Preferred retinal loci and macular scotoma characteristics in patients with age-related macular degeneration

Ronald A. Schuchard, PhD

ABSTRACT • RÉSUMÉ

Many patients with macular scotomas due to age-related macular degeneration do not perceive black spots in the visual field where the scotomas are located. Rather, they describe objects as “vanishing,” “jumping out of nowhere” or “having blurry parts,” or a combination of features. In addition, when the macular scotoma affects the fovea, the visual system uses 1 or more preferred retinal loci (PRLs) as a “pseudofovea” to perform visual tasks. Visual function testing with the scanning laser ophthalmoscope has provided a wealth of information regarding how patients perceive the visual world and how the oculomotor system directs eye movements. This article describes 2 specific functions of the oculomotor system, fixation stability and refixation precision, with data collected from normally sighted people and patients with visual field loss. The implications of the characteristics of PRLs and macular scotomas for clinical testing are discussed.

Plusieurs patients qui ont des scotomes attribuables à une dégénérescence maculaire liée à l’âge ne perçoivent pas de points noirs du champ visuel là où se situent les scotomes. Ils décrivent des objets « qui disparaissent », « venus de nulle part » ou « partiellement flous » ou ayant un mélange de ces caractéristiques. De plus, lorsque les scotomes maculaires affectent la fovéa, l’appareil visuel utilise une ou plusieurs zones de rétine préférentielles comme « pseudofovéa » pour accomplir des tâches visuelles. L’examen de la fonction visuelle avec l’ophthalmoscope laser à balayage a donné une abondance de renseignements sur la perception qu’ont les patients du monde visuel et sur la façon dont le système oculomoteur dirige les mouvements de l’œil. Cet article décrit 2 fonctions particulières du système oculomoteur, la stabilité de la fixation et la précision de la refixation, avec des données recueillies chez des personnes qui ont une vue normale et des patients qui ont subi une perte du champ visuel. Il traite aussi des implications des caractéristiques des zones de rétine préférentielles et des scotomes maculaires pour les tests cliniques.

The visual system with a central scotoma from age-related macular degeneration (AMD) chooses (often without the conscious knowledge of the patient) a preferred eccentric retinal area because the fovea can no longer perform visual tasks; that is, in an eye with a central scotoma affecting all of the fovea, 1 or more eccentric preferred retinal loci (PRLs) naturally and reliably develop to perform the foveal visual tasks such as recognizing objects and directing eye movements while reading or tracking objects.1–16 This choosing by the visual system of an eccentric “pseudofovea” for visual-performance functions has been

From the Department of Veterans Affairs, Rehabilitation Research & Development, Center of Excellence for Aging with Vision Loss, Atlanta, Ga.

Correspondence to: Dr. Ronald A. Schuchard, Atlanta VA Rehabilitation Research & Development Center (151R), 1670 Clairmont Rd., Decatur, GA 30033-4004, USA; fax (404) 728-4837; rschuch@emory.edu

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noted primarily by the use of the scanning laser ophthalmoscope (SLO). The SLO also allows accurate characterization of the central visual field by macular perimetry with direct retinal observation of fixation and perimetry targets.\textsuperscript{17,18} For example, fixation performance has 2 operational definitions: refixation precision is defined as the retinal area that a patient uses during repeated fixation (refixation); fixation stability is defined as the retinal area that a patient uses while maintaining fixation. Refixation precision and fixation stability show variability, of course, and the distribution of retinal positions used during fixation performance is operationally defined as the retinal locus for fixation.

The concept of using a retinal locus for visual tasks such as fixation is accepted in vision rehabilitation but seldom used with normally sighted patients. The term PRL has typically been reserved for patients whose visual system has chosen a preferred eccentric retinal area for visual tasks because of a central scotoma. However, the visual system of patients with paracentral scotomas or even normal sight does choose to use the fovea over other retinal areas; thus, the fovea can be referred to as their PRL.

**RETINAL CONSIDERATIONS**

For patients with a functioning fovea, visual tasks are performed by aiming the eye such that the image of the visual target of regard is placed within the foveal area. For patients with a central scotoma from AMD involving all of the fovea, visual tasks are performed by aiming the eye such that the image of the visual target of regard is placed within a PRL. Unfortunately, there is no conclusive way of determining where the eccentric PRL is located except by monitoring the location of visual-stimuli images on the retina. Fig. 1 shows how visual stimuli can be directly monitored with an SLO to determine scotoma and PRL characteristics. Generally, in the low-vision population with central scotomas, there is no consistent retinal location relative to the scotoma for the PRLs. In a study of 825 patients, 84.4% of low-vision eyes (1130 of 1339) demonstrated an established PRL (foveal or eccentric) for fixation, which varied from 1.0° to 9.0° in diameter.\textsuperscript{14} Only 4.4% of the patients did not demonstrate a PRL in either eye. There was a dense scotoma within 2.5° of all of the eccentric PRLs, surprisingly, and it completely surrounded 17.4% of the PRLs (ring scotoma).

