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Topographic mapping of residual vision by computer

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Background

Many low vision patients suffer from diseases that damage the retina only in selected areas, which can lead to a "scotoma" (blind spot) in perception. Most frequent are those suffering from age-related macular degeneration (AMD), whose foveal vision is often taken away by a central scotoma. This impairs vision of fine detail, which causes problems with reading and recognizing faces. One would think that differences between damaged and relatively intact areas should be painfully obvious to the patient. However, as clinical practice as well as scientific studies have shown, this is often not the case (Schuchard, 1995; Safran & Landis, 1996, 1999). Thus, patients and rehabilitation workers need to know where on the retina, or in the visual field, vision is still good enough to be useable? Having this information increases the chances for successful rehabilitation, the necessity and feasibility of which have been demonstrated (Otto, 1969; Bäckman & Inde, 1979; Park, 1999; Nilsson et al., 2003). This demonstrates the need for topographic assessment of remaining vision. The goal here is to describe the Macular Mapping Test and illustrate with case reports how it can be used in clinical practice to assist in assessment and rehabilitation of patients with central vision loss.

The ideal solution

Topographic assessment is best done by a Scanning Laser Ophthalmoscope (SLO) that shows live images of the retina and the stimulus that is scanned directly onto it. A useful vision assessment in AMD does not need to encompass the entire visual field. It can be restricted to the macula, a central area of 20 degrees diameter, where most Preferred Retinal Loci (PRL) develop (Fletcher & Schuchard, 1997). If small light spots are flashed onto the retina, the subject indicates which are detected and which are not ("micro-perimetry"). For precise placement of stimuli, modern software compensates for involuntary eye movements during testing, so that precise fixation is not necessary (MacKeben & Gofen, 2007). Since SLOs are expensive and rare, they are not available to most vision professionals.

What other means are available?

A. *Conventional perimetry* can provide relevant data, but it is time-consuming and requires sophisticated equipment and special expertise. Additionally, the resulting intensity thresholds are not needed to find useable remaining vision for rehabilitation.

B. The standard *"tangent screen test"* has shortcomings in that it makes it hard to include a discrimination (recognition) paradigm for a better measurement of visual performance. Furthermore, precisely timed target appearance and disappearance at defined locations is hard to implement, and results can vary with the skill level and personal habits of the examiner.

C. The "*Amsler Grid*" is a subjective test that is sensitive only to rather drastic changes, but not to those that develop over longer times. At best, it indicates where damage has been done, but not visual performance. In addition, the normal "filling-in" mechanism often prevents detection of scotomas of less than 5 degrees diameter (Ramachandran & Gregory, 1991; Schuchard, 1993).

Note that measuring visual acuity (v.a.) alone is insufficient, despite its importance for prescribing optical aids, because it has limited utility in predicting performance in activities of daily living, like reading (Bäckman, 2000; Crossland et al., 2005) or visually guided mobility (Marron & Bailey, 1982; Brown et al., 1986; Hassan et al., 2002) after central vision loss.

Subsets of the data presented here have been published previously (MacKeben et al., 1999; MacKeben & Colenbrander, 2000).

Test Description

Procedure: Although the Macular Mapping Test (MMT) is not new (MacKeben et al., 1999; MacKeben & Colenbrander, 2000), its role in vision rehabilitation has not been sufficiently described. It non-invasively tests detection and recognition of briefly shown single targets in the center and near periphery of the visual field. The duality of the task (detection PLUS recognition) distinguishes it from conventional perimetric procedures. Targets can be single letters, words, Landolt rings (Cs) or tumbling Es. The tested locations lie either in the center (4 trials) or on one of four concentric rings at 2, 4, 6 and 8 degrees eccentricity, each of which contains 8 locations (1 trial each). Target sizes are scaled according to eccentricity up to 8 degrees (see Fig. 1), which removes eccentricity as a variable.

