Displays 44 (2016) 15–20

Contents lists available at ScienceDirect

Displays

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

Visual acuity and contrast sensitivity screening with a new iPad application ☆

Manuel Rodríguez-Vallejo [a,b], Clara Llorens-Quintana [a], Walter D. Furlan [a], Juan A. Monsoriu [b,*]

[a] Departamento de Óptica, Universitat de València, 46100 Burjassot, Spain
[b] Centro de Tecnologías Físicas, Universitat Politècnica de València, 46022 Valencia, Spain

ARTICLE INFO

Article history:
Received 26 February 2015
Received in revised form 26 May 2015
Accepted 6 June 2016
Available online 7 June 2016

Keywords:
Visual acuity
Contrast sensitivity
Screening
iPad

ABSTRACT

We present a new iPad application (app) for a fast assessment of Visual Acuity (VA) and Contrast Sensitivity (CS) whose reliability and agreement was evaluated versus a commercial screening device (Optec 6500). The measurement of VA was programmed in the app in accordance with the Amblyopia Treatment Study protocol. The CS was measured with sinusoidal gratings of four different spatial frequencies: 3, 6, 12 and 18 cpd at the same contrast values of the Functional Acuity Contrast Test (FACT) included in the Optec 6500. Forty-five healthy subjects with monocular corrected visual acuities better than 0.2 logMAR participated in the agreement study. Bland-Altman analyses were performed to assess the agreement and Deming regressions to calculate Mean Differences (MDs) and Limits of Agreement (LoAs). Coefficients of reliability were 0.15 logMAR for our method and 0.17 logMAR for the ETDRS testing protocol. For testing the CS, our test showed no statistically significant differences compared with the FACT at any spatial frequency ($p > 0.05$). The MDs were lower than 0.05 log units for all spatial frequencies.

1. Introduction

Vision screening programs are intended to identify eye problems which occur in children or adults and refer them for further evaluation. Although there is a battery of screening methods designed to detect specific eye disorders, some screening techniques can be considered "multi-purpose," minimizing the need for several individual tests [1]. For instance, visual acuity (VA) is considered an essential part of any eye examination [2] and it is used in the screening of refractive errors [3] and amblyopia [4]. On the other hand, the Contrast Sensitivity Function (CSF) is considered an additional test for specialized clinical evaluation, and has been generally accepted as a better predictor of visual performance than high contrast VA [5–7].

Several tests and methods have been proposed for the assessment of VA and CSF. Nowadays, the Early Treatment of Diabetic Retinopathy Study (ETDRS) testing protocol is generally accepted as the gold standard of VA measurement in adults [8–10]. With regard to contrast sensitivity (CS), although the Pelli-Robson chart is considered the gold standard to compare optotype's based CS tests [11], currently there is not a commercial gold standard test to measure CS by sinusoidal gratings. Despite this fact, some clinical tests have been developed and they represent a good solution in vision screening programs; the most used are the Functional Acuity Contrast Test (FACT) [12,13] and the Vector Vision CSV-1000 [14,15]. Clinical CS tests commonly use 9 patches of sinusoidal gratings with different contrast levels. They could differ in the step sizes, ranges, or the psychophysical method to achieve the threshold [16]. The Optec 6500® is a commercial screening device that complies with the ANSI standard [17] and includes the ETDRS and FACT tests to evaluate VA and CS respectively.

Ever since computer tablets appeared, new applications (apps) have been proposed in the field of visual science [18–21]. The great advantage of using these portable devices is the potential standardization of measurements. This is because many models of tablets have screens with similar characteristics such as chromaticity and resolution. Therefore, it can be hypothesized that if a developer takes into account the technical data of the tablets in the design of an app, any operator who uses the same display in any part of the world will measure the visual function under the same conditions. However, to provide accurate presentation of test stimuli, individual device calibration may be necessary to ensure that any variances between devices, even of the same manufacturer and model, are taken into account. In this respect, in a recent paper Tahir et al. [22] suggested practical means to optimise quality of display for vision testing including screen calibration.

☆ This paper was recommended for publication by Richard H.Y. So.

* Corresponding author.
E-mail address: jmonsori@fis.upv.es (J.A. Monsoriu).

http://dx.doi.org/10.1016/j.displa.2016.06.001
0141-9382/

The assessment of the VA and CS with an iPad has recently been proposed under different approaches: Black et al. [19] implemented a platform for testing distance VA. To evaluate CS, Kollbaum et al. [20] developed an elementary test consisting of two letters on each page of an iBook, having 0.1 log units of difference between pages. This test was compared with the Pelli-Robson and Freiburg VA tests and gave significantly lower values with the first one and good agreement with the second one. On the other hand Dorr et al. [21] implemented *the quick CSF method* proposed Lesmes et al. [23], to evaluate the response to sinusoidal gratings of 16 spatial frequencies log-spaced from 0.42 to 13.7 cycles per degree (cpd). This test was validated with measurements obtained from four normally sighted subjects on specialized laboratory equipment. However, in spite of its name, this method is still rather time-consuming for screening purposes (up to 5 min) [21].