In an eye with a functioning fovea, fixation is the act of directing the eye toward the visual target of regard, causing the image of the target to be within the fovea. The anatomic fovea is a retinal area about 5° (1500 mm) in diameter in which the central 1.2°–1.7° diameter of photoreceptors (referred to as the anatomic foveola or clinical fovea) is composed entirely of cones.\textsuperscript{19,20} The traditional view is that within the centre of the fovea, where the cone density is highest, is a small and spatially invariant retinal area referred to as the optimal locus.\textsuperscript{21} The optimal locus has been hypothesized to direct the location of a fixation stimulus when fixation is initiated and to direct drifts and microsaccades to maintain fixation.

In an eye with a central scotoma affecting all of the fovea, eccentric fixation is the act of directing the eye toward the visual target of regard, causing the image of the target to be placed in 1 or more preferred eccentric retinal areas. Eccentric fixation refers to fixation performance in which the oculomotor system is
oriented to the eccentric retinal area, and the patient has the sensation of looking directly at the visual target during fixation. Eccentric viewing, on the other hand, refers to viewing performance in which the oculomotor system is not oriented to the target and the patient has the sensation of looking above, below or to either side of the target to see it. A shift of the oculomotor reference from the fovea to a preferred eccentric retinal area is possible in patients with bilateral macular disease. However, even though the saccades of patients with central scotomas can consistently direct images to the PRL, they sometimes have the latency and dynamic characteristics of nonfoveal saccades. But the latency can be shortened with practice, eventually tending asymptotically to the normal saccadic duration. Eccentric viewing or fixation naturally and reliably occurs when the foveal areas in both eyes are no longer functional, such as when both eyes have central scotomas.

**Position of Gaze Considerations**

The primary position of gaze is defined as the position of the eye when a patient is looking at a visual target that is straight ahead. From this primary position all ocular movements are initiated. More specifically, the primary position of the eye is the position against which all torsional, rotational and translational movements are measured. The position of the eye at the primary position of gaze is not necessarily identical to an anatomically straightforward position of the eye (as in an AMD patient with a central scotoma). A secondary position of gaze is defined as any position of the eye represented by a vertical, horizontal or oblique (a combination of vertical and horizontal) deviation from the primary position of gaze. It is expected that patients with functioning foveal areas (e.g., patients with paracentral scotomas or normal sight) will use the foveal area as their PRL for visual tasks when visual targets are in either the primary position of gaze or secondary positions of gaze. In addition, it is expected that patients with nonfunctioning foveal areas (owing to central scotomas) will use a preferred eccentric retinal area as the PRL for fixation when targets are in either the primary position of gaze or secondary positions of gaze. However, patients with central scotomas use 1 or more PRLs for visual tasks when visual targets are in the secondary positions of gaze and almost always use a “primary” PRL for visual tasks when the targets are in the primary position of gaze; that is, patients are more likely to use a “secondary” PRL when fixating on a target in a secondary position of gaze. The use of multiple PRLs has also been observed for different visual tasks and lighting conditions. Patients are often completely unaware of when or how they use multiple PRLs.

**PRL Characteristics**

The ability to make efficient and effective eye movements with a PRL is often considered the most difficult and yet the most valuable component of visual tasks such as scanning and reading. The more basic eye movements made by the visual system are fixation, pursuit and saccadic movements. These tasks are thought to possibly represent measurable parameters of the PRL quality for visual performance; that is, to optimally function as a retinal locus for visual performance, the PRL needs to keep a visual image in a discrete and stable retinal area (fixation stability), to track moving objects through space (pursuit) and to move rapidly to objects of interest appreciated in the visual field away from the PRL (saccadic movements). These and other characteristics of the PRL are thought to be important in activities of daily living for patients with AMD.

