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Influence of ocular dominance in the variability of the eye's anterior segment measurements

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ABSTRACT

The visual system tends to favour one eye over the other in perceptual or motor tasks. This effect, called ocular dominance, makes those small movements in one eye be smaller and more precise than in the other eye. These dynamic effects are usually small and static devices are not capable of detecting differences between both eyes. In the last years ophthalmic devices are becoming more and more precise, thus they can be sensible to such variability. The hypothesis posed here is that variability of measures acquired this way is affected by ocular dominance. With a Pentacam system we have measured several parameters of the anterior segment of the eye. Our findings show that variables measured for the dominant eye are less dispersive than for the non-dominant eye although the limited accuracy of the device can mask this effect. The trend is confirmed by a contrast experiment and by a previous work, so we accept the validity of our hypothesis. Our main conclusion is that systematic election of the right eye in analysis of reliability or reproducibility can bias the variability of results and consequently we suggest considering dominance effects.

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1. Introduction

The tendency to favour one eye over the other in perceptual or motor tasks is known as ocular dominance [1] or eye preference as a generic term [2]. Although there are three **criteria**, which serve to define the eye dominance [3,4] the most common is measuring the sighting dominance. This measure is simple and consists of fixating both eyes to a distant point through a small opening. The observer draws the opening back to the head to determine which eye is viewing the object.

Many studies deal about eye dominance; however most of them are focused on topics like refractive errors, [5–8], monovision [9] or amblyopia [10]. Relationship between dominance and eye movement has been also studied by many authors. Kenyon et al. [11] found that the eye motion was greater in the **non-dominant** eye during accommodative vergence. Recently Ehrenstein and Wagner [12] verified that eye dominance is related to oculomotor stability during prolonged fixation. This functional eye dominance in the eye movements lead us to pose the hypothesis that ocular dominance can affect to clinical measures taken with a fixation stimulus. In fact there are not many **studies**, which deal with the influence of ocular dominance in clinical measurements. Many modern devices provide accurate and precise measurements of small variations of different

ocular parameter and in our opinion researchers need to be sure that dominance is not influencing in their measurements and conclusions.

The statistical reproducibility of measurements on the eye, including the testing of instrumentation, is often proved in a clinical context. These studies are usually designed so that only one eye of each subject is evaluated because of the high correlation between both eyes. In most studies, usually the right eye is chosen with no consideration on the effects of ocular dominance on variability. Since the percentage of population with right eye dominance is larger than that of left eye dominance [5–7,12] only selecting the right eye results for clinical studies would imply a **bias**, which could decrease the variance.

In a recent work, [13], the authors presented some results related with corneal morphology. In their data they distinguished between the left and the right eye, and found that bilateral symmetry was broken in many subjects, for different Zernike components. We **did not** find any reason on why results for the left eye were systematically worse than those for the right eye. One of the hypotheses posed was that ocular dominance increases the variability of measures taken in the **non-dominant** eye. The aim of this work is to check this hypothesis.

As it was previously done a group of subjects were explored with a Pentacam system. Some measures were taken for both eyes and their coefficient of variation for the dominant and **non-dominant** eye was compared. We will see that variability of measurements is biased. Statistics show that this trend is not statistically relevant. Nevertheless a contrast study showed that our results are consistent and the Pentacam is sensible to eye dominance.

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Results here presented are not limited to measurements with Pentacam but they can be extended to many ocular measuring devices. Modern systems are sensible enough to detect differences between dominant and **non-dominant** eyes and this effect should be considered prior to any conclusion regarding variability of measurements.

2. Materials and methods

For this study, 25 healthy subjects (12 men, 13 women) aged 36.9 ± 8.9 years (ranging from 20 to 49 years) were explored. Strabismus, contact lens users and patients having undergone ocular surgery were excluded, as well as with an irregular corneal astigmatism. Subjects taking part in this study were selected from the staff and students of the School of Optics and Optometry of the University of Alicante who met the above selection criteria. We adhered to the tenets of the Declaration of Helsinki during this study. All participants were informed about the nature and purpose of the study and all provided informed consent. All examinations were performed by the same experienced examiner.

