

# Accommodation Dynamics in Divergence Excess Exotropia

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**Objective recording of accommodation dynamics was performed in four patients with divergence excess exotropia (two true and two simulated) and in three visually normal control subjects. The accommodative peak velocity/amplitude relationship was normal in the exotropic patients and in the control subjects. Latency for decreasing accommodation was increased significantly, and overshoot frequency was decreased, in the divergence excess exotropes of the true variety, thus demonstrating slightly slowed accommodation dynamics in this diagnostic group. These subtle deviations in response dynamics reflect central rather than peripheral mechanisms. Invest Ophthalmol Vis Sci 25:414-418, 1984**

The dynamic characteristics of the human accommodation system have been well-documented in visually normal individuals.<sup>1-4</sup> However, there is a paucity of such information in clinically abnormal populations. Scattered reports exist describing accommodation dynamics using objective recording techniques in disorders of either a functional (myopia,<sup>5</sup> accommodative infacility [Stark et al, submitted for publication], and insufficiency<sup>6</sup>) or pathologic (mononucleosis<sup>7</sup>) nature, but patient responses generally have not been studied systematically in any single diagnostic category. One such diagnostic group of interest is divergence excess exotropia.<sup>8</sup>

An abnormal accommodative component has been implicated in this group. Classical theory necessitates the presence of an abnormally high (approximately 15/l) accommodative convergence to accommodation (AC/A) ratio in these patients in order to account fully for the reduced ocular deviation at near—as compared with that found at distance.<sup>9,10</sup> Such high values are indeed frequently found in *stimulus* AC/A measures, especially using a distance/near procedure in which proximal vergence may be a confounding factor.<sup>11,12</sup> However, recently it has been demonstrated that objectively determined *response* AC/A ratios in patients

with divergence excess (DE) exotropia are actually within the normal to high-normal range.<sup>11</sup> This is in agreement with von Noorden's earlier clinical findings using a near-gradient clinical procedure.<sup>13</sup> Thus, presence of abnormal static accommodation and accommodative convergence cannot be used to explain the near-vergence response in these patients. A second aspect of accommodation that has also been implicated, but not investigated, in these patients involves response dynamics. In measuring objective response AC/A ratios using dynamic recording devices in patients with divergence excess exotropia, Cooper et al<sup>11</sup> presented records showing dynamic overshoots of accommodation; such overshoots may suggest a dynamic abnormality.<sup>14</sup>

Clinically, accommodative facility (ie, overall accommodative response time) can be evaluated by measuring the number of changes of accommodation in response to the introduction of alternating plus and minus lenses over a specified period of time.<sup>15,16</sup> This measure has been related to dynamic accommodation performance using infrared monitoring devices in a laboratory setting.<sup>6,17</sup> Clinical assessment commonly is done subjectively using the patient's report of target clarity<sup>15,16</sup>; but it can also be performed using dynamic retinoscopy for an objective determination of the accommodative state.<sup>18,19</sup> Although some experienced clinicians believe that patients with divergence excess exotropia may exhibit minor, nonspecific accommodative deficits, no supporting scientific documentation exists. Unfortunately, accurate measures of the individual dynamic accommodative response parameters cannot be made by the clinician. Thus, we used an objective infrared monitoring device to obtain such measures in patients with divergence excess exotropia.

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### Materials and Methods

Four patients ranging in age from 20 to 26 years were tested. Visual acuity was at least 20/20 in each eye. Stereopsis was at least 40 sec of arc as determined on the Randot test. All patients had intermittent exotropia at distance (6 m) and either intermittent exotropia or exophoria at near (40 cm) of at least 10 prism diopters less than at distance, when fixating a 20/25 Snellen letter. Based on these findings, they were classified as having divergence excess exotropia.<sup>20</sup> Patients were classified further as having either true or simulated divergence excess exotropia based on measurements taken after prolonged monocular occlusion. Patients with true divergence excess exotropia are those in whom the strabismic deviation is unchanged following occlusion; patients with simulated divergence excess exotropia will manifest a significantly larger tropia or phoria at near, following monocular occlusion. Additional clinical and static accommodative vergence findings in these four patients have been published elsewhere.<sup>11</sup> In addition, three normal subjects were tested. These subjects had no signs or symptoms of accommodative dysfunction, no tropia or significant phoria at distance or near, and were free of ocular and/or neurologic disease. Only adults were included since rigorous experimental conditions essential to obtain objective measurements necessitated the use of a bite bar and head rest to stabilize the head for extended periods of time; subjects were run at a single test session lasting 1 to 2 hr with frequent rest periods. Subjects and patients included both experienced and naive observers. Corrective lenses were worn during all tests. Informed consent was obtained from all patients and subjects prior to testing.

