Evaluation of the Improvement in Visual Acuity Using Electronic System Biofeedback

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Abstract- Human ocular refractive errors are the most common visual problems in the world. The prevalence is more recurrent in the adult population, reaching to 51% for myopia, 38% for hyperopia and 27% for astigmatism. The absence of actions to correct these diseases represents 42% of the causes of visual impairment in the world, including adults with presbyopia. Visual effort due to excessive use of electronic devices causes new strategies to be created and other methods developed such as corrective lenses, contact lenses and laser and non-laser refractive surgical procedures.

We present a technique to improve visual acuity using a signal electromyography feedback. Its implementation was through an electronic controlled lens being its power from -10 to +10 diopters, an electromyographic signal acquisition device coupling by a Labview interface. The proposed system was evaluated by means of the Snellen test applied to five people with twenty tries each one. Therefore, it is possible to improve visual acuity up to 20/20 with accurate of 90% and other errors of spherical ocular refraction such as myopia, farsightedness and presbyopia using biofeedback system.

Keywords – Visual Acuity, Refractive Errors, Biofeedback, EMG, Electronic Lenses.

I. INTRODUCTION

The Visual impairment is related to a deficiency in the decrease of visual acuity, visual field, ocular motility, color vision or depth, affecting the ability of a person to observe [1]. Visual acuity is the ability to see in detail things that surround us at a certain distance, this ability depends on the normal and coordinated working between the eyes and the brain [2]. Nowadays, are 246 million people with visually impaired and 39 million blind people in the world [3]. Visual impairment includes blindness and moderate and severe visual impairment, generally defined as low vision.

The World Health Organization estimates that there are 153 million people with visual disabilities in the world due to uncorrected refractive errors [4]. Errors such as myopia, farsightedness, astigmatism, distorted vision due to the abnormal curvature of the cornea and presbyopia being are the main causes of refractive errors. Normal vision is a visual acuity measured as a fraction equivalent to 20/20 [2]. Where the numerator is the distance at which the patient's eye sees (in feet) and the denominator indicates the distance at which a normal person sees. In the human optical system, an accommodation process is carried out through the lens, which is a biconvex lens-shaped structure that allows focusing objects located at different distances, said process is measured in diopters, which are the unit of measurement of optical power of a lens [5].

To evaluate visual acuity, it is used the Snellen test [6]. The aim of the test is to identify a group of letters located in lines within a graph (proposed by Snellen), where the letters decrease their size line by line in descending order. Each line represents a level of visual acuity, the first one is the 20/20 level or normal vision.

Biofeedback is a process that allows an individual to learn how to change physiological activity to improve health and performance [7]. This process is used to control the physiological functions of human that informs the subject of the state of the function that you want to control. Some instruments of this type measure physiological activity such as brain waves, heart function, breathing, muscle activity and skin temperature.

A first version of this research was the development of a system to control the degree of focus of a camera lens using surface electromyographic signals (EMGS) [8]. It is based on sensing of the muscles of the forehead, in which the degree of focus could be modified voluntarily from electromyographic signals.

Electromyographic signals (EMG) are electrical signals produced by the muscles during the process of contraction and relaxation. Superficial electromyographic signals (EMGS) are a source of information that can be used to control electronic and virtual devices. In general, they are collected using surface bipolar electrodes located on the skin [9].

On the other hand, a research at the University of Utah implemented a liquid crystal lens, which automatically and electronically changes its focal power, through mechanical actuators changing the radius of curvature of the lens [10].

The work developed in [11] addresses low vision disabilities through bio-feedback methods through infrared photo-stimulation and fovea stimulation to assess visual acuity, color vision, visual perimetry and sensitivity to contrast.

Study showed in [12] depict a biofeedback by increasing attentional modulation. This technique supports the brain to fix the preferred locus of the retina to achieve the rehabilitation of low vision disabilities, considering that said audio biofeedback facilitates the transmission of stimuli between the retina and the brain. The term preferred locus of the retina describes an area of the retina that acts as a pseudo-fovea to focus objects and perform visual tasks that imply a fine vision of details when there are diseases in the fovea [13].

In section 2 of this work, the specifications and description of the designs and the technology used are presented. In addition, experiments designed to assess the modification of visual acuity are described. Section 3 presents the results obtained with the conduct of the investigation and its analysis. Finally, section 4 shows the conclusions.

II. METHODOLOGY

2.1 System Implementation

The bio-feedback system using electromyographic signals to control the focus of an electronic optical system was implemented from a pair of electronically adjustable lenses EL-16-40-TC-VIS-20D manufactured by Optotune [14]. The characteristics of the controllers are described in Tables I and II.

Table 1. Main characteristics of electronic lenses el-16- 40-tc-vis-20d [14].

