Dynamics of Accommodative Facility in Myopes

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PURPOSE. To evaluate the dynamic changes in refraction during the accommodative facility test in myopes and emmetropes.

METHODS. Ten myopes and 10 emmetropes participated in the study. All were young adults, and refractive error in the myopes was corrected with soft contact lenses. Monocular accommodative facility measurements were taken for a 40-cm and a 6-m working distance with +2.00/D and plano/−2.00-D flippers, respectively. Subjective facility was recorded with automated flippers and objective measurements of dynamic accommodation response were simultaneously taken with a photorefractor.

RESULTS. Subjective and objective facility measurements showed a significantly lower facility rate in myopes when compared with emmetropes at distance (P < 0.05) but not at near (P > 0.05). The response amplitude of accommodation during facility tasks was found to be similar in the two refractive groups. However, the velocity of accommodation was found to be lower in myopes than in emmetropes for distance facility (P < 0.05) but not for near facility (P > 0.05). Velocity of disaccommodation was lower in myopes than in emmetropes at both distance and near (P < 0.05).

CONCLUSIONS. During distance accommodative facility testing, myopes exhibited a lower velocity of accommodation and disaccommodation, which led to a lower distance accommodative facility rate. For near facility measurements, however, although velocity of disaccommodation was lower in myopes, velocity of accommodation was found to be similar in the two refractive groups. A variety of factors that contribute to these differences are discussed. (Invest Ophtalmol Vis Sci. 2007;48:4375–4382) DOI:10.1167/iovs.07-0269

To evaluate the ability of the eye to alter accommodation rapidly and accurately, accommodative facility testing is often incorporated as a part of an ocular examination. The patient is given a hand-held flipper containing a pair of +2.00-D lenses on one side and −2.00-D lenses on the other side and is instructed to clear a row of reduced Snellen print at 0.4 m through one pair of lenses and to flip to the other pair as soon as the print is readable. A pair of positive and negative flips is considered as one cycle, and the number of cycles completed in a minute is recorded by the practitioner. This clinical standard for accommodative facility testing was described by Zellers et al.1 Several alternative methods for accommodative facility testing have subsequently been suggested,2 but the original method used in this study is still the most common in clinical use. In distance facility testing, the target is at 6 m and the lens pairs are −2.00 D and plano.

Facility measurements for research purposes are often obtained using automated equipment, with the time taken for clearing the positive and negative lenses being recorded as the negative and positive response time, respectively. Accommodative facility results have been shown to be a useful predictor of potential visual discomfort3 and also of academic success in Polish school children.4 Low accommodative facility is also used as a diagnostic sign for accommodative insufficiency.

Refractive error has been shown to have an effect on various accommodation measurements5 including accuracy of the accommodative response,6–8 the accommodative convergence to accommodation ratio,9–12 tonic accommodation,10,13,14 and nearwork-induced transient myopia.16–20 Jiang and White21 investigated the effect of refractive error on accommodative facility and found that monocular accommodative facility at near was not significantly influenced by refractive error. However, when the data were broken down into positive and negative response times, the difference between refractive groups in the time taken to relax accommodation (negative response time) was significant, with myopes having shorter negative accommodative times. O’Leary and Allen6 assessed monocular accommodative facility at distance and near and found significantly lower distance facility rates in myopes when compared with emmetropes, although they found no significant differences in the facility rates of the two refractive groups at near. They reported significantly longer positive accommodative response times in myopes during distance facility measurements. Allen and O’Leary5 investigated whether accommodative functions can predict the progression of myopia over a 12-month period. Their results indicated that facility of accommodation and accommodative lag were the two main independent accommodative predictors of myopia progression. Reduced accommodative facility was found to be associated with faster progression in myopia. They also showed that monocular distance facility was significantly reduced in myopes when compared with emmetropes, but again, not at near distance Pandian et al.22 measured accommodative facility in 6- to 7-year-old children and again found that distance accommodative facility was lower in myopic children when compared with their non-myopic counterparts. They found no significant difference in near accommodative facility between myopes and non-myopes.

