Predictors of Functional Success in Telescopic Spectacle Use by Low Vision Patients

Joseph L. Demer,* Franklin I. Porter,† Jefim Goldberg,† Herman A. Jenkins,† Kim Schmidt,† and Imogen Ulrich†

Telescopic spectacles can theoretically improve function of low vision patients by enlarging retinal images. However, unintended head movement may produce sufficient instability of enlarged retinal images to negate the visual benefit. We investigated this phenomenon as a cause of failure in 38 low vision patients who had previously attempted use of telescopic spectacles. Patients underwent evaluation of the vestibulo-ocular reflex, visual-vestibulo-ocular reflex, head stability in the pitch and yaw axes, and sensitivity of magnified visual acuity to head motion. Although it was impossible to distinguish successful from unsuccessful telescopic spectacle users by means of clinical or historical data, multiple logistic regression analysis was used to derive a useful predictive function based on measurements of sensitivity of magnified vision to head motion, and head instability in the pitch axis. Predictive performance was found to be superior to conventional clinical judgement. These findings support the hypothesis that retinal image stability is important to functional vision, and suggest that head-stabilizing strategies may improve function with telescopic spectacles in certain low vision patients.


Millions of people in the United States have severe visual impairment, although most have a degree of useful residual vision.1 Telescopic spectacles are commonly prescribed for low vision patients2 because of potential benefit that could be gained by image enlargement.3 Despite this, many low vision patients cannot effectively use telescopic spectacles; the patients are therefore considered to be functionally unsuccessful with the devices. Of the patients to whom telescopic spectacles have been dispensed in the Baylor Low Vision Clinics, 36% fail to make regular use of them (Porter FI, unpublished data). It is likely that this failure rate is typical of general clinical experience.

Normal locomotor activity such as walking produces head rotation velocities on the order of 50°/sec and rotational frequencies exceeding 15 Hz.4 As will be shown below, significant head rotations can be measured even at rest. These relatively small movements, which generally cannot be perceived by an observer who is not using special measuring devices, often have frequency components extending up to 15 Hz and are due normal physiologic functions such as postural sway, heartbeat and tremor (Goldberg and Chimenti, unpublished data). Vehicular travel is likely to produce even higher rotational head velocities than ambulation.

A likely cause of rehabilitation failure by patients wearing telescopic spectacles may relate to inadequate retinal image stabilization during head movements. Visual function is improved by placing an enlarged image on the retina only if that image is sufficiently immobile to permit perception. Because telescopic spectacles magnify the effects of voluntary and unintended head movements, image enlargement with telescopic spectacles may be achieved at the price of image instability, which can defeat the goal of improved visual function.5

The gain of the vestibulo-ocular reflex (VOR) is defined to be the ratio of the compensatory slow phase eye velocity response to head velocity. Ideally, VOR gain would be 1.0 to perfectly stabilize retinal images of distant objects, since this means that a given head velocity evokes an equal eye velocity in the opposite direction. In fact, measured VOR gain is usually slightly lower than this,6-8 but in light the VOR is enhanced by visual–vestibular interaction to...
increase the gain to 1.0.\textsuperscript{8} The visually enhanced VOR is called the visual–vestibulo-ocular reflex (VVOR). When telescopic spectacles are worn, maintenance of retinal image stability requires a VVOR gain equal to telescope magnification.\textsuperscript{9} If VVOR gain does not increase to match telescope magnification factor, retinal image slip will occur during any head movement.

Although some immediate visual enhancement of VOR gain occurs, instantaneous modulation of VVOR gain is limited. Additional, long-term recalibration of VVOR performance is achieved by gradual, adaptive change in VOR gain, a form of motor learning.\textsuperscript{10} The long-term adjustment of VOR gain is called VOR gain plasticity and can be demonstrated in both normal and low vision subjects after only 15 min exposure to vestibular experience during magnified vision.\textsuperscript{11}

The adaptive changes in VOR gain that occur when telescopes are worn are usually incomplete, at least at some frequencies in the spectrum of natural head movements.\textsuperscript{5,11–13} Avoidance of retinal image motion during these head movements requires that VVOR gain be instantaneously optimized by visual–vestibular interaction, as has been demonstrated to occur to a degree in low vision patients wearing telescopic spectacles.\textsuperscript{9} For many persons, however, VVOR gain does not immediately increase sufficiently to match the magnification factor of commonly prescribed telescopic spectacles,\textsuperscript{9} and substantial retinal image slip velocities occur during head movements when telescopic spectacles are worn. This retinal image motion reduces visual acuity during head movement, which we will call dynamic visual acuity (DVA).\textsuperscript{5}

Thus, acuity achieved with telescopic spectacles in a clinical situation, where head movement is prevented, might not reflect acuity in a functional situation, where head movement is ubiquitous. VOR and VVOR performance and adaptation could be anticipated to be important for use of telescopic spectacles by low vision patients. Individual head instability and the sensitivity of the individual patient’s visual system to retinal image motion could also be expected to be related to the improvement in functional vision obtainable with telescopic spectacles. With such physiologic considerations in mind, we undertook a retrospective laboratory study of compensatory ocular stabilization reflexes, head stability and DVA in low vision patients who had used telescopic spectacles. The long-term goals of the investigation included possible development of tests for prediction of successful use of telescopic spectacles by low vision patients, as well as improving understanding of the ocular motor physiology of adaptation to telescopic spectacles.

**Materials and Methods**

Clinical records of the Baylor Low Vision Clinics were reviewed to identify patients with stable ocular conditions whose best corrected visual acuities in the better eye were 20/70 or less. Approximately 500 such patients had, at least 2 months prior to the study, made a trial use of telescopic spectacles of any magnification between ×2 and ×8, either in the clinical examination, or both in the clinic and at home. Some of these patients continued to use telescopic spectacles, and some did not. It was the intention to exclude patients having records of spontaneous nystagmus, since the laboratory tests included measurements of VOR and VVOR gains that were imprecise in the presence of spontaneous nystagmus. Patients who resided in the Houston area were contacted by telephone and invited to participate. Three additional patients who were successful users of telescopic spectacles prescribed in other clinics were referred to the study. A total of 38 patients participated in laboratory testing; however, seven patients were discovered at the time of testing to have manifest spontaneous nystagmus and were thus unable to complete all parts of testing.