**Refixation precision**

Subjects were asked to fixate for 30 s on a target randomly placed in 1 of 25 positions determined by a 5 × 5 grid within the 17° × 12° SLO field of view. The centre of the grid was at the primary position of gaze, and the remaining grid locations provided 24 secondary positions of gaze. Table 1 presents the characteristics of the PRL for fixation described by a bivariate analysis that provides an elliptical fit of the 30-s retinal positions during fixation (unpublished data, 2003). The characteristics of the ellipse are orientation of the major axis (± 90° from the positive horizontal axis), eccentricity (the ratio of the major to minor axes when a value of 1 indicates a circular shape), major axis length (in minutes of arc) and area (in minutes of arc squared).

An analysis of variance in the characteristics of the PRL for fixation found by refixation precision was first performed for 3 normally sighted subjects who had extensive experience fixating. Effects with \( p < 0.05 \) are reported as significant in this and all further analyses of variance. The orientation of the major axes of the PRLs was not affected by the positions of
gaze (primary or secondary), the different fixation stimuli or the different subjects. The eccentricity of the PRLs also was not affected by the positions of gaze (primary or secondary), the different fixation stimuli or the different subjects. However, the eccentricity values in Table 1 clearly indicate that the PRL for fixation is not a circle (eccentricity = 1) except in a few cases (e.g., subject EN-3 with 1° cross at the primary position of gaze). The major axis length and the area of the PRLs were not affected by different fixation targets or different subjects. Therefore, the orientation and shape of the PRLs for fixation change in apparently random and nonsystematic ways. However, the major axis length and area were significantly larger for secondary positions of gaze than for primary positions of gaze with all 3 fixation targets and all 3 subjects (the interaction terms were not significant).

To extend the finding that the major axis length and area of the PRL is affected by the fixation-target position of gaze, additional studies were done with 4 normally sighted subjects who were inexperienced in fixation. These results and those for the experienced subjects with the 1° cross were combined for analysis. In all subjects, the major axis length and area of the PRLs were significantly larger with the primary position of gaze than with the secondary positions of gaze. However, all the inexperienced subjects had larger fixation areas than the experienced subjects. The same effect of experience on fixation performance has been reported for fixation stability.23

Patients with central visual field loss not affecting the fovea (e.g., patients with ring scotomas) would be expected to have fixation performance similar to that of normally sighted subjects. The results for 2 patients with paracentral scotomas shown in Table 1 are typical of these types of field loss: the PRLs for fixation found with primary and secondary positions of gaze were similar to those of the normally sighted subjects. However, such patients sometimes place the

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Table 1—Characteristics of ellipses representing preferred retinal loci for fixation found by refixation precision and studied by bivariate analysis

<table>
<thead>
<tr>
<th>Subject*</th>
<th>Stimulus</th>
<th>Primary position of gaze</th>
<th>Secondary positions of gaze</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Major axis</td>
<td>Major axis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Angle (degrees)†</td>
<td>Length (min of arc)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN-1</td>
<td>1° cross</td>
<td>–14.1</td>
<td>26.5</td>
</tr>
<tr>
<td></td>
<td>12’ disc</td>
<td>–23.6</td>
<td>30.5</td>
</tr>
<tr>
<td>EN-2</td>
<td>1° cross</td>
<td>–13.6</td>
<td>28.8</td>
</tr>
<tr>
<td></td>
<td>12’ disc</td>
<td>–3.0</td>
<td>28.8</td>
</tr>
<tr>
<td>EN-3</td>
<td>1° cross</td>
<td>–75.5</td>
<td>34.7</td>
</tr>
<tr>
<td></td>
<td>12’ disc</td>
<td>65.5</td>
<td>33.0</td>
</tr>
<tr>
<td>IN-1</td>
<td>1° cross</td>
<td>42.8</td>
<td>59.8</td>
</tr>
<tr>
<td>IN-2</td>
<td>1° cross</td>
<td>–38.6</td>
<td>57.9</td>
</tr>
<tr>
<td>IN-3</td>
<td>1° cross</td>
<td>78.3</td>
<td>76.9</td>
</tr>
<tr>
<td>IN-4</td>
<td>1° cross</td>
<td>10.8</td>
<td>56.1</td>
</tr>
<tr>
<td>PS-1</td>
<td>1° cross</td>
<td>47.9</td>
<td>81.9</td>
</tr>
<tr>
<td>PS-2</td>
<td>1° cross</td>
<td>–63.5</td>
<td>48.4</td>
</tr>
<tr>
<td>CS-1</td>
<td>1° cross</td>
<td>–2.2</td>
<td>212.9</td>
</tr>
<tr>
<td>CS-2</td>
<td>1° cross</td>
<td>124.6</td>
<td>390.0</td>
</tr>
</tbody>
</table>