Numerical opening	**16**	**mm**
Optical power	**-10 a +10**	**diopters**
Type of lenses	**flat - concave or flat - convex**	**-**
Response time (typical at 30 ° C, step from 0 to +/- 250mA)	**7**	**ms**
Stabilization time (typical at 30 ° C, step from 0 to +/- 250mA)	**40**	**ms**
Nominal control current	**-250 a +250**	**mA**
Supply voltage (Vcc)	**3.3**	**V**
Power consumption	**0 a 1**	**W**
Data transmission to and from controller	**FPC Flex**	**-**

Electronic components to implement the optical system to fit visual acuity were put in a structure around the head of a test subject, so that the lenses are in front of your eyes. On the other hand, the g.MOBIlab device manufactured by g.tec is selected.

This device senses surface EMG signals in humans for research purposes, considering the characteristics documented in Table III [15].

Table II. Main features of the controller: electrical lens driver 4 [16].

Maximum output current	**-290 a 290**	**mA**
Input voltage	**5**	**V**
Power consumption	**50-1100**	**mW**
Digital-analog converter (resolution)	**12**	**Bit**
Response time (step from 0 to +/- 200mA)	**2-4**	**ms**
Stabilization time (step from 0 to +/- 200mA)	**15**	**ms**
Data transmission to and from PC	**USB**	**-**

Table III. Device characteristics g.MOBIlab+ [15].

Electrode type	**Active**	**-**
Type of device	**Wireless**	**-**
Wireless data transmission to PC	**bluetooth 2.0**	**-**
Nominal Voltage (DC)	**3**	**V**
Nominal Power	**0.18**	**VA**
Number of input channels	**8**	**-**
Sensitivity (minimum)	**+/- 500**	**μV**
Sensitivity (maximum)	**+/- 250**	**mV**
Pass band	**0.5 – 100**	**Hz**
Sampling rate	**256**	**Hz**
Analog-digital converter (resolution)	**16**	**bit**

An interface in LabVIEW was designed for the coupling between the electronic optical system and the EMGS signal acquisition system. LabVIEW is a robust signal processing tool and is also compatible with the devices used.

The interface designed for the test subject has four buttons. The first one changes the direction of the variation of the optical power of the lenses. It is activated with electromyographic activity from the corrugator supercilii muscle. The second button to reset the optical power of the lenses if necessary. The third button indicates when you see in detail the things that surround the person performing the test with the bio-feedback system at a certain distance. The last button saves the experiment performed.

The acquisition of the EMGS signals and their processing are carried out by bluetooth and through the gMOBIlabplus.vi block. The data is captured, the sensitivity is selected and thus, the EMGS signal is stored. Subsequently, filtering is performed by rejecting the frequency of the power line noise (60 Hz). Then, the Trigger and Gate block is used allowing the passage of signals that exceed a predetermined threshold.

The programming of the electronic lenses and the configuration of the serial communication ports to connect the lens controllers is done using the VISA block. Using the Write Read Lens Driver block, developed by the manufacturer Optotune, the operating mode of the lenses, the optical power control mode is programmed, this control is carried out from the EEPROM memory. According to the optical power required in the lenses, the necessary current is requested from the power source, in this case the USB ports of a portable computer.

The optical power control of the lenses is carried out with conditioned structures based on comparisons of the output data of the Trigger and Gate function. Data is stored in plain text file using the Write to Measurement File block. The variables are test time, test dates and optical power of the lenses. In general, the blocks that make up the development of the biological feedback system are shown in Figure 1. On the other hand, Figure 2 depict real elements to make the experiment.

