Shift of the pupil center with pupil constriction.

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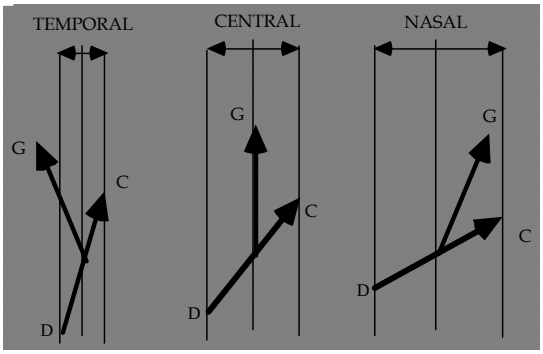
Purpose. Several studies have reported a shift of the pupil center while it constricts. The aim of this study was to evaluate the influence of gaze orientation on this phenomenon. For this purpose, we studied the relative contribution of three mechanisms : the anisotropic contraction of the iris, the mechanical displacement of the pupil due to the curvature of the lens and the optical formation of the virtual image of the pupil through the corneal diopter.

Methods. The study was performed on 6 adult subjects. We measured the position of the pupil and corneal reflex images with a photo-oculographic system from Metrovision and the geometry of the anterior chamber with an EAS1000 system from Nidek. These measurements were made for 5 gaze orientations (1 central and 1 in each quadrant at 14 degrees of eccentricity) The pupil size was varied by adjusting the ambient illumination.

Results. Our data confirm that, while the pupil constricts, its center moves in the nasal superior direction. The amplitude of this displacement varied with the eccentricity of gaze : for a change of 1 mm in pupil diameter, the displacement was 0.022 mm for temporal fixation, 0.038mm for central and 0.060 mm for nasal. Biometric measurements showed a simultaneous advance of the iris within the anterior chamber, following the curvature of the lens, of 0.072 mm.



displacement of the pupil while it constricts
as a function of gaze direction

G = gaze direction
D = center of dilated pupil
C = center of constricted pupil

Conclusions. Our results show that the slope of the displacement of the pupil while it constricts is asymmetric. This asymmetry results from a combination of movements toward the nasal superior direction and forward.

INTRODUCTION

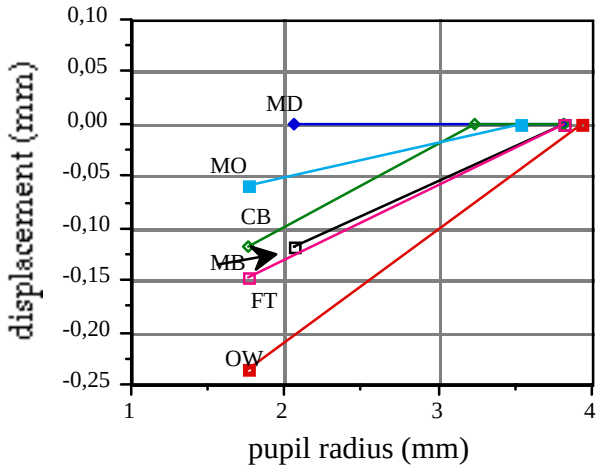
Several authors have reported a shift of the pupil center while it constricts (Legrand, 1965, Paris & Charlier, 1987, Wilson & al, 1992, Fujita & al, 1993, Buquet & Charlier, 1994). The aim of this study was to evaluate the influence of gaze orientation on this phenomenon and its possible influence on the interpretation of the Hirschberg test.
In order to evaluate the relative contribution of mechanisms responsible for this phenomenon, we studied the relative displacement of the pupil image in relationship with the movements of the pupil within the anterior chamber during variations of the ambient illumination.

