2015

Design and Creation of a Device to Induce Vergence Eye Movements

Jacob B. Jaminet
Virginia Commonwealth University, jaminetjb@vcu.edu

Paul A. Wetzel
Virginia Commonwealth University

V I R G I N I A   C O M M O N W E A L T H   U N I V E R S I T Y

VCU

Design and Creation of a Device to Induce Vergence Eye Movements

Jacob Jaminet, Paul Wetzel, Ph.D., Department of Biomedical Engineering,
Virginia Commonwealth University

Mild Traumatic Brain Injury and Parkinson's affect on eye movements

The eye is controlled by six muscles that are innervated by nerves whose bodies are located in the brain stem. Even at rest, the muscles show some activity to keep them taut and the eyes in the same position. This "tonic" activity is controlled by discharges of the nerve. Damage that causes movement disorders such as Parkinson's and mild traumatic brain injury can affect the discharging of the neurons. As the eyes are under such fine control by the nerves, the effects of Parkinson's and other neurological diseases can be detected using eye tracking systems. Previous work focused on diagnosing Parkinson's' using smooth pursuit eye movements where the eyes move together in the same direction. While there have been studies with smooth pursuit to diagnose Parkinson's and other movement disorders, there is not much done with vergence eye movements. This project explored if a repeatable stimulus could be produced that could cause vergence eye movements.

Vergence Eye Movements

There are three types of eye movements.

- Smooth pursuit (Version movements)
  - Eye movements where the eyes are moving in the same direction at the same time (Figure 1a).
  - Example: watching a Frisbee as it crosses your view from left to right.
- Vergence shift
  - Eye movements in equal and opposite directions, converging as an object comes closer, and diverging as an object moves away (Figure 1b).
  - Example: Hold your thumb out directly in front of you and move it closer to your nose while watching your thumb nail. Your eyes converge toward your nose. As your thumb moves away, your eyes diverge.
- Saccades
  - Rapid, ballistic movements of the eyes that abruptly change the point of fixation. They range in amplitude from the small movements made while reading, for example, to the much larger movements made while gazing around a room.

System Design and Calibration

To create a stimulus to induce vergence, a mirror galvanometer was used to project a laser pointer at a thin sheet of paper (Figure 2). The laser spot would appear on the paper and as the galvanometer pitched, the laser dot would move closer and further away from the view (Figure 3). As the galvanometer pitched the mirror back and forth at a steady rate, the speed at which the light appeared to move along the track varied with the light moving faster at the ends of the track and slower toward the center (Figure 4a). A steady velocity is needed to induce controlled, repeatable stimuli. By plotting the position of the light when different voltages were applied to the galvanometer, a linear regression was calculated. By passing the desired velocity and position to the regression, the light moved at the desired speed across the entirety of the board (Figure 4b). Once the device was calibrated to output the correct velocity across the entire board, the eye tracker was implemented to see if the eyes underwent convergence and divergence when viewing the stimulus.

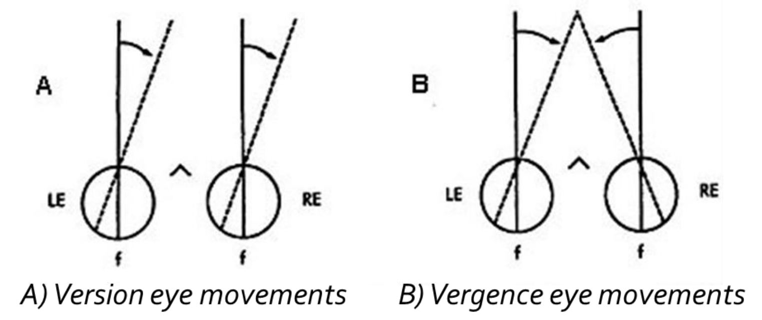

Figure 1. A) Version eye movements are eye movements where the eyes move in the same direction at the same time. B) Vergence eye movements are eye movements where the eyes move in opposite directions with the left eye moving to the right while the right eye moves left.

