Visual Accommodation and Sustained Visual Resolution in Multiple Sclerosis

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Many multiple sclerosis (MS) patients frequently experience transient blurring. We investigated the possibility that this symptom is due to the inability of patients to sustain an accommodative response to stimuli viewed at distances nearer than or farther from the individual tonus position of accommodation. In a group of MS patients and age-matched healthy control subjects, we measured (1) accommodative range and tonus position; (2) reaction time (RT) to detect a change in a small optotype (viewed in a Badal lens system) as a function of viewing distance; and (3) contrast sensitivity at a fixed viewing distance. MS patients did not differ significantly from healthy controls on near point, far point, pupil size, accommodative range, or tonus position measures. However, as a group, MS patients showed significantly slower RTs than controls to detect optotype changes for stimuli viewed at distances nearer to or farther from the individual tonus position of accommodation. All subjects showed significantly slower RTs to detect changes in optotypes viewed at extreme near and far optical distances compared to RTs to detect changes in stimuli viewed at the tonus position. This difference was significantly larger for MS patients than for controls. These data also suggest that dynamic dioptric factors contribute to the magnitude of contrast sensitivity deficits in this patient population and indicate that the relationship between the individual tonus accommodation position and viewing distance is an important variable in CS testing. Invest Ophthalmol Vis Sci 33:2744–2753, 1992

Disruption of visual function is a frequent problem for patients with multiple sclerosis (MS). Symptomatic and asymptomatic involvement of the visual pathways have been reported to occur in more than 90% of MS cases.¹ Common visual complaints by patients include increased sensitivity to light, color vision disturbances, perception that the world is “washed out,” and episodes of blurred vision. Behavioral psychophysical techniques have been used to quantify and explain many of these symptoms. For example, increased sensitivity to light in MS patients has been quantified as abnormally large losses in visual acuity after adaptation to very high light levels.² Complaints that visual scenes appear “washed out” have been studied by measuring sensitivity to low contrast patterns.³ Although episodes of blurred vision perhaps are the most commonly reported visual disturbance in MS,⁴ this aspect of vision loss has received relatively little systematic psychophysical investigation. The purpose of the present study was to investigate transient blurring by measuring subjects’ ability to sustain resolution of small optotypes.

The perception of a blurred image results from an inability to perceive luminance contrast in the high spatial frequency components of a visual pattern. Blurring, or the perceived loss of fine detail in a pattern, most commonly results from optical factors within the dioptic system of the eye (eg, refractive error, inaccurate accommodation to a stimulus). However, blurring also may result from a deficit of the visual neural mechanisms processing retinal image contrast. Hess and Plant² used the term “neural blurring” to describe chronic deficits of contrast sensitivity (CS) in optic neuritis patients. They suggested that visual losses may be caused by deficient processing capabilities of visual channels sensitive to specific spatial frequencies. In most studies of visual disturbance in MS, pathology of neural rather than dioptic mechanisms has been assumed to account for deficits.

Because we are currently concerned with the visual complaint of transient rather than chronic visual blurring, the role of optical versus neural factors in blurring must be closely examined. One possible explanation for an episode of blurred vision is transient accommodative inaccuracy. Although it is unlikely that MS affects physiologic properties of the lens itself, it is possible that demyelination affects the neural
pathways that control the lens. Support for this comes from a case study that reports accommodative abnormalities associated with MS. One of the primary goals of the study reported here was to measure accommodative function in a larger number of MS patients.

Transient blurring also could result from temporary disruptions in perceptual processing functions. One candidate mechanism for this is visual adaptation. It has been well documented in healthy control subjects that prolonged viewing of specific stimuli causes a temporary reduction in sensitivity for stimuli similar to the adapting stimulus. Studies on MS patients have shown that visual adaptation mechanisms may be abnormal. This may result in sensitivity losses that are greater in magnitude and more rapidly induced than that found in controls, as in flicker adaptation and bright light adaptation, or in sensitivity losses that may be acquired more slowly, as in contrast adaptation. An additional goal of the present experiment was to separate the possible contribution to transient blurring of abnormal adaptation from failure to sustain appropriate accommodation.

