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Augmented Reality Eyewear (ARE) for Home-Based Vision Training after Biofeedback Rehabilitation of Eccentric Viewing

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ABSTRACT

Background: Visual rehabilitation is based, in addition to the use of optical aids and neuro-enhancement factors, on methods of visual training such as neurosensory techniques. Fixation training with microperimetry biofeedback (MBF) is a rehabilitation technique aimed to improve fixation stability in patients with eccentric viewing (EV) and unstable fixation due to central scotoma. One of the EV training difficulties is that people may tend to move their head or the viewing target instead of controlling their gaze. Moreover, such MBF results may not be preserved over time, and generally, training shall be repeated in clinical sites. The challenge is to create home-based training techniques that may help patients to preserve the MBF outcomes obtained in the clinical environment. The current pilot study explored the use of Augmented Reality Eyewear (ARE) to perform home-based eccentric viewing exercises on patients with large central scotoma after MBF.

Methods: The change of fixation stability in ten patients with bilateral central geographic atrophy after eccentric viewing training was analysed. Five patients (control group) did not perform any training between the 4th and 5th MBF sessions. The other 5 (study group), after the 4th MBF session, performed home-based vision exercises with augmented reality eyewear (ARE).

Results: We observed in the group with ARE a slightly improved fixation stability of +10.16% compared to the control group, where fixation stability showed a decrease.

Conclusion: The results of this pilot study suggest that augmented reality eyewear with a dedicated home-based vision training application may help maintain fixation stability outcomes obtained during eccentric viewing training in vision centers with MBF.

Keywords: augmented reality (AR), augmented reality eyewear (ARE), eccentric viewing (EV), eccentric viewing training (EVT), fixation, microperimetry biofeedback (MBF), preferential retinal locus (PRL), visual rehabilitation, visual training

Introduction

Augmented Reality

Augmented reality (AR) is a live direct or indirect view of a physical, real-world environment whose elements are augmented by computer-generated input such as sound, video, graphics, or other multimedia data. In AR, a view of reality is modified (augmented or diminished), enhancing one's current perception of reality. AR is different than virtual reality, which replaces the real world with a simulated one.

Preferential Retinal Locus and Preferential Reading Field

When pathologies affect the central vision, an eccentric retinal area regularly substitutes for the damaged fovea.[1-3] This eccentric location is called a preferred retinal locus (PRL, Figure 1) or, in reading physiology, the preferred reading field (PRF).[4-8] PRL can be described within an area of almost 2° in which fixation is possible, while PRF is the retinal area on which patients can project the image of a reading string. A normal subject's PRL and PRF always coincide, while in low vision patients, this is not always true.

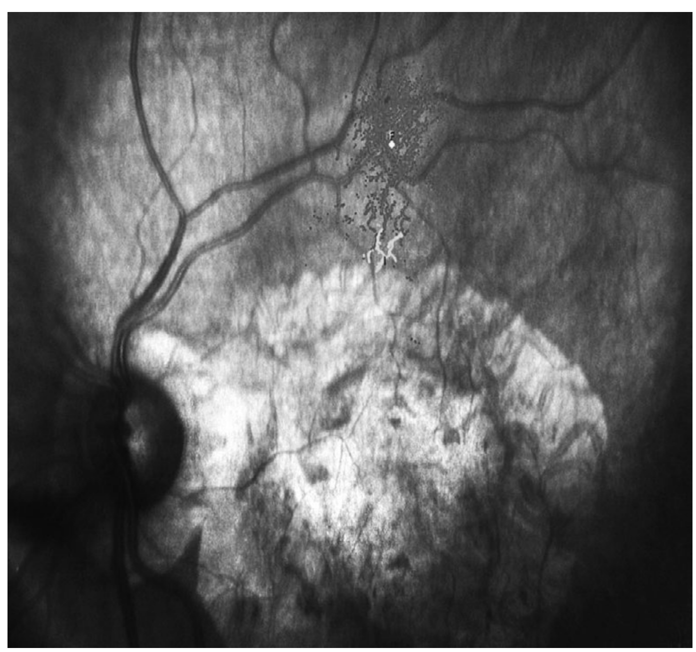

Figure 1. In patient with central geographic atrophy, normally PRL is eccentric and fixation unstable. The quality of residual vision is lower (courtesy of MU Morales).