Accommodative facility rate, although believed to be a clinical measure of accommodative dynamics, is dependent on several factors, including ocular depth-of-focus and the subject’s criteria for judging that the target is “clear”; the velocity at which the eye can accommodate or relax the accommodation to clear a target; the amplitude of the accommodative response necessary to see the target clearly; the subject’s reaction times to respond to blur, decide that the target is clear, and indicate that the target is clear; and the time taken to change the lenses, together with the operator’s reaction and motor times (if the lenses are not changed by the subject). Thus, if differences in accommodative facility are found when normal clinical testing methods are used, it is not possible to state unequivocally that these must be due to differences in the speed of accommodation. In fact, the typical accommodation...
facility cycle time of approximately 4 seconds for emmetropes is much longer than would be expected on the basis of the usual total accommodation time (reaction time plus response time) to a step stimulus of approximately 1 second.25–26

To clarify the source of the differences in accommodative facility between myopes and emmetropes, the present experiments were conducted to make objective, simultaneous measurements of the dynamic changes in accommodation response while performing distance and near accommodative facility tests. It was hoped that this would allow true differences in the time constants for dynamic accommodation to be distinguished from changes in other factors contributing to the cycling time.

**METHODS**

**Subjects**

Twenty visually normal observers participated in the study. The 10 emmetropic subjects had a mean spherical equivalent refractive error of +0.1 ± 0.08 D (range, plano to +0.25 D) with a mean age of 25 ± 4.7 years (range, 20–35 years). The mean spherical equivalent refractive error in the 10 myopes was −3.89 ± 1.79 D (range, −0.75 to −6.62 D) and their mean age was 24 ± 3.8 years (range, 20–52 years). All subjects had visual acuity of at least 6/5 and were screened to exclude astigmatism greater than 1.00 D, myopic retinal degeneration, amblyopia, or any ocular disease. Refractive error in all the myopic subjects was corrected with soft contact lenses. Any residual astigmatism was corrected with full-aperture trial lenses. Subjects gave informed consent for taking part in the study, which adhered to the tenets of the Declaration of Helsinki and was approved by the Anglia Ruskin University Ethical Committee.

**Subjective Accommodative Facility Measurements**

Monocular accommodative facility for the right eye was investigated at both 6 and 0.4 m. Accommodative facility in the distance was measured with a plano/−2.00-D lens combination mounted in a flipper with the subject viewing 6/9 letters placed 6 m away, whereas, at near, reduced 6/9 letters were viewed through a flipper consisting of a +2.00-D/−2.00-D lens combination. In both cases, the left eye was occluded with a filter (8°Wratten filter; Eastman-Kodak, Rochester, NY). This filter transmits infrared light, allowing the photorefraction (PowerRefractor; Multichannel Systems, Rütingen, Germany) to obtain an objective dynamic reading of accommodation, while occluding the visual input to that eye.

The subjects were instructed as follows: “You should look at the letters and try to keep them clear. I am going to put a lens in front of your eye and the letters will blur for a short time and then become clear again. As soon as they are clear again please tap the table. I will then change the lens, and the letters might be blurred again. Tap the table as soon as you can see the letters clearly again. I will go on repeating this procedure to see how often you can clear the lenses in 1 minute.”

The subjective accommodative facility was measured with semi-automated flippers (Vision Co-operative Research Center [CRC], Sydney, Australia). The instrumentation was similar to that used by Pandian et al.22 The flipper was mounted on a handle that contained a mercury tilt switch for cycle detection and a start button for the operator. The flipper was interfaced with a computer using a parallel port connection. The software used to run the flippers was written in a commercial program (LabWindows/CVI, ver. 6.0; National Instruments, Austin, TX). The software incorporated a 60-second timer and recorded the time between the flips. Each time the lens was flipped by the examiner (i.e., when the subject tapped the table to indicate clarity) the mercury switch triggered the circuit. Consequently, the duration and frequency of each accommodative phase was recorded by means of the flipper software program. During the measurement of distance and near accommodative facility, the −2.00-D side of the flipper was always presented first. The order of measurement (i.e., distance or near accommodative facility) was randomized.