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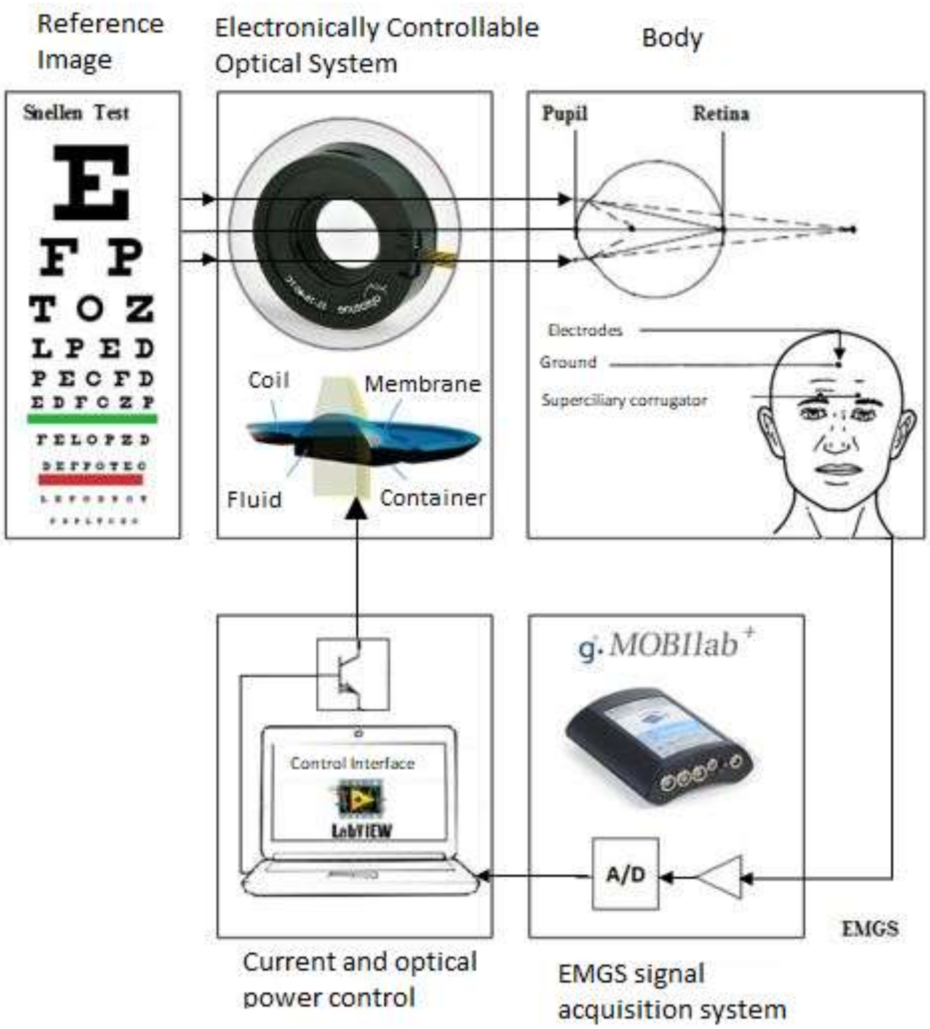


Figure 1. DWT Block diagram of the bio-feedback system.

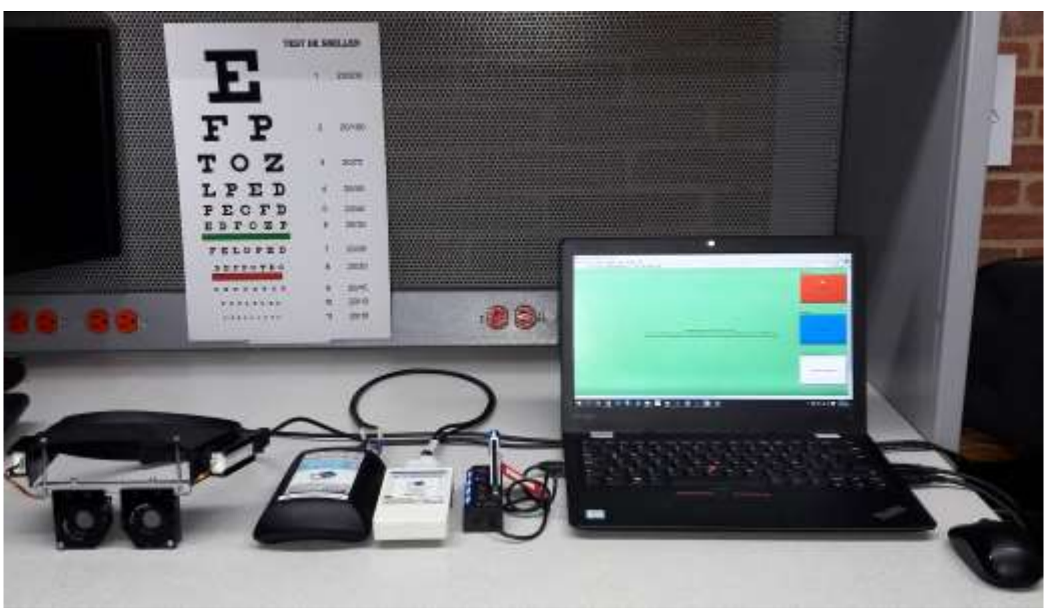


Figure 2. Bio-feedback system to evaluate the improvement of visual acuity.

2.2 Experiments

Experiments designed to testing visual acuity consist of placing electrodes in supercilii undulating muscle, as shown in Figure 1. It is necessary connecting the electronic optical system and the EMGS signal acquisition system to the computer and initializing the software. Then, the patient is placed in front of the computer and the optical system consisting of the pair of electronic lenses with their respective controllers is placed.

A Snellen Test is performed, following a designed test protocol, to evaluate the improvement of visual acuity. In this test the lens power is initialized at zero (0) diopters for myopic volunteers and at different powers (between 1 and 5 diopters randomly) for emmetropic volunteers (with normal vision).