Participating patients gave written informed consent to a protocol approved by the Institutional Review Board for Human Research at Baylor College of Medicine. The study was described to participants in detail, including potential risks and benefits. All subjects consented to release of their medical records and completed a questionnaire and interview concerning their social histories and use of low vision aids. This historical information included age, sex, living situation, education, employment, duration of visual loss, use of various types of low vision aids for specific tasks, number of hours per day of use of low vision aids, and problems with low vision aids. Clinical low vision examinations of all patients were performed by one of the authors (FIP). Best corrected visual acuity was recorded with conventional spectacle correction for each patient.

Medical records were reviewed to determine the clinician’s original assessment of the likelihood of successful use of telescopic spectacles for each patient. This determination had employed clinical judgement only. In most cases, only patients with a reasonable clinical likelihood of success had been given a trial of telescopic spectacles. Some patients felt unlikely to succeed on clinical grounds also had been allowed to use loaner telescopes. Patients expected to be successful attempted use of telescopic spectacles at home on a prescription basis, usually after an initial use of such devices on a loan basis. Patients were contacted by telephone or clinical in-
terview to ascertain their current usage of telescopic spectacles. Patients were considered to be successful telescopic spectacles users if they continued to make regular use of telescopic spectacles of any power for any application that was either made possible or was substantially enhanced by use of these visual aids. Such applications could include employment, mobility, education, recreation and social uses. All other low vision patients who had tried telescopic spectacles were considered to be unsuccessful users; these included patients who had not found telescopic spectacles to be beneficial during trial use in clinic.

Patients underwent a laboratory test battery consisting of measurements of VOR and VVOR eye movements, spontaneous head movement and visual acuity with telescopic spectacles. Visual acuity was measured binocularly at a distance of 4 meters, as previously described. The ×4 power was chosen as the testing standard because it is the most common power used clinically (Demer, Haddock, and Porter, unpublished data) and because it is a good compromise between weight and visual field.

For measurement of visual acuity, subjects were seated in a chair mounted on a vertical axis servomotor, as previously described. Static visual acuity (SVA) was measured with the subject’s head stationary against the headrest. Dynamic visual acuity (DVA) was measured during sinusoidal rotations about a vertical axis at 1.0 Hz, with a velocity amplitude of 20°/sec (position amplitude 3.2°). Subjects were oriented so that they faced the center of the projection screen during the maximum velocity portion of the sinusoidal waveform. Optotypes were continuously within the field of view of the telescopes for all acuity testing.

Horizontal eye position was recorded by bitemporal DC coupled electrooculography (EOG), with digital sampling and storage as previously described. Calibration of the horizontal EOG signal was achieved for saccades to lighted targets from center to 15° left, and center to 15° right. To enable reliable calibration of patients having central or parafoveal scotomata, calibration targets consisted of red light-emitting diodes flanked by X-shaped arrays of green light emitting diodes spaced at about 1° of arc apart and subtending a total of 9° of arc from the central light. Brightness of the display was adjustable according to individual patient need, and the flanking array could be extinguished if not needed. Calibration measurements were made with telescopic spectacles rotated upwards out of the visual axis. If necessary, patients were given a training session, including verbal feedback regarding their fixation accuracy, to establish reliable calibration. An EOG sensitivity factor was calculated for each set of saccades. Before and after each rotational stimulus, two to five calibration sets were performed and sensitivity factors were averaged. Calibration factors were required to agree to within 10% of one another for any given VOR gain measurement.

Calculations of VOR and VVOR gain were automated to avoid bias from human intervention, as previously described. VOR gain was measured in complete darkness with sinusoidal head rotation at 0.1 Hz, amplitude 60°/sec. No attempt was made to measure gains during rotations at 1.0 Hz, because preliminary studies showed that gain measurements at this frequency had an unacceptably high cycle to cycle variability (Demer, unpublished data). Patients were instructed to look straight ahead and to attempt to see anything that might be visible there. Nothing, of course, was visible in the total darkness. VVOR gain was measured using standard room lighting as patients were rotated at 0.1 Hz, amplitude 30°/sec while wearing telescopic spectacles. Alertness was maintained using mental arithmetic and alphabetical listing tasks monitored by the experimenter via an intercom.

After initial measurements, patients underwent a 15 min period of adaptation training during which they viewed through telescopic spectacles a video monitor 4 meters away while undergoing sinusoidal rotation at 0.2 Hz, amplitude 20°/sec. This period of combined visual–vestibular experience was designed to train patients to stabilize gaze against head movement while wearing telescopic spectacles. After the adaptation period, DVA, VVOR and VOR measurements were repeated.

Head stability was evaluated after eye movement testing by measuring spontaneous angular head velocity in yaw (about the vertical axis) and in pitch (about the interaural axis) using a light-weight velocity transducer (Watson Industries, Eau Claire, WI) mounted on a hatband. For these measurements, patients were instructed to stand still with eyes closed and feet together for 50 sec. The first 10 sec was discarded. After low-pass filtering (cut-off frequency 13 Hz) and digitization at 50 Hz, head velocity data were converted in four 10 sec epochs to frequency spectra using rectangular window functions, and fast Fourier transformation. Spectra covered 0–25 Hz with 0.1 Hz resolution, and were analyzed for peak-velocity component amplitude and frequency, integrated amplitude over the spectrum, and root mean square value (RMS) in each axis. Epochs in which RMS head velocity was more than 1.3 standard deviations greater than mean RMS head velocity for all epochs were automatically deleted from analysis, since these probably reflect large, voluntary postural shifts and do not represent a patient’s best stability. Amplitude
spectra for the remaining epochs were averaged, and RMS and velocity-amplitude integrals were computed for these average spectra. This method readily measures head movements not normally perceptible to an observer.

Statistical comparisons between groups were made using student t (with pooled or unpooled estimates of variance), Pearson’s chi-square and Fisher’s exact test, as appropriate. Linear regression analyses, including computation of Pearson correlation coefficients, were performed using the SYSTAT statistical package. Multiple logistic regression analysis, a method for predicting discrete outcomes based on a linearizing transformation of discrete and continuous variables, was also implemented using SYSTAT. Computations of sensitivity, specificity and predictive value were made according to conventional statistical definitions. Analysis of the relative operating characteristic of the predictive function were performed according to the method of Massof and Emmel.

Results

A total of 31 low vision patients who did not have nystagmus completed the laboratory test protocol. Of these, reliable information was available to classify 30 patients according to functional success with telescopic spectacles. Of these 30 classifiable patients, 14 were considered successful users of telescopic spectacles, and 16 were unsuccessful.