The timer in the flipper software was activated by pressing the start button on the flipper as the first lens was introduced. Each test lasted 60 seconds. The subjects were given training with the test for 20 seconds before taking the measurements.

All the subjective accommodative facility measurements were performed by one of the authors (HR), who was masked to the subjects’ refractive error group. The reaction time of the operator and the mechanics of the flipper were tested by conducting a dummy run in which the flipper was flipped at the maximum possible speed for a period of 30 seconds. The results showed that the time taken to flip the lenses on average was 0.296 second, so that operator and lens-change delays accounted for roughly 0.6 second of each cycle period. In the dummy run, no significant difference was found in the time taken to flip the lenses clockwise and counterclockwise (P = 0.683).

**Objective Accommodative Facility Measurements**

The objective measurements were obtained with a photorefractor (PowerRefractor; Multichannel Systems), which dynamically recorded the refractive error during the facility measurements. The measurements were started in synchrony with the subjective facility measurement. The start button on the flippers produced a signal that was used by an author (PA) for initializing the objective measurements in synchrony with the subjective data collection. The measurements were obtained from the left eye while the stimulus was presented to the right eye. The left-eye measurements reflect the accommodative changes in the right eye, as it has been shown that accommodation is synchronized in the two eyes.27 The flippers were presented in front of the right eye only. The flipper was set on monocular mode, which measures refraction only in the vertical meridian. The measurements were obtained at a rate of 25 Hz.

Because of large variations in calibrations among subjects,28–32 the refractor was calibrated for each subject, to achieve optimal measurement reliability during the study. It has been suggested that intersubject calibration variations may be due to differences in fundal reflectance characteristics.30 For calibration the left eye was occluded with a Wratten filter while the right eye fixed a 6/9 letter placed at 6 m. During steady fixation with the right eye, trial lenses (+4.00 to −1.00 D) were placed in front of the filter occluding the left eye. Measured refraction was compared to the refraction expected from the trial lenses. The correction factor was taken from the slope and intercept of the linear regression and incorporated into the refractor measurements from that subject.

**Data Analysis**

A sample of the objective dynamic measurement data obtained from the refractor is shown in Figure 1. Note the asymmetries between accommodation and disaccommodation in some cycles and the usual fluctuations in accommodation response.

The records were analyzed using fast Fourier analysis and also with the peak-fitting module in a software program (Origin Pro 7; Microcal Software Inc., Northampton, MA). The peak-fitting module was used to detect the peak locations automatically, by means of an irregular sinusoid function, once the baseline refractive error was specified. No averaging was performed, and each response was analyzed individually. The time constants for accommodation and disaccommodation were calculated by assuming that the accommodation response during the changes could be described by the exponential equations

\[ A = A_0 - a \times e^{-t/t_1} \]

for accommodation and

\[ A = A_1 + a \times e^{-t/t_2} \]

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for disaccommodation where, $A$ is the accommodative response; $A_n$ and $A_d$ are the accommodative responses at the near and distance peaks, respectively; $t$ is time in seconds after commencement of the response; and $\tau$ is the time constant in seconds. The amplitude of accommodative response ($a = A_n - A_d$) for each accommodative half-cycle was calculated from the data obtained from the peak locations. The amplitude data were then used to calculate the response levels when 10% and 90% of the accommodative response amplitude was reached, and the refractor records were analyzed to find the corresponding times: $t_{10}$ and $t_{90}$. These values were then used to calculate the time constants using a derivation from the above equation where,