*Subjects were experienced (E) or inexperienced (I) in fixation and had normal (N) sight or had scotomas (S), either paracentral (P) with a functioning fovea or central (C). Subject PS-2 had a ring scotoma surrounding the fovea. All scotomas were due to age-related macular degeneration.
†Plus or minus 90° from the positive horizontal axis.
‡A value of 1 indicates a perfect circle.
fixation target in an eccentric PRL for fixation. For example, patient PS-2 twice placed the fixation target in an eccentric retinal location outside the ring scotoma when the target was at a secondary position of gaze (these 2 eccentric fixation positions were not included in the bivariate analysis). The patients are often completely unaware of the change in the retinal fixation position. The last 2 patients listed in Table 1 had central scotomas affecting the fovea. The increase in size of the PRL for fixation is typical of this type of field loss. Patient CS-1 used 2 eccentric retinal areas to place the fixation target; patient CS-2 used only 1 PRL. Patients with central scotomas affecting the fovea are also often completely unaware of using different retinal positions for PRLs. It is not known why patients place fixation targets in locations less often used for fixation.

**Fixation stability**

The retinal loci for fixation found by fixation stability in 8 of the secondary positions of gaze (at the corners and the horizontal/vertical axes of the 17° × 12° SLO field) were found along with 8 primary-position trials. An analysis of variance (repeated-measures design) was performed on the characteristics of the PRLs for fixation (again significance is reported for $p < 0.05$). Like refixation precision, the orientation of the major axis and the eccentricity of the PRLs were not affected by the position of gaze (primary or secondary). Unlike refixation precision, however, major axis length was significantly affected by position of gaze. Previous studies of fixation stability in normally sighted subjects had shown PRL and foveal areas for fixation of 31.6° to 373° squared. The PRL areas found with SLO were 337° to 443° squared for small fixation targets with experienced patients. The main difference between the previously reported and the SLO values is the 3:1 ratio between the 95% and 63% equal-frequency PRLs, that is, the difference in the retinal areas in which one would expect to find 95% versus 63% of the retinal positions of fixation.

To further investigate the concept of a larger retinal locus for fixation, the 400 samples (25 samples during 8 primary-position trials and 8 secondary-positions trials) for each patient performing fixation stability in the SLO were analyzed to find the radius from the centroid for each sample. The normalized cumulative frequency indicated that 95% of the time the patients kept the fixation stimulus within a retinal area of 68' in diameter. In addition, the patients did not place the target in a small retinal area of 10.5' most of the time and very seldom placed the fixation stimulus outside the small retinal area (a Gaussian distribution). Rather, patients placed the target in a larger retinal area most of the time (a roughly flat distribution of 40' or 50') and outside this larger area very seldom.

**Comparison of results**

The PRL sizes during a fixation-stability trial, at both primary and secondary positions of gaze, were very similar to the PRL sizes for the 24 repeated fixations at the primary position of gaze during refixation-precision trials. Patients appear to use a larger retinal area for fixation when asked to fixate on a target that is away from the primary position of gaze. However, when they have fixated on a target at a secondary position of gaze, they appear to be able to maintain the image of the fixation target in a retinal locus for fixation that is the same as when they are asked to fixate and maintain fixation on a target at the primary position of gaze. Interestingly, even though the patients used a larger retinal area for secondary-position fixation, the diameters of the major axes of the PRLs were almost always 1° or less. It may not be a coincidence that the retinal positions for fixation are typically within an area of about 1.2° to 1.7° for most normally sighted patients. The central 1.2°–1.7° area of the fovea, the foveola, is a retinal area with roughly equal resolution capability.

