EFFECTS OF A SINGLE GREEN FLASH VERSUS A WHITE FLASH OF LIGHT ON SACCADIC OCULOMOTOR METRICS

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Abstract- **White light encompasses all wavelengths of the visible optical spectrum while variations of green light cover only a fraction. Saccades comprise a considerable portion of ocular activity and have been used for research in neurology, cognitive processing, reading, and weaponry design. The goal of this experiment was to study how different energies of light affect the saccadic oculomotor system. This was tested by white and green photic stimulation in eleven and eight subjects respectively as they visually attempted to locate a target. The subject was presented with a target: 15 degrees to either the right or left from the midline with no photic stimulus (control), 15 degrees to the right or left accompanied by a photic stimulus at: midline, 15 degrees to the left, or 15 degrees to the right. Data were collected using the Skalar infrared limbic tracking system and a custom LabVIEW program. Dynamics were quantified with a latency analysis and the time to acquire ± one degree of the target analysis using MatLAB. Results show that an increase in latency occurs during target location accompanied by a photic stimulus compared to target location accompanied by no photic stimulus, and that green light has a more robust effect on saccadic metrics than white light.**

I. INTRODUCTION

White light, commonly in the form of sunlight and incandescent light, encompasses all wavelengths of the visible spectrum while variations of green light, often used in traffic lights, non-lethal stunning devices, and industrial controls and indicators, cover approximately one-fifteenth of this spectrum. Previous research considers light of green wavelength (520 nm) to result in the longest readaptation time [1]. This suggests that even though green light comprises only a portion of the optical spectrum, it may have more intense effects than white light in cognitive and behavioral tasks.

Attention has been purported by psychologists as a core cognitive process, with which to study other cognitive processes such as learning. Studies suggest that attention has a direct link to saccade generation and that variances in saccadic latency occur with multiple stimuli [2]. In particular, a competition for visual attention appears to contribute to saccadic latencies [2,3].

An afterimage is a visual phenomenon in which some features of an image persist after the visual stimulus ceases. After a flash of bright light, cells within the light-exposed area of the retina become less sensitive to light than those outside that area, so they fail to respond as well to the same level of light. Exposure to bright light can produce an afterimage lasting for minutes to hours depending on intensity and duration of the source light. Afterimages can have undesired effects such as spatial disorientation while operating aircrafts or vehicles [4]. Yet, afterimages have practical applications in law enforcement and military operations in terms of stunning opposing forces without causing permanent damage.

The saccadic oculomotor system rapidly shifts the fovea to a visual target in the periphery. Saccades usually have two characteristic features: high velocity and a nearly identical eye movement measurement of both eyes [5]. Burst and tonic nerve cells in the mesencephalic reticular formation control the velocity and position of saccades. This study investigates the effects of white and green wavelengths of light on saccadic metrics.

II. METHODOLOGY

A total of thirteen subjects participated in this study with five subjects common to both protocols. Eleven subjects participated in the white light paradigm while eight subjects took part in the green light model. All subjects understood the experimental protocol and signed informed consent forms approved by the institution's review board.

This study investigated how the energy of white light versus green light affected saccadic eye movements. Horizontal eye movement data were collected with LabVIEW software in response to two control stimuli and six experimental stimuli. Control stimuli comprised of: a 15-degree target to the left or to the right visual field without photic stimulation during the entire experiment. Experimental stimuli for both white and green flash paradigms included: center foveal flash with a 15-degree target to the left or right, left flash with a 15-degree target to the left or right, right flash with a 15-degree target to the left or the right. A target consisted of a small vertical green LED bar. The subject was asked not to blink if possible during the experiment and had the choice to pause anytime if fatigued. The subject was told to visually locate the LED target after the trigger push. A bell sound signified the end of an experimental trial.

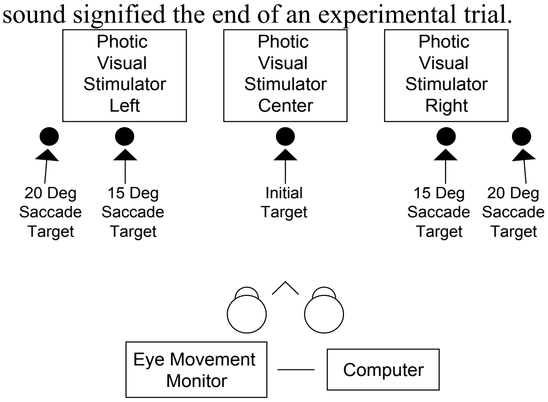

Fig. 1. Experimental set-up.

The experiment began with five-point calibration between ±20 degrees. After calibration, the subject was asked to fixate on the center target then push a trigger to initiate the experiment. Once the trigger was pushed, a random delay of 0.5 to 2 seconds occurred before the stimulus to prevent subject prediction. Then one of the eight types of stimuli was randomly presented. Each experimental response lasted 5 seconds. Five-point calibration was recorded every 10 experimental trials. For every stimulus type, approximately 10 to 20 responses were collected per subject.