$$\tau = \frac{t_{90} - t_{10}}{\ln 9}.$$  

On the above assumption of an exponential response change, the maximum velocities ($V$) of accommodation and disaccommodation were calculated as $V = \frac{dA}{dt}|_{t=0} = \frac{a}{\tau}$. A fast Fourier transform (FFT) was performed for data obtained over approximately 41 seconds, which produced 1024 data points. The amplitude of the Fourier transform at each frequency was determined by calculating the square root of the sum of squares of the imaginary and the real components of the FFT. The fundamental frequency peak obtained for this data set was then converted to the corresponding rate in cycles per minute.

**RESULTS**

**Subjective Accommodative Facility**

**Facility Rates.** The monocular subjective accommodative facility rate was found to be higher in emmetropes than in myopes (Table 1). Analysis of variance showed a significantly higher facility rate in emmetropes for distance monocular accommodative facility ($F_{1,10} = 7.4; P = 0.014$) but not for near facility ($F_{1,10} = 4.16; P = 0.06$).

**Positive and Negative Response Times.** The positive and negative subjective response times (i.e., the intervals between more- and less-negative, and less- and more-negative lens flips) for myopes and emmetropes are shown in Table 2. The data show a larger difference between myopes and emmetropes for positive and negative near objective response times. Analysis of variance was performed with response times as the dependent variable and refractive error as the independent variable. A significant difference was found between myopes and emmetropes for positive and negative response times at distance and for negative response times at near (Table 2). No significant difference was found between the positive and negative response times in either of the refractive groups (ANOVA: $F_{1,1052} = 2.64; P = 0.104$); however, a significant interaction was found between the total positive and negative response cycle and the refractive group ($P = 0.0005$).

**Objective Accommodative Facility**

**Facility Rates.** The objective facility rate was calculated by averaging the number of positive and negative peaks in a run (60 seconds data) and also from the FFT data. Objectively measured accommodative facility rates with FFT and peak-fitting techniques in myopes and emmetropes are shown in Table 1. With both techniques, analyses of variance showed significantly higher facility rate in emmetropes for distance monocular accommodative facility (peak fitting: $F_{1,19} = 4.36; P = 0.05$; FFT: $F_{1,19} = 9.02; P = 0.008$) but not for near facility (peak fitting: $F_{1,17} = 3.95; P = 0.07$; FFT: $F_{1,17} = 3.93; P = 0.058$).

**Positive and Negative Response Time.** The mean objective positive and negative response times (i.e., the time inter-

| Table 1. Average Subjectively and Objectively Measured Facility Rates in Myopes and Emmetropes for Distance and Near Viewing Conditions |
|---------------------------------|-------------------------------|-------------------------------|
|                                | Subjective Facility          | Objective Facility Calculated with Peak Fitting Module | Objective Facility Calculated from Fourier Transform |
| Emmetropes                     |                               |                                |                                                  |
| Distance                       | 17.9 ± 3.9                    | 17.9 ± 3.9                     | 18.5 ± 4.2                                      |
| Near                           | 15.2 ± 3.5                    | 13.2 ± 3.4                     | 12.3 ± 1.8                                      |
| Myopes                         |                               |                                |                                                  |
| Distance                       | 13.9 ± 2.2                    | 14.0 ± 2.1                     | 14.0 ± 2.1                                      |
| Near                           | 10.5 ± 1.6                    | 10.6 ± 1.6                     | 10.7 ± 1.6                                      |

Data are mean cycles/minute ± SD.
vals between successive accommodation maxima and minima as established using the peak-fitting procedure) for myopes and emmetropes are shown in Table 2. Analysis of variance showed similar results to those found for subjective response times (Table 2).