Ocular dominance was assessed using the Hole-in-the-Card test [14]. Subjects, wearing their spectacles, extended their arms and centred a Snellen "E" target a 6 m through a 3 cm central hole. The examiner covered one of the subject's eyes randomly, and asked if the target was still visible. When distant target disappeared the occluded eye was identified as a fixating eye. The test was repeated and all subjects had consistent results within the two series. Fifteen subjects (60%) were found to have right eye dominance and ten subjects (40%) left eye dominance.

Measurements of the anterior segment were taken with an Oculus Pentacam, a system that captures multiple images of eye's anterior segment. This device provides the pachymetry and topography of both corneal surfaces. Anterior segment examination also comprises a three-dimensional analysis of the anterior chamber: anterior chamber angle, volume and depth. For our study we have selected 25 images per scan and Pentacam's automatic release mode and ten consecutive measurements were taken by each eye. Although Pentacam instructions recommend to perform measures in complete darkness, our experience visiting several clinics showed us that this condition is seldom fulfilled and dim illumination is often used. Thus, we have reproduced such conditions: **the** ambient light is low enough to allow that measurements to be free of external glares although the subject had fixation references in both eyes.

To assess differences on variability between dominant and **non-dominant** eyes the coefficient of variation (CV) – defined as the standard deviation of the measurements divided by its **mean** – is used. We measured several variables with the Pentacam: corneal power of the flattest and steepest meridians of the anterior and posterior surface (K1, K2), iridocorneal angle (ICA), anterior chamber depth (ACD) and volume (ACV), and apex pachymetry (CCT). The Paired-Samples t-test is used to test the hypothesis of no difference between two coefficients of variation (dominant, **non-dominant**).

Additionally to these variables we have also compared the mean values of the three indexes provided by the Oculus Pentacam that inform about the quality of the exam. These indexes are provided as quality control tests and are the vertical and horizontal alignment (XY), Z alignment and eye movement; being this last one related with the fixation during the examination. Pentacam software establishes a threshold so that obtained values below it are accepted as correct. **Unfortunately** we **did not** find further explanation about what is **exactly** measured by such

variables, but since they are related with fixation effects, we decided to include their analysis in our study.

Normality of all variables was verified with the Kolmogorov–Smirnov test. All *p*-values obtained indicated that the data followed a normal distribution ($p > 0.05$). Statistical analysis of the data was performed with statistical package SPSS® for Windows (V. 11.5). Test of significance were two-tailed with a level of significance of 0.05.

3. Results

Table 1 shows the differences in variance between dominant and **non-dominant** eyes. Data are described by the mean values of **coefficient** of variation with significance value of differences. The table shows that, in general, there are **no** statistical differences between the dominant and non-dominant eye in the parameters evaluated except in the case of the flattest curvature, K2, of corneal posterior surface. Nevertheless, although the tests of statistical significance are not conclusive, one can see a clear bias in the variability between dominant and non-dominant eye: in 7 of 8 analyzed parameters the dominant eyes have less variability **than** the non-dominant one. This means that a small trend exists and less variable measurements are obtained in the dominant eye.

Table 2 shows the differences in average values of the indexes related with ocular movements and fixation quality provided by Pentacam during the examination. We can see that there are no significant differences between dominant and **non-dominant** eyes for any of these indexes. This means that these indexes cannot detect the dominance and as a consequence of this the system might be no sensible to small oculomotor movements. We can also see that, in general the three indexes are highly dispersive, specially the XY and Z alignment values. This variability is surprising when it is compared with the other parameters measured by the system.

Table 1

Mean values of coefficient of variation for the variables^a obtained with the Oculus Pentacam system and significance value (*p*) of differences.

