IL NUOVO CIMENTO **48 C** (2025) 259
DOI 10.1393/ncc/i2025-25259-x

Communications: SIF Congress 2024

Validity and repeatability of three different techniques of binocular balancing

L. Boccardo(1)(2), L. Fossetti(1)(2) and L. Parenti(1)(2)

(1) *Università di Firenze, Corso di Laurea in Ottica e Optometria - Firenze, Italy*
(2) *IRSOO Istituto Ricerca e Studi in Ottica e Optometria - Vinci, Italy*

received 6 May 2025

Summary. — This study evaluates the concordance and repeatability of three accommodation balance tests included in the default menu of the Essilor Vision-R 800 digital phoropter. These tests use different dissociation methods: polarized filters, a 6Δ Base-Up prism, and red/green filters. A total of 46 subjects participated. The polarized test demonstrated excellent repeatability (ICC: 0.91, 95% CI: 0.83–0.96), while the prism test (ICC: 0.36, 95% CI: 0.11–0.61) and red/green test (ICC: 0.63, 95% CI: 0.41–0.80) showed lower repeatability. The polarized test exhibited no bias relative to monocular refraction, with an equal probability of adding a positive sphere to either eye. In contrast, the prism test showed a mean difference of −0.20 D, indicating a tendency to add more positive power to the left eye. The red/green test exhibited a bias in the opposite direction, favoring more positive power for the right eye. Of the three tests, only the polarized filter test proved repeatable and reliable. The prism and red/green tests produced inconsistent results due to opposing biases and the subject's difficulty comparing dissimilar images, leading to indecisive responses and poor repeatability.

1. – Introduction

Subjective refraction is widely regarded as the gold standard for measuring refractive error [1]. Typically, in the initial phase, each eye is individually tested while the other eye is occluded [2,3]. This monocular approach can lead to differences in accommodation between the eyes. When binocular vision is restored, these differences can cause asthenopia and difficulty adapting to the correction [4]. To address this issue, the refractive examination concludes with an accommodative balancing test which ensures, by equalizing accommodation between the eyes, that images focus simultaneously on both retinas and that the accommodative stimulus is balanced. There is no need to perform this test if the patient has monocular vision, strabismus, or no accommodation [5, 6]. Various accommodative balancing techniques have been reported in literature, with no clinically significant differences observed between them [7-10]. The choice of balancing tests depends largely on the equipment available to the practitioner, as the results are generally independent of the technique used. Recent technological advancements have introduced digital phoropters, which allow operators to select from a range of tests via a console which coordinates the required lenses or filters on the phoropter with the corresponding targets on a computerized optotype projector. Digital phoropters offer notable benefits, such as faster working times and greater ease of use compared to traditional trial frames and lens sets [11]. The efficiency of these instruments is tied to the availability of reliable, pre-programmed tests that streamline the examination process by simultaneously controlling both the phoropter and optotype display.

This study aims to evaluate the concordance and repeatability of three accommodation balance tests included in the default menu of the Essilor Vision-R 800 digital phoropter: dissociation with polarised filters, dissociation with a 6Δ Base-Up prism, and dissociation with red/green filters, all based on comparing sharpness between the eyes.

2. – Methods

Participants were recruited from the IRSOO (Institute for Research and Study in Optics and Optometry, Vinci, Florence). The study was approved by the local ethics committee and adhered to the Declaration of Helsinki. All participants provided written informed consent. Inclusion criteria included age under 40, normal binocular vision with stereoacuity of $40''$ or better, normal color perception, and no systemic or ocular diseases. Measurements were performed in the IRSOO laboratories under consistent ambient lighting (300 lux). Objective refraction was measured with the Essilor AKR 800 autorefractometer, followed by refinement through monocular subjective refraction using the Vision-R 800 refraction unit and the Essilor CS Pola 600 LCD panel. Subjective refraction involved determining the maximum positive or minimum negative sphere for best visual acuity, measuring astigmatism with the cross-cylinder method, and refining the sphere using the Duochrome test. Ocular dominance was assessed with the "+1.50 D blur" test [12]. The subjects then underwent three accommodative balance tests using different dissociation methods: polarised filters with polarised targets, a 6Δ Base-Up prism on the right eye, and red/green filters with cyan/red targets.