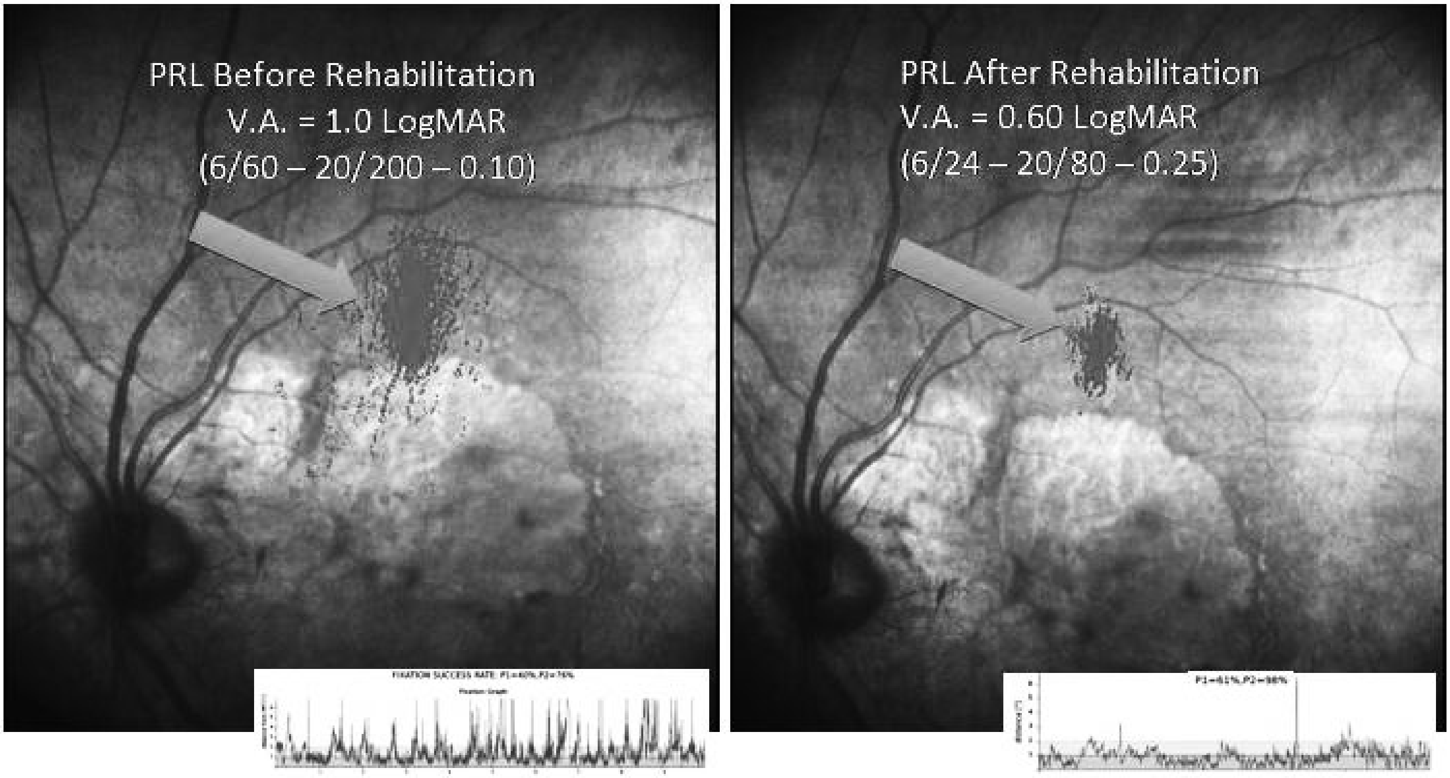

Figure 2. *Patients with eccentric and unstable fixation can improve their vision with Microperimetry Biofeedback (MBF) (courtesy of MU Morales).*