Through the bio-feedback process with electromyographic signals, the patient varies the power of the electronic lenses. The lenses are programmed to make discrete changes of ± 0.25 diopters by pressing the user buttons. The patient practices reading the lines of the Snellen graph. The test starts on the 20/20 line of sight and the patient must indicate that he saw well through the button intended for this in the user interface.

In this work a total of one hundred (100) tests were carried out with five (5) subjects, of which each subject performed twenty (20) tests, distributed in blocks of five (5) tests per day. A Snellen Test at 6 m. of distance between the graph and the patient needs letters of 8 cm x 8 cm. The tests of this work were carried out in a laboratory measuring 5.2 meters long, 3.5 meters wide, 2.2 meters high.

Therefore, the graph was printed to scale, where the first letter was 6.8 cm x 6.8 cm. These measurements are equivalent to a test with 4.7 meters between the graph and the person examined. The lighting conditions of the laboratory were given by 12 luminaires of 2506 lumens each and a color temperature of 6500 Kelvin, all this taking into account that all the tests performed were after 6 p.m. Time (Coordinated Universal Time) UTC -05: 00.

III. Experiment and Result

To perform an analysis of the improvement of visual acuity using the implemented bio-feedback system, the results of the tests performed were stored, which are shown in the graphs from Figure. 3 to 7.

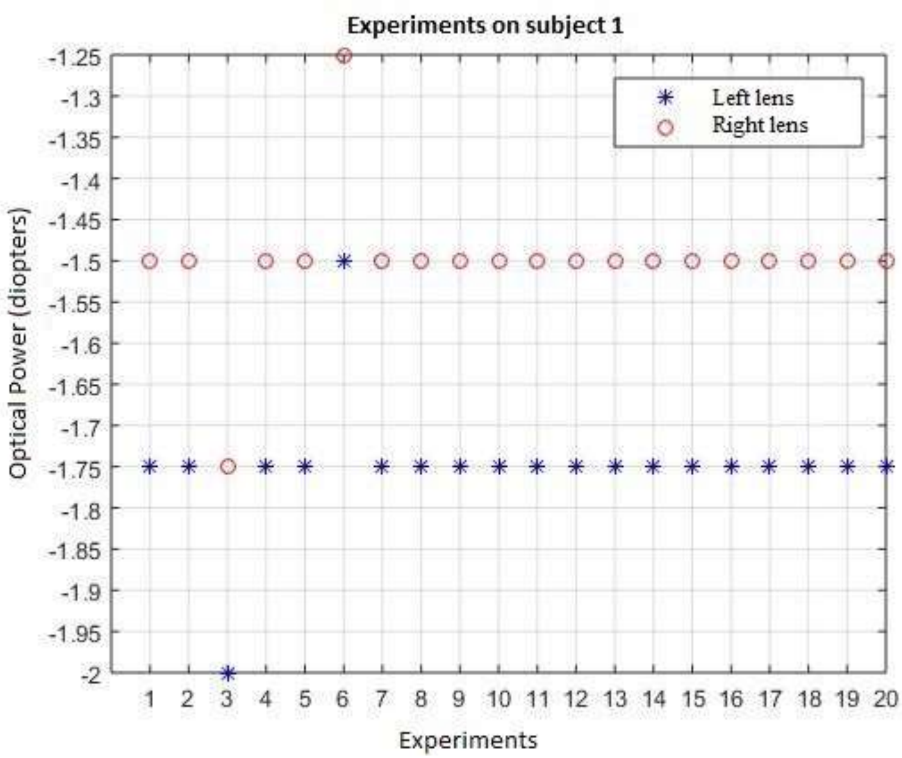


Figure 3. Results of experiments performed with test subject 1.

These graphs show the results of the 20 experiments performed with each test subject. The optical power set by the volunteers is shown for each experiment in both lenses. the results indicate that they saw in detail the line of the Snellen graph indicating a visual acuity equal to 20/20.