Clinical Data

Of the 16 unsuccessful telescopic spectacle users, three were felt to have been clearly nonmotivated to use telescopic spectacles. Nonmotivation was operationally defined to be an obvious unwillingness to give telescopic spectacles a meaningful trial. The classification of “nonmotivation” was assigned parsimoniously, and only to unequivocal cases. The remaining 13 unsuccessful users had either good or equivocal motivation. One successful telescopic spectacle user was not able to use his telescopic spectacles under normal conditions, but could do so if he stabilized his head by leaning against a fixed object such as a door frame; because this patient was not successful in the customary sense, and because his measurements were quite atypical of the other successful patients, this patient was not included in the grouped analysis. This patient is discussed separately below.

We thus analyzed a data base consisting of 26 low vision patients who were motivated to attempt use of telescopic spectacles. Of these, 13 were successful users, and 13 were unsuccessful. Clinical data for these patients are summarized in Table 1. Note that although the mean age of successful users was slightly less than that of unsuccessful users, this difference was not statistically significant. The primary clinical diagnoses of the cause of visual loss were not statistically different between the two groups (Pearson chi-square, P = 0.162). Successful telescopic spectacle users tended to have a slightly but not significantly higher frequency of associated major systemic illness, defined to be any condition that, by its direct effects or necessity for therapy, alters an individual’s lifestyle (Fisher’s exact test, P = 0.673). Examples of such illnesses include diabetes mellitus and cerebral palsy. A slightly but not significantly higher proportion of successful patients was gainfully employed. Educational attainment, as measured in years of formal education, did not significantly differ (student t, P > 0.05). Best corrected visual acuities, obtained by refraction of the better eye, were not significantly different for the two groups (student t, P > 0.05).

Table 1. Clinical characteristics of telescopic spectacle users without nystagmus

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Successful</th>
<th>Unsuccessful</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Female</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Male</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Age (mean ± SEM, years)</td>
<td>47.4 ± 3.5</td>
<td>58.8 ± 4.7</td>
</tr>
<tr>
<td>Diagnosis (number)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macular degeneration</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Optic atrophy</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Glaucoma</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Retinitis pigmentosa</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Toxoplasmis</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Diabetic retinopathy</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Retinal detachment</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Major illness (%)</td>
<td>39</td>
<td>23</td>
</tr>
<tr>
<td>Employment (%)</td>
<td>46</td>
<td>31</td>
</tr>
<tr>
<td>Education (mean ± SEM, years)</td>
<td>14.6 ± 0.6</td>
<td>13.7 ± 0.8</td>
</tr>
<tr>
<td>Corrected acuity, better eye</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logminarc (mean ± SEM)</td>
<td>1.15 ± 0.10</td>
<td>1.05 ± 0.07</td>
</tr>
<tr>
<td>Snellen (mean)†</td>
<td>20/280</td>
<td>20/225</td>
</tr>
<tr>
<td>Snellen range</td>
<td>20/90–20/1200</td>
<td>20/100–20/900</td>
</tr>
<tr>
<td>Telescope power prescribed</td>
<td>4.6 ± 0.5</td>
<td>3.7 ± 0.4</td>
</tr>
</tbody>
</table>

* None of the comparisons between groups was statistically significant at the 0.05 level.
† Mean Snellen fraction obtained by conversion of logminarc values.
as history of balance problems or vertigo, and living situation, were similar for the two groups.

Dynamic Visual Acuity

The 26 low vision patients described above underwent the standard laboratory battery of tests of visual acuity with telescopes, eye movements and head stability. SVA and DVA were measured initially before adaptation and DVA was measured again after adaptation. For most patients, head motion produced a reduction in visual acuity obtained with telescopic spectacles, as expected. This effect may be seen in Figure 1, which plots SVA and DVA for successful and unsuccessful patients. Results of acuity testing are summarized in Table 2. Mean SVA with standard ×4 telescopic spectacles was identical for successful and unsuccessful patients. However, initial DVA with telescopic spectacles achieved during standard head motion was better for successful than unsuccessful patients. When the difference between DVA and SVA (SVA minus initial DVA, units of logminarc) for each patient in the two groups was compared, there was a significantly greater loss in acuity due to head motion for unsuccessful patients (student t, \( P = 0.022 \)). Successful patients initially lost an average of about one Snellen line due to head motion, while unsuccessful patients lost about 2.5 Snellen lines.

While unsuccessful patients showed some reduction in acuity loss with head motion after the 15 min period of training adaptation with telescopic spectacles, even after adaptation their DVA was inferior to the initial DVA of successful patients. Adapted DVA for successful patients did not improve significantly over the initial value. The difference between SVA and DVA after adaptation averaged about two Snellen lines for unsuccessful patients, and less than one line for successful patients. This reduction in adapted acuity due to head motion did not differ significantly (student t, \( P = 0.097 \)) between successful and unsuccessful patients.

Ocular Stabilization

The vestibulo-ocular reflex (VOR) and visual–vestibulo-ocular reflex (VVOR), as well as the responses of each reflex to a 15 min period of adaptation training, were measured in the 26 patients. An illustrative record of such eye movements is seen in Figure 2. Figure 2 shows sampled VOR slow phase eye velocity for low vision patient 7, a successful telescopic spectacle user, during horizontal head rotation at 0.1 Hz, amplitude 60°/sec, in darkness. Initial VOR gain was 0.63 ± 0.04 (mean ± standard deviation, SD, n = 6 cycles). Initial VVOR is seen in Figure 2B, and was measured in light with ×4 telescopic spectacles, as patient 7 underwent horizontal rotation at 0.1 Hz, amplitude 30°/sec. Although stimulus amplitude was only half as great in light as in darkness, the response amplitude of the initial VVOR was greater than that of initial VOR, reflecting visual–vestibular interaction. This produced an initial VVOR gain of 1.58 ± 0.11 (mean ± SD, n = 6 cycles). Patient 7 then underwent a 15 min period of adaptation training, during which she viewed a video motion picture with telescopic spectacles while rotating in the chair at 0.2 Hz, amplitude 20°/sec. Following adaptation, VOR gain was

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**Table 2. Visual acuity with ×4 telescopic spectacles in telescopic spectacle users without nystagmus***