Understanding the above concepts allows the creation of a customized visual rehabilitation plan. A thorough low vision analysis must be able to identify both PRL and PRF areas, to determine the extension and the residual retinal sensitivity, and to judge the quality of the patient's current and potential fixation. People affected with central vision loss may learn how to use their PRL/PRF efficiently by themselves; however, without specific training, their new eccentric PRL may be unstable and inefficient.

The Diagnostic Methods

There are essentially two methods to analyse the position and the quality of the PRL: microperimetry (MP) and virtual analysis. MP is an instrument used to analyse retinal functional characteristics such as retinal sensitivity, fixation stability, and the preferred retinal locus (PRL), which is the retinal area that patients use during fixation attempts in the MP examination. In MP is a fundus-related perimetry, where an invisible infrared laser is used to image the retina (infrared retinography), while a second visible light source projects light stimuli at different light intensities in precise retinal spots in order to determine retinal sensitivity. A retinal eye-tracker follows the eye movements while patients attempt fixation during examination, with a dual purpose: to compensate the retinal location during stimuli projection and to identify visual fixation characteristics, such as the PRL with its relative distance in degrees from the fovea and the quantity of fixation stability, measured through the percentage of fixation points located within a 1-degree distance from the center of the PRL. This fixation index, labelled in the MAIA Microperimeter (Centervue, Italy) as the fixation index P1, is an objective analysis calculated automatically in MP instruments during the time the eye-tracker samples the retinal movement at 25 times per second. This is a well-known parameter used to calculate fixation stability in MP instruments and has been reported to be stable or not stable if P1 is higher or lower than 75%, respectively.[9] Fixation stability test-retest repeatability has been studied in microperimetry as interexaminer and intraexaminer reliability, reporting no significant difference in fixation stability in healthy subjects and patients with age-related macular degeneration.[10]

Although typically patients spontaneously develop the PRL, in many cases, the fixation reports appear unstable or excessively shifted with respect to the location where there might exist other retinal locations with better visual performance, such as in the case of areas with good sensitivity closer to the damaged fovea.

Microperimetry with biofeedback (MBF) has been reported to be an important aid in visual rehabilitation of patients with loss of central vision. Through biofeedback sound signals, MP helps patients to direct visual attention to an alternative target retinal locus (TRL), pre-selected by the vision specialist over the MP examination outcomes. The TRL is selected on the retinal locus corresponding to the best functional characteristics closer to the anatomical fovea. The aim of this visual training is to stabilize eccentric vision by improving fixation. During MBF sessions, the patient recognizes when he is doing a good job thanks to a change in the biofeedback sound, which increases in frequency as the patient's gaze gets close to the TRL. If he is not able to stabilize fixation on the TRL, the biofeedback sound changes. After just

