MOTOR LEARNING IN THE BINOCULAR TRACKING SYSTEM
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Abstract – Motor learning is the ability that the brain utilizes to optimize a task. The human brain has the ability to change its motor control strategy with the use of memory and learning. This study analyzed the latency of convergent and divergent eye movements from a predictable and non-predictable stimulus. Two stimulus types, a single frequency sinusoidal wave and a multi frequency sinusoidal wave, were presented to the subject. The subject was asked to track the target and data were collected utilizing an eye movement monitor. The goal of the study was to determine if the feedback portion of the vergence system changed as a result of learning. Results show that the response-timing index decreases and movements can occur before stimulus onset when learning is utilized.

I. INTRODUCTION
Motor learning is the brain’s ability to optimize a motor task. When a person begins to study a sport such as tennis, he/she is not proficient the first time he/she picks up a tennis racket. The brain must learn the task and continuously train the system to change its motor control strategy from that of a novice to one of a skilled athlete.

Learning in the visual system is a strategy that the brain uses in oculomotor control where the brain can predict or anticipate the stimulus paradigm. As a predictive machine, the cerebellum learns to anticipate sequences of events that occur repeatedly. When a subject tries to track a target that moves periodically between two different positions, the oculomotor system learns to predict the direction and temporal information of the stimulus. We will use a conditioning reinforcement learning paradigm, where the subject views the same stimulus throughout the experiment. Oculomotor learning is quantified via improved performance.

Vergence is the inward or outward turning of the eyes, to track objects moving in depth. This system utilizes dual control of feedforward and feedback mechanisms. The two-component system is known as the initiating and sustaining component to represent the feedforward and feedback mechanisms respectively.

Rashbass and Westheimer in 1961 showed that when subjects tracked sine waves, the lag of the response compared to the stimulus decreased and suggested that this behavior is due to the anticipation of future disparity changes [1]. In addition, other studies on vergence showed that when subjects track a periodic square wave stimulus there was a decrease in latency and an increase in peak acceleration as the subject learned the stimulus [2].

When a subject tracks a square wave or step stimulus the initiating component of vergence is stressed more so than the sustaining component. However, slower moving stimuli such as slow ramps or sinusoids where the subject is asked to smoothly track a moving target provokes the sustaining component of vergence. The goal of this study is to research if learning influences the sustaining component of vergence.

The two protocols utilized are a stimulus that can be learned such as a single frequency sinusoidal wave and a stimulus that cannot be learned such as a multi frequency sinusoidal wave where this stimulus is the summation of three sine waves of three different magnitudes and three different frequencies. This paradigm will test the feedback portion of the response to determine if the subject’s tonic cells can be altered through a learning paradigm similar to the modification seen by the predictable square wave responses which tested the burst cells in the system.

We proposed to study oculomotor learning by comparing a single frequency sinusoidal wave to a multi frequency sinusoidal wave.

I. METHODOLOGY
The stimulus display apparatus shown in Figure 1 consisted of a pair of oscilloscopes arranged in a haploscopic configuration. The target image consisted of two vertical lines produced on oscilloscope screens. To calibrate the oscilloscopes, two stationary targets were used. The far target was located at two degrees from each eye and the near target was located at five degrees from each eye. The vertical lines were positioned in front of the subject through partially reflecting mirrors placed 45 degrees to the subject’s line of sight. The subject was asked to fuse both lines into a single perception. The vergence responses were recorded using a limbus-tracking device with a linear ranges within 3% over ±25 degrees. The responses of each eye were sampled at 200 Hz. Custom Labview software digitized and stored data from each individual eye to be analyzed offline.

![Figure 1: Experimental Set-up](image)

An eye movement monitor was positioned on the subject, and a five-point calibration was recorded. The main task of the five-point calibration was to allow the subject’s eye movements to be transformed from volts into degrees after they were digitalized using a 12-bit digital acquisition board. The five-point calibration was done after every ten
responses were recorded. After the calibration process the subject was asked to push a trigger button to begin the next stimulus. Once the button was pushed, a random time delay of 500 to 2000 msec occurred before the stimulus was presented to ensure that the subject could not predict the position of the new target during the stimulus paradigm where learning was not provoked. All targets were shown at the midline to stimulate symmetric vergence. Each stimulus was recorded for 10 seconds.

One male subject with normal binocular vision, JLS, participated in this study. The subject signed an informed consent form that was previously approved by the university’s Institutional Review Board.

Data were analyzed by measuring the latency difference of the stimulus peak velocity (blue) to response peak velocity (red) as shown in figure 2. This difference gives the latency or timing index between the response and the actual stimulus.

In Figure 3, the plots denote the position versus time for predictable and non-predictable responses which stimulus convergence (inward) and divergence (outward) eye movements. Qualitatively one can see a decrease in the latency of response to stimuli in the predictable case where learning could be utilized. Predictable responses show an earlier onset compared to non-predictable responses.

The latency or timing index is an indicator of oculomotor performance. Figure 4 shows the results of the timing index analysis for predictable and non-predictable data in convergence and divergence responses. The blue column represents the predictable responses and the red column represents the non-predictable responses. Quantitative analysis shows that the latency is less in predictable responses compared to non-predictable responses. The mean timing index for convergence data was 0.09 ± 0.11 seconds (n=54) for predictable responses and 0.24 ± .09 seconds (n=40) for non-predictable responses. For divergence data, the mean timing index was 0.02 ± 0.14 seconds (n=50) for predictable responses and 0.20 ± 0.08 seconds (n=27) for non-predictable. The timing index significantly decreased for predictable responses. In addition, prediction also increased the standard deviation compared to non-predictable responses.

III. DISCUSSION

Previous studies concentrated on the initiating component of vergence generated by burst cells. This study focuses on the smoothly tracking aspect of vergence, which stimulates the feedback or sustaining component generated by tonic cells. Preliminary data suggest that the feedback portion of the system is also optimized by learning as seen by a decrease in the latency when comparing predictable responses to a non-predictable responses.

REFERENCES
