VISUAL REACTION TIMES: A BEHAVIOURAL METHOD FOR EVALUATING DEPTH OF FOCUS

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INTRODUCTION

Today, there are plenty of prescriptive and surgical approaches used in presbyopia correction. Most of the available modalities (e.g. monovision, bifocal and multifocal CLs and IOLs, presbyopic LASIK and corneal inlays) are targeted to ameliorate the effects of reduced amplitude of accommodation in the ageing eye, by extending the ocular depth-of-focus (DOF), "the greatest dioptric focusing error which does not result in objectionable deterioration in retinal image quality" (Smith & Atchison, 1997),

DOF is usually evaluated using various subjective, objective and computational measures. Although objective and computational techniques have a clear advantage over subjective methods in terms of repeatability and avoidance of subjective bias, they are not completely representative of clinical outcomes. Thus, behavioural methods, as well as patient-based subjective ratings, form a complementary and indispensable way to assess visual performance alongside objective measurements

The aim of this study is to develop a behavioural measure, based on visual reaction times, that can evaluate the depth-of-focus in uncorrected vision or when using different modalities of simultaneous vision correction for presbyopia.

METHODS

Experiments with human observers have shown that the speed of visual processing, as measured using simple visual Reaction Times (RTs)*, becomes slower in a predictable way as stimuli become less visible, i.e. as stimulus contrast decreases (Plainis & Murray, 2000). Since the sensory component of simple visual RTs is limited by the properties of neurons in the retino-cortical pathways, it is expected to reflect (i) the spatio-temporal properties of these neurons (Murray & Plainis, 2003) and (ii) the quality (e.g. contrast and resolution) of the retinal image, which in turn relates to the effectiveness of the presbyopic correction.

Visual RTs, have a direct relevance to perceptual-motor tasks, such as driving. For example, they have been used to estimate the time to collision with an approaching object under specific conditions and can be easily translated into stopping distances (Plainis & Murray, 2005). RTs can be used to assess through-focus performance, offering the advantage of supra-threshold, i.e. real-world, task, evaluation.

RTs were measured to the onset of a sinusoidal grating with a spatial frequency of 4 c/deg and a contrast of 10%, displayed on a Sony F-520 CRT monitor (mean luminance 30 cd/m2), using a VSG2/5 stimulus generator card (Cambridge Research Systems Ltd, UK). Fixation was maintained using a centrally placed cross. All measurements were performed monocularly (dominant eye) and binocularly at 3m viewing distance, under cycloplegia with best spectacle sphero-cylindrical correction and 4mm pupils. RTs were measured for different degrees of negative blur, induced using negative powered lenses up to -4.50 D. Simultaneous vision was simulated using multifocal contact lenses of «Low» and «Hi» addition (Air Optix Aqua Multifocal, Ciba Vision). Measurements have been performed on three subjects. Representative data from one subject (age 40) are shown here.

*Simple visual reaction time is the elapsed time between the presentation of a visual stimulus, such as a grating, and the subsequent response, under the condition that the subject is instructed to respond (e.g. to press a button) as rapidly as possible. In a typical experiment each trial represents a block of 32 measurements.

