Scene Perception in Age-Related Macular Degeneration

Tbi Ha Chau Tran,1,2 Camille Rambaud,2 Pascal Despretz,1 and Muriel Boucart1

PURPOSE. To assess the scene gist recognition in eyes with age-related macular degeneration (AMD) and to study the relationship between scene recognition and macular function.

METHODS. Twenty-seven patients with age-related macular degeneration with a visual acuity lower than 20/50 and 17 age-matched controls were included. All patients underwent a visual field test, fundus autofluorescence, and fluorescein angiography to assess the visual field defect and the lesion size. The stimuli were colored photographs of natural scenes displayed on a 30-inch screen. Two scene categorization tasks were performed: natural versus urban and indoor versus outdoor scenes. Participants were given a target (e.g., indoor scenes) and asked to press a key when they saw a picture corresponding to that target. Accuracy and response times were recorded.

RESULTS. Patients with AMD were able to accomplish both categorization tasks with a high correct detection rate (above 75% correct), though performance was lower than in controls for both natural/urban scenes and indoor/outdoor scenes. Patients with AMD were more accurate and faster for natural/urban scenes than for indoor/outdoor scenes, but performance did not differ between the two categories in controls. No significant correlation was found between performance for scene categorization and clinical variables such as visual acuity, type of AMD, size of the scotoma, and size of the lesion.

CONCLUSIONS. Scene gist recognition can be accomplished with the low spatial resolution of peripheral vision. These results support the “scene-centered approach” that initial scene recognition is based on the global scene properties and not on the objects it contains. (Invest Ophthalmol Vis Sci. 2010;51: 6868 – 6874) DOI:10.1167/iovs.10-5517

Age-related macular degeneration (AMD) is the leading cause of legal blindness among the elderly in industrialized countries.1 Vision loss, in its late stage, is a consequence of one of two processes that cause photoreceptor dysfunction: geographic atrophy (dry AMD) or choroidal neovascularization (neovascular or wet AMD).

AMD affects the region with the highest density of photoreceptors: the macula, approximately 6 mm in diameter, covering the central 15–20° of the visual field. At late stages, once the spatial resolution of the fovea cannot be used and fixation is controlled, a preferred retinal location is developed.2 It is known that central vision is responsible for resolving fine details and that peripheral vision plays a role in spatial orientation and locomotion.3 Previous publications on vision-related quality of life in patients with AMD report difficulties in performing vision-related daily tasks, such as reading, writing, cooking, and driving, leading to a progressive loss of independence and decreased related functions.4–5 Patients with AMD also encounter more difficulties than do age-matched, normally sighted individuals when shopping (finding objects on shelves), managing money, preparing meals, performing light housework, and recognizing facial expressions and pictures, especially when the illumination level is low and during the transition from bright to dim illumination.6 These questionnaires suggest impaired object and scene recognition in patients with AMD.

In contrast to reading7–9 and face recognition,10–12 few investigations have been devoted to the deleterious impact of central vision loss on object and scene perception.12–15 Since central and peripheral vision serve different purposes—for instance, neuroimaging studies have shown that objects requiring large-scale feature integration (such as buildings) activate regions of the visual cortex corresponding to peripheral vision whereas objects requiring finer analysis (faces, words) are associated with center-biased representations14–16—it is interesting to understand how patients with central vision loss recognize natural scenes.

Studies on normally sighted young participants have shown that observers recognize a real-world scene at a single glance. In less than 100 ms the visual system forms a spatial representation of the world that is rich enough to grasp the meaning of the scene, recognizing some objects and other salient information.17–18 This representation refers to the gist of a scene.19 It includes all levels of processing, from low-level features (color, orientations, spatial frequencies, etc.) to intermediate image properties (surfaces, volumes) and high-level information (objects, contextual and semantic knowledge, familiarity, etc.).

