Is blur sensitivity altered in progressive myopic children?

First and Corresponding author

Vivek Labhishetty

School of Optometry and Vision Science,

University of Waterloo, ON, Canada N2L3G1

Email: vlabhish@uwaterloo.ca

Other authors

Arijit Chakraborty

School of Optometry and Vision Science,

University of Waterloo, ON, Canada N2L3G1

William R Bobier

School of Optometry and Vision Science,

University of Waterloo, ON, Canada N2L3G1

Published In Vision Research 154 (2019) 142 - 153

Abstract

School aged children with progressive myopia show large lags in their accommodation and suggestive of a large depth of focus (DOF). While DOF measures are lacking in this age group, their blur detection and discrimination capacities appear to be similar to their non-myopic peers. Accordingly, the current study quantified DOF and blur detection ability in progressive myopic children showing large accommodative lags, compared to their non-myopic peers and adults. Blur sensitivity measures were taken from 12 children (8-13 years, 6 myopes and 6 emmetropes) and 6 adults (20-35 years). DOF was quantified using step changes in the lens induced defocus while the subjects viewed a high contrast target through a Badal lens at both 2 and 4D demands. Blur detection thresholds (BDT) were tested using a similar high contrast target in a 2 alternate forced-choice paradigm (2AFC,) at both the demands. In addition to large accommodative response lags, micro fluctuations and DOF were significantly larger in myopic children compared to the other groups. However, BDTs were similar across the three groups. When limited to blur cues, the findings of a large DOF coupled with large response lags suggests that myopes are less sensitive to retinal defocus. However, in agreement to a previous study, refractive error had no influence on their BDTs suggesting that the reduced sensitivity to the defocus in a myopic eye appears to be compensated by some form of an adjustment in the higher visual processes to preserve the subjective percept even with a poor retinal image quality.

Keywords

Myopia, accommodation, blur sensitivity, depth of focus, and blur detection.

Introduction

Progressive myopic children exhibit larger accommodative response lags to a blur only stimulus compared to non-myopic children (J. Gwiazda, Thorn, Bauer, & Held, 1993; J. Gwiazda, Thorn, & Held, 2005; D. O. Mutti et al., 2006; Sreenivasan, Irving, & Bobier, 2012). These high accommodative lags are also associated with an abnormal pattern of high response AC/A and high accommodative adaptation (J. Gwiazda, Bauer, Thorn, & Held, 1995b; J. Gwiazda et al., 2005; Labhishetty & Bobier, 2017; Sreenivasan, Irving, & Bobier, 2014). This abnormal pattern is strongly associated with the progressive nature of myopia both in children/ early onset myopes and adults/ late onset myopes (Abott, Schmid, & Strang, 1998; J. Gwiazda, Bauer, Thorn, & Held, 1995a; Jiang, 1995, 1997). It is not clear whether the high lags reported in these progressive myopic children reflect a large depth of focus (DOF). If so, it is unclear if this large DOF would result from a reduced sensitivity to retinal defocus and if it would be coupled with a reduced ability to perceive blur. Historically, blur sensitivity has been quantified in terms of DOF, defined as the variation in retinal image distance that can be tolerated without perceiving blur. DOF is typically examined by changing the object position in physical space (depth of field) and can be measured both subjectively (Atchison, Charman, & Woods, 1997; Rosenfield & Abraham-Cohen, 1999; Vasudevan, Ciuffreda, & Wang, 2007; Yao, Lin, Huang, Chu, & Jiang, 2010) and objectively (Kotulak & Schor, 1986; Marcos, Moreno, & Navarro, 1999; Vasudevan, Ciuffreda, & Wang, 2006a; Vasudevan et al., 2007; Yao et al., 2010). Blur sensitivity can also tested psychophysically using a blur detection/ discrimination task wherein the subjects would observe and compare targets with varied levels of rendered blur (Kotulak & Schor, 1986; Roberts, Stevenson, Benoit, Manny, & Anderson, 2018; Schmid, Robert Iskander, Li, Edwards, & Lew, 2002; Watson & Ahumada, 2011). While objective measures of DOF determine the defocus magnitude necessary to induce a consistent change in accommodation, perceptual measures of blur sensitivity would estimate the subjective criterion of either blur detection or discrimination with no influence of accommodation.

