Seeing infrared - two-photon vision and its accommodation parameters

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Two-photon vision, a phenomenon in which infrared light is perceived through two-photon absorption in visual pigments, offers significant potential for augmented reality by providing highly clear and sharp retinal images. As retinal image quality depends strongly on ocular accommodation, this study compared accommodative amplitude for two-photon (1040 nm) and one-photon (520 nm) vision in 12 healthy subjects. The amplitude of accommodation for two-photon vision was higher (4.0 ± 0.6 D) compared to one-photon vision (2.7 ± 0.6 D). This increased defocus tolerance enables high image quality to be maintained over a broader range of defocus, supporting the use of two-photon vision in retinal displays and AR technologies.

Keywords: accommodation, two-photon vision, infrared light, VR/AR technology

INTRODUCTION

The two-photon vision phenomenon is based on the visual perception of pulsed infrared lasers (800-1300 nm) due to the isomerization of visual pigments caused by two-photon absorption [1]. This process enables the perception of infrared light, which appears as a color corresponding to approximately half its wavelength. Two-photon visual stimuli are subjectively perceived as highly clear and sharp, which is particularly important in the context of using two-photon vision in retinal displays and augmented reality (AR) technology [2]. The quality of the image formed on the retina is strongly conditioned by the accommodation parameters of the eye. This study aimed to assess accommodation amplitude for two-photon vision and to evaluate the impact of defocus on perceived image quality.

METHODS

Twelve healthy volunteers with no diagnosed visual system pathologies participated in the study. To measure accommodation amplitude, a letter stimulus “E” of 0.2° size was displayed through fast scanning of the retina with a pulsed laser beam at a wavelength of 1040 nm for two-photon vision and 520 nm for one-photon vision, with both stimuli perceived as green. Both beams were generated by a femtosecond laser (τ=250 fs, F_{rep}=63 MHz). Using a brightness matching method, both stimuli were adjusted to have the same subjective brightness [3]. The measurement involved increasing the stimulus for accommodation by adjusting defocus in 0.5 D steps until the participant observed subjective blurring of the stimulus. Accommodative status was also evaluated using the standard optometric push-up method. Approval for the study was obtained from the Bioethics Committee of the Collegium Medicum, Nicolaus Copernicus University.

RESULTS

The accommodation amplitudes determined on the subjective blurring were higher for two-photon vision: 4.0 ± 0.6 D compared to one-photon vision: 2.7 ± 0.6 D. The results show that two-photon vision is characterized by a higher defocus tolerance, allowing for maintaining a high-quality image over a wider range of defocus than one-photon vision.

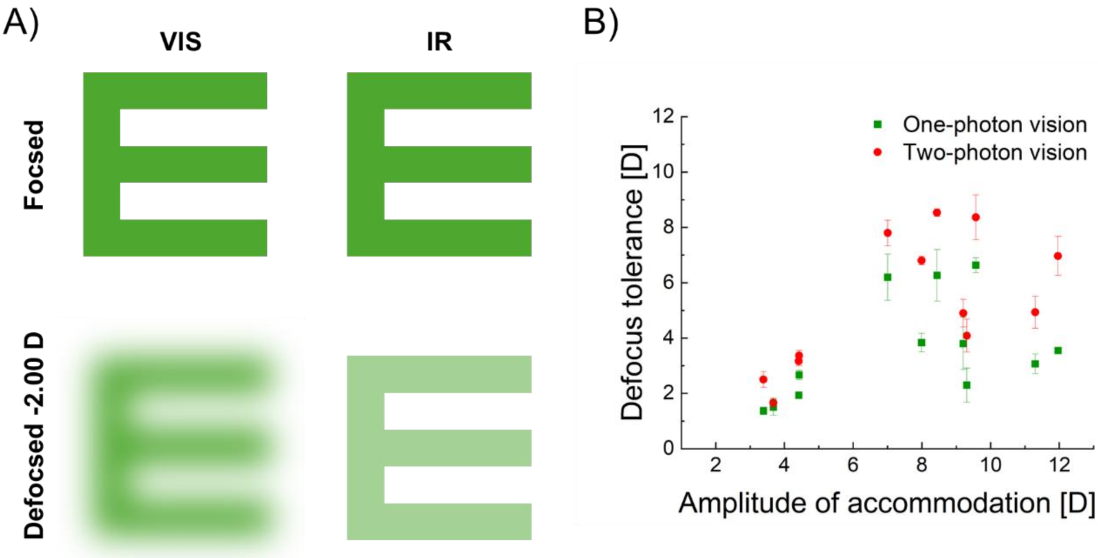

Figure. 1. A) Schematic representation of the effect of defocus on perceived stimuli in one-photon (VIS) and two-photon (IR) vision. B) The obtained defocus tolerance values for one-photon and two-photon vision. The x-axis represents the amplitude of accommodation of each subject measured with the push-up method.

CONCLUSIONS

The increased defocus tolerance in two-photon vision highlights its potential for retinal displays and AR technology, indicating distinct accommodative behavior. Future studies using adaptive optics will enable precise measurement of ocular aberrations and deeper insight into accommodation dynamics, supporting the development of two-photon–based AR systems.

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