**Binocular PRLs**

In previous investigations of PRLs each monocular PRL was studied separately, but individuals typically perform activities of daily living with both eyes open. Therefore, previous investigators have forced subjects to perform visual tasks monocularly without fully understanding the consequences for the monocular PRL characteristics. In a recent study of binocular PRLs, 67% of the patients saw stimuli with only 1 eye (monocular perception) while performing simple free-viewing binocular fixation and perception tasks. No single visual factor (acuity, contrast, threshold sensitivity, fixation stability, saccadic ability, pursuit ability or scotoma characteristics) had a statistically significant effect on perception of the stimulus, monocular or binocular. However, if the subjects had a large difference in monocular visual function (e.g., a
logMAR [logarithm of the minimum angle of resolution] difference greater than 0.66, or more than 6 lines of letters on the ETDRS [Early Treatment Diabetic Retinopathy Study] chart), the dominant PRL was the PRL with better visual-function capability. But, in the large group of subjects (82%) who did not have these large differences in visual-function capability between the 2 eyes, the only way of knowing which PRL was dominant was by a binocular perception test that directly evaluated which PRL was dominant. The only other factor that seems to contribute to monocular perception is noncorrespondence of binocular PRLs. Fig. 2 shows an example of binocular PRLs that are in different directions and at different distances from the nonfunctioning foveas. Compare the PRLs in Fig. 2 with those in Fig. 1, where the binocular PRLs are in the same direction and at relatively the same distance from the nonfunctioning foveas.

The finding that 2 out of 3 patients with central scotomas see visual stimuli at fixation with only 1 eye does not mean that the patients are seeing the entire visual world with only 1 eye. Patients reported seeing the world with both eyes, although not always appreciating that when looking at a target in the central visual field (e.g., a number, letter or word) they were seeing the target with only 1 eye. Previous studies of PRL abilities in eye movements might be considered to have been testing similar types of tasks: typically the subject was asked to fixate, saccade to a small target or follow a small target. It is possible that the eye that actually is used by the visual system in binocular tasks is a “dominant” eye that is better at eye-movement tasks; that is, the fellow eye is actually following the lead of the “dominant” eye. Therefore, determining the dominant PRL can be critical in guiding the prescription of monocular-vision-enhancing equipment, testing monocular visual function and other monocular issues.

**Implications of PRL and Scotoma Characteristics in AMD**

The idea of 1 or more PRLs instead of a single retinal point being used for visual tasks is an important concept for clinical vision testing and visual tasks. Many clinical tests or treatments presume that the eye movement system is operating by referencing a retinal point or at least a single retinal area. A few examples are presented to demonstrate the implications of PRLs and scotomas for clinical testing and visual tasks.

**Reading**

The ability of the eye to make movements so that the visual-target image is placed or kept in the PRL has been shown to be correlated to reading rate and reading errors. Previous reports on reading rate had shown that the existence of a central scotoma was a much greater predictor of reading impairments than was reduced acuity. However, the ability of the PRL to direct eye movements, both saccadic ability (measured by the number of saccades and the saccade characteristics) and fixation stability (measured by the retinal area of fixation), had a much higher correlation with reading speed and correct reading rate.
than did either acuity or scotoma existence. Furthermore, subjects with macular diseases who were undergoing vision rehabilitation clustered into 2 groups, 1 showing significant improvement and the other showing no improvement in reading with vision-rehabilitation training. That research also showed a strong association between saccade scores and reading rate or reading errors. Patients with AMD who present with low reading rates (fewer than 10 words/min and more than 2 errors with a short passage) and poor saccadic ability are less likely to show improvement in reading with vision rehabilitation.

Visual search

Unlike reading, the ability of the eye to make movements so that the visual-target image is placed or kept in the PRL has been shown to not be highly correlated to visual search efficiency or accuracy. Saccades of patients with central scotomas were found to consistently direct fixation targets to the PRL even though the saccades sometimes had the latency and dynamic characteristics of saccades not directed by the fovea. The patients with AMD also had, on average, more saccades of shorter length than normally sighted patients. However, the latency of the first saccade and the number of saccades to move the search-target image into the PRL were not correlated to the search time (together or separately). Rather, the time after the search-target image was moved into the PRL was the greatest contributor to the total visual search time; that is, patients with macular scotomas deliberated longer about the identity of the search target. Therefore, any patient with a macular Scotoma, regardless of the retinal location of the PRL, will have impaired visual search ability beyond the inability to see targets located inside the Scotoma.

Perimetry testing

The size and location of the PRL have obvious implications for perimetric testing of patients with AMD. For example, perimetric results can be translated in position, and if this translation is not recognized the location of the macular Scotoma will be inaccurately positioned in the visual field relative to the fovea. If the patient has a very large PRL for fixation or multiple PRLs, the perimetry results reported at 1 point of the visual field (e.g., the grid point in a Humphrey 10-2 test) could be the average of flashes actually presented at multiple retinal locations. The instability inherent in eccentric PRLs for fixation also makes accurate mapping of the Scotoma boundaries very difficult.