An infrared optometer (Fig. 1) was used to monitor dynamic changes of accommodation in the fixating left eye; the right eye was occluded. The optometer had a bandwidth of 5 Hz, a resolution of 0.12 diopters, and linearity of  $\pm 6$  diopters. It was insensitive to eye movements of  $\pm 2$  degrees horizontally and  $\pm 1$  degree vertically. This dynamic optometer has been fully described elsewhere.<sup>21</sup>

The accommodative stimulus consisted of a fine-lined cross etched on the front surface of a clear piece of Plexiglass that was illuminated with a small, embedded, incandescent light-source. Target luminance was 0.5 log ft-L that provided an easily visible target for the subjects. The crosses subtended an angle of 1.5 or 3.0 degrees at distance and near, respectively. The fine lines forming the crosses subtended an angle of approximately 2 to 4 min arc. In order to simulate real-life conditions, targets purposely were not equated for visual angle; thus, size, as well as other cues such as

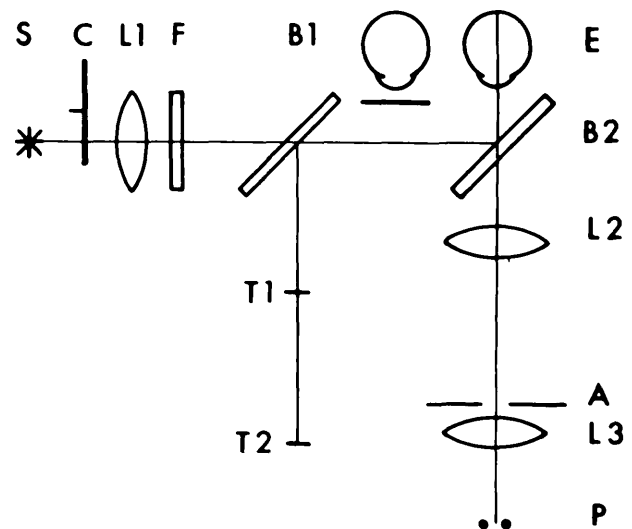


Fig. 1. Top view of apparatus used to measure accommodation consisting of four components: (1) Light source (S = halogen lamp, C = light chopper, L1 = collimating lens, F = infrared filter, B1 and B2 = beam splitters, and E = eyes). (2) Targets (T2 = far target, T1 = near target plus B1 and B2). (3) Accommodation monitor (P = photodetectors, A = aperture, L2 and L3 = focusing lenses, plus B2). (4) Occluder over nonfixating eye.

brightness, could be used to assist in the initiation and maintenance of the accommodative response. The experimenter used a silent two-position switch to illuminate either the far (67 cm, 1.5 D) or near (33 cm, 3.0 D) target (placed along the line of sight of the viewing eye) with temporal randomization of the step inputs. All testing was conducted in a dark room, with only the cross providing the primary stimulus to accommodation. Subjects were instructed to maintain accurate focus on the intersection of the illuminated cross; following a change in target, subjects were instructed to shift their focus as rapidly as possible to the new target, but not to make predictive movements. The accommodative stimulus and response were recorded on an oscillographic pen recorder (bandwidth DC to 150 Hz), from which all measurements were analyzed by hand; these measures included accommodation latency, amplitude, peak velocity, and dynamic overshoot magnitude and frequency, for both increasing and decreasing accommodation. Overshoots having amplitudes less than the average noise level of the individual accommodative records were not included in the analysis; likewise, any responses having superimposed blinks and/or baseline shifts that obscured major portions of the record were not included.

### Results

Our findings are summarized in Tables 1 and 2 (pooled diagnostic group responses). Average accom-

**Table 1.** Comparison of accommodation latency in normals and divergence excess exotropes ( $\bar{X} \pm 1$  s.d.)

	Direction of accommodation	Normals	Divergence excess	T-test
Latency (msec)	↑ and ↓	403 ± 69 (n = 89)	464 ± 103 (n = 47)	$P < 0.001$
	↑	411 ± 55 (n = 46)	430 ± 43 (n = 27)	$P > 0.10$
	↓	394 ± 81 (n = 43)	509 ± 140 (n = 20)	$P < 0.005$

modative latency in the three normal subjects and four patients with divergence excess exotropia are presented in Table 1. The only significant difference was increased latency for decreasing accommodation (and for combined trials) in the patients. However, dynamic accommodation overshoot amplitude and frequency were generally found to be greater in the exotropes (Fig 2 and Table 2). Most overshoots occurred for increasing accommodation. Analysis of these accommodative overshoots is presented in Table 2.