Studies on blur sensitivity in progressive myopic children have been limited to only blur detection and discrimination measures. Only one study examined blur detection and discrimination thresholds on 40 school aged children (Schmid et al., 2002). They found similar

blur thresholds in progressive myopic children compared to the non-myopic children. It cannot be assumed that depth of field /focus would show the same lack of difference since the psychophysical tasks of blur detection and discrimination do not act to alter the ocular image distance of the viewed target. Also, given the evidence that adult myopes tend to adapt after a prolonged exposure to blur (Cufflin, Mankowska, & Mallen, 2007; Khan, Dawson, Mankowska, Cufflin, & Mallen, 2013; Wang, Ciuffreda, & Vasudevan, 2006), a greater disparity would be expected between the ability to perceive blur and depth of focus in myopes. A recent study compared measures of blur detection, micro fluctuations and a subjective measure of DOF in 49 children (aged 3 to 10 years) and 10 non-presbyopic adults . Refractive errors in the child population ranged from +0.06 D to 4.91D. One of the strongest findings was that blur detection measures were significantly reduced in children compared to adults. Increased blur detection threshold was also associated with larger micro fluctuations, increased hyperopia and smaller pupil size. However, caution is needed before applying these results directly to myopic children. A closer inspection of their data showed that the majority of 8 to 10 year olds had a much smaller blur detection thresholds than younger subjects. The significance of this pattern was not quantified in their analysis. Subjective measures of DOF were taken on a smaller sub population of 20 children (aged 6 years and older). Similar to the blur detection, subjective DOF was found to be larger in the children compared to adults and was significantly associated with larger micro fluctuations..

Further evidence that the DOF may be increased in progressive myopia comes from the findings on accommodative micro fluctuations. Traditionally, increased accommodative lags and microfluctuations found at closer working distances have been attributed to a larger DOF that results from a reduction in the pupil size which in turn acts to reduce the retinal blur circle. Day et. al. i reported a correlation between DOF and accommodative micro-fluctuations (Day, Seidel, Gray, & Strang, 2009). When DOF was modulated by manipulating luminance level and pupil size, they found a consistent change in the magnitude of microfluctuations. In a separate study, this group also found that the increased magnitude of microfluctuations at closer distances was independent of changes in pupil size (Day, Strang, Seidel, Gray, & Mallen, 2006). In agreement, an investigation on young emmetropic adults found a relationship between objective DOF and

stimulus demand (Yao et al., 2010) and reported that the change in DOF with stimulus demand was correlated with only accommodative microfluctuations and not pupil size. Several studies reported that the accommodative lags and micro fluctuations increased with stimulus demand, significantly more in progressive myopia compared to the non-myopes (Day et al., 2006; J. Gwiazda et al., 1993; Langaas et al., 2008; Sreenivasan, Irving, & Bobier, 2011). Given that progressive myopia show greater accommodative lags and micro fluctuations with stimulus demand compared to non-myopes, differences in retinal blur sensitivity would be expected as a function of stimulus demand between the refractive groups.

Accordingly, the current study sought to compare an objective measure of the DOF and accommodative lags and microfluctuations between progressive myopic children their non myopic peers and adults with stable refractions. Data from myopic children was then compared to non-myopic children and adults. Objective DOF measures were measured using a photorefractor which detected small defocus changes induced by trial ophthalmic lenses when subjects viewed a high contrast target at two accommodative demands (2 and 4D) through a Badal optical system. Blur detection was then tested psychophysically using a computer generated task set at the same accommodative demands (50 cm and 25 cm) as those used in the DOF experiment.