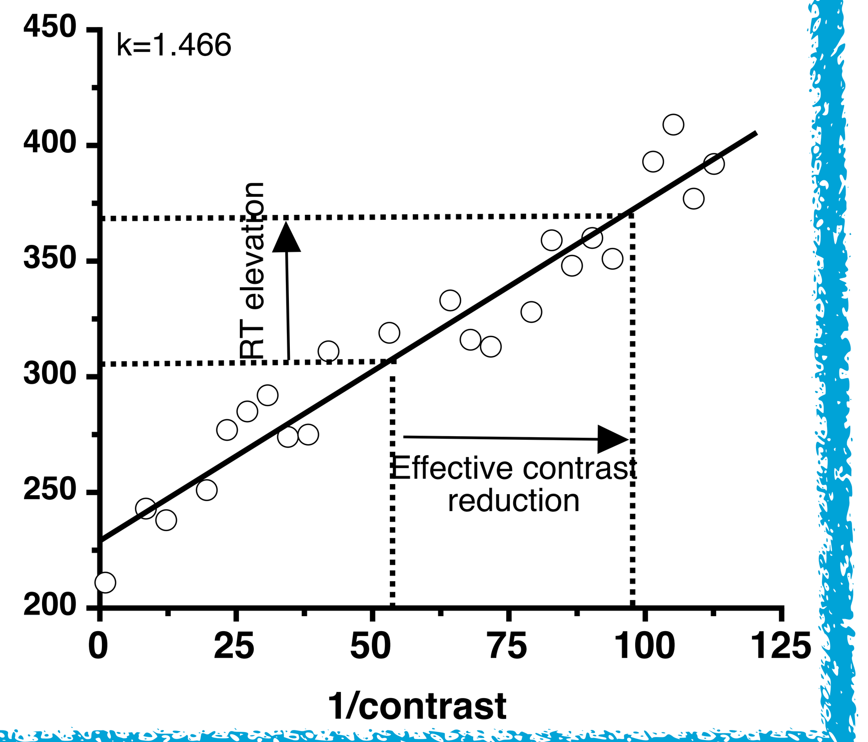


FIGURE 1: Plot of RTs vs. the reciprocal of contrast (1/C) for a 4 c/deg grating. For the specific condition extrapolating the (increased) RT under defocus back to the RT vs. 1/C plot gives a measure of effective contrast reduction.

RESULTS: DEPTH-OF-FOCUS IN "UNAIDED VISION"

Figure 2 presents the effect of defocus on RT under both monocular and binocular vision. RT increases with defocus blur, with the effect being more pronounced for monocular compared to binocular viewing conditions. Depth of acceptable perceptual blur (depth-of-focus, DOF) is calculated from the second order polynomials, which fit the RT vs. defocus blur functions. More specifically, the width of the polynomial fit is estimated for a specific RT (eg. 275 and 300 ms). Regardless of the RT criterion chosen, depth-of-focus is always greater with binocular than monocular vision (0.62D to 0.53D for 275ms – 1.04D to 0.75D for 300ms).

Depth-of focus can also be computed from the plots fitting the effective contrast for different amounts of defocus (figure 3). Effective contrast for each RT is extrapolated by the RT vs. 1/C slope (see figure 1). For example, if a criterion of 1% effective contrast is used (corresponding to 1.0 log reduction in effective contrast) the DOF is 1.00D and 0.60D under binocular and monocular stimulation, respectively.

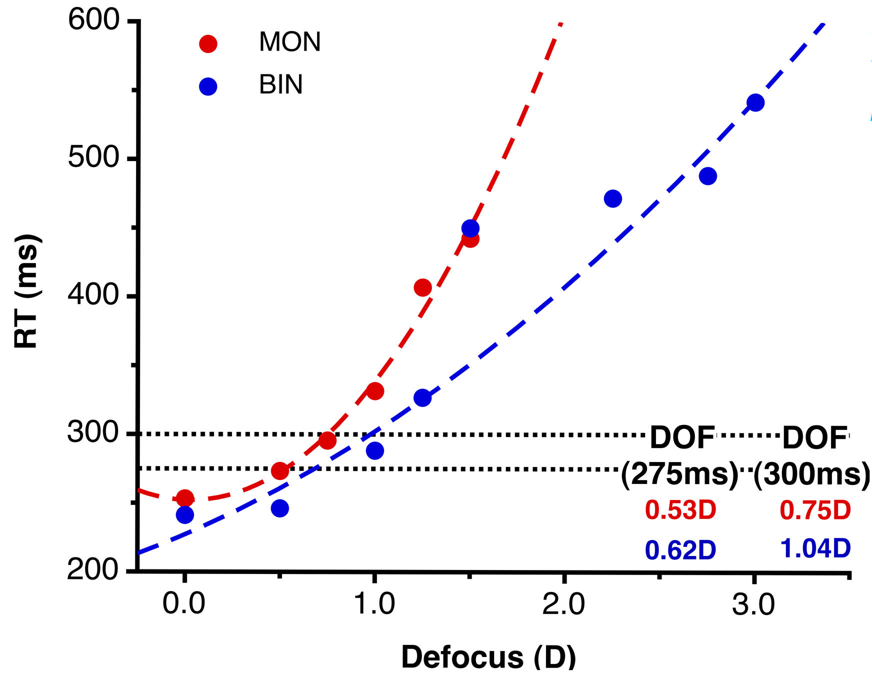


FIGURE 2: Plot of RT as a function of defocus under monocular (red circles) and binocular (blue circles) viewing conditions. The dashed lines form second order polynomials. The numbers (red: monocular, blue: binocular) correspond to calculations of the depth-of-focus using a RT criterion of 275ms or 300ms.