Inspection of individual patient data suggested subtle differences in accommodation dynamics between the true and simulated divergence excess exotropes. Thus, additional statistical analyses were performed to confirm the presence of such differences, and, further, to determine how such a finding might influence the interpretation of the grouped data (Table 1). Several trends were evident; most were highly significant ( $P < 0.01$ , t-test). Accommodative latency was increased by 40 to 100 msec in the true divergence excess exotropes for both increasing and decreasing accommodation. Magnitude and frequency of the dynamic

**Table 2.** Dynamic overshoot analysis in normal subjects and divergence excess exotropes\*

	Overshoot frequency (%)	Percentage of overshoots that occurred on increasing accommodation	Average overshoot magnitude (D)
N1	41	53	0.32
N2	08†	100	0.31
N3	15	75	0.37
TDE1	0	0	0.00
TDE2	24	100	0.47
SDE1	86	50	0.47
SDE2	73	88	0.63

\* Sample sizes are the same as specified in Table 1.

† This patient also showed static undershoots on 23% of the responses.

overshoots were greater in the simulated divergence excess exotropes (Table 2), suggesting a more rapid time-course for initial attainment of the desired response amplitude. Thus, the patients with true divergence excess exotropia can be characterized as having slightly slower accommodation dynamics than found in either simulated divergence excess exotropes or in normals. Hence, differences in the grouped data (Table 1) between subjects and patients can be attributed primarily to the slowed responses in patients with true divergence excess exotropia.

Analysis of the accommodative peak velocity/amplitude relationship (Figure 3) revealed no obvious difference between normal subjects and patients with either true or simulated divergence excess exotropia. These results compared favorably with the recent findings of Ciuffreda and Kruger (in preparation) in their normal subjects.

## Discussion

A number of factors may contribute to the clinically observed, but subtle, accommodative performance deficits found in patients with divergence excess exotropia. These include cognitive and perceptual factors, such as form recognition and sensory-motor integration,<sup>15</sup> as well as abnormalities of the accommodative sensory controller, motor controller and/or peripheral apparatus. However, with the use of objective recording techniques and simple target configurations, as used in this study, the confounding effects of the cognitive and/or perceptual factors<sup>22</sup> are minimized; the task simply required detection of a blur input with subsequent appropriate accommodative response for attainment of an in-focus retinal image. To demonstrate the integrity of the motor controller and peripheral apparatus, one can use the peak velocity/amplitude relationship<sup>23</sup> (Ciuffreda and Kruger, in preparation). For the normal human accommodative system, there is a relationship between response amplitude and peak velocity.<sup>19</sup> One could not discriminate patients with divergence excess exotropia from normal subjects using this criterion (Fig. 3). Further, values from all subjects and patients in this study fell within the limits of the peak velocity/amplitude distribution found by Ciuffreda and Kruger (in preparation) for normal subjects under similar test conditions. These findings strongly suggest that the motor controller and peripheral apparatus were functioning normally in the patients with divergence excess exotropia. Thus, the increase in accommodative latency found in patients having true divergence excess exotropia must reflect a processing delay in the sensory controller.

Patients with simulated divergence excess exotropia exhibited rapid accommodation dynamics as demonstrated by the short latencies and increased overshoot frequency and amplitude. Such findings probably do not reflect any abnormality of accommodation, as they are frequently found in normal subjects<sup>24</sup> (Ciuffreda and Kruger, in preparation), but rather represent a time-optimal response strategy similar to that found for the saccadic eye movement system.<sup>25</sup> Further, in our patients we speculate that these responses are of a complex, preprogrammed nature. The scenario may be as follows. It has been suggested that such patients exhibit a fusional after-effect,<sup>11</sup> presumably due to increased vergence effort necessary to maintain fusion and accurate bifixation. Such increased vergence effort, in turn, would overdrive the accommodation system via the convergence/accommodation relationship.<sup>26,27</sup> Since our objective testing was begun several minutes after the patient had been placed under monocular viewing conditions, one would predict that most, or all, of any fusional aftereffect would have decayed.<sup>11</sup> However, if this vergence response is a learned, preprogrammed phenomenon, then it may still be manifest indefinitely, even under monocular test conditions, unless specific training is conducted to promote extinction of this response in the absence of fusible images. Thus, what we may be observing is a residual, dynamic counterpart of the fusional aftereffect, being related more to the vergence-driven, rather than blur-driven component of accommodation.