In the present report, we reason that transient blurring may be best observed in the laboratory by measuring subjects' abilities to sustain resolution of small optotypes for extended periods of time. Sustained visual resolution of stimuli subtending small angles on the retina requires, among other things, the continuous availability of a well-focused, high quality retinal image. Image quality can depend heavily on the accuracy of visual accommodation. Therefore, factors that determine the ability to accommodate accurately and to sustain that response can affect how well and how long a small visual stimulus may be resolved.

The most important stimulus parameter that determines the effectiveness of an accommodative response is the optical distance between the observer and the stimulus. When stimulus size, luminance, and contrast are held constant, changes in viewing distances can produce significant changes in accommodative accuracy and, consequently, reductions in grating acuity. Snellen acuity, and CS. Moreover, the ability to sustain visual resolution of small letters or high spatial frequency gratings also depends on the optical distance of the stimulus.

Research on accommodative function has shown that the relationship between viewing distance and accommodative accuracy is not a simple function of the optical distance between observer and stimulus. Rather, it depends on the relative distance between the stimulus position and an observer characteristic known as tonic accommodation (TA) or resting position. It has been clearly established that accommodation assumes an individually characteristic tonic, or resting, position under a number of specific conditions, eg, in the absence of visual contours, when the stimulus to accommodation is degraded, or when the accommodative feedback loop is opened (ie, when the accommodative level is independent of the quality of the retinal image). TA varies widely among individuals, and, in healthy young adults, typically corresponds to an intermediate value of about 1.5 D when measured with a laser optometer.

Johnson found that accommodation was most accurate when stimuli were viewed at a distance that corresponded to the individual's TA position. At stimulus distance relative to the TA position was increased or decreased, accommodative accuracy decreased, being biased toward the observer's TA position and, thus, producing the often observed "lead" and "lag" of accommodation. Most behavioral measures of visual function (eg, acuity and CS) show a similar dependence on optical distance relative to the observer's optical TA position.

It seems possible that continuous effort is required to maintain an accommodative response for stimuli viewed at any optical distance that is different from that corresponding to the tonus accommodation position. Behavioral support for this idea can be found in two previous studies in which sustained resolution of small letters or high spatial frequency gratings patterns was measured as a function of optical distance relative to the observer's TA position. Sustained resolution was found to be maximal for young healthy observers when stimuli were viewed at distances corresponding to the TA position, and the ability to maintain a clear image was found to decline for nearer or farther viewing distances.

Because MS generally is characterized by muscular or neural fatigue upon prolonged effort, patients may show an inability to sustain an accommodative response for a prolonged period. To evaluate this possibility and to determine the role of visual adaptation in transient blurring (as induced in the laboratory), we asked a group of MS patients and a group of healthy control subjects to continuously view a small letter for an extended time (2 min). The letter changed at random intervals during the viewing period and the subject was required to indicate as rapidly as possible when the letter change occurred. This task was performed with a variety of optical viewing distances, but with a constant retinal image size, to vary the stress on the accommodative system. When the stimuli are viewed at an optical distance corresponding to the TA position, little or no accommodative effort should be required to sustain accurate accommodation, and reaction time (RT) to detect the letter change should be short. In this condition, maximal visual adaptation would be experienced because a high contrast image.
should be continuously present on the retina. When stimuli are viewed at distances nearer or farther than the TA position, greater accommodative effort should be required to sustain accurate accommodation. If maintaining this effort were difficult, accommodative accuracy would be maintained more poorly and RT maintaining this effort were difficult, accommodative accuracy than healthy controls.