METHODS

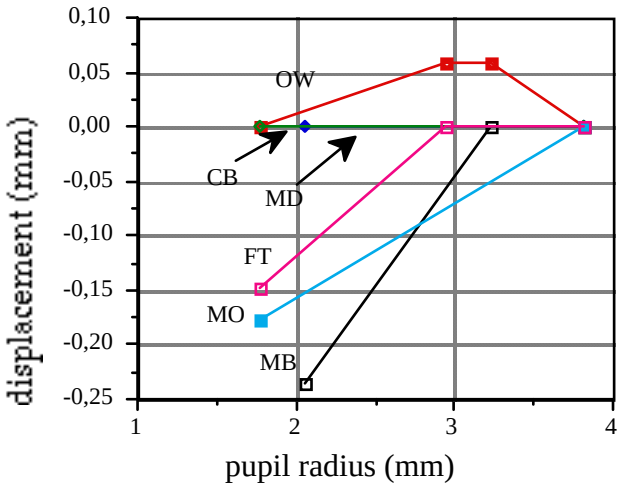
Subjects were fixating monocularly a 5 arc min target at a distance 1.25 meters with their head fixed with a bite board. The positions of the centers of the pupil contour and corneal reflex images were measured with a photo-oculographic system from Metrovision (near infra-red illumination at 880 nm, sampling rate = 30 images per second).
These measurements were made for 5 gaze orientations (1 central and 1 in each quadrant at 14 degrees of eccentricity). The pupil size was varied by adjusting the ambient illumination.
The geometry of the anterior chamber was measured from digital images recorded with an EAS1000 system from Nidek.

RESULTS

The following figures show the horizontal and vertical displacements of the pupil as a function of the pupil radius measured from 6 subjects for a central fixation

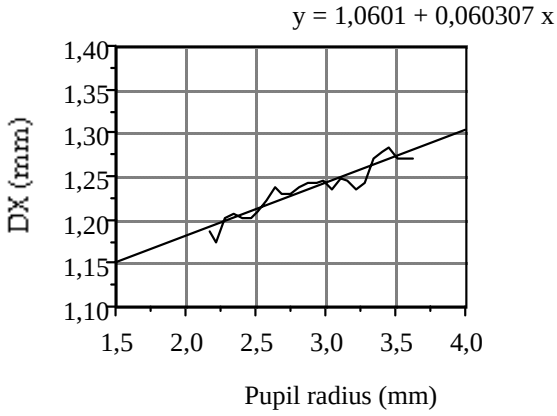


horizontal displacement
of the pupil center

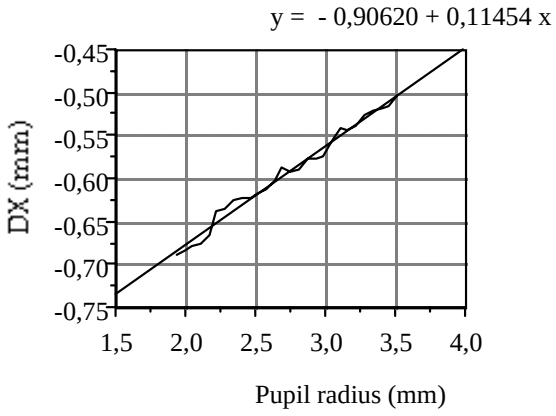


vertical displacement
of the pupil center

The following figures show an example of the horizontal and vertical displacements of the pupil as a function of the pupil radius measured from the same subject for central and eccentric fixations

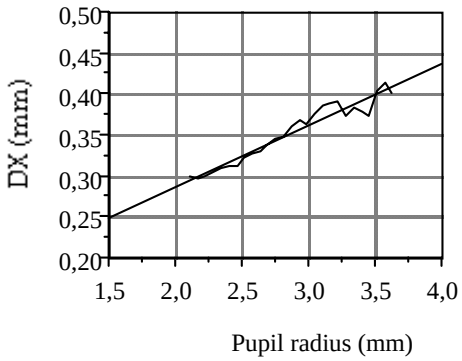


Horizontal displacement of the pupil
for superior-temporal fixation



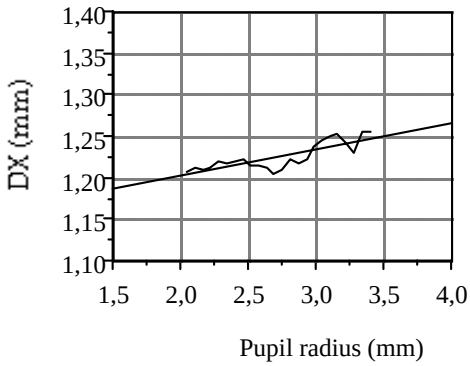
Horizontal displacement of the pupil
for superior-nasal fixation

