Convergence Dynamics as an Indicator for Progressive Addition Lens Acceptability among Presbyopes

Sang J. Han[1], John L. Semmlow[2], Bérangère Granger-Donnetti [3], Tara L. Alvarez[1]
[1]New Jersey Institute of Technology, Depart. of Biomedical Engineering Newark, NJ,
[2]Rutgers University, Piscataway, NJ, USA and Department of Surgery, Bioengineering,
Robert Wood Johnson Medical School UMDNJ Piscataway, NJ, [3] Essilor International, St.Maur, France

Abstract—**Presbyopia is a universal vision problem caused by the aging process. Progressive addition lenses (PALs) are a preferred solution; however, some patients can not adapt to the lenses. The acceptability is not well understood. Sixteen presbyopic subjects (9 subjects adapted to progressive lenses (PL) and 7 subjects who could not adapt to progressive lenses (PD)) participated in a motor learning study. The motor learning experiment recorded baseline and modification responses where the dynamics of the 4° step responses were compared. Results show that both baseline and modified convergence dynamics were significantly greater in PLs compared to PDs. An adaptive neural network (ANN) classification technique using the baseline and modification velocity parameters with a linear classifier resulted in 94% correct classification. Therefore, baseline 4° convergence dynamics and its modification rate may be used as indicators to predict progressive addition lens acceptability among presbyopes.**

I. Introduction

Presbyopia is part of the aging process and all humans will become presbyopic. The ability to accommodate or focus on objects diminishes with age. Approximately at 40 years of age, many individuals notice difficulty reading at near. Common symptoms are blurred vision at near as well as difficulty changing or maintaining focus.[1] One treatment for presbyopia is wearing progressive addition lenses (PALs). However, wearing PALs can cause blurriness or peripheral aberrations called "swim" which can be more noticeable to some patients [1]. Many individuals can adapt to PALs, however there are some patients who can not adapt. The acceptability to PALs is poorly understood. Previously, baseline vergence dynamics[2], vergence variability quantified by wavelet entropy[3] and by sample entropy[4] have been investigated to study progressive lens acceptability.

This research investigates if differences in behaviors exist between PLs and PDs in an oculomotor learning experiment. Vergence adaptation, a form of motor learning, has been reported previously to have clinical implications.[5] We hypothesize that those who have faster convergence dynamics and a greater ability to modify their vergence dynamics may be more likely to adapt to progressive lenses. The broader impact of this work is to understand oculomotor learning in general and then to potentially develop methods to facilitate oculomotor learning in individuals who have difficulty with adaptation.

II. Materials and Methods

Subjects

Sixteen presbyopic subjects with normal binocular vision assessed through a Randot Stereopsis test participated in this experiment. The subjects were divided into nine presbyopes adapted to PALs (PLs) and seven presbyopes who have tried but could not adapt to PALs (PDs). Refraction for near vision was corrected to subjects' prescription. Subjects signed an informed consent form approved by NJIT IRB.

Experimental setup and Procedures

Eye movements were recorded with a limbus tracking system (λ= 950 nm) manufactured by Skalar Iris (model 6500) at a sampling rate of 200Hz, which is well above the Nyquist frequency for vergence eye movements. Green LEDs placed along the subject's midline were used for the visual targets. Experiments were controlled using a custom program written in Labview version 8. The experiment had two phases: a baseline phase and a modification phase. For baseline, only 4° convergence steps responses were recorded. The modification phase contained 4° convergent steps randomly intermixed with 4° double convergent steps in a 1:5 ratio. A 4° double step is a 4° step followed by a subsequent 4° step with a delay of 200 msec. Calibration of the eye movement responses was preformed using the output of the eye movement monitor at two known positions before and after each response.

Data analysis

The left and right eye responses were subtracted to yield the net vergence movement (Fig 1). Peak velocity and the correlation coefficients were calculated using Matlab. Data were compared using a student T-test with SAS to compare the peak velocity of the responses between the PL and PD groups, and between baseline and modification dynamics. Subjects were categorized into the PL or PD group using a linear Adaptive Neural Network (ANN) classifier and the categorization accuracy was shown using a two by two confusion plot.

III. Results

Figure 1 shows the ensemble responses from a typical PL subject (PL4) and a typical PD subject (PD2). Figure 1 shows a steeper slope of PL4's baseline dynamics (plot a) compared to PD2's baseline dynamics (plot c). Furthermore, PL4 shows greater overshoots compared to PD2 in the modification phase (plot b versus d). Data are quantified in Figure 2. A t test shows a statistically significant difference in the baseline dynamics between PL and PD group (P=0.008). Figure 2 shows a strong correlation between baseline and modified dynamics for PL but a poor correlation between baseline and modified dynamics of PD. The correlation coefficient between baseline dynamics and modified dynamics were R=0.978 (P<0.001) for PL and R=0.283 (P=0.539) for PD.