### Materials and Methods

#### Patients and Control Subjects

A group of MS patient volunteers and a group of healthy subjects matched to patients for age, sex, and time of day of testing participated in the study. All patients were selected from the Multiple Sclerosis Clinic at the Calgary General Hospital. The patient group was made up of seven females and two males who ranged in age from 23 to 34 yr (mean 30.3 yr; standard deviation 3.5 yr). All were diagnosed “definite multiple sclerosis” according to the criteria set out by Poser, Paty, and Scheinberg et al. Relevant clinical data are summarized in Table 1. Visual acuity for each patient is found in Table 2. Four of the MS patients studied had only one eye tested. Two of these patients experienced exacerbations after the first experimental session, in which they had one eye tested but were unable to have the second eye tested. Two subjects had acuity in one eye worse than 20/70; therefore, these eyes were not tested. Control subjects matched to these patients also were tested in one eye only.

The control group was made up of seven females and two males, all of whom had visual acuity of 20/40 or better and no reported history of neurologic or ophthalmologic disorder. Control subjects’ ages ranged

### Table 1. Visual indications in multiple sclerosis patients

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Sex</th>
<th>Age (yr)</th>
<th>Visual indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>31.0</td>
<td>diplopia, ARPD, abn VER, optic atrophy</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>33.0</td>
<td>ARPD, nys, abn VER, optic atrophy</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>27.6</td>
<td>ON (rt), pale optic discs, nys, abn VER, optic atrophy (rt)</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>33.2</td>
<td>bilateral ON, ARPD (lt), pale optic discs</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>23.9</td>
<td>ON (rt)</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>33.9</td>
<td>bilateral INO, diplopia, nys, abn VER, abn ABR</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>31.0</td>
<td>ON (rt), abn VER (lt), optic atrophy (rt)</td>
</tr>
<tr>
<td>8</td>
<td>F</td>
<td>26.0</td>
<td>none</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>32.0</td>
<td>blurred vision</td>
</tr>
</tbody>
</table>

ARPD, relative afferent pupillary defect. abn VER, abnormal visual evoked response. nys, gaze-induced nystagmus. ON, optic neuritis. INO, internuclear ophthalmoplegia. abn ABR, abnormal auditory brainstem response.

### Table 2. Individual patient data

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Eye</th>
<th>Acuity</th>
<th>Range (D)</th>
<th>TA* (D)</th>
<th>Near slope †</th>
<th>Far slope ‡</th>
<th>CS loss</th>
<th>Color vision</th>
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<tr>
<td>1</td>
<td>R</td>
<td>20/20</td>
<td>8.04</td>
<td>0.80</td>
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<td>20/20</td>
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<td>242§</td>
<td>mid</td>
<td>normal</td>
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<tr>
<td>3</td>
<td>L</td>
<td>20/20</td>
<td>13.89</td>
<td>1.67</td>
<td>221§</td>
<td>644§</td>
<td>none</td>
<td>normal</td>
</tr>
<tr>
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<td>R</td>
<td>20/30</td>
<td>6.57</td>
<td>1.05</td>
<td>295§</td>
<td>99</td>
<td>none</td>
<td>normal</td>
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<tr>
<td>5</td>
<td>L</td>
<td>20/20</td>
<td>11.80</td>
<td>N/A</td>
<td>29</td>
<td>245</td>
<td>mid/high acquired defect</td>
<td></td>
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<tr>
<td>6</td>
<td>R</td>
<td>20/15</td>
<td>10.86</td>
<td>2.17</td>
<td>34</td>
<td>242†</td>
<td>mid</td>
<td>congenital defect</td>
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<tr>
<td>7</td>
<td>R</td>
<td>20/30</td>
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<tr>
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<td>257†</td>
<td>mid/high acquired defect</td>
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<tr>
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<td>L</td>
<td>20/20</td>
<td>11.63</td>
<td>0.45</td>
<td>3708</td>
<td>55</td>
<td>high acquired defect</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>L</td>
<td>20/15</td>
<td>8.13</td>
<td>1.99</td>
<td>147</td>
<td>78</td>
<td>mid/high normal</td>
<td></td>
</tr>
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</table>

* Tonus accommodation as measured by the laser. † Slope of the function relating reaction time (RT) differences to positive (near) relative optical stimulus distances (ROSD). ‡ Slope of the function relating RT differences to negative (far) ROSD.