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Successful</th>
<th></th>
<th>Unsuccessful</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Static visual acuity (×4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logminarc</td>
<td>0.46</td>
<td>0.07</td>
<td>0.46</td>
<td>0.09</td>
</tr>
<tr>
<td>Snellen†</td>
<td>20/58</td>
<td>20/58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynamic visual acuity (×4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logminarc</td>
<td>0.54</td>
<td>0.06</td>
<td>0.72</td>
<td>0.06</td>
</tr>
<tr>
<td>Snellen†</td>
<td>20/69</td>
<td>20/105</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adapted</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logminarc</td>
<td>0.53</td>
<td>0.05</td>
<td>0.64</td>
<td>0.06</td>
</tr>
<tr>
<td>Snellen†</td>
<td>20/68</td>
<td>20/87</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial acuity loss, moving§</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logminarc</td>
<td>-0.09</td>
<td>0.03</td>
<td>-0.26</td>
<td>0.07</td>
</tr>
<tr>
<td>Snellen lines</td>
<td>~1</td>
<td>~2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adapted acuity loss, moving§</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logminarc</td>
<td>-0.07</td>
<td>0.03</td>
<td>-0.18</td>
<td>0.06</td>
</tr>
<tr>
<td>Snellen lines</td>
<td>&lt;1</td>
<td>~2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* 13 patients in each group.
† Mean Snellen fraction obtained by conversion of logminarc values.
‡ SVA minus DVA.
§ \( P < 0.05 \).
Fig. 2. Ocular stabilization reflex response during sinusoidal head rotation at 0.1 Hz in the horizontal plane for low vision patient 7. The points represent sampled slow phase eye velocities; the solid curves are best-fit sinusoids. The sinusoidal head velocity stimulus waveform is not shown. Gain is defined to be the ratio of the amplitude of the response sinusoid divided by the amplitude of the stimulus sinusoid. (A) Initial VOR response recorded in darkness with a stimulus amplitude of 60°/sec. Initial VOR gain was 0.63 ± 0.04 (mean ± SD). (B) Initial VVOR response recorded in light during wearing of ×4 telescopic spectacles with a stimulus amplitude of 30°/sec. Initial VVOR gain was 1.58 ± 0.11. (C) Final VOR gain. Conditions similar to (A). Adapted VOR gain was increased to 0.74 ± 0.10 by 15 min of adaptation training. (D) Final VVOR gain, following 15 min of adaptation training. Conditions similar to (B). Adapted VVOR gain increased to 1.89 ± 0.01. The data censoring algorithm automatically excluded the first, second and sixth cycles because their amplitudes fell below the statistical criterion.

again recorded (Fig. 2C) and was found to be significantly ($P < 0.025$) increased to 0.74 ± 0.10 (n = 6 cycles); this represents an adaptive gain increase of 17%. There was greater cycle to cycle variability after adaptation than before. VVOR gain after adaptation increased significantly to 1.89 ± 0.01 (n = 3 cycles); three cycles were automatically deleted from analysis by the data censoring rule. The adaptive VVOR gain increase was 20%.

Mean initial and adapted values of VOR and VVOR gain are shown for the 26 low vision patients without nystagmus in Table 3. Neither initial or adapted VOR gains differed significantly (student t, $P > 0.05$) between successful and unsuccessful telescopic spectacle users; the percentage change in VOR gain following adaptation was similar for both groups. Although there was a trend toward higher initial and adapted VOR gains in successful as compared with unsuccessful users, this was not statistically significant ($P > 0.05$). The change in VVOR gain following adaptation training was also not significantly different between patient groups.

Motion Discomfort

Head rotation during wearing of telescopic spectacles occasionally produced motion discomfort, consisting of a feeling of visceral unease accompanied by nausea and diaphoresis. Motion discomfort was graded as absent, moderate or severe. By definition,

Table 3. Ocular stabilization reflexes in telescopic spectacle users without nystagmus

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Successful Mean</th>
<th>Successful SEM</th>
<th>Unsuccessful Mean</th>
<th>Unsuccessful SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOR gain (0.1 Hz)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial (mean ± SEM)</td>
<td>0.68</td>
<td>0.07</td>
<td>0.63</td>
<td>0.09</td>
</tr>
<tr>
<td>Adapted (mean ± SEM)</td>
<td>0.76</td>
<td>0.08</td>
<td>0.79</td>
<td>0.08</td>
</tr>
<tr>
<td>Plasticity (%)</td>
<td>16</td>
<td>8</td>
<td>22</td>
<td>7</td>
</tr>
<tr>
<td>VVOR gain (0.1 Hz)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial (mean ± SEM)</td>
<td>1.44</td>
<td>0.15</td>
<td>1.07</td>
<td>0.15</td>
</tr>
<tr>
<td>Adapted (mean ± SEM)</td>
<td>1.48</td>
<td>0.18</td>
<td>1.14</td>
<td>0.17</td>
</tr>
<tr>
<td>Plasticity (%)</td>
<td>1</td>
<td>4</td>
<td>16</td>
<td>7</td>
</tr>
</tbody>
</table>

* 13 patients in each group; none of the comparisons between groups was statistically significant ($P > 0.05$).
patients with severe motion discomfort requested that rotation be halted and did not complete testing. Patients who noticed motion discomfort but were nonetheless able to complete the test protocol were considered to have moderate motion discomfort.

Among unsuccessful telescopic spectacles users, three patients had moderate motion discomfort and one had severe motion discomfort; the rest had no motion discomfort. Among successful telescopic spectacle users, three had moderate motion discomfort and the rest had none. There was no statistically significant difference in motion discomfort between successful and unsuccessful patients (Fisher's exact test, $P = 1.00$). Most moderate motion discomfort was transient and remitted spontaneously during or shortly after adaptation. No subject experienced emesis, and when severe motion discomfort was present, it remitted within 30 min of cessation of rotation.

Head Stability

Spontaneous head motion in the yaw and pitch axes was measured in the 26 low vision patients without nystagmus. Illustrative records of these data for pitch are seen in Figure 3, but records for yaw had a similar appearance. Head stability data for all 26 patients are summarized in Table 4. There were no significant differences between successful and unsuccessful telescopic spectacles users in peak component of spontaneous yaw head velocity, amplitude of yaw head velocity integrated over frequencies from 0–25 Hz, or in root mean square (RMS) yaw head velocity. However, in pitch, each of these measures was significantly (student $t$, $P < 0.05$) greater for unsuccessful than successful users.