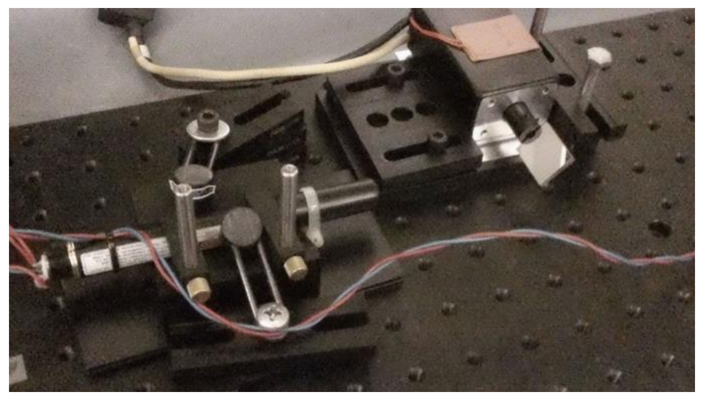

Figure 2. The laser pointer was directed to project on the board by the mirror galvanometer. As the mirror pitched, the laser pointer would move closer or further away from the viewer.

Figure 3. Vergence eye movement inducer. A laser dot was directed by a mirror galvanometer to appear on the board. The galvanometer would move the dot so it would come closer and further away from the viewer. As the viewer focused on the dot, their eyes would convergence and diverge.

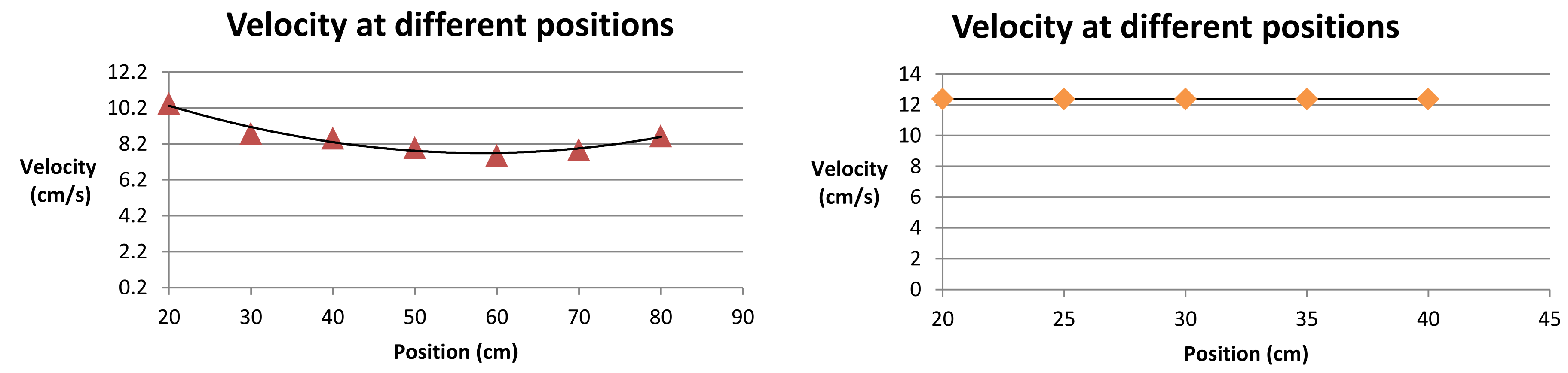

Figure 4. A) The velocity of the stimulus is much faster at the ends of the board then at the center when the galvanometer moved at a steady rate. The position of the laser was recorded while different voltages were applied. A linear regression was then calculated and used to correct the change in position. B) After the linear regression was calculated, the desired velocity was passed to the regression and the desired voltage was applied to the galvanometer. This made it so the velocity was the same along the length of the board.