§ Abnormal 99% confidence level. † Abnormal 95% confidence level. N/A, insufficient data to measure. CS, contrast sensitivity.
from 23 to 35 yr (mean 30.1 yr; SD 3.7 yr). The nature of the procedure was explained fully and informed consent was obtained from all subjects prior to their participation. Subjects wore their usual corrective lenses as needed.

Apparatus

One channel of a two channel Badal optical system employed a laser optometer to measure TA. Subjects initiated a 500 msec laser flash as often as necessary to identify the perceived direction of motion in the laser speckle pattern. A bracketing technique was used to determine TA. A chromatic correction of −0.33 D was applied to the data obtained.

The second channel was used to display optotypes for measurement of sustained resolution using a procedure previously described. Optotypes were generated by an Apple Ile microcomputer and displayed on a Zenith (ZVM-121) green phosphor monitor (Zenith Data Systems, St. Joseph, MI). These stimuli were viewed monocularly through the second channel of the optical system. The subject’s eye was positioned 20 cm anterior to a 5 D Badal lens. The object of the Badal lens consisted of the virtual image of the optotype formed by a minifying −10 D lens positioned 20 cm anterior to the monitor screen. The monitor and minifying lens were mounted on a movable platform to allow for precise movement of the optotype’s image within the optical system. The Badal lens was employed so that stimulus viewing distance could be altered without causing an apparent change in the size or brightness of the image. Retinal image size for all optical distances corresponded to a 20/70-size Snellen letter. The luminance of the symbols, as measured at the monitor face with a spot meter (Salford Electrical Instruments Ltd., Ilford, London), was approximately 43.1 cd/m². The luminance of the background was approximately 0.2 cd/m². Each stylized stimulus, an E or a 3, consisted of 17 pixels. To transform one optotype to the other, the appropriate two pixels in the vertical segment of the character extinguished simultaneously and were brightened in the alternate, appropriate two locations 16 msec later. Subjects responded to the change in optotype by depressing a button on a microcomputer game paddle. RT was recorded with a measurement error of approximately 1 msec.

Head position for sustained resolution and TA measurements was stabilized with a chin rest and forehead restrainer. An artificial pupil (2 mm in diameter placed 7 cm in front of the eye) was used to maintain a constant ocular depth of focus in the presence of different naturally occurring pupil sizes. This circular field stop produced an unfocusable field edge. The pinhole was used for tonus accommodation measures and in the letter resolution task but was not used for any of the other measures. Photographs of the subject’s pupil were taken with a Pentax K1000 camera, a Pentax 50 (F 2.8) macro lens, and a Starblitz 160A flash unit (Fugi-Koeki Corp., Tokyo, Japan). All photographs were taken in a darkened room while the subject was seated at the apparatus, focused on the optotype at its nearest point (4.0 D).

The near and far points of accommodation were measured with a black 20/40 Snellen E mounted on a white card for maximum contrast. Badal optics were employed for far point measures. Near (or far) point was measured by decreasing (or increasing) the optical distance of the target from the nearest (or farthest) point of sharp focus until a point of blur was just noted. Each near and far point measure was taken three times. A Farnsworth Psychological Corp. (New York, NY) 15-hue test was used to assess hue discrimination. Visual acuity was measured using a standard far vision Snellen chart. A Tektronix (Wilsonville, OR) 608 (P31 phosphor) high resolution monitor and a Picasso (Innifree, Cambridge, MA) digital image generator were used to generate sine wave grating patterns for CS testing. Contrast was defined as

\[
\frac{L_{\text{max}} - L_{\text{min}}}{L_{\text{max}} + L_{\text{min}}} \times 100\%
\]

where \(L_{\text{max}}\) and \(L_{\text{min}}\) refer to the maximum and minimum luminance on the screen, respectively. The image generator was controlled by an appropriately interfaced microcomputer (Apple Ile), which timed stimulus presentation and recorded subjects’ responses.

