DeCREASEd Dynamics in the Adaptation Phase Signifies that Short Term Adaptation Exists in Convergence and Divergence Ocular Movements

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Abstract- Adaptation is the process in which one optimizes to the present environment. Many physiological systems including the ocular system adapt to its surroundings. The goal of this paper is to study the effects of short-term adaptation on disparity vergence. Disparity vergence refers to convergence, the inward turning of both eyes, and divergence, the outward turning of both eyes. Four subjects participated in this study. A small stimulus of one degree and a large stimulus of four degrees were presented to the subjects using a haploscope. Data were collected using the Skalar infrared limbic tracking system. An experiment consisted of three phases: baseline, adaptation and recovery. Only large stimuli were presented during the baseline and the recovery phase. In the adaptation phase, stimuli were presented in a ratio of 5 small stimuli to 1 large stimulus to determine how the small stimuli affect the dynamics of the larger responses. Dynamics were quantified using the main sequence and results show that adaptation does occur as exhibited by a decrease in the main sequence observed in the adaptation phase compared to baseline. The dynamics in the recovery phase return to values similar to baseline, suggesting that fatigue was not the cause of the decreased dynamics.

I. INTRODUCTION

Adaptation occurs when an individual changes a certain feature to account for a change in the environment. Cells adapt to the body’s internal environment in a process called homeostasis. Similarly, the ocular system adapts to various visual stimuli.

In binocular vision, the brain integrates images received from both the right and left eye to form a single image. Diplopia, double vision, is a condition in which the images received by the brain from the eyes do not coincide. To alleviate this situation, one will perform a vergence movement. There are two types of vergence movements, convergence and divergence. A convergence movement occurs when a person focuses from a far target to a near one, causing an inward movement of both eyes toward the nose. A divergence movement is an outward turning of the eyes caused by a shift in focus from a near target to a far one. Burst and tonic nerve cells located in the mesencephalic reticular formation, will determine the velocity and the degree of the eye movement [1].

There have been many experiments which provide credence that adaptation exists in the numerous eye movements. In fact, the saccadic system has shown a 20-25% velocity decrease when affected by adaptation [2]. Also, the smooth pursuit system also exhibits decreased dynamics after adaptation occurs [3]. This study deals with short-term adaptation and its effects on convergence and divergence eye movements.

II. METHODOLOGY

Four subjects, HKB, JLS, MDN, and RMD, participated in this study. All the subjects were male and had normal binocular vision. All subjects signed informed consent approved by the institution’s review board.

In this experiment, information of horizontal eye movements were collected in response to two different step stimuli; a small one degree step and a large four degree step. The study investigated how the small steps influenced the large steps. Each experiment consisted of three stages: a baseline phase in which the subject received only large four degree steps, an adaptation phase in which the subject received on average five small steps to every one large step, and a recovery stage in which the subject received only large steps. The individual was asked to push a button and fuse the two lines. After the trigger was pushed a randomized delay of 500 to 2000 msec occurred before the stimulus began. Each response lasted for two to three seconds. In every experiment approximately 25 responses were collected.

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

The apparatus is shown in Figure 1. It consists of two partially reflective mirrors positioned 45 degrees to the subject’s line of sight, two oscilloscopes which provide the step stimulus, and a limbic tracking system which collect the eye movements. The oscilloscopes were calibrated using two stationary targets. The far one is located at two degrees from each eye while the closer target is located five degrees from each eye. Each oscilloscope emits a line stimulus towards the mirrors, which in effect produce two lines that the subject would fuse into single line. After the subject pushed the trigger, the two lines would move in a step manner. The subject would follow the stimulus and would once again fuse the lines. The Skalar Iris model 6500, a limbus-tracking device, was used at a sampling rate of 200 Hz to collect the eye movements during the experimental phases. The eye movement monitor has a resolution of 2 minutes of arc and a linearity of ±25 degrees. This instrument is placed on the subject’s head and is adjusted to the left and right eye. The eye monitor collects data from
each eye where left and right eye movements are individually stored to be analyzed offline.

Data analysis was carried out using the main sequence where the left and right eye responses were subtracted to yield a net vergence response. The main sequence is the ratio of peak velocity to response amplitude. It is calculated from the phase domain, plot of velocity as a function of position, where the peak velocity and response amplitude are denoted in Figure 2. The main sequence was chosen because one can quantify and compare the dynamics of different responses with varying magnitudes.

Figure 2: Main Sequence Analysis

III. RESULTS

In Figure 3, the lower traces denote the position versus time for typical convergence and divergence eye movements from the baseline, adaptation, and recovery phases. Above the position traces are corresponding velocity versus time graphs. The solid line is a response collected during the baseline phase, the dashed line represents a response during the adaptation phase, and the dotted line is a recovery response. Observing this graph, one can clearly see that the small responses significantly affected the large ones. The velocity and position curve of responses obtained from the adaptation phase are slower, suggesting the intermixing of the large and small steps will cause a decrease in dynamics in the large step responses.

Figure 3: Typical Example of Convergence and Divergence Eye Movement from baseline, adaptation, and recovery phases

Figure 4 shows a graphical summary of the dynamics in convergence and divergence using the main sequence to quantify the eye movement responses. Observing this graph, one can make three significant conclusions. First, the small steps in the adaptation phase caused a decreased in the main sequence dynamics of the large steps. Secondly, the dynamics of the recovery phase returned to those similar to baseline, suggesting that adaptation, not fatigue, as the cause of the decreased dynamics during the adaptation state. Finally, this graph suggests that the dynamics of convergence are faster than that of divergence.

IV. DISCUSSION

The data collected suggests that the intermixing of the large and small stimuli causes a decrease in dynamics during the adaptation phase of disparity vergence movements. Recovery data suggests that fatigue was not the cause of the decrease in dynamics but the decrease was caused by short-term adaptation effects. Also, the fact that convergence movements are more vibrant than the divergence movements might be due to the fact that humans contain more convergence burst and tonic cells than divergence burst and tonic cells [1]. This might also explain why divergence data is more difficult to collect compared to convergence data. More divergence data needs to be collected on the subjects in order to determine if this trend continues after the addition of more divergence data.

REFERENCES