**Comparison between Objective and Subjective Accommodative Facility.** Facility rates measured with both objective and subjective methods were found to be similar, since both depend on the same lens changes (Table 1). Repeated-measures analysis of variance showed no significant difference in facility rates measured with objective and subjective methods ($F_{2,59} = 1.34; P = 0.235$). The subjectively measured time constants were found to correlate significantly with the subjective response times (Table 2, Pearson correlation $= 0.996, P = 0.0005$).

**Amplitude.** The mean amplitude of the fundamental sinusoid obtained with the FFT was found to be similar in myopes (distance: $1.22 \pm 0.17$ D; near: $1.53 \pm 0.13$ D) and emmetropes (distance: $0.85 \pm 0.13$ D; near: $1.59 \pm 0.21$ D) for both distance and near facility measurements. Note that this amplitude is not equal to half the difference between the highest and lowest levels of response, because the latter also depends on the Fourier harmonics and their relative phases. Analysis of variance showed no significant difference in the amplitude between myopes and emmetropes for both distance ($F_{1,19} = 3.01; P = 0.100$) and near ($F_{1,19} = 0.05; P = 0.834$). Not surprisingly, however, a significant difference was found between the amplitude measurements at distance and near ($F_{39} = 4.39; P = 0.043$), corresponding to the larger dioptric difference in the near stimuli (i.e., $2.00$ D compared with $4.00$ D). No significant interaction was found between the refractive group and the test distance with amplitude as the dependent variable (ANOVA: $F_{1,39} = 2.61; P = 0.115$).

The amplitude calculated using the peak-fitting technique (i.e., the difference between the highest and lowest levels of response) also showed no significant difference between myopes and emmetropes for both distance (ANOVA: $F_{1,50} = 2.53; P = 0.112$) and near (ANOVA: $F_{1,390} = 2.06; P = 0.152$) conditions.

**Time Constants.** The time constants for accommodation and disaccommodation cycles for distance and near are shown in Table 3. The time constant for accommodation was lower than that for disaccommodation for distance (ANOVA: $F_{1,390} = 14.6; P = 0.0005$) and near (ANOVA: $F_{1,198} = 18.5; P = 0.0005$) measurements. The time constant was found to be higher in myopes than in emmetropes. All the differences were significant, except that for accommodation at near (Table 3).

On comparing the accommodation and disaccommodation time constants within each refractive group data, no significant difference was found between accommodation and disaccommodation in the emmetropic group at near ($F_{1,226} = 1.84; P = 0.176$) but a significant difference was found for measurements at distance ($F_{1,350} = 62.2; P = 0.0005$). The myopic group showed a significant difference between accommodation and disaccommodation time constants, both at distance ($F_{1,516} = 42.2; P = 0.0005$) and near ($F_{1,169} = 19.2; P = 0.0005$).

**Maximum Velocity of Accommodation and Disaccommodation.** Figure 2 shows the mean peak velocity of accommodation and disaccommodation in myopes and emmetropes for accommodative facility measurements at distance and near. The velocity of accommodation was found to be higher than the velocity of disaccommodation, at distance (ANOVA: $F_{1,647}$

### Table 2. Mean Positive and Negative Response Times in Myopes and Emmetropes Measured Subjectively and Objectively

<table>
<thead>
<tr>
<th></th>
<th>Emmetropes</th>
<th>Myopes</th>
<th>$P^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive response</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>time</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distance</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Subjective</td>
<td>1.48 ± 0.64</td>
<td>2.09 ± 0.77</td>
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<tr>
<td></td>
<td>Objective</td>
<td>1.58 ± 0.71</td>
<td>2.27 ± 1.02</td>
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<tr>
<td></td>
<td>Near</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Subjective</td>
<td>2.44 ± 1.21</td>
<td>2.66 ± 1.20</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td>2.04 ± 1.12</td>
<td>2.38 ± 1.46</td>
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<tr>
<td></td>
<td>Negative response</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>time</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Distance</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Subjective</td>
<td>1.59 ± 0.34</td>
<td>2.09 ± 0.79</td>
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<tr>
<td></td>
<td>Objective</td>
<td>1.48 ± 0.69</td>
<td>1.95 ± 0.95</td>
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<tr>
<td></td>
<td>Near</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Subjective</td>
<td>2.01 ± 0.74</td>
<td>2.85 ± 1.28</td>
</tr>
<tr>
<td></td>
<td>Objective</td>
<td>2.39 ± 1.14</td>
<td>3.24 ± 1.33</td>
</tr>
</tbody>
</table>

Data are mean diopters ± SD.