Psychophysical Procedure

Two sessions were run on separate days for each subject. All tasks were monocular and only one eye was assessed per session. The eye tested initially was randomly chosen for each subject. At the start of each session, hue discrimination, visual acuity, and accommodative range were assessed. The subject then was positioned in the optical system and given specific verbal instructions regarding the TA and sustained resolution measurement procedures. Three measures of the TA position were obtained. After this, an initial block of the sustained resolution test was conducted, an additional three measures of the TA position were assessed, another block of the sustained detection task was conducted, and a final three measures of the TA position were obtained. A photograph of the pupil then was taken. Finally, CS testing was conducted.

Sustained resolution measurements were obtained for five different optical viewing distances (0.0, 1.0, 1.6, 2.5, or 4.0 D), each distance being tested once in each of two blocks of trials. For each subject, one block consisted of a series of trials in which optical viewing distance increased progressively on succes-
sive trials. The other block consisted of a similar series, except that optical viewing distance decreased progressively. The block initially tested was randomly chosen for each subject.

Each trial began with a short auditory tone followed by the immediate presentation of a single optotype. The optotype on the screen was changed into the other optotype after a random interval of 2 to 10 sec. The optotypes alternated in this manner until the trial was terminated at the end of a 2 min period. The subject was instructed to fixate the optotype and to press a button as soon as the optotype change was detected. RT to respond was measured. If the subject had maintained accurate accommodation on the stimulus, RTs were expected to be short. If, however, accommodation fatigued and drifted from the stimulus location, RTs were expected to be longer. If the subject failed to detect the stimulus change after a 2 sec interval, it was recorded as a "miss" and an auditory tone cued a button press. In this event, the RT measure was disregarded. False positive responses also were recorded.

CS was measured using a computer-automated method of limits. After an auditory tone, a mid-contrast sample grating was presented for a brief period. The sample grating was used to reduce stimulus uncertainty by informing the subject of the spatial frequency to be tested. Three estimates of contrast threshold then were determined for that spatial frequency. For each estimate, the initial contrast value was zero and contrast was increased at a constant rate. Subjects were instructed to depress a button as soon as they could just detect the grating. Over the course of the test, six threshold estimates were obtained for each of six spatial frequencies (0.5, 1.0, 3.0, 5.0, 7.0, 10.0 c/deg) presented in a randomized order. CS is the reciprocal of contrast threshold. Testing was performed in a dimly lit room at a viewing distance of 57 cm (1.75 D). A chinrest was used to stabilize gaze.

Results

Near Point, Far Point, Accommodative Range, Pupil Size, and Resting Position

MS patients and healthy control subjects did not differ significantly on near point, far point, accommodative range, pupil size, and TA measures. As can be seen in Table 2, accommodative measures obtained from all individual MS patients fell well within the distribution of control subjects' values. Analyses of variance (ANOVA) on these data revealed that none of these measures distinguished the MS patient group from the healthy control group.

The average range of accommodation across all subjects was 10.34 D (SD = 2.40), the average near point was 10.26 D (SD = 2.40), and the average far point was -0.15 D (SD = .34). These results are consistent with previous data reported for this age group. The mean pupil size was 4.2 mm for MS patients (SD = 0.8 mm) and 4.4 for controls (SD = 0.8 mm).

Figure 1 depicts individual mean TA, as measured by the laser optometer, for subjects in both groups. The TA measures varied over a relatively large range (0.00 D – 3.51 D) with a mean of 1.81 D (SD = 1.11). As has been previously reported, variability in an individual test session was relatively low and an ANOVA revealed a nonsignificant difference between groups. The group mean variability was 0.15 D for the MS patients (SD = 0.07) and 0.16 D for the controls (SD = 0.02).

