Does cover test overestimate systematically the phoria values?

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Presentation Number: 761

Purpose:
To analyze the differences in horizontal phoria when measured as the displacement of a single eye and when deviations of both eyes are considered during the cover test.

INTRODUCTION

The alternate cover test is a commonly used technique for the detection of phoria and strabismus [1] . However, ocular alignment can also be assessed objectively using an eye tracking system [2-3]. Then, some limitations of the conventional clinical method can be overcome (Table 1).

Alternate cover test	Objective and automated cover test
Test accuracy is limited by the optical quality of the prisms.	The reliability of the results is limited by the eye-tracker's accuracy.
2 Prism Diopters (PD) is considered the smallest deviation detected by an examiner with the naked eye under ideal conditions [4].	The smallest measurable deviation depends on the noise level of the signal.
Interexaminer variability (experience, endpoint of the movement, time of occlusion, etc).	The results do not depend on the ability nor the criteria of the examiner.
The covered eye cannot be observed.	Movements of both eyes can be measured simultaneously.

Table 1. Drawbacks of the alternate cover test which can be overcome with an eye tracking system.

METHODS

Right and left eyes' movements were recorded with the eye-tracker embedded in the Eye and Vision Analyzer (EVA, Davalor Salud, Spain) during the cover test at 40 cm (Fig. 1). The viewing sequence was:

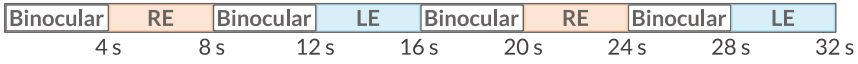


Fig. 1. EVA

The phoria was measured with two different methods:

1. **Absolute:** Displacement of the occluded eye from its position in the binocular state.

$$phoria_{abs} = |L_{occ} - L_{bino}|$$

2. **Relative:** Difference between the displacements of the occluded and fixating eyes from their respective binocular positions.

$$phoria_{rel} = |L_{occ} - L_{bino}| - |R_{occ} - R_{bino}|$$

L_{occ}, left eye occluded; L_{bino} left eye binocular;
R_{occ}, right eye occluded; R_{bino} right eye binocular

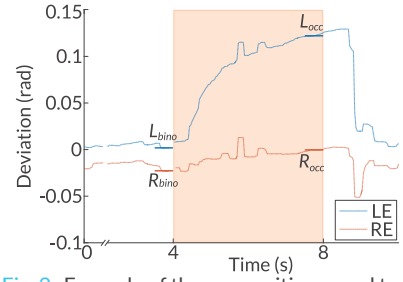


Fig. 2. Example of the eye positions used to measure phoria.

RESULTS

19 participants: mean age ± SD of 22.3 ± 3.5 years, visual acuity ≥ 20/20 and a horizontal phoria > 1 PD (8 exophoric and 11 esophoric). Mean ± SD eye-tracker's accuracy: 0.37° ± 0.18°.

Absolute mean difference ± SD (PD)	Minimum (PD)	Maximum (PD)	Cases with differences > 1 PD
0.67 ± 0.47 *	0.17	1.68	21.1%

Table 2. Absolute mean difference ± SD, minimum and maximum differences between the phoria values computed as $phoria_{abs}$ and $phoria_{rel}$ and percentage of cases with differences greater than 1 PD.
* Statistically significant differences (p<0.001).

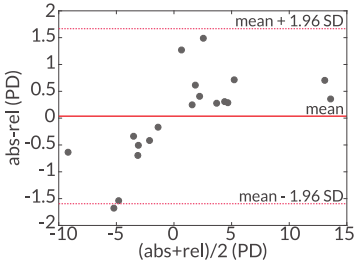
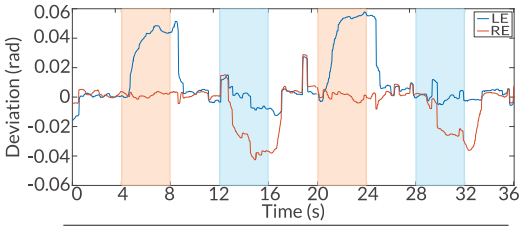
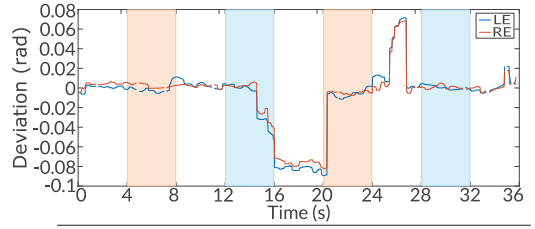


Fig. 3. Difference in phoria using both methods as a function of their mean.



$phoria_{rel}$	4.29 e	3.25 e	4.69 e	3.18 e
$phoria_{abs}$	4.32 e	3.78 e	5.38 e	3.44 e

Fig. 4. Eye tracking recording of an esophore (e) patient and measured deviation in PD in each occlusion.



$phoria_{rel}$	0	0	1.27 e	0
$phoria_{abs}$	0	4.65 ET LE	8.61 e	0

Fig. 5. Eye tracking recording of a patient that was not looking at the stimulus and measured deviation (PD) in each occlusion.

CONCLUSIONS

- The objective measurement of phoria with an eye-tracker overcome the main limitations of the current clinical methods.
- Under dissociated conditions, the fixating eye might move according to *Hering's law*, which leads to an overestimation of the phoria when deviations of one single eye are measured.
- The measurement of phoria considering the deviation of both eyes increases robustness against patients who do not fixate the stimulus during the objective and automated cover test.

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Acknowledgements: Spanish Ministry of Science and Innovation (grant DPI2014-56850-R), European Union and DAVALOR SALUD. Generalitat of Catalonia by Predoctoral grant (C. Mestre)
Disclosure: C. Mestre, C. Otero, J. Gautier & J. Pujol, DAVALOR SALUD (Code F), Generalitat de Catalunya (Code F), Spanish Ministry of Economy and Competitiveness (Code F), J. Gautier, DAVALOR SALUD (Code E).