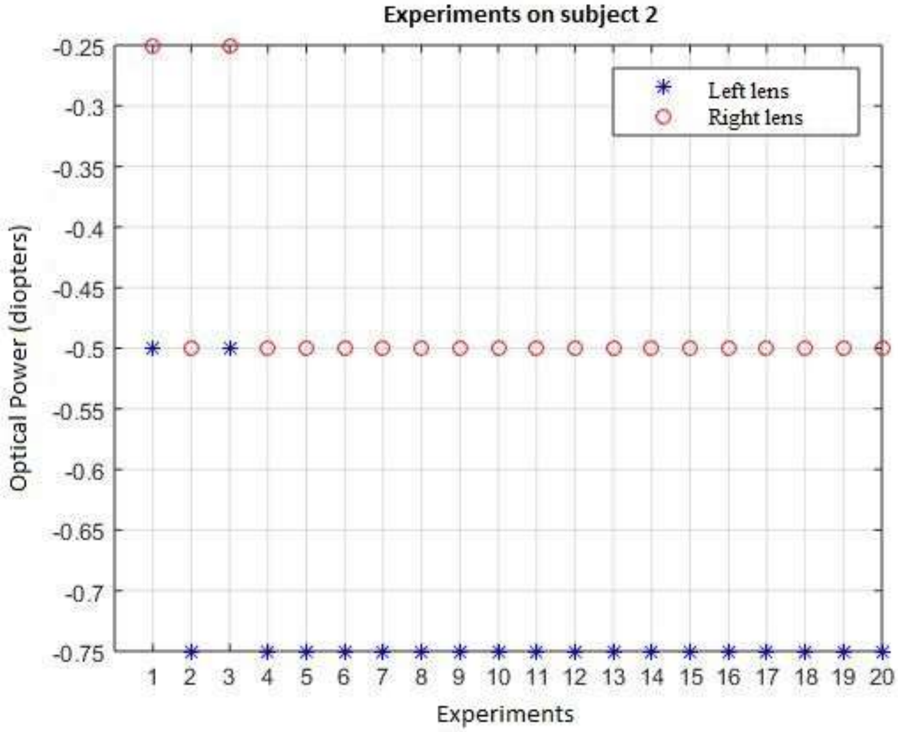


Figure 4. Results of experiments performed with test subject 2.

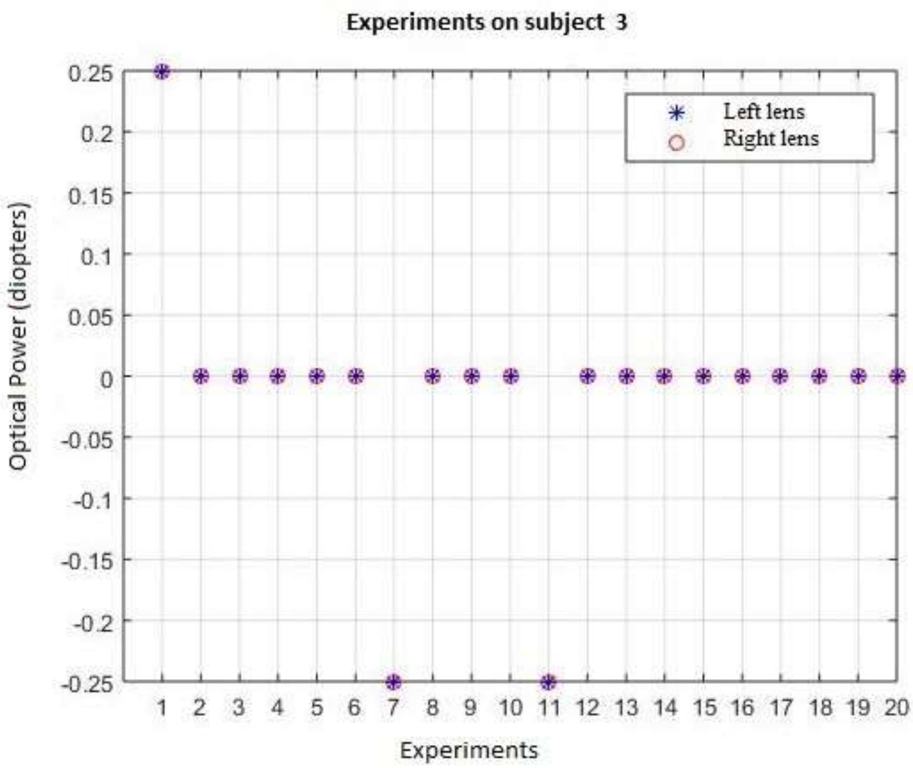


Figure 5. Results of experiments performed with test subject 3.

The results shown in Figs. 5, 6 and 7 correspond to emmetropic test volunteers (normal vision). In this trial, the lenses were initialized at a power between one (1) and five (5) diopters randomly. The patients indicated that they saw in detail the line of the Snellen graph that indicates a visual acuity equal to 20/20, graduating the power of the lenses by 0 diopters, up to 85% of the tests performed.