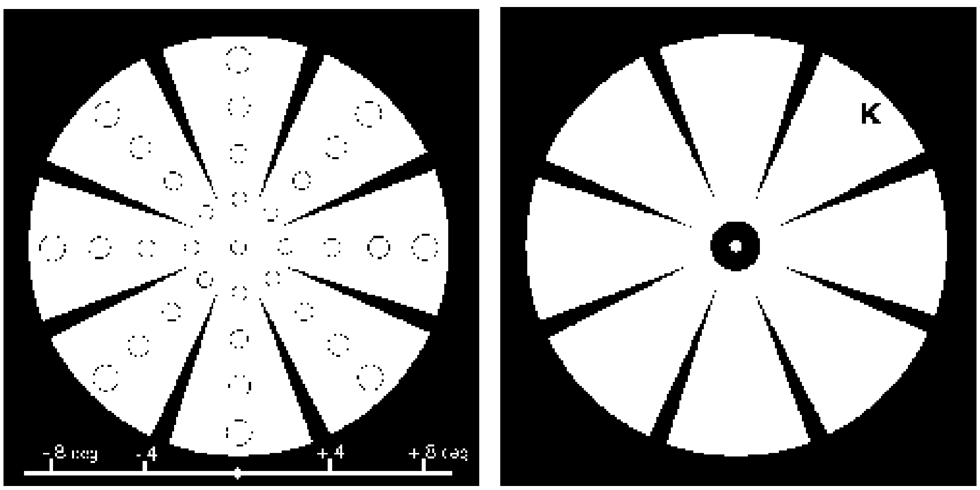

Figure 1 – *Left*: All locations, tested in random sequence. Diameters of circular symbols are scaled by eccentricity and denote target size. *Right*: This is what a subject might see during one trial (with fixation mark).

Thus, 33 locations are tested in 36 trials which takes about 3 minutes, on average. Each target appears at an unpredictable location and typically remains visible for ¼ second.

In the context of rehabilitation, the MMT has the goal of assessing and graphically displaying remaining macular vision. This aids finding intact retinal areas that are useable for eccentric viewing, of which the patient may be unaware. Moreover, it can also serve as tool for status assessment after therapy or training.

Subjects: The examples shown here were drawn from a group of tests run without pupil dilation on 134 eyes of 103 patients with AMD of all stages or Stargardt's disease, recruited from our Low Vision Service. All gave their informed consent, and the experiments were approved by the IRB at California Pacific Medical Center, San Francisco, and at The Smith-Kettlewell Eye Research Institute. All procedures were in compliance with the tenets of the declaration of Helsinki.

Instructions: It is crucial that subjects stabilize their gaze as much as possible during the test. The "wagon wheel" background pattern helps this purpose by providing peripheral feedback when an inadvertent eye movement occurs.

The following instructions are recommended: "Do you have a sense where the center of the circular display area is?" They invariably answer "Yes". And then: "Direct your gaze at that center and keep it there as still as possible – even if this makes the center disappear." Without such instructions, it is hard to know upon what part of the display subjects center their gaze. Those who have had a central scotoma for a long time are likely to automatically use a PRL (White & Bedell, 1990). Note that such patients may benefit less from this test, since they already have established eccentric viewing habits. On the other hand, if good visual acuity indicates that foveal vision has been spared so far, one can use a central fixation mark. Stabilizing the head with a chin rest is helpful, but not essential. It is necessary to use best optical correction for the viewing distance (typically 30 inches (73 cm) and to cover the non-tested eye.

Technique: The MMT runs on any PC under Windows (3.1 and later) by anyone without special computer expertise. It requires little hard disk space and memory and no hardware additions,

Procedure: The subject's task is to indicate verbally whether the target was detected and, if possible, recognized, which the examiner enters via keyboard. There are 3 possible responses: "Recognized", "detected but not recognized", and "not detected". The program scores each response and enters it into a database, from which they can be recalled and graphically displayed. To simplify the assessment of overall performance, the MMT provides a "field score" that combines the scores from all tested locations to a single number. Thus, a score close to 0 represents poor performance, one close to 36 signifies good performance. Target and background brightness can be set at 16 gray levels each to reduce contrast, which makes the test more sensitive to subtle changes that may not be noticeable by the patient if they do not affect the fovea, as in a "ring scotoma" (Messias et al., 2007).

