Static vergence and accommodation: population norms and orthoptics effects

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Abstract. The steady-state characteristics of the accommodation and vergence systems can be described by a model with six major oculomotor parameters. These include the system biases (tonic vergence and accommodation) and forward-loop gains (vergence and accommodative gains), as well as the interactive system gains (AC/A and CA/C ratios). We investigated these parameters in two populations: (1) 22 visually-normal asymptomatic individuals, and (2) 21 visually-abnormal symptomatic individuals before and after conventional orthoptic therapy. Two parameters related to system gain differentiated between the symptomatic and asymptomatic individuals: the slope of the fixation disparity curve with accommodation open-looped and the slope of the accommodative response/stimulus curve. Following orthoptic therapy, 4 static model parameters and 1 dynamic clinical parameter showed changes toward the normal mean; this included tonic accommodation, slope of the fixation disparity curve with accommodation closed-loop (2.5D), slope of the accommodative response/stimulus curve, the CA/C ratio, and the ± 2D monocular accommodative flipper rate.

Introduction

The ability to see objects clearly, singly, and comfortably at various distances and directions of gaze involves complex interactive control processes between the accommodation and vergence systems (Hung and Semmlow, 1980). Important components of these neural control processes include the individual system's bias (tonic vergence and tonic accommodation) and gain (derived from fixation disparity measurements for vergence and slope of the response/stimulus curve for accommodation), as well as the interactive system gains (AC/A and CA/C ratios). While some (generally only one) of these parameters have been measured in various populations (Ogle et al., 1967; Borish, 1970; Cooper et al., 1983; Schor and Ciuffreda, 1983), measurement of all in the same population has not been done, especially within the framework of a model of steady-state accommodation and vergence (Figure 1) (Hung and Semmlow, 1980).

We have conducted such an investigation using standard clinic tests as well as parameters derived from this model in two populations: (1) visually-normal asymptomatic individuals, and (2) visually-abnormal symptomatic individuals
Figure 1. Overall block diagram model of the static interactive dual-feedback accommodation and vergence system. Accommodative error (AE) is the difference between the accommodative stimulus (AS) and accommodative response (AR). The deadspace (+) DSP reflects the depth of field of the eye. Output from the deadspace operator (AE1) drives the accommodative controller which exhibits nonlinear accommodative controller gain (ACG). Output from the accommodative controller (ACC) is summed at a summing junction and is also cross-linked to the vergence system via gain AC. The accommodative bias under the no stimulus condition (ABIAS or tonic accommodation) is also summed at summing junction along with the cross-link from the vergence controller output (VCC) via CA. The output from the summing junction goes through a saturation element, which reflects the plant saturation of the accommodative subsystem, to give the accommodative response (AR). Vergence error (VE), or fixation disparity, is the difference between the vergence stimulus (VS) and vergence response (VR). Vergence error drives the vergence controller with non-linear vergence controller gain (VCG) to give VCC. The VBIAS (i.e., tonic vergence), VCC, and the cross-link from the accommodative controller output via AC all sum at the summing junction to give the vergence response VR.

before and after conventional orthoptic therapy for remediation of their vergence and/or accommodation abnormalities (Griffin, 1976). Such a complete set of measures allows for multi-dimensional intra- and inter-subject statistical comparisons, establishes useful clinic population norms in a variety of diagnostic groups, and provides for quantitative assessment of the component contribution of orthoptic therapy in the visually-abnormal symptomatic population.

Methods

A. Instrumentation and measurements

Many different measures of static accommodation and vergence associated with the model were taken. These included: tonic accommodation and tonic vergence, accommodative vergence and vergence accommodation, monocular accommodative response to blur-only stimulation, and vergence response error (i.e., fixation disparity) to disparity-only stimulation with accommodation either open- or close-looped (Semmlow and Hung, 1979).

Stimulation of these oculomotor systems and measurement of their multiple responses required a versatile device such as the Dynamic Binocular