Short Term Adaptation of Disparity Vergence: A Suppressive Stimulus Study.

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Abstract - Adaptation is the modification of structure or form due to environmental conditions. It is a key aspect of species survival and is found in most major physiological systems. This study analyzed adaptive effects of the vergence system using an infrared limbus-tracking device to record eye movements. Specifically, this study investigated how small steps of 1 degree influence 4, and 8 degree steps. Adaptation was observed in the two subjects studied as noted by the decrease in velocity of vergence eye movements.

I. INTRODUCTION

Throughout the day, adaptation continuously occurs as our nervous systems examines and fine-tunes the correlation between sensory input and motor output. An example of a system that displays adaptation is disparity vergence, the inward or outward turning of the eyes. In binocular vision, the brain integrates images received from the right and left eye and fuses them, which is the underlying mechanism of how the visual system perceives images in stereoscopic depth. If retinal disparity, the stimulus to the disparity vergence system, is large then diplopia or double vision occurs. The retinal disparity stimulates the system to move the eyes inward or outward utilizing the medial and lateral recti muscles resulting in a single perception. Vergence eye movements exhibit two key behaviors, speed and accuracy. The Dual Mode Theory depicts these behaviors by modeling the system using two control strategies. The fusion-initiating component accounts for the high speeds and performs coarse adjustments, in response to large retinal disparities through feed forward or open loop control. The fusion-sustaining component accounts for the accuracy using fine-tuning through a feedback control mechanism.

There are many studies that have examined adaptation of velocity and position gain in several physiological systems. While studying the saccadic system, Straube and Deubel \cite{2} reported position gain and velocity decreases of 20-25%. These results depict adaptation does influence the saccadic system.

Adaptation has also been noted in the vergence system. Munoz and colleagues \cite{1} depicted significant gain and velocity increases while studying the effects of a positive step ramp stimulus on a step response. In their study, the step ramp was a 4 deg step with a 4 to 16 deg/sec ramp superimposed. Takagi and colleagues used the double step paradigm to study vergence adaptation \cite{3} and reported that it was possible to increase or decrease the gain in responses depending on the experimental protocol. They concluded that the dynamic changes seen in the vergence system were similar to those found in the saccadic or initial portion of the smooth pursuit system. Our study will analyze vergence eye movements to determine if a decrease in adaptation gain and velocity is possible when single large and small steps are intermixed.

II. METHODS

During this experiment horizontal eye movements in response to two stimulus patterns were recorded. The stimulus patterns included a training stimulus, which was a 1 degree step, and an experimental stimulus, which was a 4 degree step (Fig. 1). This study investigated how the training or small stimulus influenced the experimental or large response. The experimental run was composed of two stages, 1) a baseline mode in which a subject received only 4 degree steps, and 2) an adaptation mode in which a subject received stimuli using a 5 to 1 ratio of 1 degree steps to 4 degree steps. In one experiment, a recovery mode was included to determine if the responses dynamics would return to the values noted in the baseline mode. To avoid prediction, a randomized delay of 500 to 2000 msec was given. Responses were recorded for a two second duration.

A total of three experiments were recorded. One male subject, JS, and one female subject, TS participated in this study. Subject JS participated in two of the experiments; one with a 4 deg experimental stimulus and one with an 8 deg experimental stimulus, on two different days. Subject TS participated in one experiment using a 4 deg experimental stimulus. Both subjects had normal binocular vision. Only one subject, JS was experienced, and both subjects were aware of the goals of this study.

The stimuli were displayed on two oscilloscopes. Stimuli...
were seen through two mirrors situated at 45 degrees to the line of sight to form a stereoscopic pair. Before each experiment, the oscilloscopes were calibrated using two stationary targets located 5 degrees from each eye (10 degrees total) and at 2 degrees from each eye (4 degrees total). The vergence eye movement responses were measured using the Skalar Iris model 6500, a limbus-tracking device, at a sampling rate of 200 Hz. The eye movement monitor has a resolution of 2 minutes of arc and a linearity of ±25 degrees. Left and right eye movements were calibrated and recorded separately.

III. RESULTS

A typical eye movement recording can be seen in Fig. 2 where a response before adaptation is noted on the left and a response during adaptation is noted on the right. The bottom traces depict the position response while the upper traces denote the velocity of the response. This figure demonstrates that smaller degree responses influence larger responses as noted by a decrease in the velocity trace. The peak velocity was quantified for many measurements as seen in Fig. 3.

Two subjects were studied to determine the affects of 1 degree responses on 4 degree responses. In both subjects studied, a decrease in velocity was noted when 1 degree stimuli where intermixed with 4 degree stimuli at a 5:1 ratio as noted in Fig. 3. One subject, TS showed a decrease in velocity from $21.18 \pm 7.46$ deg/sec to $14.74 \pm 3.17$ deg/sec, while the other subject JS showed a decrease in velocity from $26.54 \pm 4.22$ deg/sec to $24.03 \pm 5.57$ deg/sec.

Another experimental paradigm was studied where 1 degree steps were intermixed with 8 degree steps also in a 5:1 ratio. Subject JS responses decreased during the adaptation phase. A recovery phase was also recorded to determine if the maximum velocity of the responses would return to similar values as noted in the baseline phase. It was found that the maximum velocity of responses from Subject JS did return to similar values as those in the baseline mode signifying his responses exhibited a decrease in velocity due to adaptation and not to fatigue as noted in Fig. 4.

IV. DISCUSSION

Preliminary data suggest that that using single small step stimuli of 1 degree intermixed with 4 or 8 degree stimuli did result in adaptation to the vergence system. Subjects TS and JS showed a decrease in velocity, when using the 4 degree experimental stimulus. A more challenging experiment was created by intermixing 1 and 8 degree stimuli to determine if more adaptation could be attained. While using the 8 degree experimental stimulus subject JS also displayed a decrease in maximum velocity during adaptation and returned to approximately the baseline velocity during recovery (Fig. 4) signifying the decrease in velocities was due to adaptation not fatigue. Further study is needed to determine if 1 degree stimuli have more adaptive affect on 8 degree responses compared to 4 degree responses.

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REFERENCES