	Dominant eyes	Non-dominant eyes	<i>p</i>
Anterior surface			
K1	0.2423	0.2656	0.59
K2	0.2716	0.3158	0.20
Posterior surface			
K1	0.6600	0.8534	0.04
K2	0.7581	0.7991	0.48
ACD	0.6394	0.8137	0.20
ICA	3.1891	3.6001	0.23
ACV	2.0385	1.9237	0.53
CCT	0.8555	0.8920	0.71

^a Curvature of the corneal surfaces in the flattest (K1) and steepest (K2) meridian, iridocorneal angle (ICA), anterior chamber depth (ACD), anterior chamber volume (ACV), and central corneal thickness (CCT).

Table 2

Mean values for the index monitoring with the Oculus Pentacam system.

	Dominant eyes	Non-dominant eyes	<i>p</i>
Eye movements	53.5 ± 15.0	50.1 ± 14.9	0.130
Alignment XY	369.2 ± 97.1	356.6 ± 124.17	0.731
Alignment Z	210 ± 135.7	199.2 ± 143.2	0.725

4. Discussion

In this work we have analyzed the effect of the ocular dominance on the variability of some measurements obtained with Oculus Pentacam. The selected population show a percentage of right ocular dominance of 60%, in accordance to similar studies that also used the hole in the card test [2,7,15,16].

The first conclusion of this work is that, according to values of coefficient of variation (CV) a good repetitiveness of all measurements is observed with a mean coefficient of variation lower than 4%, which is in accordance with studies showing the reliability of the Oculus Pentacam system [17].

Results show that, although differences between dominant and not dominant eye are not statistically significant exists a bias in the variability due to measurements being less variable in the dominant than in the non-dominant eye. This finding is in accordance with our previous results in Ref. [13], which lead us to make this study. In both studies measurements have not been done in total darkness, contrary to the recommendations of the Pentacam system – but in accordance with the normal clinical practice. Appearance of rivalry effects requires the visual stimuli to be present for both eyes. Thus a low illumination was needed to allow vision in the non-observed eye. In any case, these conditions are admitted by the system according the Quality Specification (QS) parameter, which controls the influence of the illumination during the exam.

With respect to the indexes related with ocular movements and fixation stability one can see that they present a higher variability than the other parameters under study. This effect has been also observed in individual subjects. Otherwise there is no statistical difference between dominant and non-dominant eye in those parameters and we believe that those values are not really connected with such ocular movements. Unfortunately we could not find any work that state the reliability of such parameters, so we could not verify this point.

Results in Tables 1 and 2 may seem contradictory. In order to check that the results in Table 1 were not produced because of artifacts or posture habits a contrast study was performed in total darkness for 11 subjects. This experience brought out that differences disappeared and no bias in the variability of the dominant eye is observed in total darkness.

The two experiments here performed – with low light and in total darkness – show that the differences observed between dominant and non-dominant eyes are not by accident. Results are also in accordance with those obtained by Mas et al. [13]. In our opinion, the limited accuracy of the system does not allow to detect the small ocular movements although they influence the measurements since data obtained with the dominant eye are more stable than those with the other eye.

Recently, Kasprzak and Iskander [18] described the fine head movement in a standard ophthalmic headrest. They measured absolute head displacements of about 200 μm due to cardiopulmonary pulse. Pentacam does not take one static image of the eye but captures 25 different meridians in 1 s while the head and the

eye is moving. Although Pentacam's repetitiveness is high, these fine oscillations may increase the dispersion of measurements and also their variability. We are convinced that with a strong stabilization of the headrest in the Pentacam, it is possible to reduce the variability and thus to observe the effects of eye dominance.

Our main point here is that systematic election of the right eye in analysis of reliability or reproducibility can bias the variability of results. On Pentacam and other devices, which measure in total darkness this effect will not be observed. Nevertheless, there are many other devices – commercial or not – that are used on one eye while the other is uncovered. In such cases, we suggest to take always the dominant or non-dominant eye or even the mean variability between both eyes to know the real repeatability of the instrument. Moreover if one wants to make very precise measurements we recommend taking always the dominant eye in order to reduce dispersion of the results.

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