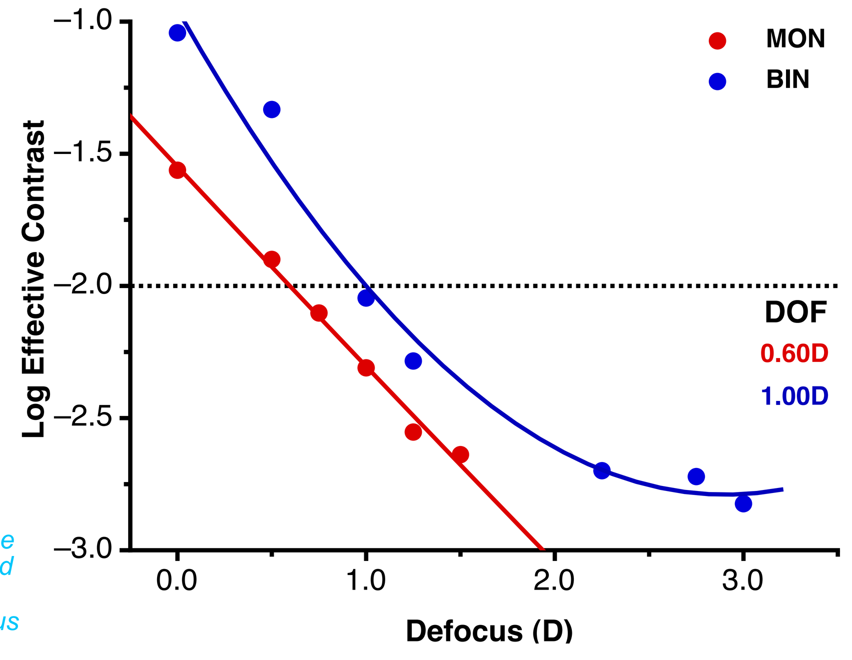


FIGURE 3: Plot of log effective contrast as a function of defocus under monocular (red circles) and binocular (blue circles) viewing conditions. The dashed lines form second order polynomials. The numbers (red: monocular, blue: binocular) correspond to calculations of the depth-of-focus using a criterion of 1 log reduction in effective contrast.

RESULTS: DEPTH-OF-FOCUS IN "SIMULTANEOUS VISION CORRECTION"

Figure 4 shows the effect of defocus on RTs in the presence of simultaneous vision correction (multifocal Cls of «low» and «high» addition), claim to provide extended depth-of-focus. It is evident that RTs, although slower for «optimal» focus, are more tolerant to defocus compared to "unaided vision". DOF is found higher compared to «unaided vision», with the effect being more pronounced under binocular vision.

Figure 5 presents extrapolated effective contrast (from the RT values in figure 4) as a function of defocus. Again, it is clear that DOF is extended compared to unaided vision. Note, that DOF is found lower for the «Hi» than the «Low» addition contact lenses in monocular viewing for the criterion of 1% effective contrast.