Case reports

<u>Case 1:</u> 82 year old man, AMD, v.a. 20/80, was unaware of topographic vision variations. Central scotoma of at least 4 deg diameter, some damage also in the upper right, right and below (see Fig. 2A), a field score of 8, reads at 40 WPM with struggle. Two locations showed the possibility for PRLs in the upper and lower left (marked by "+" signs) because of intact space to the right of them. After training, reading speed had doubled, subjective sense of unease diminished.

<u>Case 2:</u> 72 year old woman, no diagnosis, v.a. 20/40, absolute scotoma in upper quadrant of visual field (see Fig. 2B), of which she is unaware, but says that her "vision is not as good as it used to be", reads fluently at 120 WPM. Sustained mild head injury by collision with a shelf.

<u>Case 3:</u> 74 year old woman, early AMD, v.a. 20/30, performed well at 92% contrast (field score = 30), and poorly at 14 % contrast (field score = 5.5). She requires very bright light for reading, but then reads 100 WPM.

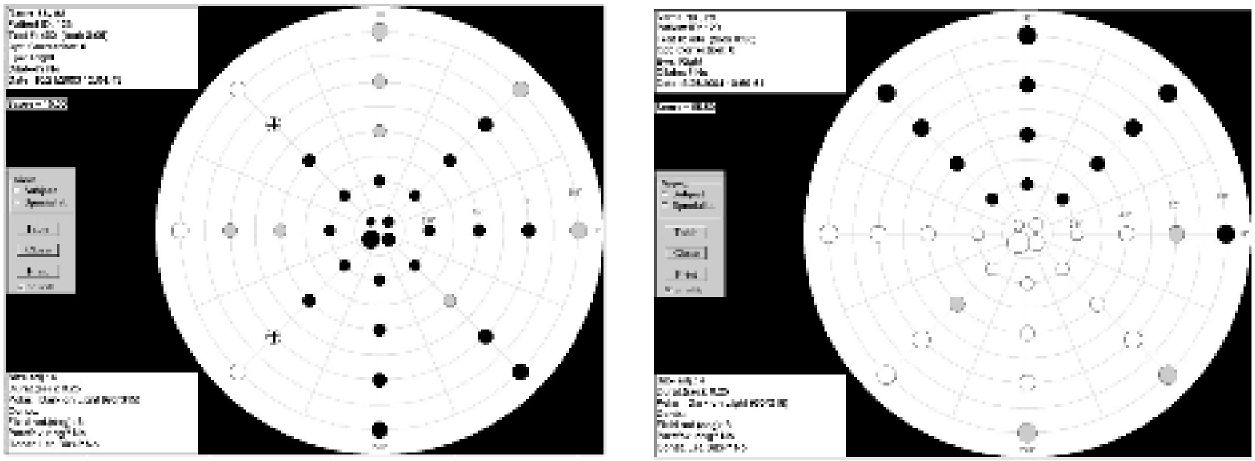

Figure 2 – Result charts from two patients (cases 1 + 2, see text for details). Symbols: Clear = target recognized, gray = detected, but not recognized, and black = not detected. *Left* – Two locations (marked by “+”) are candidates for PRLs. *Right* –No target detection in the upper quadrant, but intact foveal vision; four locations show only detection, but no recognition. This eye was asymptomatic in visual acuity testing (20/30).