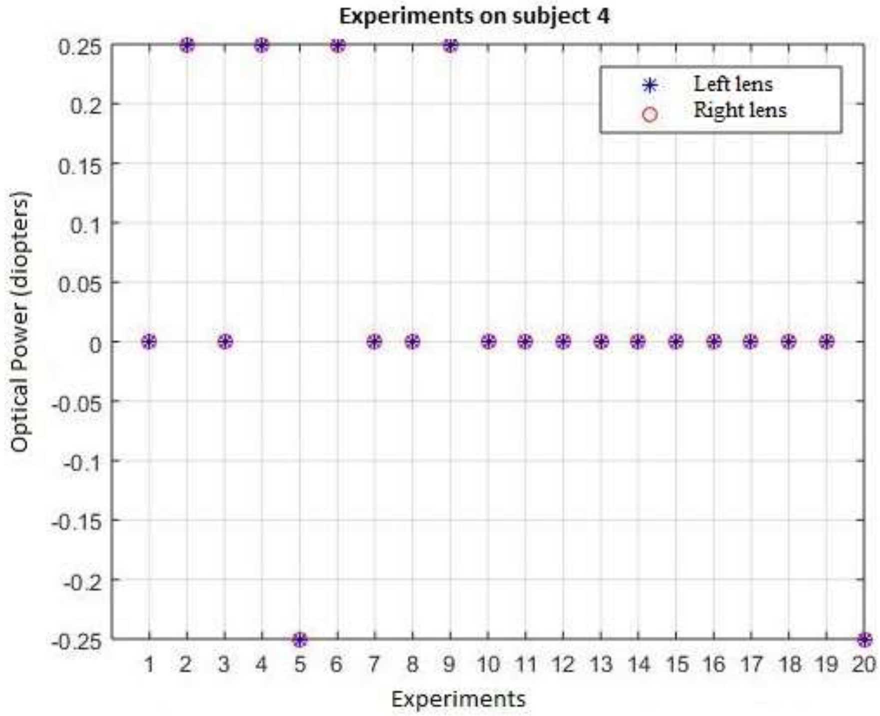


Figure 6. Results of experiments performed with test subject 4.

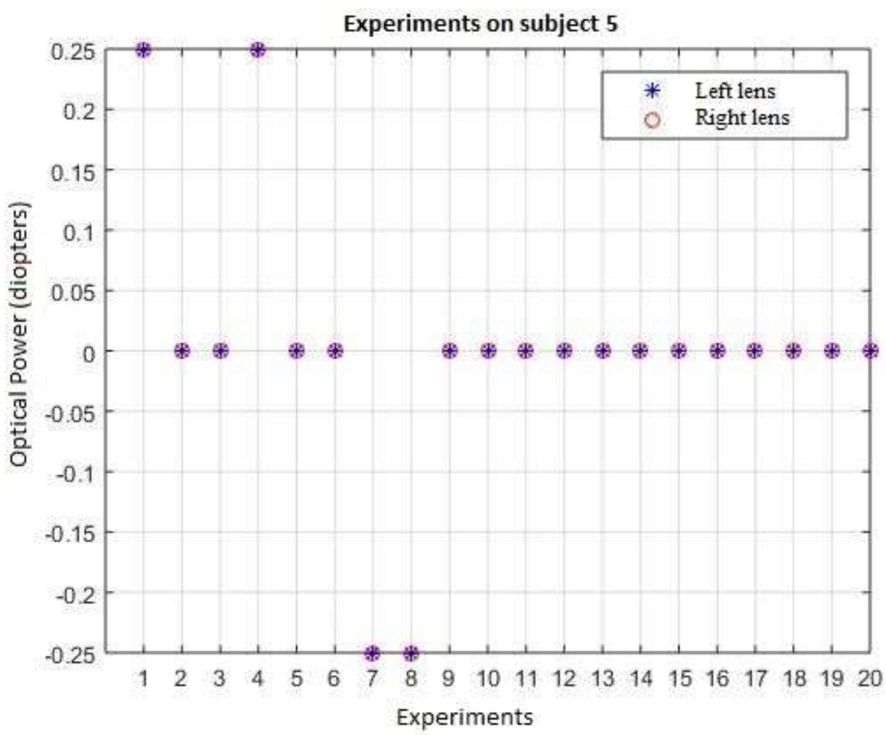


Figure 7. Results of experiments performed with test subject 5.