Sustained Letter Recognition

Mean RT to detect a change in an alphanumeric character was calculated for each subject and for each optical distance. (RTs for false alarms and misses were not included in the data analysis. In no case was an individual mean RT calculated with less than four values.) When individual mean RT was plotted as a function of optical stimulus distance, U-shaped functions were obtained for all of the 28 eyes tested. The stimulus viewing distance that produced the function minimum varied among individuals. This viewing distance was taken to represent the individual's TA position. The mean TA position obtained this way was 1.80 D for the MS group and 1.70 D for the control group, the group differences being nonsignificant.
The mean difference between an individual eye’s TA position measured with the laser and that measured with the sustained viewing task was 0.02 D for the MS group and 0.07 D for the control group. The two measures were highly correlated ($r = 0.541, P < 0.01$).

The group mean RT plotted as a function of optical stimulus distance is shown in Figure 2. MS patients responded with longer RTs than control subjects for all viewing distances. The mean magnitude of the difference between MS and control RT across viewing distance is 355 msec. Both groups demonstrated slower response times at very close and very far distances.

Individual data from two typical MS patients and two control subjects are shown in Figure 3. Although the MS patients (panels A and B) demonstrated higher response times as a group, panel D illustrates that some individual control subjects also demonstrated high RTs. However, note the shallow function obtained from each control subject (panels C and D) compared to the remarkably steeper functions obtained for each of the MS patients.

The TA position (defined here as the optical distance producing the lowest RT) varied widely among individuals. Therefore, to examine the effect of accommodative effort on RT, we subtracted the RT measure at the TA position from that measured at every other optical distance for each subject. The group RT data in Figure 2 were replotted as individual data in Figure 4 as a function of optical distance relative to the individual TA value. This relative optical stimulus distance (ROSD) was defined as the individual TA position value minus the optical viewing distance. Hence, negative ROSD values refer to viewing distances farther than the TA position, and positive values refer to optical distances nearer than the TA position. The data shown here have been adjusted to eliminate the overall slowness in responding found...
Fig. 4. Least squares lines as fitted to individual reaction time (RT) data plotted as a function of relative optical stimulus distance (ROSD) near (positive) and far (negative) values. Filled circles represent individual RT values for the control group. Open circles represent individual RT values for the MS group.

among MS patients. Although motoric or central factors, such as visual adaptation, probably contribute to abnormally long RTs in the MS patient group, these factors would not be expected to vary significantly with optical stimulus distance.

A regression analysis was conducted separately for the positive (near viewing) and negative (far viewing) ROSD values. This analysis revealed that the slopes of the “near” and “far” lines (see Fig. 4) fitted to the MS data were significantly \( P < .01 \) steeper than those for the control group. The correlation coefficients for these slopes ranged between .54 and .74 and were significant in all cases \( P < .01 \). The results of this analysis suggest that MS patients, as a group, are less able than controls to sustain an accommodative response for viewing distances nearer to and farther from their TA position.

To examine individual differences in the sustained resolution task, we calculated slopes for near and far viewing for individual subjects. These slopes were calculated using RT differences for ROSD values within \( \pm 2 \text{ D} \). This limited range was used to ensure that an equal number of data points contributed to each subject’s slope calculations. These data are shown in Figure 5. A repeated measures ANOVA was conducted on the absolute values of these slopes and revealed a significant main effect of group \( F[1,19] = 8.24, p < .01 \) and a nonsignificant main effect for far versus near and a nonsignificant interaction effect. The control group mean slope for near ROSDs was 97.7; for far ROSDs it was 98.3. The MS group mean slopes were more than double these values, at 198.6 and 224.6, respectively.

