Figure

Ground Discrimination in Age-Related Macular Degeneration

Thi Ha Chau Tran,1,2 Nathalie Guyader,5 Anne Guerin,5 Pascal Despretz,1 and Muriel Boucart1

PURPOSE. To investigate impairment in discriminating a figure from its background and to study its relation to visual acuity and lesion size in patients with neovascular age-related macular degeneration (AMD).

METHODS. Seventeen patients with neovascular AMD and visual acuity <20/50 were included. Seventeen age-matched healthy subjects participated as controls. Complete ophthalmologic examination was performed on all participants. The stimuli were photographs of scenes containing animals (targets) or other objects (distractors), displayed on a computer monitor screen. Performance was compared in four background conditions: the target in the natural scene; the target isolated on a white background; the target separated by a white space from a structured scene; the target separated by a white space from a nonstructured, shapeless background. Target discriminability (d') was recorded.

RESULTS. Performance was lower for patients than for controls. For the patients, it was easier to detect the target when it was separated from its background (under isolated, structured, and nonstructured conditions) than it was when located in a scene. Performance was improved in patients with increasing exposure time but remained lower in controls. Correlations were found between visual acuity, lesion size, and sensitivity for patients.

CONCLUSIONS. Figure/ground segregation is impaired in patients with AMD. A white space surrounding an object is sufficient to improve the object’s detection and to facilitate figure/ground segregation. These results may have practical applications to the rehabilitation of the environment in patients with AMD.

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Age-related macular degeneration (AMD) reduces central vision in elderly persons, resulting in reduced capacity to perform many daily activities.1–3 Although difficulties with reading and face perception are the most common clinical symptoms of patients with AMD, vision function questionnaires show the AMD patients exhibit difficulty finding objects under crowded conditions.1,2 Some studies have examined object perception in persons with low vision3–5 with pictures of objects in isolation. Yet objects in the real world rarely appear without some background. Objects are always located within a setting and within other objects. Boucart et al.6 compared performance with photographs of isolated objects and with the same objects in their natural environments in 15 patients with AMD and 11 age-matched normally sighted persons. Photographs were presented for 300 ms each, and observers were asked to press a key when they saw an animal. The results showed that persons with AMD were more accurate in detecting isolated objects than in detecting the same objects in scenes. Normally sighted persons were equally accurate for the two versions of images, but they were faster for objects in their natural settings than for isolated objects. The improved performance for isolated objects, compared with objects in a natural scene, was attributed to a higher sensitivity to crowding in persons with AMD, who must rely on their peripheral vision. Crowding refers to the decreased visibility of a visual target in the presence of nearby objects or structures. It impairs the ability to recognize objects in clusters, and its detrimental effect is more pronounced in the periphery.7–9

The present study further explores the nature of figure/background discrimination in patients with AMD. Crowding has been suggested as a contributor to impaired peripheral reading in previous studies in persons with central vision loss. However, two recent studies10,11 reported that an increase in line spacing provided little benefit for patients with AMD. Chung et al.10 found that as long as line separation is approximately 1× to 1.25× the standard, there is no added benefit of printing text at a larger line separation for patients with AMD. Calabrese et al.11 controlled two other aspects that can interfere with the effect of interline spacing. One is the presence of an island of spared vision within the macular scotoma (with such an island, adjacent lines of text above and below are likely to be masked by the scotoma irrespective of interline spacing). The other is that the estimated eccentricity at which reading occurs as the key signature of crowding is that it is proportional to eccentricity.12 Calabrese et al.11 found a small effect of interline spacing on maximal reading speed. They concluded that increasing interline spacing benefits only very slow readers.

To our knowledge, no study has investigated whether introducing a space between an object and its background would reduce crowding and help figure/ground discrimination in persons with low vision. In the present study, we compared performance for detecting a target object in a photograph of a scene, for detecting a target object when it is isolated on a white background, and for detecting a target object when it is separated from the background by a white space.
It has been reported that the magnitude of crowding is affected by the configurable properties of the surrounding. Livne and Sagi found that crowding was reduced, and even disappeared, when the flankers were arranged in a continuous complete circular configuration compared with the same configuration without closure. Based on this finding, we compared performance for a target object located in a structured background (a natural setting) versus for a target object located in a nonstructured, shapeless background. Examples are presented in Figure 1. Studies on normally sighted young observers have shown that an object is more easily detected on a structured background that is consistent with the object (e.g., a toaster in a kitchen) than when the object is located on a nonstructured, meaningless background. If the background appearing in the periphery is processed efficiently in persons with AMD, performance should be better for a target located on a structured background than for the same object in a nonstructured background. We were also interested in assessing whether exploration time facilitates object recognition and figure/ground segregation in patients with central vision loss. The pictures were displayed for a duration allowing a single fixation and for a longer duration allowing exploration. Finally, we studied the correlation of the performance of neovascular AMD patients with visual acuity and the size of the lesion.

**TABLE 1.** Inclusion and Exclusion Criteria for the AMD Participants

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

**Patients and Methods**

**Patients**

Seventeen patients (7 women, 10 men; mean age, 77 years) with neovascular AMD were included. They exhibited no cognitive impairment as assessed by the Mini Mental State Evaluation (MMSE). Scores varied between 25 and 30 (mean, 28.5). Neovascular AMD was confirmed by fluorescein angiography. Only one eye of each patient was studied. In patients with bilateral AMD, we considered the eye with the best-corrected visual acuity (BCVA). If both eyes had equal acuity, one eye was randomly selected. Criteria for inclusion and exclusion are displayed in Table 1. Patients had a visual acuity of 0.7 ± 0.4 logMAR (equivalent Snellen visual acuity 20/80).