* Analysis of variance.

### Table 3. Mean Time Constants for Accommodation and Disaccommodation in Myopes and Emmetropes during Distance and Near Accommodative Facility Measurements

<table>
<thead>
<tr>
<th></th>
<th>Emmetropes</th>
<th>Myopes</th>
<th>$P^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Accommodation</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Distance</td>
<td>0.306 ± 0.223</td>
<td>0.397 ± 0.237</td>
</tr>
<tr>
<td></td>
<td>Near</td>
<td>0.479 ± 0.310</td>
<td>0.506 ± 0.229</td>
</tr>
<tr>
<td></td>
<td>Disaccommodation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distance</td>
<td>0.456 ± 0.201</td>
<td>0.557 ± 0.244</td>
</tr>
<tr>
<td></td>
<td>Near</td>
<td>0.566 ± 0.337</td>
<td>0.777 ± 0.376</td>
</tr>
</tbody>
</table>

Data are mean diopters ± SD.

* Analysis of variance.
modulated state. Similarly, the time interval in the most disaccommodated state is calculated from the time interval between reaching 90% of disaccommodation and 10% of accommodation. These intervals approximate the times that the eye spends in static states between the main dynamic changes. In the absence of prediction effects, one might expect these to have a value at least as long as the sum of the time taken to change the lenses (~300 ms) and the accommodation reaction time (~360 ms).

The means and standard errors of the time intervals in the accommodated and disaccommodated states at distance and near are shown in Figure 3. Analysis of variance with time interval as the dependent variable showed a significant difference between the refractive groups ($F_{1,96} = 4.1; P = 0.044$) and between distance and near measurements ($F_{1,96} = 41.98; P = 0.004$). No significant difference was found between accommodation and disaccommodation time intervals ($F_{1,55} = 3.08; P = 0.08$) in the myopic group. However, a significant difference was found between time intervals for accommodation and disaccommodation in the emmetropic group ($F_{1,540} = 13.14; P = 0.0005$).

**Accommodation and Disaccommodation.** The response times in myopes and emmetropes are given in Tables 2 and 3, and the basic form of the response change over each cycle for the two subject groups and test distances is shown schematic-
cally in Figure 4. For simplicity, the response to each stimulus change is shown as varying linearly over a time interval that corresponds to that between \( t_{00} \) and \( t_{10} \) (i.e., \( \ln 9 \times \) the time constant, or 2.2 \( r \)). Viewed in this way, it appears that the part of the cycle that most noticeably differs between the two refractive groups, at both distance and near, is that including the active and the steady disaccommodated phases. Compared with the emmetropes, the myopes with corrected visual acuity seemed to find it harder to relax accommodation to optically distant targets (~0.17 D in the distance test and ~0.50 D in the near test) and, once their accommodation had relaxed, were slower to signal that the target had cleared so that the next part of the cycle could start.

**Changes in Accommodative Dynamics with Time.** To investigate the effect of training or fatigue during the facility task, we explored the correlation between the cumulative (objectively measured) response time, amplitude of accommodation change, and disaccommodation and response amplitude and time constant for accommodation and disaccommodation. No significant correlation was found between the cumulative response time and the time constant or the objective response amplitude of accommodation (\( P > 0.05 \)), indicating that no training or fatigue effects are found on amplitude and time constants in the 1-minute duration of accommodative facility test.

