

A SIMULATION STUDY FOR INTEROCULAR DIFFERENCES IN VISUAL LATENCY INDUCED BY REDUCED-APERTURE CORNEAL INLAYS OR CONTACT LENSES FOR PRESBYOPIA



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1. INTRODUCTION

It has long been known that ocular depth-of focus increases as pupil diameter decreases¹. This led to the suggestion that the intermediate and near vision of emmetropic presbyopes could be improved by artificially reducing the pupil diameter in one eye. Originally this was considered for contact-lens corrections but the idea never found favour, largely because of the associated reduction in retinal illuminance in the lens-wearing eye². More recently, however, the concept has been applied to corneal inlays³. The aim of the study was to explore the interocular differences in the temporal responses of the eyes induced by the monocular use of small-aperture optics designed to aid presbyopes by increasing their depth-of-focus.

2a. METHODS: Pupil apertures

In the experiments four types of afocal, hand-painted, opaque soft contact lenses (74% water content, Cantor & Nissel Ltd, Brackley, UK) were used. Three were opaque over an 8 mm diameter but had central clear circular apertures of 1.5, 2.5 or 3.5 mm in diameter. A fourth lens had a smaller annular (A) opaque zone with outer and inner diameters of 4.0 and 1.5 mm respectively, which approximately simulated the geometry of the Kamra inlay.

If we assume that the lens is centered to the natural pupil, the effective entrance pupil geometry in the CL-wearing eye is modified by that of the lens. The changes in the relative retinal illuminance in the eyes as a function of the natural pupil diameter can then be calculated in terms of the relative areas of the pupils. Fig. 1 shows the relative illuminance in eyes wearing each of the four CL types.

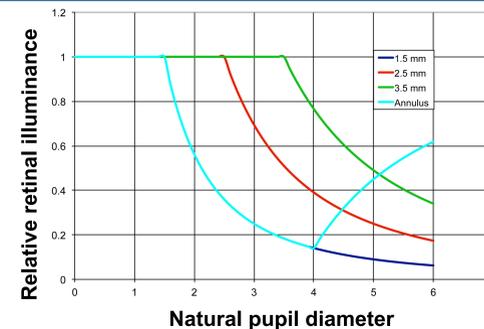
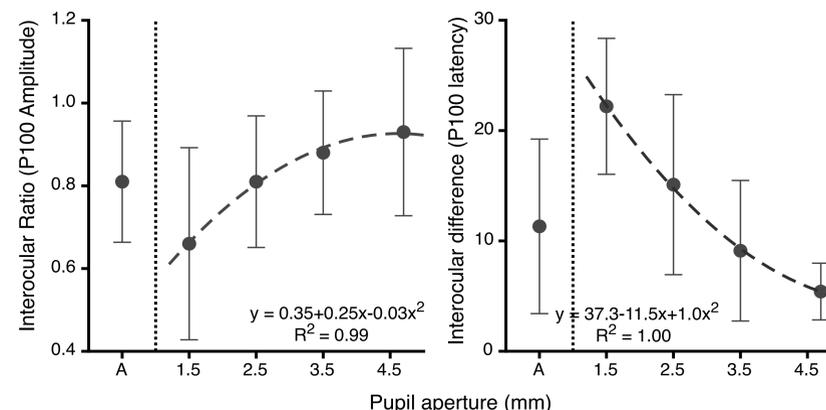


Figure 1: The retinal illuminance in the eye wearing a reduced-aperture CL relative to that of the eye with its natural, unobstructed pupil.

3a. RESULTS: Effect of pupil diameter at constant test luminance

The small-aperture contact lenses reduced the amplitude of the P100 component of the VEP and increased its latency. Interocular differences in latency rose from 5.4 ± 2.5 ms when both eyes have 4.7 mm pupils to 22.2 ± 6.1 ms when the pupil diameter of the non-dominant eye was reduced to 1.5 mm. A similar trend was found for the interocular P100 amplitude ratios (see fig. 3). The interocular amplitude ratios and latency differences with the non-dominant eye wearing the “annular” (A) lens were comparable to those that would be expected for a circular pupil of similar area, having a diameter of about 2.9 mm.

Figure 3: Mean interocular amplitude ratio (left) and interocular latency difference in ms (right) in the VEP P100 component as a function of the central aperture of the contact lens (used in the non-dominant eye) under monocular stimulation. The dominant eye had its full, unobstructed natural pupil (~4.7 mm). The bars indicate ± 1 SD. The dashed lines form second-order regressions. The “A” in x-axis represents the “annular” lens.



