

Eye Stretching with the Assistance of a Three-dimensional Image Can Improve Accommodative Function

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Abstract

Background: Heavy use of video screens causes eye fatigue and pseudomyopia, and may lead to true myopia. One possible preventative measure is the “stretching” of the eye – deliberately and smoothly cycling back and forth from near to far focus, the ocular equivalent of range-of-motion limb exercises.

Purpose: To determine if eye stretching using a three-dimensional (3D) target image facilitates accommodation responses, which could prevent pseudomyopia.

Methods: Twenty healthy adults (20.9 ± 0.7 years old) who work on visual display terminals 6 or more hours/day were included. Each subject gazed at the 3D image on a monitor 50 cm away for 1 minute under full refraction correction; objective refraction and objective amplitude of accommodation before and after 3D image viewing were measured. Objective refraction during 3D image viewing was continuously measured. A circular stereo target appearing to be 5 m away (distant condition, ipsilateral parallax, visual angle 0.8°) gradually approached to 0.05 m (near condition, no parallax, visual angle 8°), then cycled back to the distant point. The target underwent 7 such cycles with a period of about 8.5 s/cycle. To enhance realism, the image background was gradually blurred as the stereo target approached (and vice versa). Paired t-tests were used to compare values before and after target viewing.

Results: All subjects were able to track the perceived target depth with a continuous and smooth refocusing response. The 3-cycle mean refraction change from distant to near for all subjects was 1.43 ± 0.37 m⁻¹ (diopters [D]). The average objective refraction values before and after target viewing were not statistically different (-3.24 ± 2.15 D and -3.31 ± 2.11 D, respectively; $p = 0.65$). The objective refraction amplitudes of accommodation significantly improved from before to after target viewing (6.26 ± 1.95 D to 7.10 ± 1.34 D, respectively; $p = 0.02$).

Conclusions: Subjects demonstrated a continuous and smooth focal eye stretching response to the 3D image and background blurring/sharpening, with improved accommodation responses. This technique may prove useful in alleviating ocular fatigue and pseudomyopia in heavy users of visual display terminals.

Keywords: Pseudomyopia; Ocular Fatigue; Visual Display; Accommodation; Myopia

Abbreviations

3D: Three-Dimensional; D: Diopters; VDT: Visual Display Terminal

Introduction

In recent years, smartphones, tablets, and other easily portable computers with relatively small video screens have rapidly become popular due to the development of miniaturisation technology. It is estimated that by the year 2018 about 84% of the world's population will be using such items [1]. Especially in younger people, these and other visual display terminals (VDTs) have penetrated deeply into everyday life; indeed, even VDT communication is becoming commonplace. Frequent use of VDTs is known to cause distant and near blurred vision, eye dryness, asthenopia, spasm of accommodation, and weakening of accommodative power. In fact, such vision difficulties can become a social problem [2-5]. In addition, spasm of accommodation causes pseudomyopia, which has been shown to progress to true myopia when experienced over the long-term [6,7]. Because reducing VDT exposure in the modern world, in which VDT-equipped devices are indispensable in both work and recreation times, is at best difficult and at worst impossible, other alternatives to improve ocular health must be found. Previous reports have shown that spasm of accommodation and pseudomyopia can be alleviated by eye "stretching", the act of cyclically, continuously, and smoothly shifting the focus of the eye between distances of 25 and 70 cm [8]. Ideally, the distant focal point should be as far away as possible, but the room size and other similar variables restrict the available distance. Furthermore, it is difficult to continuously and smoothly shift focus without a special visual target.

In recent years, stereoscopic image technology has enabled viewing of three-dimensional (3D) images on many devices. Perception of a 3D image can be very similar to reality, but reports suggest that the eye is focused not on the target, but on the VDT surface [1,9]. However, we hypothesize that accommodation responses could occur during 3D image viewing, in which case it would be possible to continuously and smoothly shift the focal point even on the VDT, thus allowing eye stretching over a larger range of focal points even inside a room. To analyse the effectiveness of this protocol, we created a 3D image that can continuously and smoothly shift the focal point of the eye, and then measured the degree of accommodation when targeting the 3D image. In addition, we examined the change in accommodation power before and after 3D image viewing.