The question of the contribution of central versus peripheral vision in scene gist recognition was recently addressed in normally sighted young people by Larson and Loschky.20 Participants were presented with photographs of real-world scenes (27° × 27° of visual angle) for 106 ms. Each scene was followed by a name (e.g., river). Participants were asked to decide if the scene matched the name. Performance was compared in two conditions: a window condition showing the central portion of the scene and blocking peripheral information, and a scotoma condition blocking out the central portion and showing only the periphery. The radii of the window and scotoma were 1°, 5°, 10.8°, and 13.6°. Performance was barely above chance in the 1° window condition, suggesting that foveal vision is not useful for recognizing scene gist. Accuracy increased as the radius of the window increased. Conversely, when participants had information from everything but not foveal vision (in the 1° scotoma condition), performance was equal to seeing the entire image. Based on these data, the authors suggested that peripheral (and parafoveal vision) is

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more useful than high-resolution foveal vision for scene gist recognition.

In the present study, we assessed whether scene gist recognition can be accomplished by low-resolution peripheral vision in people with central vision loss. We compared performance for two spatial properties corresponding to different levels of scene analysis: a categorization based on naturalness (natural versus urban scenes) and a categorization in terms of indoor versus outdoor scenes. Though these two properties are considered as holistic or global (i.e., the categorization can be based on the overall layout), studies on young normally sighted observers have shown longer categorization times (around 470 ms) for indoor versus outdoor scenes than for naturalness (around 390 ms), likely because a more local (object) analysis is required to discriminate between indoor and outdoor scenes whereas a coarse perception based on orientation and color is sufficient to decide if a scene is natural or urban. As central vision is involved in fine perception and information is more coarsely encoded in the periphery, we expected patients with AMD to be more impaired in the indoor/outdoor categorization task than for naturalness. Second, we investigated the correlation between visual acuity, scotoma size, lesion size, and performance for scene categorization.

**METHODS**

**Participants**

**Patients with AMD.** Twenty-seven patients with a confirmed diagnosis of AMD were recruited. Inclusion and exclusion criteria are summarized in Table 1. Only one eye of each patient was studied. In cases of bilateral AMD, we considered the eye with the best corrected visual acuity. If both eyes had equal acuity, one eye was randomly selected.

**Controls.** The age-matched healthy controls consisted of 17 volunteers. The control participants had no history of ophthalmologic or neurologic diseases and no cognitive impairment. Control participants were either relatives of participants with AMD or patients who have had successful cataract surgery with uncorrected visual acuity ranging from 20/25 to 20/20. Controls were tested monocularly on their preferred eye.

Both participants with AMD and controls were recruited from March 2009 to January 2010 in the Ophthalmology Department of Saint Vincent de Paul Hospital, Lille, France. The study was approved by the ethics committee of Lille, in accordance with the tenets of the Declaration of Helsinki. Written informed consent was obtained from all participants.

**Clinical Examination**

**Ophthalmologic Examination.** Best corrected visual acuity was determined using early treatment diabetic retinopathy study charts at a distance of 4 m, which was converted to logMAR visual acuity for statistical purposes. Slit lamp examination, intraocular pressure, and funduscopy were performed in all patients and controls.

**Imaging Studies and Lesion Size Measurement.** Fundus autofluorescence was performed in atrophic AMD and fluorescein angiography in neovascular AMD, using a confocal scanning laser ophthalmoscope (Heidelberg Retina Angiograph, HRA2; Heidelberg Engineering, Dossenheim, Germany). The optical and the technical principles of this have been described previously. The area of geographic atrophy (mm²) was measured by outlining dark atrophic areas using image analysis software (Heidelberg Eye Explorer; Heidelberg Engineering).

The diagnosis of neovascular AMD was confirmed by fluorescein angiography.

The entire complex component (choroidal neovascularization, elevated blocked fluorescence, thick blood) is considered to constitute the neovascular lesion. Lesion components also included contiguous flap-blocked fluorescence, fibrous tissue, and thin flat scars. The area of the lesion (mm²) was measured from digital angiograms by outlining the lesion, using image analysis software (Heidelberg Eye Explorer).

**Visual Field Test.** Central and peripheral visual fields were assessed using an evaluation program (Mix-30 with Vision Monitor; Metrovision, Lille, France). This program combines the evaluation of the peripheral visual field with the kinetic perimetry to the evaluation of the central field with the FAST perimetry (94 points) (more technical details can be found at http://metrovision.fr).

