Dynamic Analysis Comparing Esophoria and Exophoria

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***Abstract* - This study analyzed eye movements of an esophoric and an exophoric subject using an infrared limbus-tracking device. Converging and diverging one and two degree step stimuli were given to both subjects. Preliminary results suggest that dynamic differences may exist between the two populations.**

I. INTRODUCTION

Our society is evolving to become more dependent on near vision tasks such as reading, deskwork, and computer viewing [1, 2]. People who have a vergence dysfunction develop ocular discomfort or become fatigued attempting to sustain near vision tasks, thereby reducing visual performance [1]. Symptoms associated with vergence anomalies are blurred vision, headache, ocular discomfort, diplopia, motion sickness, loss of concentration during task performance and ocular or systemic fatigue [2].

When two disparate images are perceived, a large retinal disparity error is created. Retinal disparity is the stimulus to the vergence system. Convergence, the inward turning of the eyes or divergence, the outward turning of the eyes, will be mediated to reduce retinal disparity so that the two images are perceived as one. Recent results show that of 256 people studied in an optometry clinic, binocular dysfunction was present in 12.9% of the population [3]. The four most common vergence anomalies are Convergence Insufficiency (CI), Convergence Excess (CE), Divergence Insufficiency (DI), and Divergence Excess (DE). When a person perceives an image moving from far to near, a convergence response is mediated. The two anomalies associated with convergence are CI, which is typically defined as an abnormal decrease in near convergence compared to that at distance and CE, which is denoted as an abnormal increase in convergence at near relative to that at distance. Whereas, when a person views an image from near to far, they perform a divergence movement. Similarly there are two anomalies associated with divergence; DI, defined as a high esophoria at distances greater than the near deviation and DE, which is characterized by high exophoria at distance greater than the near deviation [1].

Esophoria is defined as the inward-lateral deviation of one eye in the fusion-free state, an open-loop disparity vergence system. When the person returns to a closed-loop disparity environment, the person must mediate a divergence movement. Conversely, exophoria is the outward lateral deviation of the eye in a fusion-free state, so that when the person returns to a closed-loop disparity environment, a convergence movement is mediated. Understanding the dynamics of the eye movements may lead to a better understanding of the vergence anomalies. Patients who have DI or CE typically are esophoric; whereas, patients who have CI and DE are exophoric. This investigation presents preliminary research to determine if the dynamics of esophoric and exophoric eye movements differ.

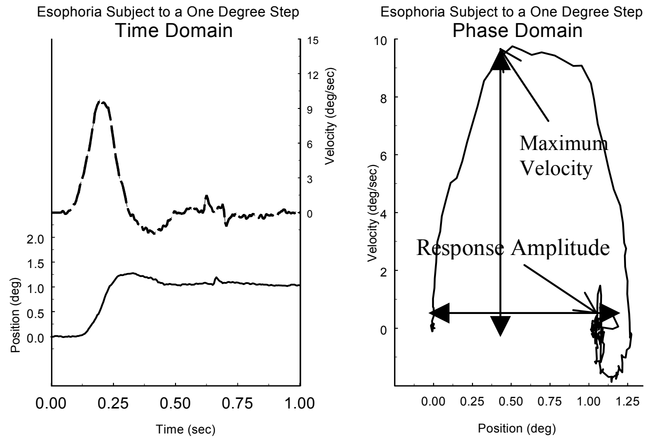

Fig. 1. Time and phase domain of a Typical Response

II. METHODS

Experiments were conducted on 2 human subjects: JS who is exophoric, and TA who is esophoric, where both subjects were aware of the goals of the research. A computer controlled data acquisition as well as the presentation of the stimuli. Subjects were requested to fuse two vertical lines produced by two oscilloscopes. Introducing a randomized delay of 500 to 2000 msec and randomizing the step stimuli avoided prediction.

Four step stimuli were studied; two converging steps (1 deg and 2 deg) and two diverging steps (1 deg and 2 deg). Calibration and recording of the two eyes were done separately. The eye movements were measured using the Skalar Iris 6500, an infrared, limbus-tracking device, having a resolution of 2 minutes of arc, and linearity of ±25 degrees. Data was sampled at a rate of 200 Hz.

During analysis, the vergence response was constructed as the difference between left and right eye movements. The phase domain, a plot of velocity as a function of amplitude, was used to quantify the first-order dynamics of the eye movements. The main sequence was obtained by measuring the ratio of peak velocity to response amplitude as depicted in Fig. 1 from the phase plane plot [4].

III. RESULTS

Fig. 2 depicts the phase plane representation of four typical movements; convergence and divergence responses from an esophore and an exophore. These results were quantified for many responses using the main sequence analysis [4] and are depicted in Fig. 3 and 4. The results demonstrated that subject JS, who is exophoric had faster convergence responses as compared to his divergence responses. However, subject TA, who is an esophore also displayed faster convergence as compared to her own divergence responses.