Predictive Function

An implementation of multiple logistic regression analysis in the SYSTAT statistical package was used in stepwise fashion to identify factors predictive of successful use of telescopic spectacles by the 26 low vision patients. Patients not motivated to attempt use of telescopic spectacles had been previously excluded. All demographic factors, historical factors and laboratory measurements discussed above were evaluated separately, and promising variables were evaluated in independent and interactive combination. The best predictive function used measurements of acuity reduction due to head velocity $X_1$ (in logminarc) and RMS head velocity in the pitch axis $X_2$ (in deg/sec). Although other measures of head stability in the pitch axis, such as peak amplitude component or amplitude integral, can also be used in a predictive function, RMS velocity is more robust and was the best

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Successful</th>
<th>Unsuccessful</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SEM</td>
</tr>
<tr>
<td><strong>Yaw</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak component (deg/sec)</td>
<td>0.411</td>
<td>0.066</td>
</tr>
<tr>
<td>Amplitude integral (deg-Hz/sec)</td>
<td>1.089</td>
<td>0.122</td>
</tr>
<tr>
<td>Root mean square (deg/sec)</td>
<td>0.976</td>
<td>0.112</td>
</tr>
<tr>
<td><strong>Pitch</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak component† (deg/sec)</td>
<td>0.397</td>
<td>0.039</td>
</tr>
<tr>
<td>Amplitude integral† (deg-Hz/sec)</td>
<td>1.376</td>
<td>0.108</td>
</tr>
<tr>
<td>Root mean square† (deg/sec)</td>
<td>1.040</td>
<td>0.080</td>
</tr>
</tbody>
</table>

* 13 patients in each group.
† $P < 0.05$.
Fig. 4. Predicted probability of successful use of telescopic spectacles by low vision patients, plotted as a function of visual acuity loss due to head motion with telescopic spectacles and spontaneous RMS head velocity in the pitch axis.

The predictive function is defined by the logit,

\[ y = -6.843 - 1.010x_1 + 4.233x_2 \]  

where the probability of successful telescope use

\[ P(\text{success}) = 1 - \frac{e^y}{1 + e^y} \]  

This function has \( \chi^2 = 12.3 \) with two degrees of freedom \( (P < 0.005) \), and is plotted as a three-dimensional surface in Figure 4. Thus, it is possible to predict the numerical odds of successful use of telescopic spectacle low vision aids for any given patient from measurements of SVA and DVA with \( \times 4 \) telescopic spectacles, and from spontaneous pitch head velocity.

The relative importance of each measurement contributing to the predictive function can be assessed by representing coefficients for \( x_1 \) and \( x_2 \) in standard units. This is done by multiplying each coefficient by the standard deviation of the measured variable. In these terms, the relative contributions of visual acuity loss and pitch head velocity to the predictive function were similar (standardized coefficient for acuity loss = 2.102; standardized coefficient for RMS pitch head velocity = 2.235).

The sensitivity of the predictive function is the proportion of successful patients who will be correctly predicted to succeed; the specificity of this test is the proportion of unsuccessful patients who will be correctly predicted to fail. For realistic use of the predictive function, a criterion level of threshold probable success must be chosen for making predictions. For illustrative purposes, we chose to predict success if the predicted probability of success was greater than 0.5. Based upon this criterion, the prediction was correct in 22 cases and incorrect in four cases. Two successful patients were incorrectly predicted to fail, and two unsuccessful patients were incorrectly predicted to succeed.
patients were incorrectly predicted to succeed. This implies a positive predictive value (number actually successful of those predicted successful/number predicted successful) of 11/13 = 85%, and a negative predictive value (number actually unsuccessful of those predicted unsuccessful/number predicted unsuccessful) of 11/13 = 85%. For this selection of criterion, it may be seen from Figure 5 that the sensitivity and specificity of the predictive function are both also equal to 85%.

Examination of incorrect predictions is instructive. Patient 16 had a predicted probability of success of 0.960, but failed to use telescopic spectacles; this patient complained of uncomfortable sensations of confinement when she tried telescopic spectacles in clinic. Her failure was presumably due to psychological factors not addressed by the predictive function. Successful patient 17 had a predicted probability of success of 0.350 and thus would be predicted to be unsuccessful; this prediction is plainly but inexplicably incorrect. Unsuccessful patient 21 had an equivocal predicted probability of success of 0.508; a prediction based upon this probability would have to be regarded as equivocal. Similarly, successful patient 24 had a predicted probability of success of 0.488, also a weak prediction of failure. The predictive function thus made two equivocal, incorrect predictions, and two unequivocal, but incorrect, predictions. The remaining predictions were all correct, although for patient 1, a correct prediction of failure \[P(\text{success}) = 0.500\] was equivocal.

Linear regression analysis was used to examine the relationship between predicted probability of success and the reported number of hours per day of telescopic spectacle use by low vision patients. Telescopic spectacle usage was significantly linearly correlated with predicted probability of success \((P = 0.005, r = 0.555)\).

Conventional Clinical Predictions

The overall clinical impression of the low vision specialist at the time of prescription of telescopic spectacles was evaluated using each patient’s medical records. The clinician made the prediction in a non-standardized way, based upon results of clinical examination, history and informal evaluation of patient personality and motivation. The three patients obviously lacking motivation to try telescopic spectacles were not included in this analysis, but it should be noted that two of these were clinically identified as likely failures.

In eight of the 26 classifiable, motivated patients who were included in analysis of the predictive function, failure with telescopic spectacles was anticipated on the basis of overall clinical impression. Despite this, these eight patients were given a trial of telescopes. No patient succeeded with telescopic spectacles if the initial clinical expectation was for unsuccessful use. Nine patients were expected on clinical grounds to succeed with telescopic spectacles, and did in fact succeed. Six patients were expected on clinical grounds to succeed with telescopic spectacles, but failed nonetheless. In two patients who were ultimately unsuccessful in using telescopic spectacles, the records did not indicate a clinical impression regarding the likelihood of success. One patient was already a successful user of telescopic spectacles at the time of referral, and data on this patient were not considered in evaluating clinical predictions.