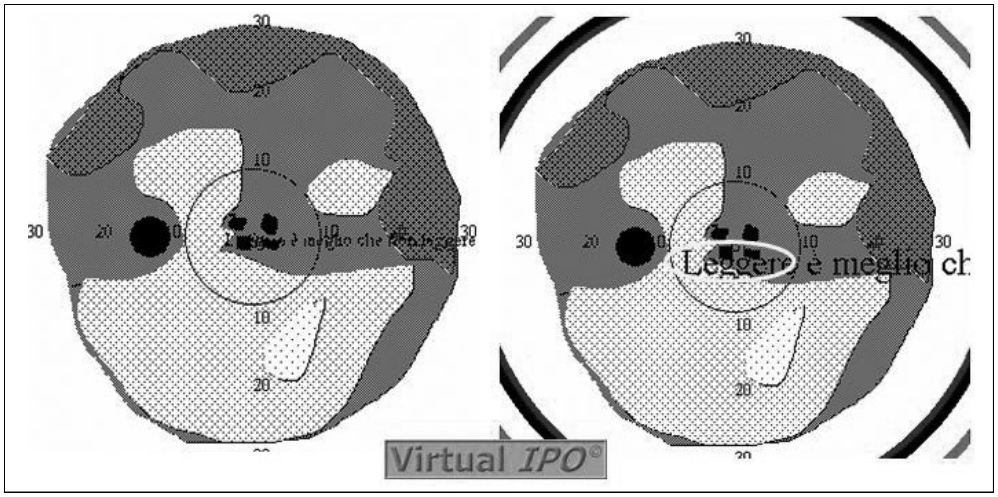

Figure 3. *With the analysis of the visual virtual map, you can be informed about the ideal magnification to read the 10 point size and also the position of the PRL, the location, and the extension of the PRF. In the case here represented, the ideal magnification is 2x and the PRL, coinciding with the PRF, is at 1.6 ° from the fovea (courtesy of PG Limoli).*

Figure 4. *VUZIX Wrap 1200AR can be used as a monitor located close to the eye to project images shown in a computer or a mobile device (tablet, iPad, etc.) (courtesy of VUZIX, Rochester, New York).*

a few sessions (normally ten for the first cycle), the patient learns how to keep the sound sharp in the TRL, which means that he learns to keep fixation more steady, developing a new PRL (Figure 2).[11-14]

The most difficult part of the MBF process is the selection of the TRL used during fixation training exercises. The Virtual*IPO*© software is able to recreate visual possibilities out of the visual field reported by microperimetry in order to visualize schematically the characteristics of low vision patients, offering the opportunity to study a virtual model representing the patient's vision and select precisely the TRL. The virtual model leads to other advantages: the examination can be reproduced where and when desired, it presents different predictive solutions which can be applied after thorough low vision evaluation, and it is a valuable education tool to help patients understand their low vision conditions.

With Virtual*IPO,*© it is possible to define the best way to read with the best magnification aid in patients with loss of central vision. In other words, we can know the best PRL or PRF for each low vision patient, as it allows the design of customized exercises to stimulate and to improve the use of eccentric vision (Figure 3).[15-17]

The visual training

As mentioned above, fixation training with MBF is a rehabilitation technique aimed to improve fixation stability in patients with central scotoma and unstable fixation. With Virtual*IPO,*© it is possible to define the best TRL to perform MBF; however, one of the eccentric viewing training difficulties is that people with loss of central vision may tend to move their head or the viewing target instead of controlling their gaze. In addition, such MBF results may not be preserved over time, and generally after 4 to 6 months, the MBF training shall be repeated in clinical sites. The challenge is to create home-based training techniques that may help patients to preserve the MBF outcomes obtained in the clinical environment.[18-21]

Purpose

The current pilot study explored the use of Augmented Reality Eyewear (ARE) to perform home-based eccentric viewing exercises on patients with large central scotoma after visual training performed with Microperimetry with biofeedback (MBF) was used to select the target retinal locus (TRL) using the Virtual*IPO*© software.

Methods

Ten patients, 6 female and 4 male, with a mean age of 74 years (max = 83, min = 68) with bilateral central geographic atrophy secondary to dry age-related macular degeneration (AMD) and unstable or relatively unstable fixation were selected for eccentric viewing training (EVT) with microperimetry and biofeedback technique (MBF). Only patients with superior or inferior PRL were selected. The study eye was the right eye.