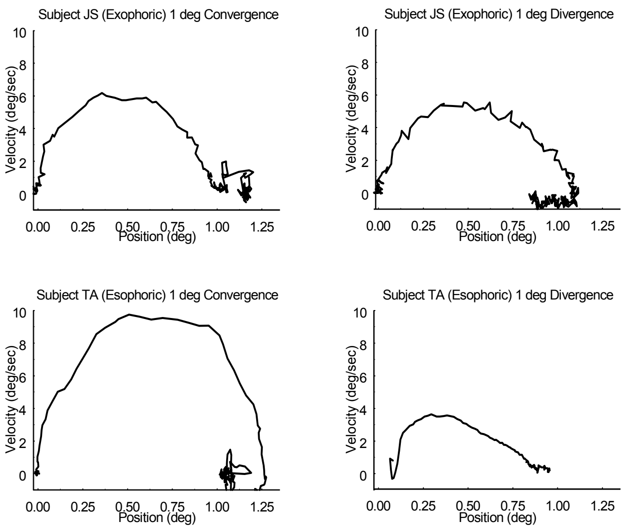

Fig. 2. Phase domain of a Convergence and Divergence Movement for Esophoric ad Exophoric Responses

IV. DISCUSSION

There are several hypotheses to be considered. One hypothesis regards comparing the convergence and divergence dynamics of subjects who are esophoric with subjects who are exophoric. When a person is esophoric, he or she will diverge their eyes to attain fusion when changing from an open-loop to a closed-loop disparity vergence system. Whereas, a person who is exophoric, will converge their eyes to attain fusion when changing from an open-loop to a closed-loop disparity vergence system. Subjects who are esophoric may have faster divergence dynamics compared to the divergence dynamics of exophoric subjects. Similarly, people who are exophoric will converge from their phoria level to attain fusion, which may cause adaptation to occur. Thus, it is hypothesized that the dynamics of convergence in an exophoric may be faster than an esophoric. The second hypothesis is to compare the variation within a given subject. So, for a given subject who is esophoric he or she would have faster divergence dynamic responses compared to their own convergence dynamic responses. Furthermore, a subject who is exophoric would have faster convergence dynamic responses compared to their own divergence dynamic responses. The third hypothesis is that there may not be any consistent variation regarding phoria level and vergence dynamics.

Surprisingly, the esophore exhibited faster convergence responses and slower divergence responses compared to the exophore. These results reflect the opposite outcome described by the first hypothesis (dynamic comparison between two populations, exophores and esophores.) This may be explained by the bias or offset of the experiment that differed between the two subjects. Subject TA had an 8 degree bias; whereas, subject JS had a 4 degree bias. It is believed that the dynamics may be faster if an object is appearing closer to the subject as was the case for the esophoric subject. More data should be recorded to determine if a trend exists in divergence. The future direction of this work will be to maintain a fixed bias level between subjects, collect more data and determine if the first hypothesis is supported.

Furthermore, preliminary data show that for the exophoric subject studied his divergence dynamics were slower than his convergence dynamics, which agrees with the second hypothesis that an exophore should exhibit faster convergence compared to divergence dynamics. For the esophore, we postulated that convergence responses would be slower than divergent responses. There were only two divergent responses obtained where more data should be obtained before a conclusion is reached.

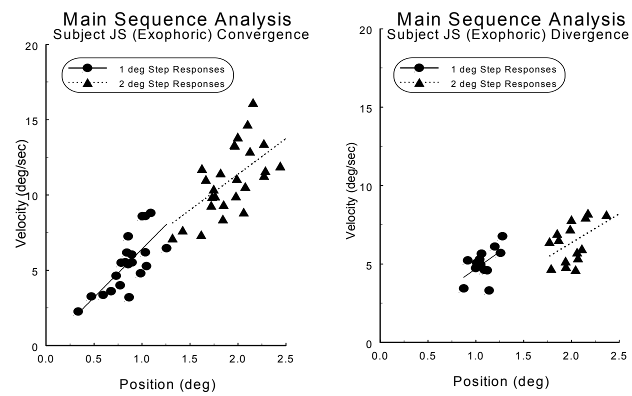

Fig. 3. Main Sequence Analysis for Exophoric Subject

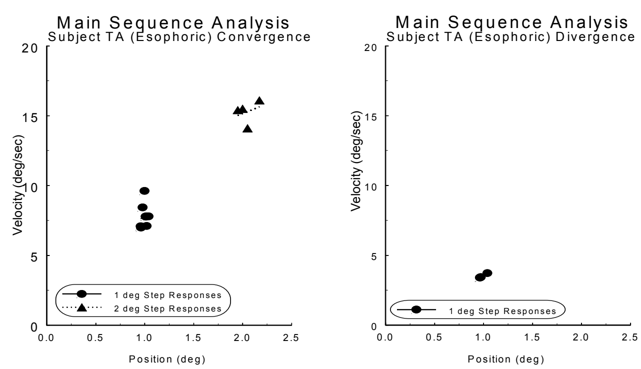

Fig. 4. Main Sequence Analysis for Esophoric Subject

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