If the two patients for whom incomplete data are available are disregarded, the clinical prediction was accurate in 17 of 23 cases (74%) where telescopic spectacles were newly tried. If, as is likely, these two patients with incomplete clinical data were expected to succeed, then the clinical prediction was accurate in 17 of 25 patients (68%). If one considers only the 23 patients in whom clinical data was available on the expectation of success, the sensitivity (proportion of successful patients correctly predicted to succeed) of the clinical prediction was 9/9 = 100%; the specificity (proportion of unsuccessful patients correctly predicted to fail) of the clinical prediction was 8/14 = 57%. Since the clinical prediction did not depend upon a quantitative criterion or threshold, the trade-off between sensitivity and specificity cannot be explored for other combinations of these values. The positive predictive value (number actually successful of those predicted successful/number predicted successful) of the clinical prediction was 9/15 = 60%; the negative predictive value (number actually unsuccessful of those predicted unsuccessful/number predicted unsuccessful) of the clinical prediction was 100%.

Patients with Nystagmus

Seven additional low vision patients were found at the time of laboratory testing to have manifest nystagmus, precluding precise measurements of VOR and VVOR gains. Six of these were successful users of telescopic spectacles, and completed partial test protocols. Visual acuity data with ×4 telescopic spectacles are shown for low vision patients with nystagmus in Table 5. By comparison with similar data for patients without nystagmus in Table 2, it may be seen that although SVA and DVA for patients with nystagmus were slightly better than those of successful patients without nystagmus, none of the differences between successful patients without nystagmus and...
successful patients with nystagmus were significant at the 0.05 level (student t). Initial loss of SVA due to head motion was significantly \((P < 0.05)\) less for successful patients with nystagmus than for unsuccessful patients without nystagmus.

Table 6 lists head stability data for four successful telescopic spectacle users with nystagmus who were tested in this way. Comparison of Table 6 with Table 4 shows that measurements in yaw did not differ significantly between patients with nystagmus, and either successful or unsuccessful patients without nystagmus. In pitch, however, all measurements for nystagmus patients were significantly greater than those for successful patients without nystagmus (student t, \(P < 0.05\)), and not significantly different from unsuccessful patients without nystagmus. Head stability measurements were not performed for the unsuccessful patient with nystagmus.

It was possible to apply the predictive function to the four successful patients with nystagmus in whom measurements of both head stability and DVA were obtained. Two of these patients were predicted to be successful, and two were predicted to be unsuccessful, based upon a criterion threshold level of probability of 0.500.

**Discussion**

This report categorized low vision patients who had previously attempted use of telescopic spectacles into successful vs. unsuccessful groups. The criterion for successful use of telescopic spectacles was intentionally chosen to be liberal, including use of telescopic spectacles of any magnification for any significant task on a regular basis, regardless of amount of time spent on that task.

Analysis of clinical and historical data on low vision patients without nystagmus who had attempted use of telescopic spectacles indicates that successful users were similar to unsuccessful ones. In particular, neither age, diagnosis, presence of systemic illness, employment, educational attainment, or best corrected visual acuity were useful predictors of successful use of telescopic spectacles. While gross absence of motivation to seriously attempt use of telescopic spectacles was, of course, predictive of failure, it is reasonable to expect that any clinician would identify the great majority of such patients and would not make futile attempts to prescribe telescopes for purchase by such patients. Nevertheless, in our sample from the practice of an experienced low vision clinician, only nine of the 15 low vision patients to whom telescopic spectacles had been conventionally prescribed with expectation of success made any meaningful functional use of the devices. The clinical prediction of unsuccessful telescopic spectacle use was, in this series, always correct; the negative predictive value of clinical judgement was 100%. However, clinical judgement was overly optimistic in predicting successful telescopic spectacle use in a substantial fraction of patients, giving a positive predictive value of only 60%. This implies that these devices, which have a cost of around $1000.00, are useless to some 40% of patients for whom they are purchased. Although this waste of resources might be mitigated to some extent by trial of telescopic spectacles on a loan basis, it should be noted that telescopic spectacles having highest optical quality, integrated refractive correction, optimal mounting characteristics, minimum weight and largest visual field must be custom-manufactured for the individual patient. It may be the case that an optimal trial of telescopic spectacles would always require expensive custom fabrication. Clinicians must also commit valuable time to train low vision patients in the use of telescopic spectacles.

**Table 5. Visual acuity with \(\times 4\) telescopic spectacles in telescopic spectacle users with nystagmus**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Successful*</th>
<th>Unsuccessful†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static visual acuity ((\times 4))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Snellen§</td>
<td>0.36</td>
<td>0.55</td>
</tr>
<tr>
<td>Dynamic visual acuity ((\times 4))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial Logminarc</td>
<td>0.42</td>
<td>0.65</td>
</tr>
<tr>
<td>Snellen§</td>
<td>20/53</td>
<td>20/100</td>
</tr>
<tr>
<td>Adapted Logminarc</td>
<td>0.44</td>
<td>0.65</td>
</tr>
<tr>
<td>Snellen§</td>
<td>20/55</td>
<td>20/100</td>
</tr>
<tr>
<td>Initial acuity loss, moving§ Logminarc</td>
<td>-0.07</td>
<td>-0.10</td>
</tr>
<tr>
<td>Line‡</td>
<td>&lt;1</td>
<td>~1</td>
</tr>
<tr>
<td>Adapted acuity loss, moving§ Logminarc</td>
<td>-0.08</td>
<td>-0.10</td>
</tr>
<tr>
<td>Line‡</td>
<td>&lt;1</td>
<td>~1</td>
</tr>
</tbody>
</table>

* Six patients.
† One patient.
§ Snellen fraction obtained by conversion of logminarc values.
‡ SVA minus DVA.

**Table 6. Spontaneous head velocity in four successful telescopic spectacle users with nystagmus**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Mean</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yaw Peak component ((\text{deg/sec}))</td>
<td>0.401</td>
<td>0.089</td>
</tr>
<tr>
<td>Amplitude integral ((\text{deg-Hz/sec}))</td>
<td>1.235</td>
<td>0.283</td>
</tr>
<tr>
<td>Root mean square ((\text{deg/sec}))</td>
<td>1.008</td>
<td>0.272</td>
</tr>
<tr>
<td>Pitch Peak component ((\text{deg/sec}))</td>
<td>0.576</td>
<td>0.101</td>
</tr>
<tr>
<td>Amplitude integral ((\text{deg-Hz/sec}))</td>
<td>1.749</td>
<td>0.222</td>
</tr>
<tr>
<td>Root mean square ((\text{deg/sec}))</td>
<td>1.328</td>
<td>0.176</td>
</tr>
</tbody>
</table>
and could better allocate this time to other rehabilita-
tion strategies if telescopic spectacles were known in
advance to be infeasible. For these reasons, it is desir-
able to have a method of identifying those low vision
patients who would be likely to benefit from tele-
scopic spectacles.