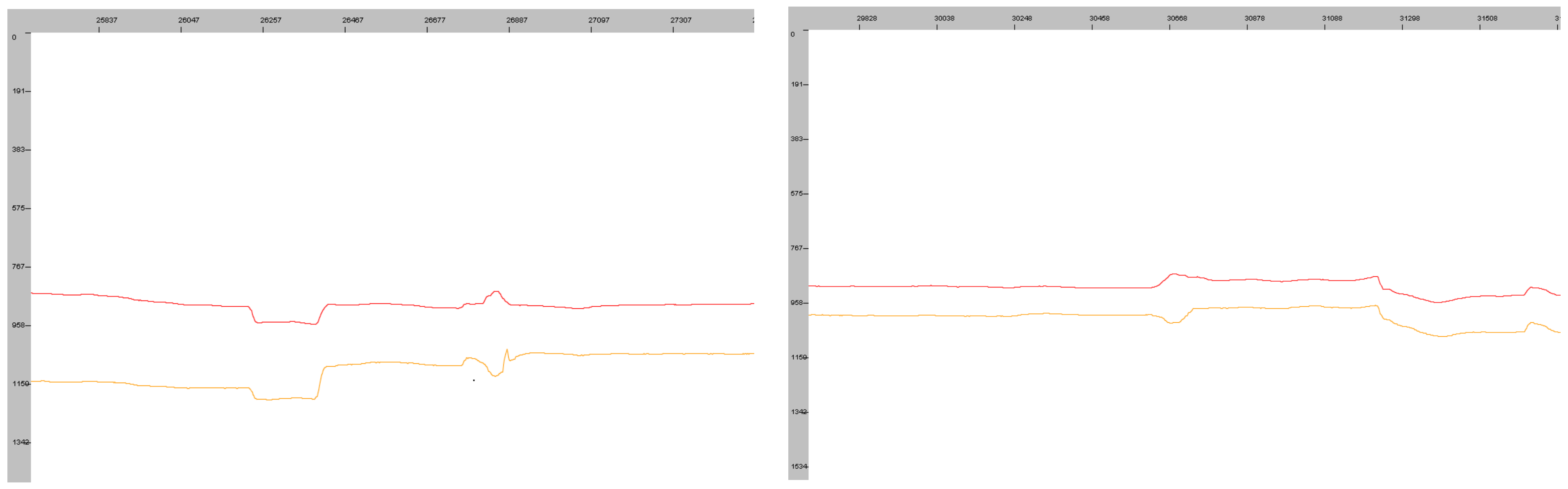

Figure 6. A) Eye tracker data showing the positions of the eyes. The red line is the position of the left eye and the yellow line is the position of the right eye. Up on the graph represents the eyes moving left and vice-versa. Versional eye movements are when both eyes move in the same direction as they did between 26257 and 26467 seconds. Vergence eye movements are shown at 26887 seconds when both eyes moved in opposite directions. B) Vergence eye movements occurred at 30668 seconds with versional eye movements occurring after ~31094 seconds.

Eye tracker

The eye tracker works by bathing the eye with infrared light and the reflection of the infrared light captured by two cameras determines the position of the eye. The initial eye tracker used (Figure 5) obstructed view of the stimulus as the laser dot approached the viewer. A different eye tracker with the cameras and infrared lights mounted above the eyes was used later for data collection as it did not impede the view of the viewer

Figure 5. The eye tracker bathes the viewer's eyes with infrared light. The reflection of the light off the pupil is captured by the cameras and used to calculate the position of the eye.

Results

Once the system was calibrated so that the velocity remained constant across the entire board, the eye tracker was used to follow the eye movements while the stimulus was run. The data was recorded and plotted in Microsoft Excel (Figure 6). The vergence stimulus system projected a laser dot that the viewer focused their gaze on. The laser dot moved away and toward the viewer at constant rates and jumped between different positions.

Conclusions and Future Direction

This system is able to induce vergence eye movements as seen by the positions of the eyes moving in equal and opposite directions (Figure 6). Different eye trackers will need to be tested to determine which one will be able to collect the most accurate data without obstructing the view of the stimulus. Baseline data will then be collected from those with normal sight which will then be used to compare to those with a known history of brain injury to compare any differences. This system could eventually be used as a diagnostic tool to determine brain injury noninvasively and can potentially be used as a

Acknowledgements

I would like to thank Dr. Wetzel for his mentorship during this project, the Honors College for their support and housing for both summers. I would also like to thank Dr. Smith-Mason, Michael Walker, and Nathan Wilson for their work in making the Honors Summer Undergraduate Research Program possible. I also want to thank Philip Maxwell and Zoe Villamar for their help with the eye tracker.

References

Mays, L. E., Porter, J. D., Gamlin, P. D. R., & Tello, C. A. (1986). Neural control of vergence eye movements: Neurons encoding vergence velocity. *Jouranl of Neurophysiology, 56*(4).
Sato, F., Akao, T. Kurkin, S., Fukushima, J., & Fukushima K. (2004). Adaptive changes in vergence eye movements induced by vergence-vestivular interaction training in monkeys, *Exerpimental Brain Research, 156.*
Thiagarajan, P., Optom, B. S., & Ciuffreda, K. J. (2013). Effect of oculomotor rehabilitation in mild traumatic brain injury, *Journal of Rehabilitation Research and Development, 50*(9). doi: 10.1682/JRRD.2012.12.0235
Westheimer, G. & Blair, S. M. (1973). Oculomotor defects in cerebellectomized monkeys, *Investigative Ophthalmology & Visual Science, 12.*