Materials and Methods

This research was approved by the Kitasato University Human Sciences Ethics Committee (#2017-019), and the methods were carried out in accordance with the tenets of the Declaration of Helsinki. Potential subjects were given detailed information about the study and its possible consequences, and their roles as participants, and written informed consent was obtained from all included subjects.

We recruited 20 healthy adults (20.9 ± 0.7 years old) using VDTs (smartphone, tablet, computer work, television viewing) for more than 6 h/day. Subjects were seated in front of a monitor 50 cm away and presented with a circular stereo target image on a 3D background image (Figure 1). We measured the objective refraction and objective amplitude of accommodation, then had the subject focus on the target image for 1 minute under full refraction correction, after which we repeated the measurements. The target was set to an initial virtual distance of 5m (distant condition, ipsilateral parallax, visual angle 0.8°), then gradually approached the viewer to a virtual distance of 0.05m (near condition, no parallax, visual angle 8°) in a pendulum-like manner. The target image then gradually receded from 0.05m to 5m distance; the cycle would then repeat until 7 cycles had occurred. Each cycle spanned 8.5s (60s in total). The appearance of the measurement environment during the experiment is shown in figure 2. In order to make the image more realistic, the background was clearly depicted when the stereo target was distant, and gradually blurred as the stereo target approached the near point; this is a common phenomenon of daily viewing conditions. For measurement of objective refraction and objective refraction amplitude of accommodation, an autorefractometer (ARK-1s, NIDEK) was used. We also measured objective refraction continuously during the 3D image viewing period. A binocular open autorefractometer (WAM-5500) was used for continuous objective refraction monitoring. Since this device is a binocular open-type device, any external target can be used. Objective refraction during 3D image viewing was measured during 3 - 5 cycles. The mean refraction values and amplitudes of accommodation were calculated for the subject population before and after target image viewing. Paired t-tests were used for statistical analyses of objective refraction and objective amplitude of accommodation, as well as for the change in refraction across time points, before and after video viewing, with values of $P < 0.05$ considered to be significant.