A total of 26 low vision patients without nystagmus
completed a battery of laboratory tests of dynamic
visual acuity, head stability and ocular stabilization
reflexes. All patients had tried to use telescopic spec-
tacles, but only half of these were successful. When
using telescopic spectacles in the laboratory, unsuccess-
cessful patients exhibited a significantly greater loss of
dynamic visual acuity during standardized, vertical
axis (yaw) head motion than did successful patients.
Although this difference between the two groups was
only about 1.5 Snellen lines for the standard 20°/sec,
1 Hz head movement, natural head movements are
not only of much higher velocity, but also can occur
about the horizontal (pitch) and torsional (roll) axes
as well. The difference in the loss of visual acuity
between the two groups of patients during small ve-
locities of head movement about the vertical axis
probably reflects a much larger difference for natural
head movements.

Spontaneous head motion was measured for suc-
cessful and unsuccessful low vision patients who had
attempted use of telescopic spectacles. During this
measurement, patients were asked to close their eyes
in order to eliminate effects of vision and to evaluate
vestibular and proprioceptive contributions to post-
tural stability. Head stability in the yaw axis did not
differ significantly between successful and unsuccess-
ful users of telescopic spectacles. However, by all
measures, head stability in the pitch axis was signifi-
cantly worse in unsuccessful patients than in success-
ful ones. Head stability in the third possible axis, roll,
was not measured. It seems likely that the greater
pitch instability of unsuccessful patients in this test
may reflect greater pitch instability during natural
head movements, such as standing, ambulation and
vehicular travel. Thus, the visual systems of unsuccess-
cessful patients are not only more sensitive to head
motion when telescopic spectacles are worn, but these
patients also have a greater degree of head motion
with which to contend.

The horizontal VOR and VVOR, as well as short-
term adaptation of these reflexes to wearing of tele-
scopic spectacles, were measured in the laboratory in
26 low vision patients without nystagmus. Perform-
ance of the horizontal VOR, the principal vestibul-
arily driven ocular compensatory reflex for head mo-
tion in the yaw axis, did not differ significantly be-
tween successful and unsuccessful telescopic
spectacle users. Both successful and unsuccessful tele-
scopic spectacle users exhibited similar adaptive in-
creases in VOR gain after only 15 min of head rota-
tion during wearing of telescopes. This supports the
observation that VOR gain plasticity can be demon-
strated in patients having substantially decreased
central visual acuity. When \( \times 4 \) telescopic spectacles
were worn, the VVOR gain of successful users tended
to be more appropriately higher than that of unsuccess-
ful users, but this trend did not achieve statistical
significance. Perhaps because of their initially higher
VVOR gains, successful patients did not experience
a significant plastic increase in VVOR gain after the
adaptation period; a small but not significantly
greater adaptive increase was observed in the unsuccess-
ful patients.

The finding that successful users of telescopic spec-
tacles can be distinguished from unsuccessful users by
their visual sensitivity to head motion as well as their
pitch head instability confirms the hypothesis that
retinal image stability is important to functional use
of telescopic spectacles. This implies that visual
acuity achieved with a telescopic spectacle by a pa-
tient whose head is stabilized by the headrest of the
examining chair may be substantially better than
functional acuity achieved with the same visual aid
when, for example, the patient is standing or riding
on a moving bus. However, considerations of retinal
image stability might initially suggest that the VOR
and VVOR should also differ between successful and
unsuccessful users. There are two possible explana-
tions for the failure of this study to demonstrate such
differences. First, the VOR and VVOR were mea-
sured about the vertical, or yaw, axis, while the most
important postural instability was found to be in the
pitch, and not the yaw axis. If the VOR and VVOR
had been measured in pitch, significant differences
between successful and unsuccessful patients might
have been found. However, study of the VOR for
pitch head movements requires measurement of ver-
tical eye movements. Electrooculography is not gen-
erally accurate for vertical eye movements, necessi-
tating use of the more complex technique of scleral
magnetic search coil recording for future such
studies.22

A second explanation for the lack of demonstrable
difference in VOR and VVOR gains between success-
ful and unsuccessful users may lie in viewing strategy.
Dell’Osso and Daroff have demonstrated that pa-
tients with congenital nystagmus modify their nys-
tagmus waveforms to prolong target foveation.23 It is
similarly possible that some low vision patients
briefly boost VVOR gain or otherwise modify their
eye movements only long enough to identify opto-
types, a strategy that would not be reflected during
gain measurements based on complete sinusoidal
cycles at 0.1 Hz. However, study of this or other idiosyncratic viewing strategy would require methods of simultaneous measurement of visual acuity and eye position with very high temporal resolution not achievable with apparatus in our laboratory.

The visual–vestibular conflict produced by wearing of telescopic spectacles can produce motion discomfort during head movements of sufficient velocity. Mild symptoms of motion discomfort were noted during head rotation with telescopic spectacles by both successful and unsuccessful patients, so that these two groups did not differ significantly in this regard. Motion discomfort often remitted during or after the adaptation period, probably due to adaptation of the VOR and VVOR to reduce visual–vestibular conflict. Since adaptation was similar for both groups of patients, it is not surprising that motion discomfort symptoms did not differ. Despite this, it is possible that use of telescopic spectacles might be infeasible in certain individual patients who have an unusually high susceptibility to motion sickness, but this situation did not apply to any of the patients in this study.

In contrast to the weak positive predictive value of standard clinical and historical information, a logistic predictive function based upon measures of sensitivity of dynamic visual acuity to head motion, and head stability in pitch, was found to be reasonably accurate in predicting success or failure of low vision patients in use of telescopic spectacles. Massof and Emmel have advocated the relative operating characteristic (ROC) curve as a criterion-free, parameter-free, distribution-independent index of the performance of a diagnostic test. The relative operating characteristic (ROC) curve is a plot of sensitivity against specificity of a test for all possible values of threshold. The area under the ROC curve, as applied to the current study, has been shown to be equal to the probability of correctly predicting, in a two-alternative, forced-choice decision task, success or failure of a given low vision patient in use of telescopic spectacles. The area under this curve is 0.905, equivalent to a 90.5% probability of correctly predicting success in a two alternative, forced-choice test for any one patient. This value could be compared with similarly calculated values for alternative tests, in order to determine the superiority of one test over another.