y = 0,13323 + 0,076040 x



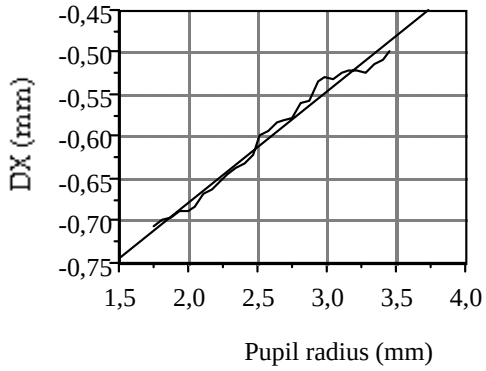
Horizontal displacement of the pupil
for central fixation

y = 1,1374 + 0,032282 x



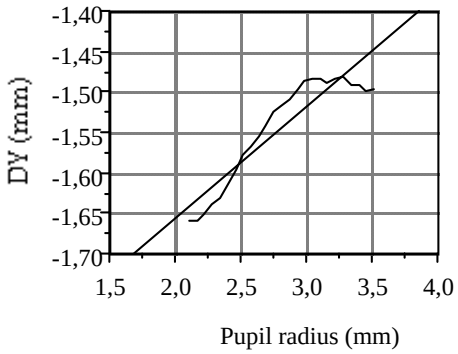
Horizontal displacement of the pupil
for inferior-temporal fixation

y = - 0,94268 + 0,13214 x



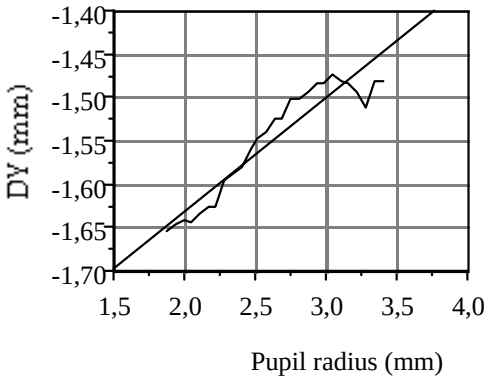
Horizontal displacement of the pupil
for inferior-nasal fixation

y = - 1,9342 + 0,13839x



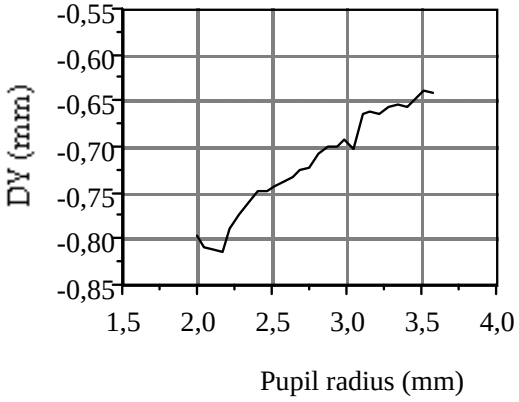
Vertical displacement of the pupil
for superior-temporal fixation