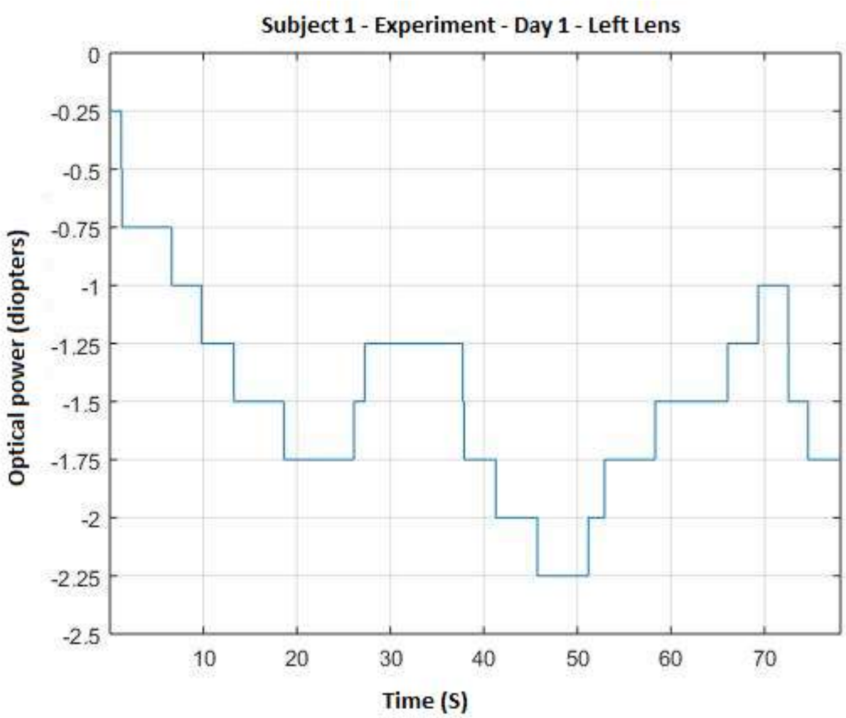
A summary of the results is presented in Table IV. First-order statistics are applied to calculate the mean, mode, variance and confidence interval of the optical power for each lens and for each of the test subjects.

TABLA I. Summary of the results.

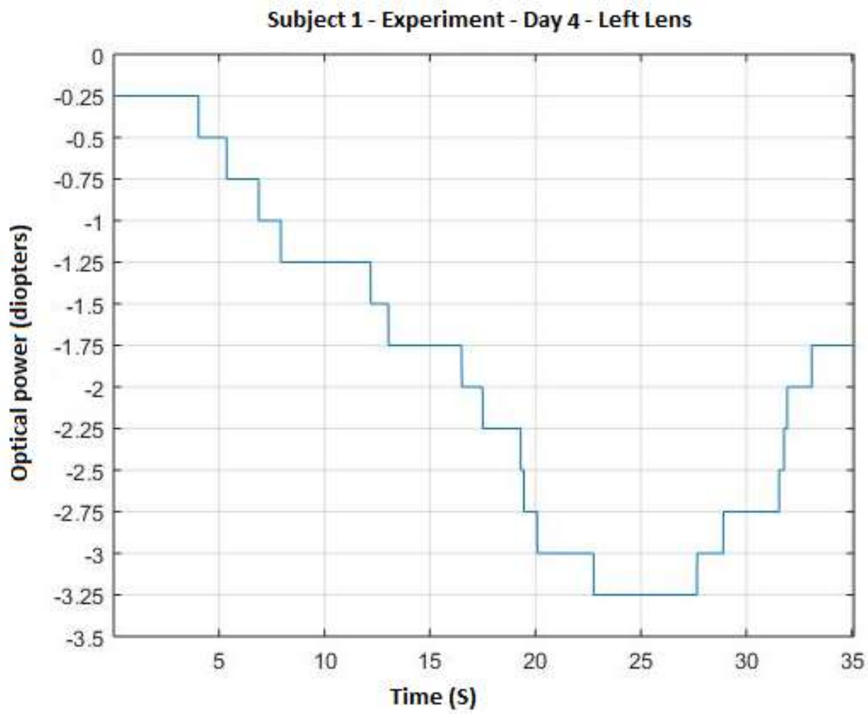
Units (diopters)	Lens	Average Optical Power	Optical Power Mode	Standard Deviation of Optical Power	95% Confidence Interval
Subject 1	Right	-1,5	-1,5	0,081	-1,54 − -1,46
	Left	-1,75	-1,75	0,081	-1,79 − -1,71
Subject 2	Right	-0,48	-0,5	0,077	-0,51 − -0,44
	Left	-0,73	-0,75	0,077	-0,76 − -0,69
Subject 3	Right	-0,01	0	0,099	-0,06 − +0,03
	Left	-0,01	0	0,099	-0,06 − +0,03
Subject 4	Right	0,03	0	0,138	-0,04 − +0,09
	Left	0,03	0	0,138	-0,04 − +0,09
Subject 5	Right	0	0	0,115	-0,05 − +0,05
	Left	0	0	0,115	-0,05 − +0,05

Additionally, it was observed that the data of a complete experiment, from the initial optical power to the final optical power set by the subject in the lenses, that the test subjects as they performed more experiments acquired a greater skill to use the bio-feedback system implemented.

In Figure 8 and 9, the results obtained from test subject 1 are shown. The patient on day 1 took 73.51 seconds to set the optical power with which he indicated he could read the level indicating a visual acuity 20/20 on the Snellen chart and on day 4 it took 35.04 seconds to fix the same optical power on the lenses.