The apparatus is shown in Fig. 1. It consisted of 3 Grass PS33-Plus photic stimulators adjusted to flash intensity settings of 8 placed 57 cm from the subject, 5 LED targets also 57 cm from the subject, and a limbic tracking system which collected eye movement data. Green light was created by using green filters superimposed with the white photic stimulators. The photic stimulators were positioned at the midline and at 15 degrees in the left and right visual fields. The saccade LEDs were located at 15 and 20 degrees from the midline in the right and left visual fields. The Skalar Iris model 6500, a limbus-tracking device, was used at a sampling rate of 1000 Hz which is well above the Nyquist frequency for saccadic movements. This eye movement monitor had a resolution of 2 minutes of arc and a linearity of ±25 degrees. This instrument was placed on the subject's head and adjusted to the left and right eye. It collected data from each eye where left and right eye movements were individually stored to be analyzed post-experiment.

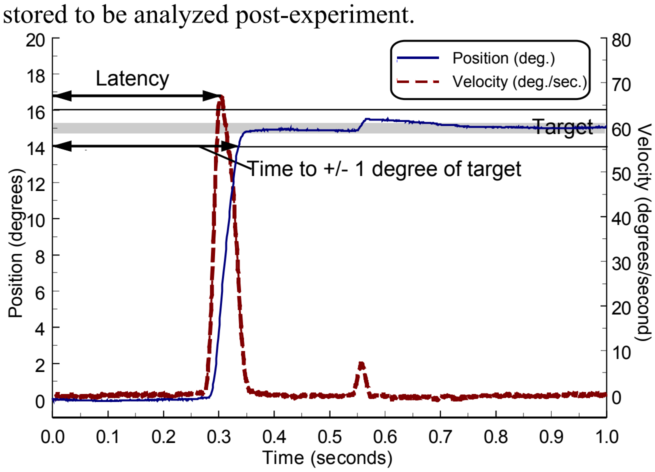

Fig. 2. Analysis of latency where time was measured from stimulus onset to the time where peak velocity occurred and analysis of time to ± 1 degree of a 15-degree target.

Data analysis occurred offline with MatLAB software where the left and right eye responses were summed, then halved, to yield an average saccadic response. Latency analysis, where time was measured from stimulus onset to the time where peak velocity (saccade to a target) occurred, is shown in Fig. 2. The solid line (position) and the dashed line (velocity) were plotted as a function of time. The time the response acquired ± 1 degree of the target was also quantified, illustrated in Fig. 2.

III. RESULTS

Fig. 3 shows a summary of the means and standard deviations of the latencies from control and experimental stimuli for photic stimulation with a white flash of light and a green flash of light. Latencies of green photic stimulation versus controls were determined to be more significant for all visual fields studied, while latency of white photic stimulation was significant only for trials where subjects experienced a flash at the same field as the target movement (n=11 for white stimulation and n=8 for green stimulation).

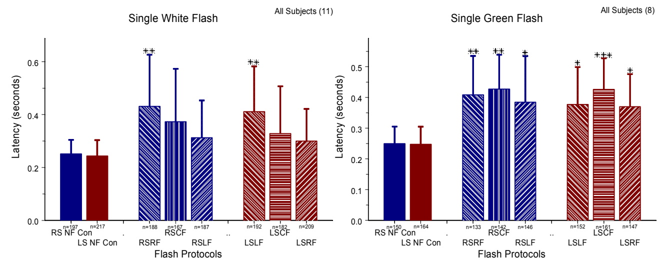

Fig. 3. Mean latencies of 15-degree saccadic eye movements of controls (no photic stimulation), and of photic stimulation in the center, right, and left visual fields for photic stimulation with white light and green light. *: 0.01<p<0.05, **: 0.001<p<0.01, ***: p<0.001.

Fig. 4 illustrates a summary of the means and the standard deviations of the time the response acquired ± 1 degree of the target. Green photic stimulation resulted in significantly greater delays than white photic stimulation for all visual fields studied, while white photic stimulation caused significant delay in only one protocol, where subjects experienced a flash to the right field with target movement to the same field.

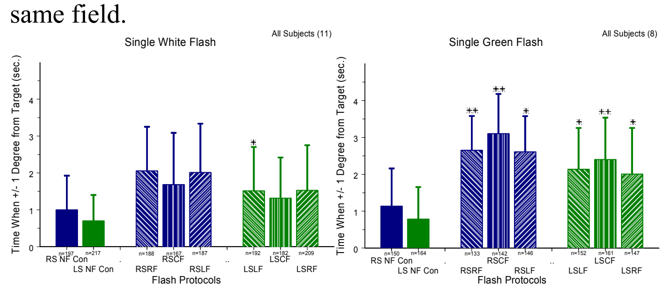

Fig. 4. Means and standard deviations of the time the response acquired ± 1 degree of the target. *: 0.01<p<0.05, **: 0.001<p<0.01, ***: p<0.001.

IV. DISCUSSION

Results indicate that green light stimulation has a more robust effect on saccadic metrics over white light. Latencies due to a white or green flash of light may be due to afterimage as well as a competition for visual attention [2,3]. Experimental protocols in which the flash of light was of similar wavelength as the target may cause target salience to decrease, suggesting an increase in latency. In addition, white light stimulates all retinal photoreceptors, while green only stimulates green photoreceptors. This more acute photic stimulation may have a more potent effect than general photic stimulation. Findings from this study necessitate the study of the effects of stimulation of the other two key photoreceptors: red and blue.

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