The test luminance of central and intermediate isopters was adjusted automatically to obtain responses at 30° and 15° eccentricity. Eight additional measurements were used to determine the blind spot contour. The stimulus was displaced at a constant velocity of 10° per second for the peripheral isopter, 5° per second for the intermediate, and 2° per second for the central isopter and the blind spot contour. Fixation was monitored throughout the examination with an infrared camera. Only visual field tests with <2 losses of fixation were used for statistical analysis. The volume of sensitivity loss (dB/deg²), computed by the software described above, was used to measure visual field deficit. Clinical assessment and experiments were scheduled within 1 week.

**Experiments**

**Stimuli.** The stimuli were photographs of natural scenes. Two scene properties were selected: naturalness (natural versus urban scenes) and indoor/outdoor scenes. Examples are shown in Figure 1. The angular size of the photographs was 15° × 15° at a viewing distance of 1 m. The participant’s head was not fixed.

**Apparatus.** Pictures were centrally displayed on a 30-inch screen (Dell, Dallas, TX) connected to a computer (T 3400; Dell). Participants responded on a box containing two keys connected to the computer. The software was written by one of the authors (PD) in a general-purpose programming language (C++). People were tested in a dimly

<table>
<thead>
<tr>
<th>Table 1. Inclusion and Exclusion Criteria for AMD Participants</th>
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<tbody>
<tr>
<td><strong>Inclusion criteria</strong></td>
</tr>
<tr>
<td>Willing to give informed consent</td>
</tr>
<tr>
<td>Clinical diagnosis of atrophic AMD or neovascular AMD well defined with subfoveal involvement confirmed by fluorescein angiography</td>
</tr>
<tr>
<td>Best corrected visual acuity between 20/40 and 20/400 in the eye to be studied</td>
</tr>
<tr>
<td>Refraction between +3 D and −3 D</td>
</tr>
<tr>
<td><strong>Exclusion criteria</strong></td>
</tr>
<tr>
<td>History of any neurological or psychiatric disease</td>
</tr>
<tr>
<td>History of ophthalmologic disease other than AMD that might compromise its visual acuity or peripheral vision during the study (amblyopic, uncontrolled glaucoma, optic neuropathy, diabetic retinopathy, uveitis)</td>
</tr>
<tr>
<td>Unable to communicate (deafness)</td>
</tr>
<tr>
<td>Treated with medication that might compromise concentration (benzodiazepine, narcoleptics)</td>
</tr>
<tr>
<td>Mental deterioration with MMSE &lt; 24</td>
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</table>

MMSE, Mini-Mental State Examination.
illuminated room. The luminance of the gray background was 56
cd/m², measured by a photometer (CS 100; Minolta, Paris, France).

Procedure. A black fixation cross (5°) was centrally displayed for
500 ms and followed by a single photograph of a scene centrally
displayed for 300 ms. This duration was long enough for the patients
to perceive it but short enough to allow a single fixation.

Participants were given a target for each categorization task. For
naturalness, urban scenes were chosen as target for half of the partic-
ipants and natural scenes for the other half of the participants. The
same procedure was used for indoor/outdoor scenes. A scene ap-
peared every 3 seconds. Participants were asked to press a key as soon
as they saw a picture corresponding to the predefined target. There
were 100 trials/category: 50 targets (e.g., natural scenes) and 50 dis-
tractors (e.g., urban scenes). Participants were given a few trials to
familiarize with the exposure duration and the task, usually <20.

Measurements. Responses were recorded on the basis of the
signal detection theory with correct detections of the target (natural
or urban; indoor or outdoor) quoted as hits, detection of a target when
there was none quoted as a false alarm, failure to detect the target
when it was present quoted as an omission, and no response when the
target was absent quoted as correct rejections. Based on these data the
d' index of sensitivity was computed for each participant for each
categorization. Performance was evaluated in terms of hits, false
alarms, and response times (RTs).

Statistical Analysis

The differences between groups were assessed by analyses of vari-
ance. The between-subject factor was group (controls, patients
with AMD). The within-subject factor was the type of categorization
(natural/urban scenes and indoor/outdoor scenes).