The aim of this study is to introduce a new iPad app designed for a fast screening of VA and CS, which represents an alternative to other expensive and large-format screening instruments. The obtained VA and CS records and test-retest reliabilities are compared with those achieved with the *Optec6500*.

2. Methods

The proposed app was developed with ActionScript 3.0 programming language for mobile devices and then compiled for IOS with Adobe Flash Builder (Adobe Systems, Inc.). The tablet used to perform this research was a third generation iPad with a retina display (2048-by-1536-pixel resolution at 264 pixels per inch). The suitability of this device for visual psychophysics purposes has been previously reported [21,24]. A Spyder4Elite colorimeter was used to measure the chromaticity of the iPad screen at maximum brightness. Data obtained from the colorimeter were used to create the CS stimuli. The room lighting during measurements was controlled with the luminance meter LX1330B Luxmeter. The app consists of two primary components, intended to be useful for a fast screening of VA and CS.

2.1. Fast Screening of Visual Acuity (FSVA)

The assessment of the VA with the proposed app follows the Amblyopia Treatment Study (ATS) testing protocol [25]: The subject has to recognize which of the four letters (HOTV) with 50% crowding bars appear isolated in the centre of the screen, (Fig. 1, left). On each visual acuity level, a black optotype is presented over a white background with a luminance of 342 cd/m^2. The presentation distance was 3 m. The optotype size was automatically fitted for this distance by the application. The psychophysical method to reach the VA threshold was also included in the app, as described by the ATS testing protocol. In this way, the operator task only consists in touching one of the five click buttons at the margin of the screen (corresponding to the HOTV letters plus one button for a null response) according to the answer given by the observer. Even though the ATS protocol consists of a binocular pre-test followed by a monocular screening, the first one was omitted to shorten the task, and it starts directly with monocular screening at 0.8 logMAR. The reinforcement phase described in the ATS protocol was also omitted and the application automatically goes from phase 1 to phase 2. In this way, each VA measurement can be completed in approximately one minute.

2.2. Fast Screening Contrast Sensitivity (FSCS)

For a rapid assessment of the CS we propose the use of sinusoidal gratings of four different spatial frequencies: 3, 6, 12 and 18 cpd. The contrast of the gratings was determined by the luminance difference of the white and dark bars, as described by Pelli in Ref. [26]. The sinusoidal gratings appear in a vertical orientation or tilted ±15° from the vertical and are presented in circular patches with blurred edges that fade the gratings into an achromatic background of mean luminance (85 cd/m^2). The angle subtended by the patchs from the presentation distance was 1°. A total of 9 patches of different contrasts were generated for each spatial frequency and each orientation. Stimuli were programmed with *MATLAB* software (The MathWorks, Natick, MA) and the library *COLORLAB* [27]. The CS values for each frequency and the psychophysical procedure were programmed using the same parameters of the FACT [12,13,28] in order to obtain comparable results (see Table 1). The measurements of the CS thresholds for four spatial frequencies were completed in a mean of two minutes and a half per eye.

2.3. Subjects and procedures

Forty-five subjects, comprised of 21 males (mean age: 36 ± 11 years) and 24 females (mean age: 33 ± 10 years), were recruited from university staff and students at the University of Valencia, Spain. Exclusion criteria included strabismus or any cause of monocular reduced visual acuity worse than 0.2 logMAR with habitual correction (measured with ETDRS). Informed consent was obtained from each subject just before starting the procedures. The research was conducted in accordance with the principles laid down in the Declaration of Helsinki. Approval from the human research ethics committee of the Universitat de València (Spain) was obtained before the study began.

All trials were performed in the same room illumination (15 lx). The same procedure was carried out in all sessions by the same operator and with the patient wearing the habitual correction. VA and CS were measured with the iPad test and, after a short break, with the *Optec6500* using the *day testing* option (85 cd/m^2

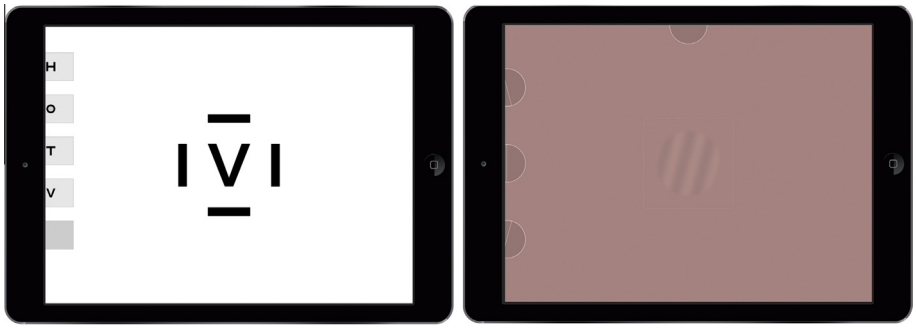

Fig. 1. iPad application patterns. Crowded optotype in the FSVA (left) and sinusoidal grating in the FSCS (right). FSVA: Fast Screening of Visual Acuity, FSCS: Fast Screening Contrast Sensitivity.