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Central and near peripheral retinal contributions to the depth-of-focus using naturalistic stimulation ☆

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Abstract

Although the depth-of-focus (DOF) has been investigated separately in the central retina and in the near retinal periphery, knowledge about their combined relative contribution to overall blur perception has remained unknown. In the present study, the DOF was measured psychophysically with a naturalistic pictorial stimulus as a function of spatial extent across the near retinal periphery under monocular Badal viewing conditions with accommodation paralyzed. The group mean total DOF progressively increased linearly with target size. Based on the individual DOF responses, the group was categorized into two subgroups: a predominantly centrally-driven and a centrally plus peripherally-driven subgroup. The results implicated partial cone pooling of blur information, as well as influence from perceptual, attentional, and optical aspects. However, the subgroup response profiles suggested individual differences in the weighting of the near peripheral blur information at the retinal level, and perhaps at higher-level areas of the visual system, involving spatial integration and global attentional processing.

Keywords: Defocus; Accommodation; Blur; Peripheral vision; Retinal eccentricity

1. Introduction

During viewing of our everyday surrounds, one has the sense of an extended range of clear vision. This is due, in part, to the inherent neuro-optical properties of the visual system, namely depth-of-field and related depth-of-focus (DOF), as well as correlated perceptual and attentional aspects (Jiang, 1997; Wang & Ciuffreda, 2004a, 2004b, 2005a). Furthermore, models of accommodation (e.g., Hung, Ciuffreda, & Rosenfield, 1996; see Hung, Ciuffreda, Khosroyani, & Jiang, 2002, for a review) indicate that if the accommodative error is smaller than the DOF, there would be no accommodative response change, as the retinal defocus error would not exceed the requisite neurosensory threshold (Ciuffreda, Hokoda, Hung, & Semmlow, 1984). The neurosensory depth-of-focus allows small amounts of accommodative error to be tolerated without the perception of blur. Without such subjective tolerance to defocus, the eye would have to be perfectly in focus at all times to maintain clear vision, which is impractical (Ciuffreda, 1998).

Although numerous studies have been conducted on the DOF of the human eye at the fovea (e.g., Campbell, 1957; Jacobs, Smith, & Chan, 1989; see Ciuffreda, 1991, 1998 for reviews), only a paucity have been performed with regard to either the near (Wang & Ciuffreda, 2004a, 2004b, 2005a) or far (Ronchi & Molesini, 1975) retinal periphery. The findings of the above studies showed a progressive increase in DOF with retinal eccentricity. However, no study has been conducted investigating the combined effect of the foveal and

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retinal peripheral contributions to the DOF, despite the fact that this is how one may function in the normal visual environment. The results of such a study would provide valuable insight into the relative weighting of the central and peripheral retinal regions into the overall blur perception process (Ciuffreda, 1991; Wang & Ciuffreda, 2004b). Such information is also critical to understanding basic accommodative control (e.g., accuracy) (Bullimore & Gilmartin, 1987). Furthermore, all earlier studies used isolated non-naturalistic stimuli (e.g., a variable aperture edge). In the present investigation, the effect of the combined central retina and near retinal peripheral contributions to the DOF of the human eye was determined using a naturalistic, pictorial stimulus.

2. Methods

2.1. Subjects

Ten visually-normal healthy adults (6 males and 4 females), all of whom were students at the SUNY State College of Optometry, served as subjects. Ages ranged from 23 to 30 years, with a mean of 25 years. Their experience in general psychophysical experiments ranged from modest to moderate. Each achieved corrected Snellen visual acuity of at least 20/20 in the tested right eye. The group mean spherical and cylindrical refractive correction of the right eye was -1.83 ± 0.54 D and -0.18 ± 0.15 D, respectively, which was either placed in a holder in the spectacle plane (cylindrical component) or compensated for by the optical system with placement at the individual's far point (spherical component) during all testing. The spherical refractive component ranged from 0 to -5.50 D, while the cylindrical refractive component ranged from 0 to -1.50 D. A licensed optometrist performed the vision screening to avoid any potential adverse effects from the topical administration of 1% cyclopentolate HCL, which achieved both cycloplegia and pupillary dilatation during the test. The experiment was undertaken with the full understanding and written informed consent of each subject, as well as approval by the local Institutional Review Board, according to the guidelines of the World Medical Association Declaration of Helsinki (1996).

2.2. Apparatus

The apparatus consisted of a Badal optical system which was positioned in front of and aligned along the line-of-sight of the subject's right eye (Fig. 1A). An artificial pupil (AP) of 5 mm diameter was positioned in front of the tested eye. To preclude the measured values from exceeding the 5D proximal and 5D distal range of the Badal optical system, a relatively large artificial pupil size was used. To maintain head stability, a carefully aligned headrest/chinrest assembly was used. When properly aligned, the entire circular test field

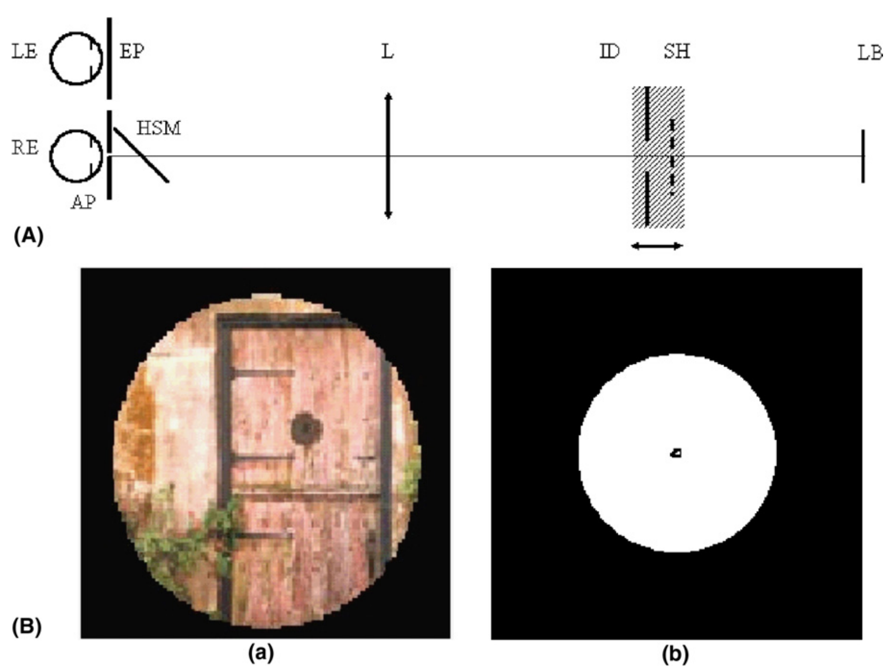

Fig. 1. (A) Top-view schematic representation of the Badal optical system used to measure DOF. Symbols: RE = right eye, LE = left eye, EP = eye patch, AP = artificial pupil (5 mm), HSM = half-silvered mirror, L = Badal camera lens, ID = iris diaphragm, SH = slide holder, and LB = light box. (B) Pictorial and foveal test targets: (a) near retinal peripheral test target of different field sizes depicting a wooden doorway with surrounding wall and shrubbery; (b) foveal test target consisting of an annular, high contrast, irregular black-and-white form.