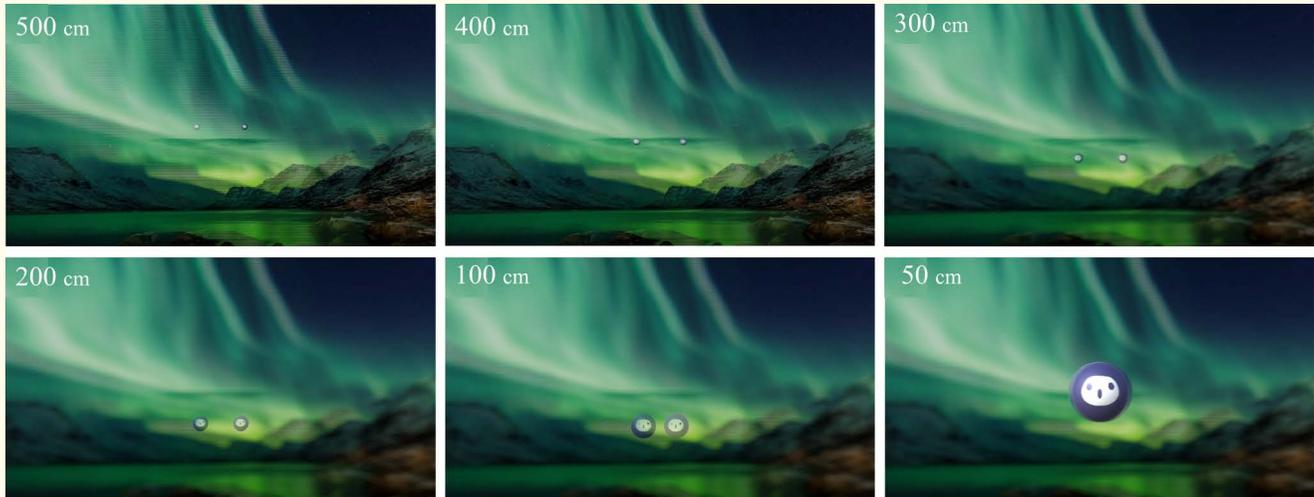


Figure 1: 3-dimensional image of the motion of the pendulum created. The background was clearly depicted when the stereo target was far away, and the background was gradually blurred as the stereo target appeared nearer.



Figure 2: Appearance of the measurement environment.

Results

The continuous objective refraction changes during 3D image viewing for all subjects are shown in figure 3. All subjects achieved a continuous and smooth focus response that tracked the movement of the target image. The group mean (3-cycle) refraction change from the distant to near points was 1.43 ± 0.37 D. The average objective refraction values before and after 3D image viewing were -3.24 ± 2.15 D and -3.31 ± 2.11 D, respectively, and were not statistically significantly different ($p = 0.65$). The objective refraction amplitudes of accommodation before and after 3D image viewing were 6.26 ± 1.95 D and 7.10 ± 1.34 D, respectively; the increase from before to after viewing represented a statistically significant improvement ($p = 0.02$).

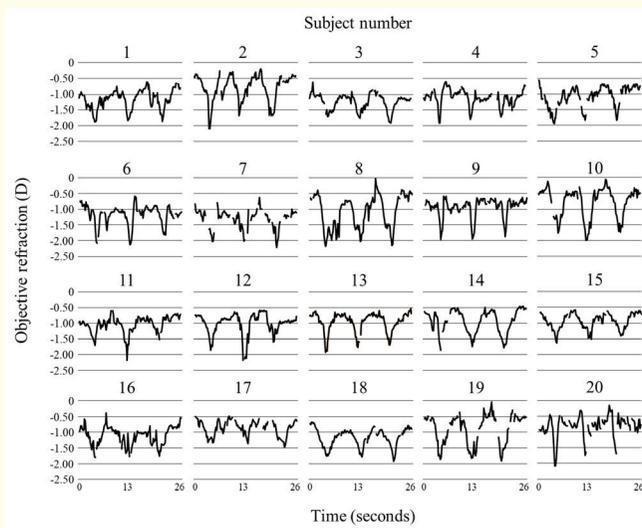


Figure 3: Continuous objective refraction changes during 3-dimensional image viewing for all subjects.

Discussion

In this study, obvious accommodation responses during 3D image viewing were observed, although the focal length of the eye has been reported to be the (fixed) distance to the display surface and not the target image [1,9]. However, convergence and divergence movements occur before accommodation responses when gazing at separated binocular images [10-12]. The accommodation response was induced by such convergence/divergence movements, and was stabilised by gazing at the separated binocular image during the continuing change. In our actual everyday viewing environment, a nearby image is blurred when focusing on a distant one and vice versa. However, we did not consider blurring the target, a conventional 3D image; instead, we utilised this natural blurring effect on the background image in relation to the stereo target image. We hypothesize that the natural accommodation response occurred as a result of the 3D visual illusion as processed by the brain. In this study, an increase in objective refraction amplitude of accommodation was observed after 3D image viewing. This is likely due to stabilisation of the accommodation response by the eye-stretching exercise [8], given that unstable accommodation responses can cause ocular fatigue and pseudomyopia [6]. We believe this technique can potentially alleviate these VDT-related symptoms.

Conclusion

In conclusion, it was shown that a continuous and smooth accommodation response can be obtained by using a 3D target image with realistic blurring of the background. Future studies and clinical applications may be able to employ virtual reality images that are highly realistic and now encompass a wider viewing angle to conveniently allow users to engage in daily eye stretching exercise when needing to mitigate the symptoms of heavy VDT use.

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