The 99% and 95% confidence limits then were calculated (using standard deviations) on the absolute values of the control slopes for near and far viewing. As shown in Table 2, 12 of the 14 MS patient eyes (86%) and 2 of 12 control subjects (17%) had slopes that exceeded the upper 95% limit for near or far viewing. Using the 99% confidence limit, eight MS eyes (57%) and no control eyes were identified as abnormal for near or far viewing. Using this criterion, three MS eyes were abnormal for far viewing only and five were abnormal for near viewing only. No subject was abnormal for both near and far viewing using the more stringent criterion.

Although slight losses in acuity for some patients and controls would be expected to contribute to reduced performance on the RT task, such acuity deficits are nonsignificantly correlated with slope measures. Patients with 20/15 acuity (eg, patient 9) had abnormally steep slopes, and the right eye of patient 8, with 20/30 acuity, had normal slopes.

The number of errors was calculated individually for all ROSDs. A mixed-design ANOVA, used to analyze total errors (sum of misses and false alarms) revealed no significant differences. The mean error at the TA position of the control group was 0.7, whereas the mean error at the TA position of the MS group was 5.3 (from a total of approximately 40 trials per
subject). A separate statistical analysis of each error type yielded similar results. Note that a nonsignificant interaction effect of group by relative distance indicates that error differences cannot account for the unusually large rise in RT for viewing distances nearer to and farther from the TA position found for the MS group.

Cycloplegic Condition

To test the assumption that changes in RT as a function of viewing distance resulted from changes in accommodative control, a cycloplegic (cyclopentolate hydrochloride; 1% solution) was introduced into the right eye of one control subject. Accommodative range, TA position, and ability to sustain recognition then were assessed. Accommodative range was found to be reduced to 1 D. However, the TA position was similar to the TA position measured in the same eye before cycloplegia (1.3 D cyclopleged versus 1.4 D uncyclopleged).

In the sustained recognition task, it was found that the optotype was visible for the entire interval only for optical stimulus distances of 1.6, 1.0, and 0.0 D. Differences between mean RTs for these three distances did not differ. The optotypes presented at closer viewing distances were not resolvable and no RTs were recorded. These results suggest that in a healthy subject with 20/20 acuity, a dioptric error of about ±0.8 D can be tolerated before the blur that is produced impairs letter discrimination. RT to detect the letter change did not differ for the three distances. This further supports the idea that increments in mean RT measured for stimuli viewed at distances closer to or farther from the tonus position have an accommodative basis.

Contrast Sensitivity

An analysis of the CS data indicated that both groups showed the expected pattern of response, ie, maximal sensitivity at mid spatial frequencies (1–3 c/deg) with attenuated sensitivity for lower and higher spatial frequencies. The 99% and 95% confidence limits were calculated (using SDs) on the control data for each spatial frequency. Of the 14 MS eyes tested, 10 (71%) showed significant losses in CS. Five of these MS eyes (36%) had CS deficits for high spatial frequencies, with or without losses for mid- or low spatial frequencies. The remaining five eyes (36%) had mid-frequency losses in the absence of high spatial frequency deficits.

As reported in Table 2, all four MS eyes tested with normal CS exhibited abnormal sustained resolution for near or far viewing. This suggests that CS deficits cannot account for sustained resolution abnormalities. In further support of this point, it was found that two of the five MS eyes (two patients) with high spatial frequency CS deficits appeared normal on the sustained resolution task.

Note that CS testing was conducted at a viewing distance that corresponded to an optical distance of 1.75 D for all subjects. This fell within ±0.5 D of the TA position for some eyes but not others. The sustained resolution data reported above suggest that MS patients have greater difficulty than controls sustaining an accommodative response for viewing distances away from the individual TA position. Within the context of the CS test, this suggests that MS patients with TA positions corresponding to the CS testing distance should show less CS deficit than patients whose TA positions differed substantially, ie, more than 0.5 D, from the CS testing distance. Controls whose TA values fell near the testing distance would not be expected to differ substantially on CS measures from control subjects whose TA values did not correspond to the testing distance.