y = - 1,8922 + 0,13042x

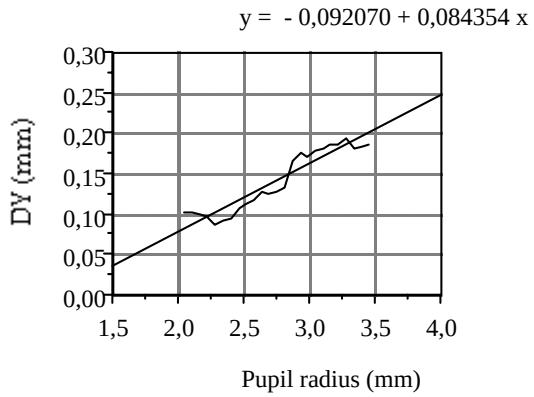


Vertical displacement of the pupil
for superior-nasal fixation

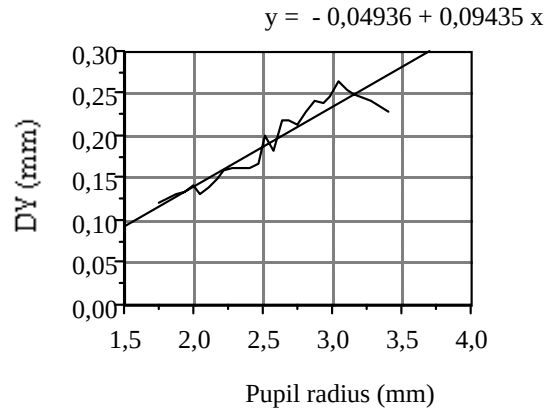
y = - 1,0349 + 0,11381 x



Vertical displacement of the pupil
for central fixation

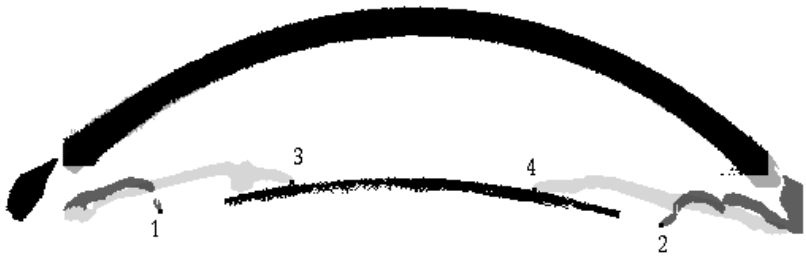


Vertical displacement of the pupil
for inferior-temporal fixation



Vertical displacement of the pupil
for inferior-nasal fixation

The following figure shows one example of the displacement of the pupil associated with its constriction.



Nasal OD Temporal
(angle = 45 degrees relative to the horizontal plane)

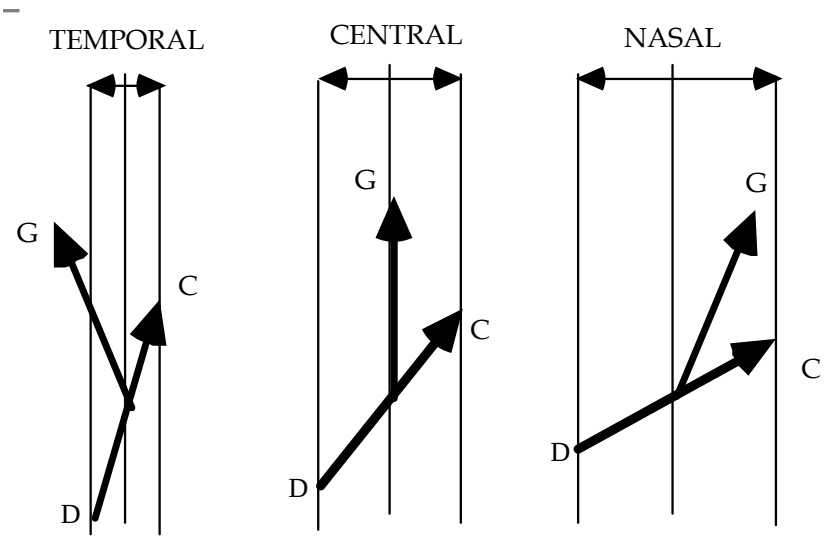
radius of the virtual image of the pupil (mm) :	MB	MO
dilated	3.59	3.98
constricted	1.82	1.93
"forward" displacement	0.37	0.52

DISCUSSION

Our data confirm that, while the pupil constricts, its center moves in the nasal superior direction. The amplitude of this displacement varies between subjects but seems to be reproducible in the same subject.
On average, for adult subjects, 1 degree of rotation results in a displacement of the pupil center relative to the corneal reflex of 0.082 mm. Therefore the shift of the pupil center associated with its constriction may reach values equivalent to 4 degrees of rotation !!!

This effect varies with the eccentricity of gaze : for a change of 1 mm in pupil diameter, the displacement was 0.022 mm for temporal fixation, 0.038mm for central and 0.060 mm for nasal.

Biometric measurements showed a simultaneous advance of the iris within the anterior chamber, following the curvature of the lens, of 0.072 mm.
The changes in pupil shift observed at different eccentricities are found to result from the combination of movements of the pupil within the anterior chamber. While the pupil constricts, its center moves simultaneously in the nasal superior direction and forward.



displacement of the pupil while it constricts as a function of gaze direction

G = gaze direction
D = center of dilated pupil
C = center of constricted pupil

CONCLUSIONS

Precise measurements of gaze direction based on the Hirschberg principle should take into account displacements of the pupil center associated with its constriction. The appropriate correction seems to be constant for each subject. It varies asymmetrically with the eccentricity of

fixation, as the result of a combination of movements of the pupil toward the nasal superior direction and forward, in a manner which can be predicted from the curvature of the lens.

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