**DISCUSSION**

The results of both objective and subjective monocular accommodative facility measurements are in agreement with previous studies\(^5,8,21\) which demonstrate that myopes exhibit a significantly lower accommodative facility rate when compared with emmetropes for distance viewing conditions but not for near tasks. The objective and subjective measurements of positive (Pearson correlation = 0.995) and negative (Pearson correlation = 0.996) response times correlated well with each other in all the subjects and their dependence on test distance and refractive group was similar to that found in earlier work.\(^21\)

In principle, the task presented for the measurement of accommodative facility should be an easy one, since the subject decides when the target vergence should be changed, making the task entirely predictable and minimizing true accommodation latencies.\(^33,34\) Nevertheless, the mean cycle times of 3 seconds or more (corresponding to 0.3 Hz or less) were much longer than might be expected merely on the basis of typical step response times (usually <1 second\(^23,26\)) or the known ability of the accommodation system to respond at frequencies of up to approximately 2 Hz.\(^25\)

There are several obvious reasons for these apparently lengthy cycling times in the accommodative facility tests. Most obviously, the nature of the test means that the accommodative cues provided are often in conflict. For example, in the near test, a strong proximal cue is provided by the physical target, which opposes the vergence cue provided by the positive lenses and may make it harder to relax accommodation to the appropriate level. Furthermore, rather than simply being asked to accommodate as in most accommodation studies, the subject is required to make a conscious decision that the target has cleared and then must make the motor response involved in tapping the table. Finally, as noted earlier, each cycle is extended by around 0.6 second, due to operator delay and the time for lens change.

A possible explanation of the difficulties of myopes in relaxing accommodation is that the more distant target vergences are close to, or perhaps beyond, the lower limits of their range of accommodation. The distance refraction measurements in the present study were performed for a test distance of 6 m (0.17 D vergence) and the minimum minus/maximum plus correction required to achieve the best visual acuity was determined. Clinically, there is a similar tendency to minimize the negative correction and to rely on depth-of-focus for clear vision at distance. It may be a real struggle to relax accommodation appropriately to the required level. In contrast, the “emmetropes” include low hypermetropes, some of whom may, in fact, already be accommodating slightly, so that the “distance” stimuli lie well within the limits of their range of accommodation. Tucker and Charman\(^26\) have given examples of the long time constants that may be involved in relaxing accommodation to see distant targets for low myopes.

A further possibility relates to the fact that the present data were obtained under monocular conditions of observation. It is known that individuals use a variety of monocular and binocular cues to guide their dynamic accommodation responses, and it may be that the lower monocular accommodative facility

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**Figure 4.** Mean changes in stimulus (dashed line) and response (solid line) with time for the emmetropic and myopic groups. For simplicity, the responses are shown as changing linearly over a time interval that corresponds to either \( t_{00} \) to \( t_{10} \) (accommodation) or \( t_{15} \) to \( t_{20} \) (disaccommodation).
shown by myopes arises because the latter normally tend to place greater reliance on disparity cues than do emmetropes.

As noted earlier, in the accommodative facility test, it is the subject him- or herself who initiates the lens change and thus the changes must be entirely predictable. Thus, it would be expected that the normal reaction time to a change of stimulus would be minimized and that the initiation of the response would be closely synchronized with the lens flip. Examination of Figure 4 suggests that, in accommodation, the 10% response change was reached very rapidly (within approximately 200 ms) after the lens flip. In disaccommodation, the response declined to the 90% level even more quickly, apparently preceding the lens flip in some cases. Thus, anticipation is indeed present. We speculate that proximity cues may favor greater anticipation effects in the case of disaccommodation.