The area under the ROC curve is independent of the criterion, or threshold level, of probable success chosen to categorize patients as likely successes or likely failures. However, in practical use of this test as a predictive instrument, a threshold level must be chosen. In our analysis of the accuracy of the test, we chose a greater than 0.500 probability of success as a criterion for predicted success. This choice led to correct predictions in 85% of patients; the difference between this value and the area under the ROC curve is due to the relatively small number of subjects tested and choice of threshold. Since we have demonstrated that clinical judgement has an excellent negative predictive value, it is unlikely that clinicians would obtain a predictive test for patients clinically predicted to be unsuccessful candidates for telescopic spectacles. The present predictive function might be of clinical use in patients in whom the clinical prediction is of likely success, since the positive predictive value of clinical judgement is only 60%. In cases where the predicted probability of success is close to 0.500, and is therefore equivocal, a prudent clinician should take into account the penalties of misclassification. Since the consequences of depriving a patient with a borderline prediction of success of a chance to attempt telescopic spectacle use are probably worse than the consequences of giving that patient a costly visual aid that cannot be used, a clinician might choose to use a threshold of probable success of 0.400 in this situation. This decision might depend upon economic and social resources available to patient and clinician.

The logistic predictive function derived in this study was based only upon patients who did not exhibit an obvious and complete lack of motivation to use telescopic spectacles. It is the contention of the authors that this obvious motivational state can be easily recognized by clinicians. This basic but easily applied motivational screen is the only way in which the predictive process takes psychological factors into account. Since low vision patients are a very heterogeneous group in age, pathologies and social characteristics, and since they use telescopic spectacles for a myriad of tasks, it is remarkable that a predictive function based only upon simple physiological measurements can achieve the 85–90% accuracy of the present function. It is quite likely that psychological factors, including motivation, could explain the residual inaccuracy. However, valid measurement of motivation is complex and must be made with specific reference to the population under study and to the task under consideration. To our knowledge, no psychological instrument has been developed to quantitatively evaluate motivation in this visually impaired population. Even if no qualitative screening for obvious lack of motivation is attempted by the clinician, the predictive function remains useful, albeit at somewhat reduced accuracy. The usefulness of the predictive function in motivated patients also confirms the physiological importance of retinal image stabilization in functional use of telescopic spectacles by low vision patients.

Two other types of patients were excluded from
derivation and analysis of the predictive function. One patient was a successful user of telescopic spectacles who had a low predicted probability of success because of a high degree of head instability. This patient was unable to use telescopic spectacles unless he stabilized his head by leaning against a stationary object such as a doorframe or lamp post. This patient would have failed with telescopic spectacles had he not fortuitously learned a strategy for minimizing retinal image motion. The experience of this patient suggests remedial clinical training for other patients predicted by the logistic function to fail with telescopic spectacles because of excessive head instability. Such patients might be warned that telescopic spectacles will not work for them unless they are resting their heads against stationary objects. Similar patients contemplating uses of telescopic spectacles that permit this strategy might then be good candidates for telescopic spectacles with appropriate instruction.

The predictive function also excluded patients with manifest nystagmus from its derivation. Successful telescopic spectacle users with nystagmus had visual loss due to head movement, as well as head instability, that were between the values obtained for successful and unsuccessful patients who did not have nystagmus. Where predictions were made for such patients, who were studied as a separate group, the predictions were frequently inaccurate. This finding suggests that patients with nystagmus may have a different underlying visual sensitivity to retinal image motion. The presence of nystagmus may be a favorable predictive factor in use of telescopic spectacles.

The retrospective nature of the current study necessitates some caution in interpreting the differences between successful and unsuccessful patients. While the concept of a predictive function assumes that these differences are a priori characteristics, it remains possible that the differences are results of chronic use of telescopic spectacles by successful patients. This issue can be addressed only by a lengthy prospective study, currently underway.

Other limitations on the predictive function must be acknowledged. First, it was derived from a retrospective sample of low vision patients from one clinician’s practice. It is impossible to be certain if such patients are representative of all low vision patients nationwide in their demographic, social and medical characteristics. To our knowledge, such characteristics have never been nationally surveyed for the specific low vision population studied here. It is possible that the process of recalling such patients for testing tended to select a disproportionate number of unsuccessful patients. In some cases, successful patients might not have been willing to participate in laboratory testing because of employment or social obligations. It is possible that the low vision specialist allowed clinical impressions concerning likely success or failure to influence his efforts to optimally prescribe, train, and encourage patients to use telescopic spectacles. If less clinical effort had been directed to patients not expected to succeed with telescopic spectacles, this may explain the 100% negative predictive value of a clinical prediction of failure. The generality of the predictive function may also be limited by exclusion of patients with nystagmus. The current study does not address the question of whether unsuccessful patients could become successful if provided with more intensive training or a different type of telescopic spectacle from the one originally prescribed. Such considerations dictate further testing for the predictive function before its widespread clinical use can be advocated.

Several practical considerations deserve mention concerning the clinical use of the predictive information above. Although in this report DVA was measured using a standard head motion generated by a computerized, servomotor-driven chair, such equipment may not be essential for clinical purposes. It may be feasible to perform a similar test using head movements actively generated by the patient, in synchrony with a simple metronome. Such a simplified clinical test of DVA is being evaluated in parallel with the prospective laboratory trial. Measurements of RMS head velocity could be performed relatively inexpensively using a battery powered version of the velocity transducer employed in this study; no digital computer is required to obtain this robust measurement, although one was employed here in order to evaluate other aspects of head stability that ultimately proved to be less valuable than RMS velocity.

The data presented here raise additional questions for clinical and laboratory study. However, data currently at hand permit several recommendations for low vision clinicians. First, since retinal image slip is exacerbated by magnification, in the presence of head motion a lower telescope power may actually give better visual acuity than a higher power. The clinician should prescribe telescopic spectacles of the lowest power effective for the task. Since head motion is usually present during functional use of telescopic spectacles, the naive patient trying them in clinic should be encouraged to experience the effects of standing and moving about on magnified vision and equilibrium. This would serve to quench unrealistic expectations and would allow the teaching of head stabilization strategies that might enable certain patients to make successful use of telescopic spectacles.

Key words: dynamic visual acuity, head stability, low vision, telescopic spectacles, visual-vestibular interaction
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