Correlations between parameters of performance (hits, false
alarms) for each level of categorization and logMAR visual acuity, lesion
size measurement, and size of scotoma were performed by using
Pearson’s correlation or nonparametric Spearman rank correlation
coefficient \( r \) when necessary and the matching significance of the
correlation \( P \). Statistical significance is reported as \( P < 0.05 \). All
data were analyzed using statistical software (Statistica, v8; Statsoft,
Mains-Alfort, France).

RESULTS

Demographic and Clinical Data

The demographic details and clinical data of both AMD and
control groups are summarized in Table 2. Twenty-seven pa-
tients with AMD were included in the study: 10 had dry AMD,
and 17 had neovascular AMD. The mean age was 79 years,
ranging from 59 to 91. The mean logMAR visual acuity was

| Table 2. Demographic and Clinical Data of the Study Population |
|-----------------|-----------------|
| AMD participants, \( n \) | 27 |
| Age in years, mean ± SD (range) | 79 ± 7.5 (59–91) |
| Sex, M/F | 10/17 |
| MMSE score, mean ± SD | 28 ± 1.5 |
| LogMAR VA, mean ± SD | 0.9 ± 0.3 |
| Lesion size in mm², mean ± SD (range) | 13.4 ± 14 (1.46–52) |
| Loss of sensitivity in dB/deg², mean ± SD (range) | 806 ± 483 (91–1492) |
| Controls, \( n \) | 17 |
| Age in years, mean ± SD | 74 ± 8.5 |
| Sex, M/F | 4/13 |
| LogMAR VA, mean ± SD | 0.03 ± 0.04 |
| MMSE score, mean ± SD | 29.5 ± 1.1 |

MMSE, Mini-Mental State Examination.
0.9 ± 0.3 (approximate Snellen visual acuity 20/100). The size of the lesion was variable, ranging from 1.46 to 15 mm² with a mean size of 13.4 ± 14 mm². In dry AMD the mean surface of atrophia was 19 mm², and in neovascular AMD the mean surface of the lesion was 10.5 mm². The mean greatest diameter of the lesion in neovascular AMD was 3.7 mm, corresponding to a central scotoma of approximately 12° of visual angle.²

Central and peripheral visual fields were available in 24/27 patients. Examples are shown in Figure 2. In three patients, visual field measurement was not possible because of fatigue and poor vision (20/400) and multiple loss of fixation during the test. No patient exhibited constriction of the peripheral isopter. They responded to the test luminance (310 cd/m²) at least 60° temporally, 45° nasally, 30° superiorly, and 45° inferiorly. FAST perimetry revealed a central scotoma in all patients, which included absolute (deficit above 20 dB) and relative scotoma (loss of sensitivity) in 20/24 eyes. Relative scotoma was found in 4/24 eyes. The scotoma were recorded eccentrically in four patients, because of new preferred retinal locations. Perimetric results can be considered as valid if interpretation accounts for eccentric fixation.²⁰ The absolute scotoma size varied from 5° to 30° of eccentricity. Since the patterns of the scotoma was variable, and macular scotometry based on conventional perimetry has limited accuracy because of unstable fixation,²⁰ the volume of sensitivity loss, computed by software (VisionMonitor Software LLC, Lille, France) was used for statistical purposes.

Results of the Experiments

Performance, in terms of correct detections (hits) and d’ index of sensitivity, is displayed in Figure 3.

Scene Category for Both AMD and Controls. Averaged over all participants, there was no significant difference in terms of correct detections (hits) and response times between indoor (606 ms and 85.8% hits) and outdoor (613 ms and 84.8% hits).
The purpose of the study was to investigate the role of peripheral vision in scene gist recognition. The results indicate that scene gist recognition can be accomplished with low-resolution peripheral vision as patients with central vision loss were able to recognize scenes with high accuracy in two types of categorization: natural versus urban scenes and indoor versus outdoor scenes in people with AMD (d' = 3.6 vs. 2.33, \( t_{(26)} = 4.59, P < 0.01 \)), but not for controls (d' = 5.15 vs. 4.79, \( t_{(15)} = 2.29, P = 0.05 \); Fig. 3).