In summary, it appears that there are differences in

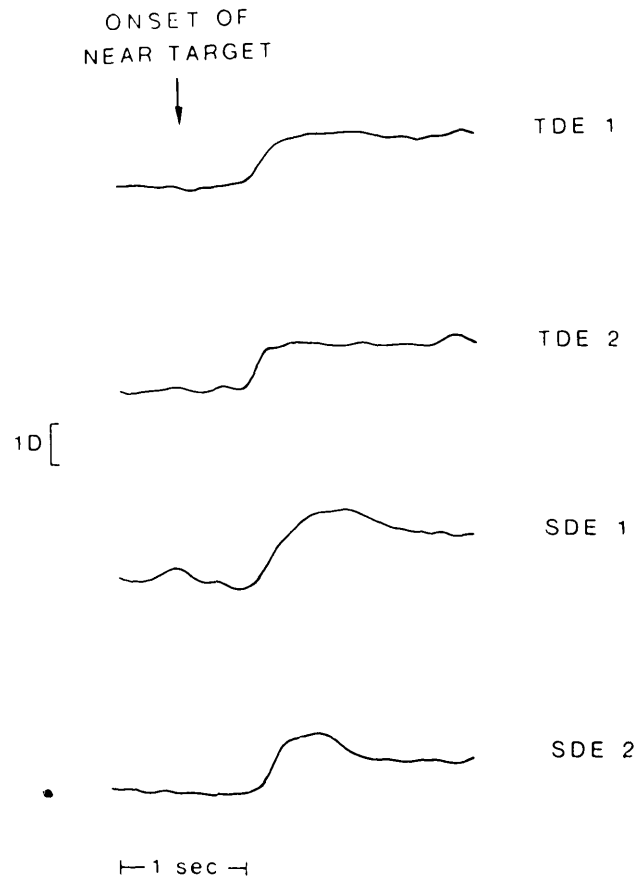
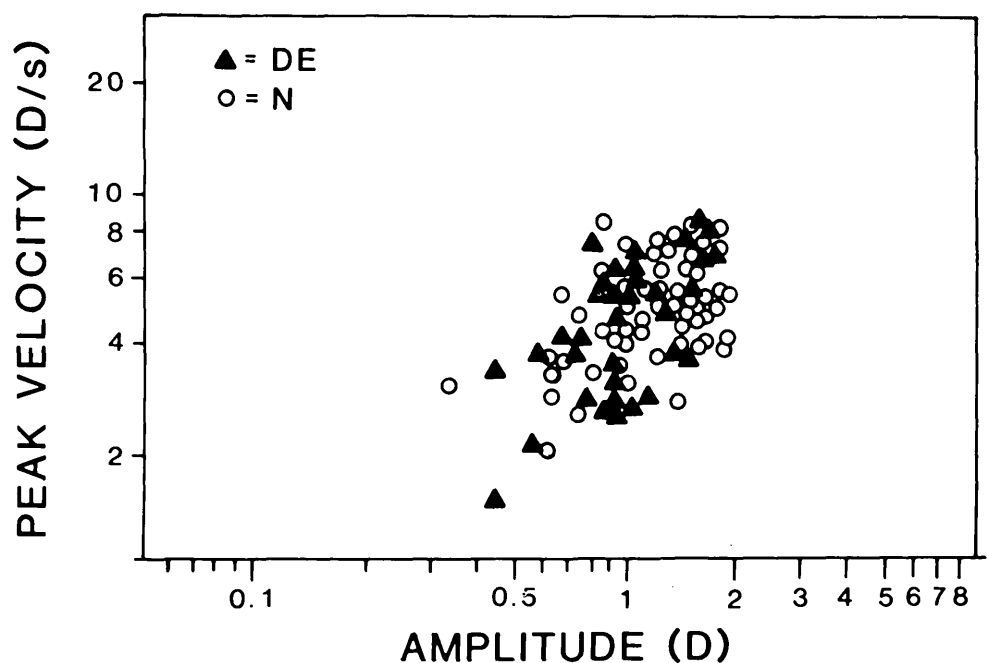


Fig. 2. Dynamic accommodation responses in two true (TDE) and two simulated (SDE) divergence excess exotropes. Step input; far (1.5 D) to near (3.0 D). Dynamic overshoots of accommodation evident in simulated divergence excess exotropes.

Fig. 3. Plot of relationship between accommodation amplitude and peak velocity for patients with divergence excess exotropia (▲) and normal subjects (○). Cluster of values is similar in both diagnostic groups.



accommodation dynamics between true and simulated divergence excess exotropes. These differences are subtle, however, and not likely to be readily apparent during routine clinical examination. However, under rigorous experimental test conditions they become manifest, thus confirming clinical suspicions and adding to our understanding of the possible different mechanisms<sup>11</sup> underlying these apparently similar clinical entities.

**Key words:** accommodation dynamics, divergence excess exotropia, strabismus, orthoptics

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