4. CONCLUSIONS

The anisocoria induced by small-aperture approaches to aid presbyopes produces marked interocular differences in visual latency. The literature of the Pulfrich effect suggests that such differences can lead to distortions in the perception of relative movement and, in some cases, to possible hazard.

We suggest that presbyopic patients should be made aware of the possible visual problems in movement perception associated with the unilateral use of “pinhole” type inlays or lenses and that active steps should be taken to ascertain their impact, if any.

2b. METHODS: VEP recordings

Seven volunteers with an average age of 29 ± 5 years participated in the study

Monocular pattern reversal visual evoked potentials (VEPs) were measured at a mean photopic field luminance of 30 cd/m^2 with either natural pupils (4.4 ± 0.4 mm) or when the non-dominant eye wore each of the four types of CLs, inducing anisocoria. To investigate whether any observed changes in VEP characteristics for the lens-wearing, non-dominant eye were the result of changes in retinal illuminance, VEPs were repeated with varying stimulus luminance ($5, 13.9, 27.2$ and 45 cd/m^2) and a fixed 3.0 mm artificial pupil. The successive values of this sequence bear the same ratios to one another as the areas of the circular apertures in the CL and the natural pupil diameter (i.e. $1.5^2, 2.5^2, 3.5^2, 4.5^2$).

VEPs were elicited using reversing 10 arcmin checks at a rate of 4 reversals per second (2 Hz) with square-wave temporal modulation. VEP P100 amplitude and latency were derived from the average waveform.

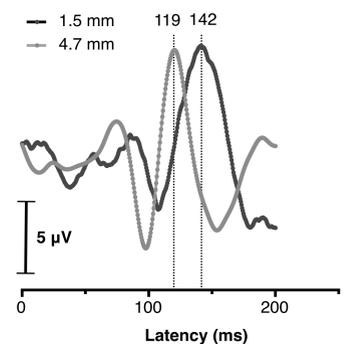


Figure 2: Grand-averaged (64 epochs) monocular VEP waveforms from one subject for a pupil diameter of 1.5 mm (black line) and 4.9 mm (grey line).

3b. RESULTS: Effect of test luminance at constant pupil diameter

The effect of varying the stimulus luminance (and hence the retinal illuminance) on the VEPs in the non-dominant eye with the fixed pupil was found to be very similar to that found when a constant stimulus luminance was used but retinal illuminance varied as a result of changes in the pupil size. VEP amplitude increased and latency decreased as the stimulus luminance was increased.

If we assume that in both cases the VEP characteristics depend only on retinal illuminance we can replot the VEP data for the two experiments in terms of retinal illuminance, where retinal illuminance in trolands is simply the product of pupil area (mm^2) and field luminance (cd/m^2) (Fig.4). The combined data agree quite well with the hypothesis that the VEP variation in both experiments is due to the changes in retinal illuminance, and is independent of whether such illuminance variation is produced by changes in pupil diameter or stimulus luminance.

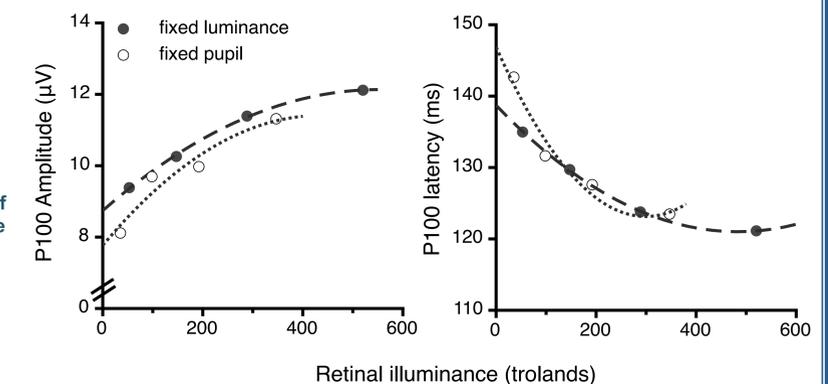


Figure 4: Changes in VEP amplitude and latency as a function of retinal illuminance for 3 subjects. Changes in retinal illuminance were produced combinations of either variable pupil diameter and fixed luminance (filled symbols) or variable luminance and fixed pupil diameter (open symbols). The dashed and dotted lines are second-order regressions to each data set.

References

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