm and was around 2.5 cm away from the veridical distance, which corresponds to an accommodative demand error of around 0.11 D, a value that is below the value usually considered as critical in clinical practice (*i.e.*, 0.25 D).

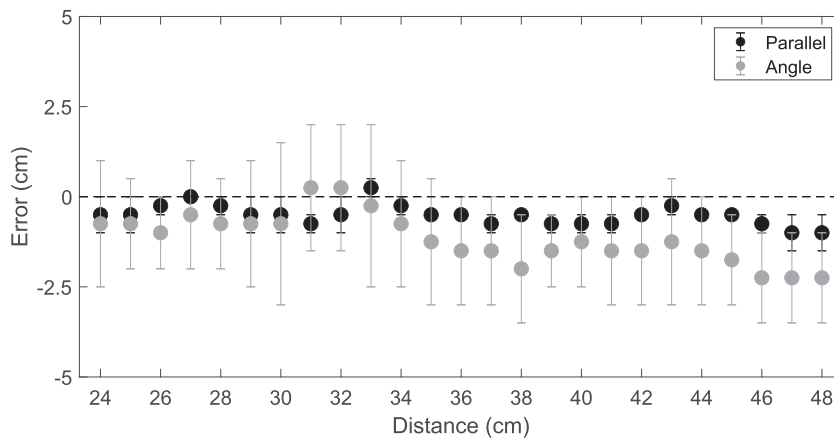


Fig. 3. – Errors in the estimation of face-to-screen distance through a specific teleometry smartphone application. Blue dots depict the Parallel Condition in which the smartphone was kept parallel to the face of participants, while red dots depict the Angle Condition in which the smartphone was arranged to form an angle to simulate typical viewing.

4. – Conclusions

In the present work, we aimed at determining visual habits adopted by smartphone users of different ages and at assessing the precision of a specific teleoptometry application in evaluating smartphone usage distance.

In agreement with previous reports [9,10], we showed that *NP* and *P* use different distances when reading a text on a smartphone, with *P* adopting higher distances. We also showed that *P* use larger character sizes as compared to *NP*, although reading acuities were found to be comparable across the two groups. Indeed, while *NP* tend to increase angular size by reducing reading distance, *P* increase character size, a behavior in line with previous reports [11] and likely due to the reduced lens accommodative power in *P*. Furthermore, participants with suprathreshold scores in the NAVQ used significantly larger character sizes as compared to participants reporting subthreshold scores.

Multiple evidence suggest a causal link with eyestrain symptoms and the prolonged use of smartphones [2,12]. These symptoms could be more evident in younger individuals who usually spend more time and are exposed to a higher accommodative demand because of the closer smartphone reading distances adopted. In this view, a comprehensive assessment of accommodation and vergence system could be included as a further visual examination for those users spending several hours a day on a digital screen [13]. In the near future, we could expect that these examinations could be preceded by a day-by-day smartphone-dependent monitoring of patients' visual habits, which would provide clinicians with a clear and objective picture of time of use, distance of use, critical angular size and many more information. We here showed that measurements of usage distance assessed by a specific smartphone teleoptometry application showed a relatively good reliability. This result is important for the development of teleoptometry applications exploiting built-in functionalities. For instance, we here showed that both usage distance and character dimension were predictive of the age group of the participants. Furthermore, the character size not only discriminated between *NP* and *P*, but also dissociated between *P* having difficulties in near vision from those that did not have. This information could be potentially implemented into future applications aiming at monitoring users' visual habits in order to timely spot incoming visual problems and to suggest the necessity to consult a professional optometrist.

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