These tests, included in the Vision-R 800 phoropter menu, were performed in random order and repeated three times each. The monocular refractive values used were the same for all balancing procedures. In each test, balance was achieved by comparing the sharpness of the upper and lower lines of letters, as illustrated in fig. 1.

The same procedure was followed for all the three tests: +0.50 D binocular blur was applied; dissociation was introduced; the top and bottom lines were compared; if the lines were not equally blurred, +0.25 D was added to the eye that saw better; if equally blurred images could not be achieved, better vision was left on the dominant eye; finally, both dissociation and binocular blur were removed.

The data were recorded in an Excel spreadsheet and then processed by calculating the differences between the balanced refraction result and the value obtained from the monocular refraction, as described in table I.

Repeatability of each test was assessed using the Intraclass Correlation Coefficient (ICC) [13]. Concordance among the three tests was evaluated with Bland-Altman plots [14].

3. – Results

A total of 46 subjects (19 females) participated in the study, with ages ranging from 18 to 38 years (median age: 21). The spherical equivalent ranged from −4.88 D to +1.00

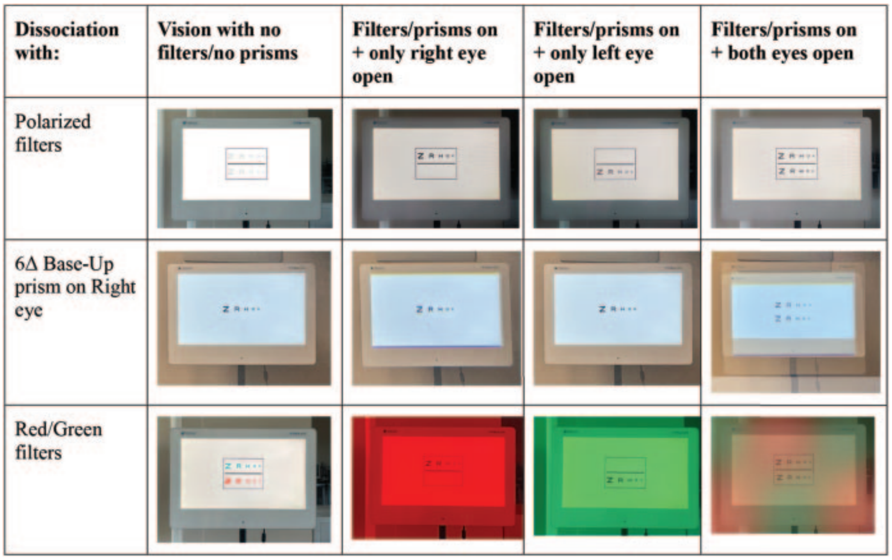

Fig. 1. – Patients' vision with the tree different tests.

D (median: −0.38 D) in the right eye and from −4.63 D to +0.88 D (median: −0.38 D) in the left eye, with astigmatism <2.50 D and anisometropia <1.50 D.

In terms of repeatability, the polarised test demonstrated an ICC of 0.91 (95% CI: 0.83–0.96), the prism test an ICC of 0.36 (95% CI: 0.11–0.61), and the red/green test an ICC of 0.63 (95% CI: 0.41–0.80).

The results of the first administration of each test were used to compare monocular refraction and the three balancing tests, using the Bland-Altman plots. Table II presents the mean differences and concordance limits for the comparisons between the value obtained from the monocular refraction and the result of the balanced refractions. The polarised test shows no bias relative to monocular refraction, meaning there is an equal likelihood of adding a positive sphere to either the right or left eye. When balancing with a 6Δ Base-Up prism on the right eye, a mean difference of −0.20 D is observed, indicating a tendency to add a more positive sphere to the left eye. A bias is also observed with the red/green filters, but in the opposite direction, with a tendency to add more positive power to the right eye.

Table I. – *Differences between the result of the balanced refraction and the value obtained from the monocular refraction.*

Power added to right eye (D)	Power added to left eye (D)	Delta (D)	Description
0	0	0	No change, difference is zero.
+0,25	0	+0,25	Positive power added to right eye, result is positive.
0	+0,25	−0,25	Positive power added to left eye, result is negative.