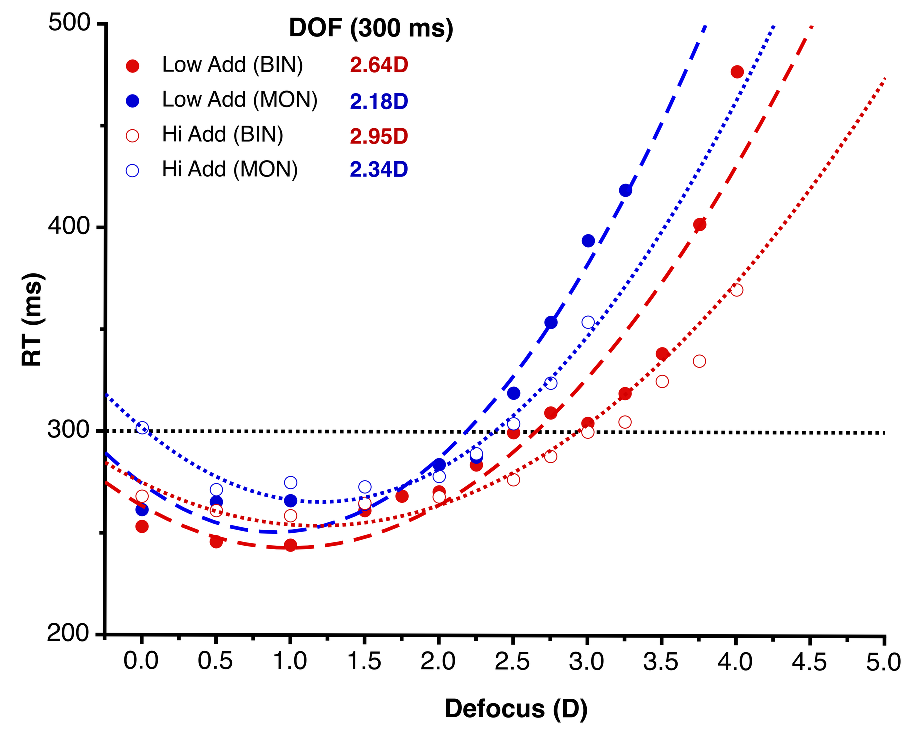
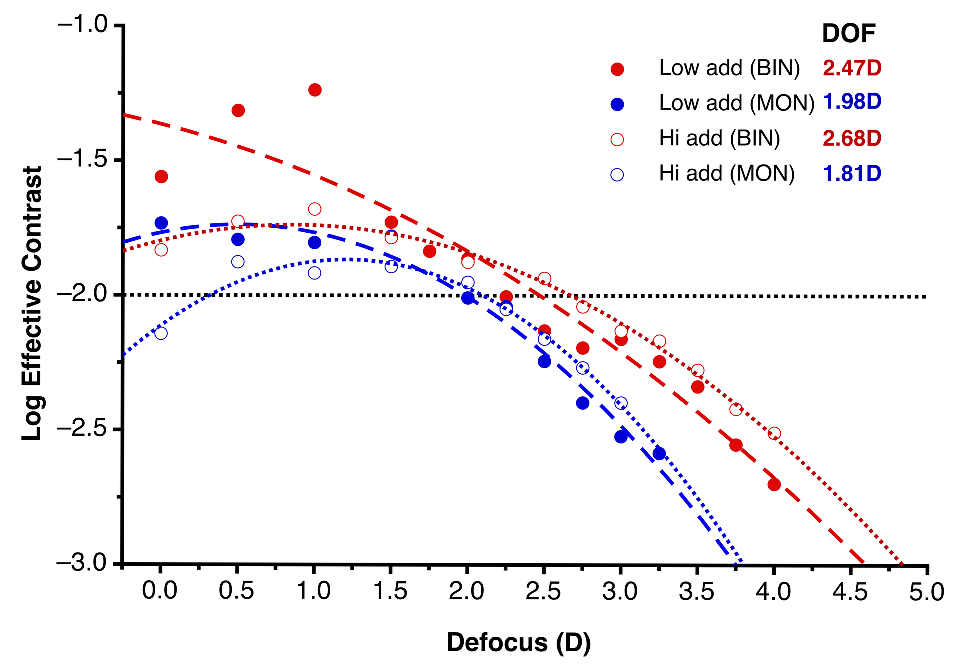


FIGURE 4: Plot of RT as a function of defocus under monocular (red circles) and binocular (blue circles) viewing conditions with multifocal CLs of «low» (filled circles) and «hi» (open circles) addition. The dashed (high add) and dotted (low add) lines form second order polynomials. The numbers correspond to calculations of the depth-of-focus using a RT criterion of 300ms.

FIGURE 5: Plot of log effective contrast as a function of defocus under monocular (red circles) and binocular (blue circles) viewing conditions with multifocal CLs of «Low» (filled circles) and «Hi» (open circles) addition. The dashed (high add) and dotted (low add) lines form second order polynomials. The numbers correspond calculations of the depth-of-focus using a criterion of 1 log reduction in effective contrast.



CONCLUSIONS

1. Binocular summation results to greater amounts of depth-of-focus in both "unaided" and "simultaneous" vision.
2. Depth-of-focus is improved when using simultaneous vision correction, as provided by multifocal contact lenses.
3. Like visual acuity and contrast sensitivity, simple visual RTs can be used to assess through-focus performance, offering the advantage of supra-threshold, i.e. real-world, task, evaluation, under both monocular / binocular viewing conditions.
4. The technique described here could be also used with different stimuli (other than gratings, which and are not very sensitive to defocus) and another type of RTs, such as choice or recognition RTs.

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