**Relationship between Visual Function, Lesion Size, and Performance of Categorization**

There was a correlation between the volume sensitivity loss and response times in the category indoor/outdoor (r = -0.47, P = 0.05). No relationship was found between parameters of performance (in terms of hits and d') and clinical data (visual acuity, lesion size, loss of sensitivity in any type of AMD) in indoor/outdoor categorization. No relationship was found between performance (in terms of hits and d') for natural/urban categorization and any clinical data.

**DISCUSSION**

The purpose of the study was to investigate the role of peripheral vision in scene gist recognition. The results indicate that scene gist recognition can be accomplished with low-resolution peripheral vision as patients with central vision loss were able to recognize scenes with high accuracy in two types of categorization: natural versus urban scenes and indoor versus outdoor scenes in people with AMD (d' = 3.6 vs. 2.33, \( t_{(26)} = 4.59, P < 0.01 \)), but not for controls (d' = 5.15 vs. 4.79, \( t_{(15)} = 2.29, P = 0.05 \); Fig. 3).

**Table 3. Difference in Performance between Groups for Each Scene Category**

<table>
<thead>
<tr>
<th>Category</th>
<th>AMD Patients</th>
<th>Controls</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both Categories Combined</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hit, %</td>
<td>81.8</td>
<td>95.7</td>
<td>&lt;0.025</td>
</tr>
<tr>
<td>Response times, ms</td>
<td>576</td>
<td>563</td>
<td>NS</td>
</tr>
<tr>
<td>False alarms, %</td>
<td>9</td>
<td>3.5</td>
<td>&lt;0.002</td>
</tr>
<tr>
<td>Natural/Urban</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hit, %</td>
<td>84.4</td>
<td>96</td>
<td>&lt;0.009</td>
</tr>
<tr>
<td>Response times, ms</td>
<td>565</td>
<td>548</td>
<td>NS</td>
</tr>
<tr>
<td>False alarms, %</td>
<td>6.4</td>
<td>2</td>
<td>&lt;0.023</td>
</tr>
<tr>
<td>Indoor/Outdoor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hit, %</td>
<td>79.2</td>
<td>95.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Response times, ms</td>
<td>628</td>
<td>579</td>
<td>NS</td>
</tr>
<tr>
<td>False alarms, %</td>
<td>11.6</td>
<td>5</td>
<td>&lt;0.006</td>
</tr>
</tbody>
</table>

NS, not significant.

Both groups (AMD: 11.6% vs. 6.4%, \( t_{(26)} = 2.79, P < 0.01 \), and controls: 5% vs. 2%, \( t_{(15)} = 2.68, P < 0.01 \); Table 4).

Sensitivity (measured by the d' of the signal detection theory) raised a better sensitivity for natural/urban than for indoor/outdoor scenes in people with AMD (d' = 3.6 vs. 2.33, \( t_{(26)} = 4.59, P < 0.01 \)), but not for controls (d' = 5.15 vs. 4.79, \( t_{(15)} = 2.29, P = 0.05 \); Fig. 3).

**Table 4. Difference in Performance between Categories in AMD and Control Groups**

<table>
<thead>
<tr>
<th>Category</th>
<th>Natural/Urban</th>
<th>Indoor/Outdoor</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hit, %</td>
<td>84.4</td>
<td>79.2</td>
<td>&lt;0.003</td>
</tr>
<tr>
<td>Response times, ms</td>
<td>565</td>
<td>628</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>False alarms, %</td>
<td>6.4</td>
<td>11.6</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>d' sensitivity</td>
<td>3.6</td>
<td>2.33</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hit, %</td>
<td>96</td>
<td>95.4</td>
<td>NS</td>
</tr>
<tr>
<td>Response times, ms</td>
<td>548</td>
<td>579</td>
<td>NS</td>
</tr>
<tr>
<td>False alarms, %</td>
<td>2</td>
<td>5</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>d' sensitivity</td>
<td>5.15</td>
<td>4.79</td>
<td>NS</td>
</tr>
</tbody>
</table>

NS, not significant.
Scenes of daily life, such as movies, stairs, street signs, and nature, are critical to vision-related quality of life.202122 The authors thank Aude Oliva for providing her photographs of scenes.

The authors thank Aude Oliva for providing her photographs of scenes and to Lucie Descamps for testing participants.

References