(a)



(b)

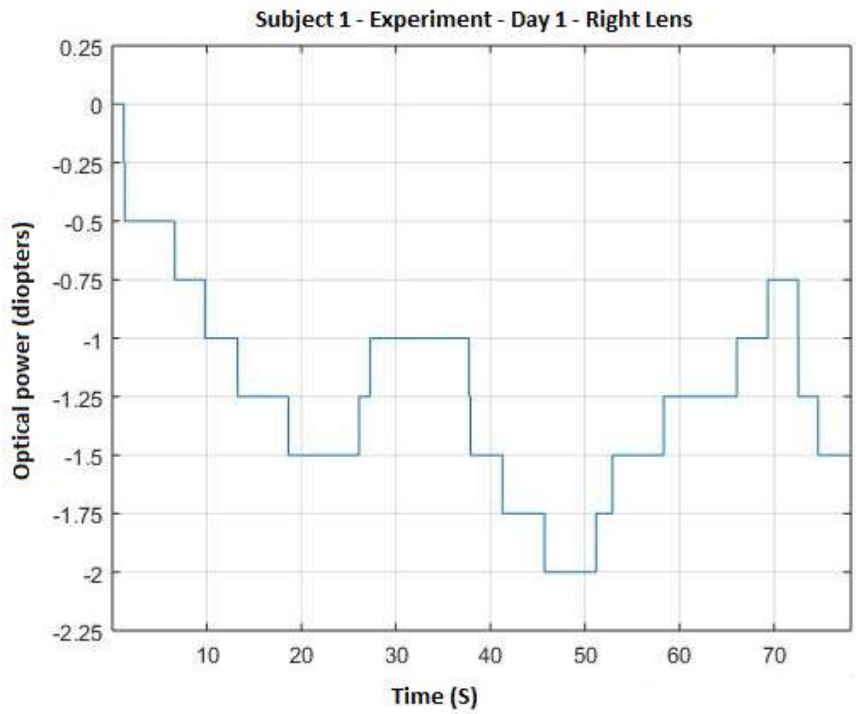
Figure 8. Comparison of results in experiments performed with test subject 1 [Left Lens - Day 1 (a) Vs. Day 4 (b)].

IV.CONCLUSION

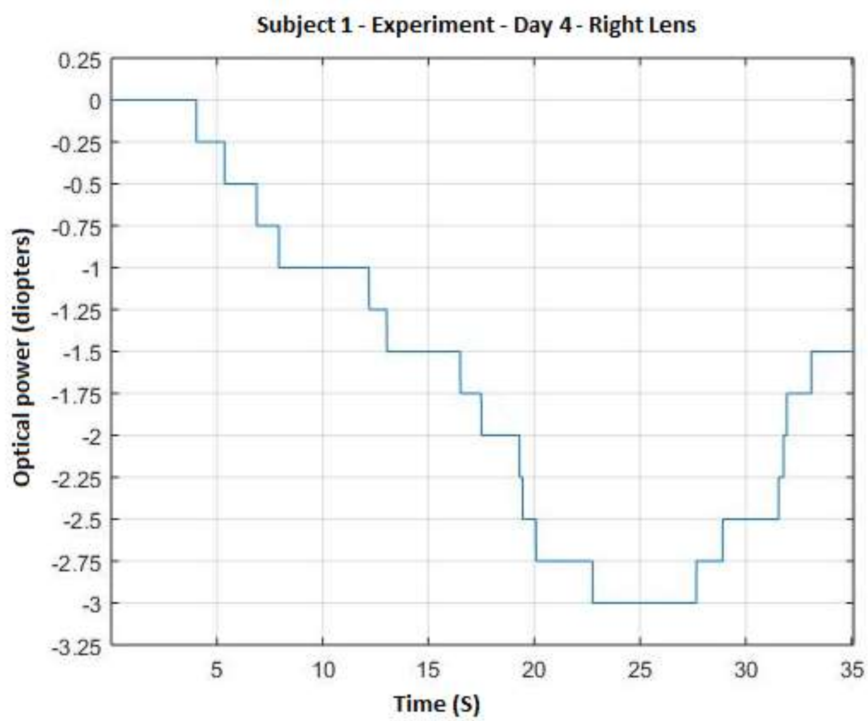
Analyzing the results, is possible concluded that it is possible to improve spherical ocular refractive errors related to the decrease in visual acuity, with a bio-feedback system using EMG signals.

The test subjects indicated up to 90% of their tests performed, that with the same optical power graduated with said system, they saw in detail the line of the Snellen graph, which indicates a visual acuity equal to 20/20.

As the test subjects conducted more experiments, they acquired greater skill in using the implemented bio-feedback system. This was demonstrated by the decrease in time taken to indicate that they read well the level that indicates a 20/20 visual acuity in the Snellen chart.



(a)



(b)

Figure 9. Comparison of results in experiments performed with test subject 1 [Right Lens - Day 1 (a) Vs. Day 4 (b)].

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