TABLE II. – *Mean differences and concordance limits from the Bland-Altman plots for the comparisons among the three tests.*

Bias & limits (D)	monocular *vs.* polarised	monocular *vs.* prism	monocular *vs.* R/G
Mean difference +1.96 SD	+0,44	+0,36	+0,76
Mean difference	0,05	−0,20	+0,25
Mean difference −1.96 SD	−0,34	−0,76	−0,26
Range of agreement	±0,39	±0,56	±0,51

4. – Discussion

The aim of this study was to evaluate the concordance and repeatability of three accommodation balance tests included in the default menu of the Essilor Vision-R 800 digital phoropter.

The literature does not provide repeatability data for individual tests but indicates high interchangeability between them [7, 8]. However, in this study, the various tests produced different and, in some cases, opposing results.

The polarised test demonstrated high repeatability. Furthermore, compared to monocular refraction, it showed no bias, and its range of agreement was relatively narrow. For individual subjects, some difference from monocular refraction was expected, as this is the purpose of the test. However, an average difference was not anticipated, as there is no reason to expect errors in accommodation control to occur more frequently in one eye than the other. Thus, the polarised test has proven to be both repeatable and reliable.

The prism test demonstrated very low repeatability, with a mean difference of −0.20 D compared to monocular refraction, indicating a tendency to add a more positive sphere to the left eye. This bias arises from using a prism on only one eye, which causes the images seen by each eye to differ. The prism introduces chromatic dispersion, creating colored edges around the image, which become more pronounced as the prism's power increases. With a 6Δ Base-Up prism on the right eye, patients perceive warm colors at the top and cool colors at the bottom (fig. 2(a)), degrading image quality. This prompts practitioners to add a +0.25 D lens to the unaffected eye to balance perceived image quality, not accommodation. To resolve this issue, splitting the prism power

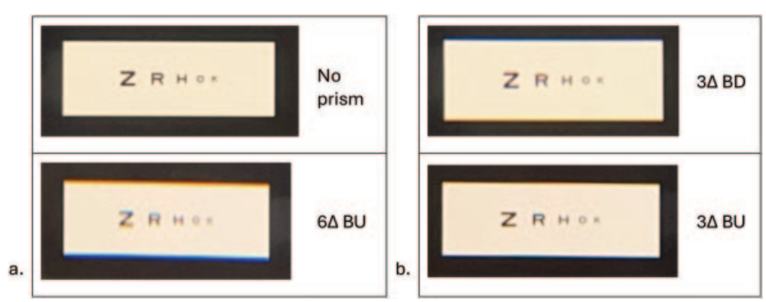

Fig. 2. – (a) Patients' vision with 6Δ Base-Up prism placed only on the right eye; (b) patients' vision with 3Δ Base-Up prism on one eye and a 3Δ Base-Down prism on the other.

between the eyes using two 3Δ prisms with opposite bases is recommended [7-9]. This reduces and equalizes the dispersion between the eyes (fig. 2(b)). While many phoropters include a 6Δ Base-Up prism for phoria measurement, it should not be used for balancing accommodation. For ease and reliability, phoropters should include two 3Δ prisms as a default setting instead of a single 6Δ prism.

Dissociation using red/green filters is widely used in binocular vision tests, such as those measuring phorias and tropias, where comparing sharpness between the eyes is not required. Balancing tests with red/green filters, to the best of our knowledge, are not described in the literature and are present on only a few instruments. The test uses a target with one line of cyan letters and another of red letters. Through the filters, the patient sees black letters on a yellowish or red/green shifting background with both eyes open. The red/green filter balance test evaluated in this study showed moderate repeatability and demonstrated a mean difference of +0.25 D, indicating a tendency to add more positive power to the right eye. This test is influenced by the eye's chromatic aberration [15]. When using red and green filters, the green image focuses before the retina, while the red image focuses beyond it. To inhibit accommodation during the test, a +0.50 D lens is placed in front of both eyes, shifting the green image focus closer to the lens and the red image focus closer to the retina. Consequently, the patient reports clearer vision with the right eye (red filter). Following the test protocol, a +0.25 D lens is added to the right eye to balance the blur, and this introduces an excess of positive power on the right eye. After removing the filters and +0.50 D lenses, the eyes —assuming they were originally well-corrected— will remain unbalanced, with an excess of positive power in the right eye (fig. 3).