Pericentral fixation targets are used when the purpose of the testing is to measure visual function in the central macular retinal area (foveal area). These targets are intended to guide fixation by stimulating the perifovea (the outer limit of the macular area) while providing no visual stimulation of the inner macular area, including the foveal area. When subjects are instructed to “fixate in the centre of the target,” clinicians often assume that patients with central scotomas place the centre of the pericentral fixation target within the PRL for fixation. They also often assume that, when instructed to “look directly at the centre of the target,” patients place the target centre in the foveal area, even though the fovea is no longer functioning owing to the central Scotoma. However, most patients with central scotomas appear to orient images of targets to the PRL, and verbal instructions do not change the location of the pericentral fixation target. Therefore, one cannot assume that using pericentral fixation targets in clinical tests (e.g., a big X in the tangent screen or Amsler grid), with or without verbal instructions, provides testing with the fovea directed at the centre of the test area.

Patient awareness of macular scotomas

The presence of scotomas in the macula hinders the performance of many daily activities, such as reading, but most patients with AMD are unaware of even large defects in their central visual field. A valuable application of the information gained from PRL testing and macular perimetry is to educate the patient about the presence of the scotomas, especially when they occur relative to fixation. Macular perimetry methods can be used to demonstrate to the patient what a Scotoma is and what compensatory eye movements can be used to “move the Scotoma out of the way.” These compensatory techniques are especially important for the nearly 1 out of 5 low-vision patients who have fairly good visual function (as good as 20/40) but ring scotomas surrounding the PRL (Fig. 3). The patient who has gained an awareness of the Scotoma’s effects on visual tasks is more likely to make accurate compensatory eye movements to search for, find and identify pertinent visual informa-
tion. The ability to be aware of the scotoma’s effects on visual tasks is even more challenging when the patient is using multiple PRLs (Fig. 4), often without conscious knowledge of changing retinal positions for different lighting conditions or visual tasks.

**Calibration of eye-position instruments**

The calibration of eye trackers for vision testing is another example of when the concept of retinal locus for fixation is important. Calibrating eye trackers (e.g., the pupil eye tracker in the Humphrey Visual Field Analyzer) is done by having patients fixate on targets at known spatial locations. The recordings from the trackers are transformed to real-world dimensions by the relationships between these recordings and the known spatial locations of the fixation targets. The underlying assumption is that patients place the fixation targets in exactly the same retinal position each time they are instructed to look at the target; that is, one must assume that the PRL has no shift in retinal position when the fixation target is placed in different spatial locations, even though multiple PRLs occur. To make matters worse, the SLO results show that patients use a larger retinal locus for fixation when looking at fixation targets in secondary positions of gaze (see Table 1). To develop the transformation algorithm for calibration, one must have patients look at fixation targets in many secondary positions of gaze.

**Eccentric-viewing training**

The orientation of the oculocentric system (fovea or eccentric PRL) affects eccentric-viewing training. Many vision rehabilitation practitioners believe that patients with central scotomas benefit greatly from such training. A goal of this training is to enable the patient to use a specific eccentric area of the retina as if it were a fovea. To the extent that the PRL can play this role, this goal is reasonable. Results of fixation performance and visual-search performance, as
measured with an SLO, indicate that patients with central scotomas are able, and indeed likely, to use a PRL. The PRL appears to be developed by a patient simply through experience of a central scotoma, without formal training. However, it is certainly possible that eccentric-viewing training could facilitate this behaviour, making fixation more stable and accurate or influencing the patient to use a more optimal eccentric retinal area for eccentric viewing. It is not known whether patients with central scotomas can be trained to develop a new, more optimal, PRL as the reference for the oculocentric system. Further results are needed to determine what factors (e.g., resolution, field of view, proximity to the nonfunctioning fovea and binocular conditions) the visual system uses when naturally choosing a retinal area as the PRL.

**Conclusion**

Although there have been reports concerning some aspects of the PRL, the characteristics of the PRL are still not well known and understood. For example, more results need to be collected to determine whether single or multiple PRLs are influenced by retinal abnormalities. Also, what is known from previous work needs to be reevaluated, since it was never determined that the PRLs that were studied were actually used by the visual system in binocular (natural) viewing tasks. However, the characteristics that are known about the PRL have been shown to be important in their relationship to activities of daily living for patients with AMD. Therefore, clinicians may want to consider assessing the PRLs and scotomas of their patients as part of a complete evaluation.

**References**

Preferred retinal loci—Schuchard


Key words: age factor, macular degeneration, ocular fixation, scotoma