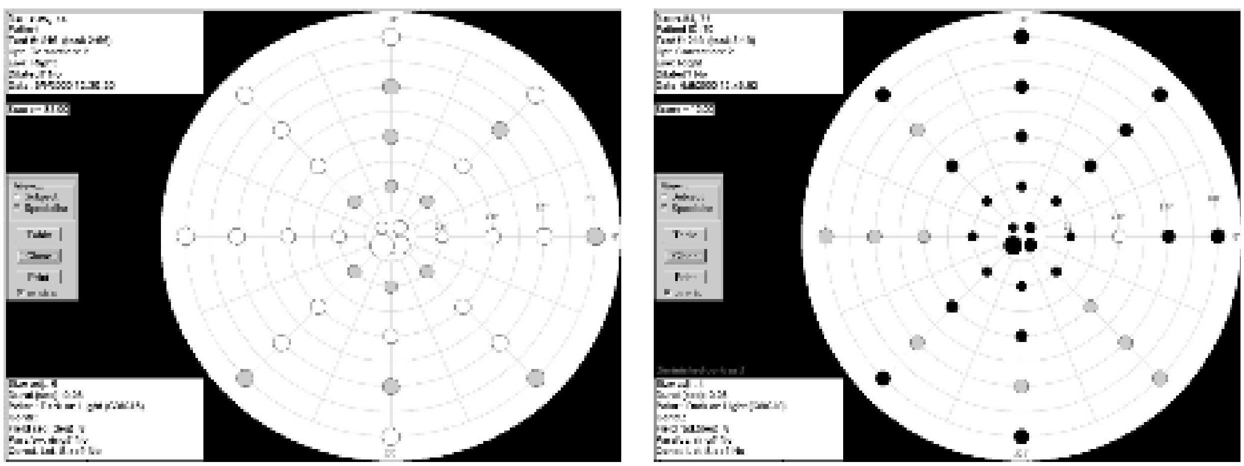

Figure 3 – Two charts from the same AMD patient, at high contrast (92%, left) and at 14 % contrast (right, see text for detail). Note substantial loss at the lower contrast, including complete loss of foveal vision.

These examples illustrate conspicuous topographic differences between individuals. Although many develop a dense central scotoma, this does not mean that early stages of AMD always affect the fovea first (see case #3, Fig.3, left).

Most of the patients considered here had visual acuities of 20/40 or better and, thus, did not necessarily have a reason to consult an eye care professional yet. However, they did, possibly for a check-up because the fellow eye had already been diagnosed with AMD.

Rehabilitation workers are concerned with finding areas of useable remaining vision, that is finding relatively intact areas that might be candidates to become a PRL for eccentric viewing. This topographic knowledge enables them to give patients specific advice to redirect gaze such that the object of interest falls on the candidate PRL (see Fig. 2A, locations marked “+”) and then to note whether the gaze adjustment was beneficial.

Most patients in this study reported that the MMT procedure was helpful, either by confirming what they had tentatively noticed before, or by teaching them something new. This is an important feature of the MMT, since the results are immediately visible and intuitive, and can easily be explained by the examiner.

Discussion

The MMT is not a high-precision procedure, but a simple tool to estimate the topography of remaining vision without the use of expensive and sophisticated equipment. Comparing MMT data with kinetic manual perimetry has shown good correspondence of the detection aspect of the task (Trauzettel-Klosinski et al., 2003). Additionally, many locations yielded sub-optimal scores due to the added requirement for recognition.

The success and accuracy of the MMT depend mostly on the steadiness of gaze, as does conventional perimetry. In people with beginning AMD, relatively steady gaze can be achieved in two ways: 1. By residual foveal vision, which allows using the fixation mark, or 2. by instructions to "use the old center of the retina", which many can do by their volition. For rehabilitation, people with already established eccentric viewing habits are not the best candidates for the MMT anyway, because they have already adjusted to their absolute central scotoma.

Advice given to the patient based on MMT results does not need to be of high precision, since the patient receives immediate sensory feedback that makes the process self-correcting. In essence, if the recommendation goes in the right direction, patients will take care of the rest, because they will know instantaneously what looks best to them and intuitively correct their gaze adjustment.

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Conflict of interest – The Macular Mapping Test is a commercial product published by "MMTest" (San Francisco), a small business owned by the author.

You can go to http://www.ski.org/Rehab/MacKeben/General/MMTest-webpage.html for a demonstration.

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