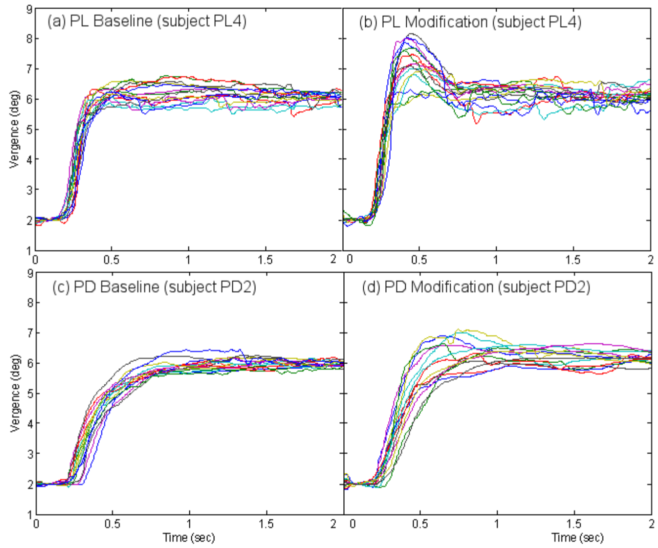

Fig .1. Ensemble 4° vergence responses plotted as position (°) as a function of time (s). The upper plots are the baseline (a) and modification (b) responses from a PL subject and the lower plots are the baseline (c) and modification (d) responses from a PD subject.

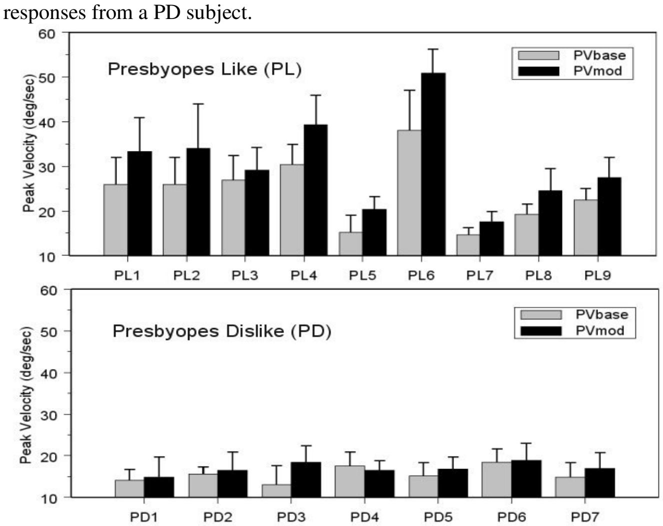

Fig.2. Comparison between baseline dynamics and modified dynamics for PL (upper plot) and PD (lower plot).

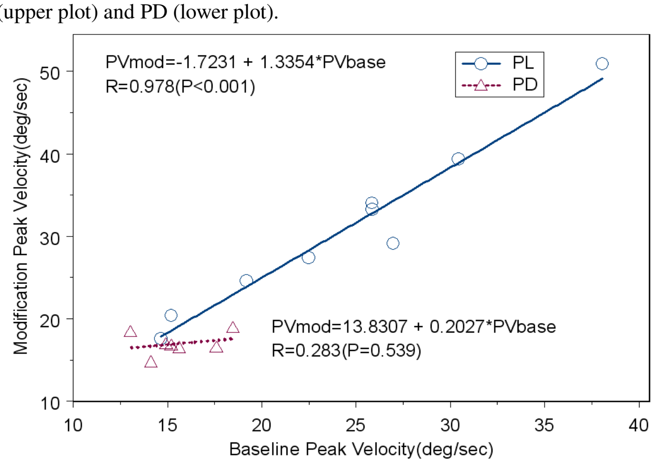

Fig.3. Baseline peak velocity (°/sec) versus modification peak velocity (°/sec) from 9 PL subjects (circle) and 7 PD subjects (triangle).

Table 1, which is a confusion plot, shows 94% classification success rate by a linear Adapted Neural Network (ANN). All nine PL subjects were classified correctly while only one out of seven PD subjects was misclassified as a PL.

Table1: Classification Results from an ANN. One PD was misclassified as a PL

	PL	PD
PL	9	0
PD	1	6

IV. Discussion

Faster vergence dynamics may lead to a greater ability for the vergence system to adapt to different visual environments. The PD group peak velocities on average were significantly slower than the PL group (15.56 ± 1.90 °/sec versus 24.30 ± 7.45 °/sec, respectively). There was more variability in the PL group dynamics as shown by a larger standard deviation. When using baseline and modification dynamics the classification resulted in a 94% correct classification which is highly accurate.

The goal of this research is to help clinician's determine which patients will easily adapt to progressive lenses and who will have more difficulty adapting. Future work includes studying other clinical parameters to determine other correlates with progressive lens acceptability. In addition, more investigation is needed to determine if paradigms can be developed to facilitate adaptation to progressive lenses.

V. Conclusion

Both baseline peak velocity and the modification rate have potential for identification of progressive lens acceptability among presbyopes.

Acknowledgement

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