The MS patient group and the healthy control group were divided into “TA = testing distance” and “TA ≠ testing distance” groups. A mixed-design ANOVA revealed nonsignificant differences between the MS “TA = testing distance” group and the control “TA = testing distance” group. However, the analysis indicated significant differences between the MS “TA ≠ testing distance” group and the control “TA ≠ testing distance” group (F[1,10] = 341.88; P < .05). The mean CS functions for each subgroup are shown in Figure 6. It can be seen that greater CS deficits are
found for the MS “TA ≠ testing distance” group than for the MS “TA = testing distance” group. Comparing the two control groups revealed a modest loss in high spatial frequency sensitivity for the “TA ≠ testing distance” group. These data suggest that the relationship between an individual TA position and viewing distance is an important variable in CS testing. Although we were unable to conduct a second CS test for those MS patients in the “TA ≠ testing distance” group at a viewing distance corresponding to their TA positions, comparison of the “TA ≠ testing distance” group and the “TA = testing distance” group strongly suggests that dynamic dioptic factors contribute to the magnitude of CS deficits in this patient population.

Discussion

The results of the present study suggest that although MS patients did not differ significantly from healthy controls on near point, far point, accommodative range, or tonus accommodation position measures, these patients, as a group, demonstrated a significant reduction in the ability to sustain resolution for stimuli viewed at distances closer to or farther from the individual TA position.

The RT measures obtained in the sustained resolution task yielded U-shaped curves when plotted as a function of relative optical stimulus distance for all subjects. RT reached a minimum for distances corresponding to the individual TA position (as determined with the laser optometer) and were longer for nearer and farther optical distances. The sustained resolution task assesses discriminability of a small optotype at a given instant in time during a prolonged viewing interval as a function of optical distance. Because of the Badal optics employed, the stimulus characteristics of the optotype were not changed by adjusting optical distance. Thus, the effect of optical distance on RT must have an accommodative basis. It is most likely that drifts in accommodation increase as optical distance deviates from the individual tonus accommodation position, thereby increasing RT and response variability. An accommodative explanation for the RT data is supported by the results from the cycloplegia condition and the observation that the optical distance that produced the RT minima for each subject correlated significantly with the TA position as measured with the laser optometer.

Compared to controls, MS patients showed a significantly greater increase in RT for stimuli viewed at relative near and far optical distances. This deficit cannot be accounted for by generalized RT differences, increased Troxler fading of images, or chronic contrast sensitivity losses, because near and far viewing RT measures were evaluated relative to those obtained for stimuli viewed at the TA position of accommodation. Moreover, because none of these factors would be expected to vary as a function of optical stimulus distance, it is unlikely they could contribute systematically to changes in RT.

The data reported here suggest that dioptic factors, specifically dynamic factors, may make an important contribution to the spatial visual losses that have been reported previously in MS patients. It is generally accepted that damage of specific spatial frequency tuned mechanisms in the cortex largely accounts for CS deficits in MS patients. Although pathology of this type is undoubtedly an important factor in spatial vision losses in some patients, our data suggest that dioptic instability also may make a substantial contribution to contrast sensitivity losses. This assertion is supported by a study in which CS was measured in healthy subjects as a function of optical stimulus distance for gratings viewed in a Badal optical system. The results showed that sensitivity to mid- and high spatial frequency gratings was degraded for distances nearer than and farther from the tonus accommodation position of accommodation. Moreover, the data from this study indicate that when MS patients are tested at distances corresponding to their TA position, they perform more like controls than MS patients tested away from their TA position. The CS measure of control subjects was less affected by viewing distance. The contribution of accommodation instability in CS measures in controls and MS patients could be minimized by using a cycloplegia and refracting the subject for the viewing distance.

Finally, these results have implications for MS patient complaints regarding episodes of blurred vision. If, as our data suggest, such episodes are caused by an inability to sustain an accommodative response away from the individual TA position, the appropriate application of refractive correction may minimize this particularly disruptive visual aspect of MS.

Key words: visual accommodation, multiple sclerosis, blurring, visual resolution, contrast sensitivity

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References