An apparently more surprising feature of Figure 4 is the relatively long time interval between the time at which the response approaches an appropriate level for the retinal image to be clear (the 10% or 90% response point) and the initiation of a lens change (typically >0.5 second but extending to >1 second for accommodation at near), since it may have been thought that this delay could be minimized by anticipation. However, it must be remembered that the subject first makes a decision on clarity and then performs a motor response (tapping on the table). The operator then must flip the lens (taking ~0.3 second). Thus, part of the delay is associated with the methodology of the test, rather than being an intrinsic part of accommodation dynamics. It would obviously be useful to have an entirely objective test in which accommodation was assessed objectively and the stimulus was automatically changed immediately after the appropriate response level was achieved.

The amplitude of accommodation change during accommodative facility measurements showed no significant difference between myopes and emmetropes. This shows that, contrary to the assumptions that one may make considering the lower blur sensitivity in myopes and their poor accommodative response to negative lenses, during the accommodative facility task, myopes and emmetropes demonstrated similar accommodative response to the stimuli. However, it should be remembered that the reduced accommodative responses to negative lenses in young adults are only evident in some viewers with progressive myopia, whereas the present study measured accommodative response in a group of young adults in whom myopia may have stabilized. Data on myopia progression were not recorded in the present study. Nevertheless, most of the myopes within the age group of the subjects recruited in the study (25–35 years) are likely to have stable myopia.

Accommodative facility measurements at distance showed that emmetropes had shorter time constants and higher velocity of accommodation than do myopes. For facility measurements at near, the accommodation time constant and velocity of accommodation were not significantly different in the two refractive groups. The lower velocity of accommodation in myopes for distance targets is in contradiction with some previous studies that found no significant difference between accommodation dynamics in myopes and emmetropes. The differences between the findings of the earlier and present studies may arise from differences in the associated accommodative tasks. Schaeffel et al., presented accommodative targets by altering the target distance, whereas in the present study accommodation was stimulated with a -2.00-D lens for distance accommodative facility measurements. It has been shown that accommodative response to negative lens-induced blur is significantly different from accommodative response to altering distance in myopes. It is possible that differences also exist in accommodation dynamics for these visual tasks.

The time constant of accommodation in myopes became similar to that of emmetropes for near accommodative facility measurements. This change in time constant in the myopic group is perhaps due to the nature of the accommodative stimulus. For distance facility, the blur induced and accommodation stimulated was around the operating range of retinotopic blur (~1.50 D), whereas the near accommodative target presented a spatiotopic blur (>2.00 D). Seidel et al. showed a deficit in retinotopic control of accommodation in myopes (particularly late-onset myopes) leading to increased variability in the steady state response and reduced performance in dynamic tasks. The myopic group in the present study consisted of six participants with early-onset and four with late-onset myopia. The small and unequal numbers in each of these subgroups make it inappropriate to compare the differences in accommodation dynamics of these subgroups in this study. To establish the differences between early-onset and late-onset myopes, studies on a much larger cohort are necessary.

The peak velocity of accommodation at near (4.00-D stimulus change) was found to be higher than that at distance (2.00-D stimulus change), in both the myopic and the emmetropic groups. These results are consistent with findings of Kasthurirangan and Glasser, where peak velocity of both accommodation and disaccommodation increased linearly with the starting point: similar amplitude responses were associated with a higher peak velocity and a smaller time constant at proximal starting points than at distal starting points.

In addition to the lower velocities of accommodation and disaccommodation, myopes also showed a larger time interval at maximum accommodation when compared to emmetropes during distance accommodative facility measurements, suggesting that they required larger intervals of time to make a decision on clarity of the target.

In conclusion, both objective and subjective measurements of accommodative facility showed a significantly lower distance facility rate in myopes when compared with emmetropes. The positive response times were significantly longer in myopes than in emmetropes. It was found that myopes exhibit a lower velocity of accommodation and disaccommodation during distance facility measurement and also longer time intervals. The near accommodative facility rate was similar in both the refractive groups, and no significant differences in velocity of accommodation were found between the two groups, although velocity of disaccommodation was relatively lower in myopes when compared to emmetropes. A variety of factors may contribute to these differences.

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References