At first, patients performed a MAIA microperimetry examination to evaluate retinal sensitivity and the preferred

Table 1. Study Results

	Px ID	Sex	Age	Fixation Quality	P1 after 4th MBF (%)	P1 after 5th MBF (%)	Fixation gain between 4th and 5th MBF (%)
Control Eye	LC-001	F	83	U	31	28	-9.68%
	LC-002	F	80	U	61	58	-4.92%
	LC-003	F	75	U	33	26	-21.21%
	LC-004	F	68	U	23	18	-21.74%
	LC-005	M	76	U	24	22	-8.33%
				mean:	34	30	-13.18%
Study Eye	LC-006	F	75	R	82	87	6.10%
	LC-007	M	70	R	78	79	1.28%
	LC-008	M	72	U	34	40	17.65%
	LC-009	F	77	U	20	22	10.00%
	LC-010	M	68	U	19	22	15.79%
				mean:	47	50	10.16%

retinal locus (PRL) position and to measure fixation stability through the MAIA fixation index P1, which corresponds to the quantity of fixation located within a 1° distance of the patients' PRL reference centre.[8] Secondly, all patients underwent 2 weekly MBF sessions during 2 weeks. The target retinal locus (TRL) to perform MBF was selected through the Virtual*IPO*© software.

Five patients (control group), did not perform any training between the 4th and 5th MBF session. The other 5 (study group), after the 4th MBF session performed home-based vision exercises with ARE (VUZIX eyewear WRAP1200AR, Rochester, N.Y.; Figure 4) for one month, three times per week, 10 minutes per session. The ARE was connected to an iPad or an iPhone. The eyewear see-through option was not activated; therefore, the ARE was used as a monitor extension of the iPad or iPhone, projecting the content on the ARE monitor. The ARE home exercises were customised for every patient. Different central targets were available as black spots and 5-letter words in different sizes, plus a red horizontal line selectable in different positions depending on the distance and direction where the TRL was located from the fovea in the MAIA MP. For this study, we initially chose a 1° black dot central target and subsequently, a word of five letters point size 10.

One month after the 4th training session, a 5th MBF session was done to evaluate the consistency of fixation stability gain on the last MBF session. The main study outcome was the change in fixation stability measured by the MP fixation index P1 between the 4th and the 5th MBF session.

Results

The microperimetry mean value of fixation stability index P1 in the control group was 34% after the 4th MBF and 30% after the 5th MBF sessions, demonstrating a mean fixation stability decrease of -13.18% (min = -4.92%, max = -21.74%). The study group showed mean P1 values of 47% after the 4th MBF and 50% after the 5th MBF session, demonstrating an increase of 10.16% (min = 1.28%, max = 15.79%) in the ARE group (Table 1).

Discussion

Several studies have demonstrated the efficacy of microperimetry with biofeedback training on patients with eccentric vision and unstable fixation.[19,22-25] This EVT deserves several sessions in order to improve fixation stability. In general, at the end of every MBF session, the MP fixation index P1 outcome is normally noted to be increased, demonstrating the patient's ability to improve fixation stability. The improvement rate is different on every patient; however, there is always a tendency to be increased. Patients who were not able to attend the weekly MBF sessions demonstrated slower or null fixation stability improvement.

In this pilot study, we substituted in the study group 12 sessions of the regular MBF training, which is normally performed in the clinic, with home-based EVT visual exercises through the ARE glasses. The gain of fixation stability of the study group is an indicator that such home-based training may be considered a substitution or a complement to the visual training performed in the clinic with MP.

The decrease of fixation stability in the control group was not unexpected, as this is a regular result in patients who suspend for a certain period of time the fixation training with MP in the clinic. As mentioned above, the increased rate of fixation stability during EVT is variable in patients with low vision; however, there is always a tendency to increase fixation stability if the training is performed regularly and periodically and to decrease fixation stability when patients can't commit to the weekly sessions in the clinic.