Methods

12 school aged children, 6 myopes & 6 emmetropes (Age: 9–14 years), and 6 naïve adults (25 -32 years) were recruited from the optometry clinic at the University of Waterloo School of Optometry and Vision Science. Sample size calculations for this particular study were done based on the pilot data on the DOF obtained from 3 myopes and 3 non-myopes (Appendix I). The mean and standard deviation of the DOF measures obtained from the myopes (0.95 ± 0.18D) and non-myopic children (0.62 ± 0.12D) were used to calculate the effect size. Based on the effect size, a sample size of 6 subjects/ group was calculated (with $\alpha = 0.05$; Power $(1-\beta) = 0.90$). All the myopic subjects had a progressive history of > 0.5D/year change in the refractive error and 4 of them were recruited from a previous study which found larger accommodative lags in myopes compared to their non-myopic peers (Labhishetty & Bobier, 2017). Informed consent and assent were obtained after a verbal and a written explanation of the study. The study

followed the tenets of Declaration of Helsinki and received ethical approval from the University of Waterloo office of research ethics review board. Children were classified into two refractive groups based on their cycloplegic refraction. The myopic group (MYP) had equivalent spheres between –1.25D to -7.00D. Emmetropic children (EMM) had equivalent spheres between +0.50D to 0D. There were 4 emmetropes and 2 stable myopes in our adult subgroup. Given that their accommodative behavior was found to be similar previously (Labhishetty & Bobier, 2017), they were not subdivided based on refractive error. All the myopic subjects were habitual contact lens wearers and wore their lens during the study. Critical visual parameters such as the distance and near visual acuity, near phoria and cycloplegic refraction were measured to confirm the visual status of all the children prior to the measurement visit (Table 2). The measurement session followed the screening session by not more than a week. During the measurement session, objective DOF and blur detection thresholds were collected over two separate visits.

Objective depth of focus (DOF)

Experimental design

Accommodative response change to optical lens defocus was measured while the subject viewed a high contrast target through a simple Badal optical system (figure 1). The subject was seated 1m away from the photorefractor with the left eye occluded. An IR passing mirror (Optical cast IR filter, Edmund Optics, USA) allowed an orthogonal presentation of the targets along with a continuous measure of accommodation using the dynamic photorefractor. Two targets (T1, T2) were manually placed at different distances from a +5D Badal lens. Each target was a high contrast (white on black) vertical line that was back illuminated using a white LED. The luminance of the target was 180cd/m^2. The angular size of the target was 6^0 and was kept constant across the stimulus demands. A small horizontal offset was present between the distance and the near target (maximum offset was ≈1.5^0). While the far target (T1) was always set at optical infinity, the near target (T2) was moved to one of the two distances from the Badal lens to create an accommodative demand of either 2 or 4D. Step changes between the targets T1 and T2 were achieved using a stimulus control tool box with a button that allowed for an instantaneous switch between the targets so that the subject viewed only one high contrast target at a time.