Ultimately, when comparing the prism and red/green filter balance tests, results are very different due to each test exhibiting a bias in opposite directions compared to monocular testing. As a result, neither test appears to be reliable. Furthermore, subject's diffi-

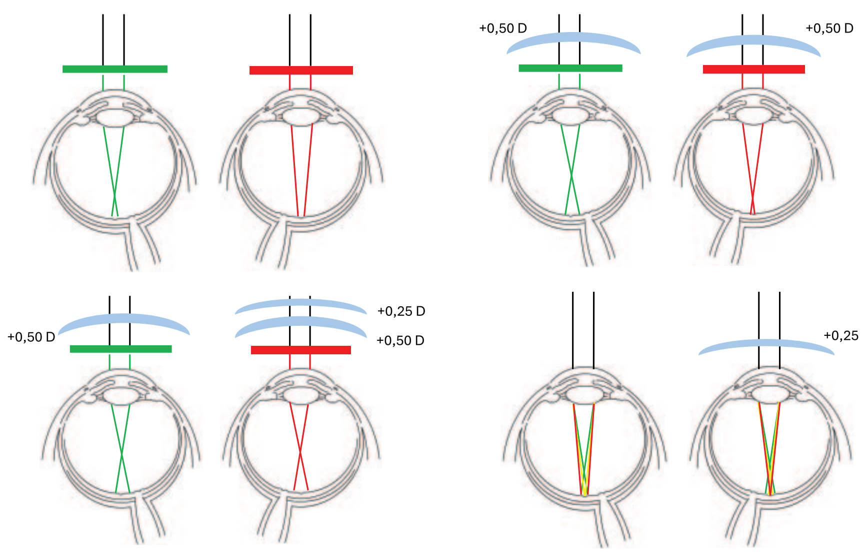

Fig. 3. – Focusing of the rays with red and green filters, after applying the +0.50 D blur, with the +0.25 D lens on the right eye to equalize the blurring, and finally after removing the filters and blur.

culty in comparing dissimilar images leads to indecisive responses and poor repeatability.

In conclusion, of the three tests we evaluated, only the test with polarised filters proved to be repeatable and reliable. This is because, in this test, the two lines of letters seen by the eyes are truly equal and comparable. The results of this study suggest that it is essential to use two identical prisms with opposing bases for prismatic dissociation and that dissociation with red/green filters is not appropriate when performing an accommodation balance test.

The results of this study should be considered preliminary and require further investigation through additional studies. These should include a sample of patients with a wider range of ametropia; a comparison between dissociation using a 6Δ prism and two 3Δ prisms; and a comparison with other balancing techniques that do not rely on sharpness comparison between two lines of letters, such as the prism-dissociated Duochrome balance and the Humphriss Immediate Contrast method.

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The authors are grateful to Alessia Montecalvo and Nicole Oddo for their valuable contribution to data collection.

REFERENCES

[1] Elliott D. B., *Ophthalmic Physiol. Opt.*, **37** (2017) 115.
[2] Benjamin W. J., *Borish's Clinical Refraction*, 6th edition (Butterworth-Heinemann Oxford) 2006.
[3] Elliott D. B., *Clinical Procedures in Primary Eye Care E-Book* (Elsevier Health Sciences) 2020.
[4] Rabbetts R. B., *Bennett & Rabbetts' Clinical Visual Optics*, third edition (Butterworth Oxford) 1998.
[5] Amigo G., *Optom. Vis. Sci.*, **45** (1968) 511.
[6] Gentsch L. W. and Goodwin H. E., *Optom. Vis. Sci.*, **43** (1966) 658.
[7] Ashraf T. and Sarwar M. S., *Pak. J. Ophthalmol.*, **6** (2016) 23.
[8] Mathebula S., *S. Afr. Optom.*, **60** (2001) 135.
[9] Momeni-Moghaddam H. and Goss D. A., *Clin. Exp. Optom.*, **97** (2014) 422.
[10] West D. and Somers W. W., *Ophthalmic Physiol. Opt.*, **4** (1984) 155.
[11] Ohlendorf A., Leube A. and Wahl S., *Healthcare*, **4** (2016) 41.
[12] Pointer J. S., *J. Optom.*, **5** (2012) 52.
[13] Shrout P. E. and Fleiss J. L., *Psychol. Bull.*, **86** (1979) 420.
[14] Bland J. M. and Altman D. G., *Stat. Methods Med. Res.*, **8** (1999) 135.
[15] Howarth P. A. and Bradley A., *Vis. Res.*, **26** (1986) 361.