The red horizontal line projected on the ARE, corresponding to the crossing of the anatomical foveae, works as a visual reference, helping patients with central scotoma to perceive the eccentric training target (Figure 5). According to the theory of filling-in completion, patients are able to perceive such a foveal guide line, helping eccentric viewers with their vision stabilization. The projection of an intermittent point or a short word in an eccentric retinal locus (PRL) correlated to good retinal sensitivity calculated with microperimetry and, confirmed with Virtual*IPO*© software, allowed patients to recognize the angular distance between the anatomical fovea and the PRL that they needed to use while shifting

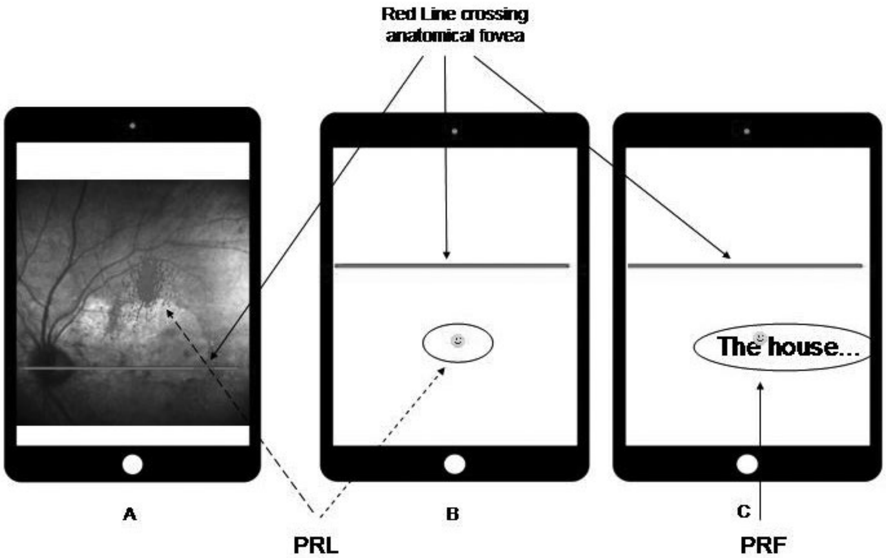

Figure 5. *With a VUZIK and a tablet, we can project a red line on the anatomical fovea and a visual target (dot or a short word) on the PRL-PRF. In this way, the patient learns to recognize the angular distance between the anatomical fovea and the PRL, and his viewing can became more stable.*

their gaze during EVT training. Therefore, doing frequent exercises with a reference guide line may help patients with unstable fixation during the EVT process, resulting in a more stable eccentric vision.

Conclusion

Vision therapy is just like physical therapy for other parts of the body. Visual rehabilitation of patients with eccentric vision deserves, as does any other rehabilitation process in specialized healthcare, high-frequency exercise training to be more effective. The length of rehabilitation is specific to each patient, and motivation can make a difference in those who continue to improve versus those who stop progressing.

The main disadvantage of microperimetry with biofeedback visual training is that patients with low vision need to commute frequently to eye-care centres. Such training has proven to be effective only if it is performed constantly; however, not all patients have the ability to be accompanied constantly to the clinic.

As demonstrated in this pilot study, with the increase of fixation stability measured with microperimetry, augmented reality eyewear with a dedicated home-based vision training application may help to maintain or to improve fixation stability outcomes obtained during eccentric viewing training in vision centres with MBF and may work as a temporary substitution of the vision training performed in the clinic. Another advantage of using augmented reality eyewear is the ability to perform gaze-moving exercises independent of the patient's head movement.

Several disadvantages were found in this study. The ARE glasses are highly expensive, patients have reported that they are not easy to use, and there is a lack of a retinal tracker to control eye movements with biofeedback. However, this is the first time such home-based rehabilitation glasses have been approached to maintain the outcomes of fixation stability gained in the clinic with microperimetry biofeedback training in patients with eccentric vision.

Commercial Relationships Disclosure

None of the authors declare any financial interest with the VUZIX augmented reality eyewear.

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