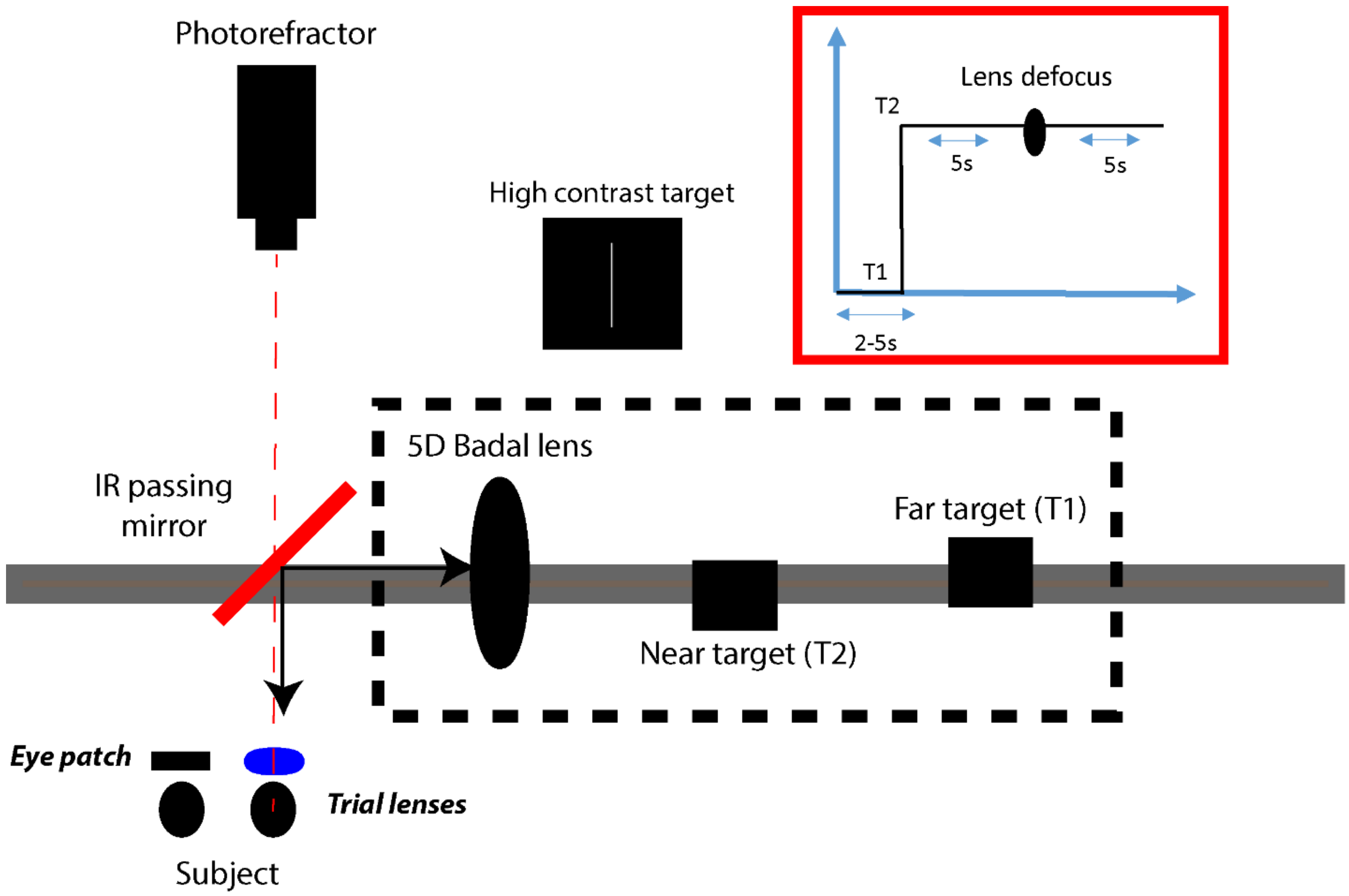

Figure 1: Experimental design used to stimulate accommodation change to defocus. Badal optical system was used to stimulate step changes in accommodation. Fixation was stepped between the two targets (T1 set at optical infinity and T2 set either to 2D or 4D). Each target was a high contrast vertical line subtending a visual angle of 6 degrees. Accommodative response and pupil size were monitored using a photorefractor. The inset illustrates the sequence where accommodation is initially relaxed viewing the distant target (T1) and then randomly stepped to the near target (T2) at either 2 or 4D. Once accommodation was steady at T2 for 5-10 sec., a trial lens was introduced and accommodation was recorded for an additional 5-10 seconds.

Instrumentation

A custom built dynamic photorefractor (PROSILICA CAM (EC750), Allied Vision Technologies, Canada) was used to record an accommodative change and changes in the pupil size (Labhishetty, 2014; Labhishetty & Bobier, 2017; Suryakumar, Kwok, Fernandez, & Bobier, 2009). The dynamic photorefractor works at a sampling frequency of 70Hz, giving an output every 0.014 seconds. Photorefraction videos were later analyzed offline using the dynamic photorefraction system (DPRS) for refractive estimations. The calibration procedures followed in this study were similar to ones described previously (Schaeffel, Wilhelm, & Zrenner, 1993; Suryakumar, Meyers, Irving, & Bobier, 2007).