**Controls**

The age-matched control group with normal visual acuity was composed of 17 observers (10 women) ranging in age from 61 to 86 (mean, 74.6 years). Scores varied between 25 and 30 (mean, 29.3). They had no ocular or neurologic diseases. Control participants were either relatives of the participants with AMD or patients who had undergone cataract surgery. Controls were tested monocularly on their preferred eye. Clinical and demographic data are given in Table 2.

Both participants with AMD and the controls were recruited from July 2009 to January 2010 in the Ophthalmology Department of Saint...
TABLE 2. Demographic and Clinical Data of the Study Population

<table>
<thead>
<tr>
<th>AMD participants (n = 17)</th>
<th>Sex, M/F</th>
<th>Age in years, mean (range)</th>
<th>Mean MMSE</th>
<th>Mean logMAR VA</th>
<th>Lesion size in mm², mean (range)</th>
<th>Greatest diameter in mm, mean (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10/7</td>
<td>81 ± 8 (60–92)</td>
<td>28.5 ± 1.4</td>
<td>0.7 ± 0.4</td>
<td>9.38 ± 7.7 (1.88–34)</td>
<td>3.3 ± 1.2 (1.7–6.5)</td>
</tr>
</tbody>
</table>

Values are mean ± SD unless otherwise noted.

Vincent de Paul Hospital in 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. BCVA was determined using Early Treatment Diabetic Retinopathy Study (ETDRS) 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 on all patients and controls.

Imaging Studies and Lesion Size Measurement. 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 flat, blocked fluorescence, fibrous tissue, and thin flat scars. The area of the lesion (mm²) and the greatest diameter of the lesion were measured from digital angiograms by outlining the lesion using image analysis software (Eye Explorer; Heidelberg Engineering, Heidelberg, Germany).16–17 Clinical assessment and experiments were performed at the same visit.

Stimuli and Apparatus

The stimuli were displayed on a 50-inch color monitor (Dell, Round Rock, TX) connected to a computer (T3400; Dell). The stimuli were colored photographs of natural scenes taken from a large commercial CD database (Corel, Ottawa, ON, Canada). They were displayed on a light gray background (56.2 cd/m²). The software was developed by one of the authors (PD) in C++ and was used to display the scenes on a monitor. The scenes contained an animal (the target), and the other half (distractors) contained no animal.

Animal targets included fish, birds, mammals, insects, and reptiles. Distractors included landscapes, trees, flowers, various objects, monuments, and means of transportation. The image resolution was 768 (horizontal) × 512 pixels, with a screen set at a resolution of 1024 × 768 pixels. At a viewing distance of 1 m, the angular size of the pictures was 20° horizontally and 15° vertically. The original photographs (the “scene” condition) were manipulated with imaging software (Photoshop CS, version 8.01; Adobe, San Jose, CA) to generate three new versions of each image: one in which the target animal or a distractor object was extracted from the scene and presented at the same spatial location on a white background (the “isolated” condition), one in which the target or the distractor object was surrounded by a white rectangle and replaced in the scene (the “structured background” condition), and one in which the target or the distractor object was surrounded by a white rectangle and replaced in a modified disorganized version of the original background (the “nonstructured background” condition). The nonstructured backgrounds were built from the original scenes using an algorithm proposed by Portilla and Simoncelli18 that captures the local structure of the original image and transforms it in a disorganized texture by means of a wavelet transform (see Fig. 1). This results in a synthesized image with artificial textures in which colors and shading remain. Responses were recorded by means of a response box containing two keys connected to the computer.

Procedure

A black (5°) central fixation cross was displayed for 500 ms, followed by a blank interval of 500 ms, and then by a centrally presented stimulus. A go/no-go paradigm was used. Participants were asked to press a key when they saw an animal and to refrain from responding when no animal was present. They were told that an animal would be present in 50% of the images. Participants were tested in two sessions—one short exposure duration session in which each stimulus was displayed for 300 ms and one long exposure duration session in which the stimulus was displayed for 3000 ms—separated by a pause of 10 minutes. Half the participants in each group started with the short exposure duration, and the other half started with the long exposure duration session. Each session was composed of 200 trials determined by 50 scenes (25 targets and 25 distractors) for each background condition (isolated, scene, structured, and nonstructured).

For each condition, an image was randomly selected from a set of 50 images with an animal (targets) and 50 images featuring no animals (distractors). The intertrial interval was fixed at 2 seconds; that is, participants were given 2 seconds to respond in the go condition (when an animal was present), and a new image appeared after 2 seconds in the no-go condition (when no animal was present). Responses were recorded on the basis of the signal detection theory with the correct detection of the target animal designated as a hit, the detection of a target when absent designated as a false alarm, the failure to detect the target when present designated as an omission, and no response in the absence of the target designated as a correct rejection.

To avoid the problem of infinite z-score values for 100% hits and 0% false alarms in cases of perfect discriminability, a correction was applied: the proportions of hits and false alarms were set at 0.99 (for 100%) and 0.01 (for 0%). Based on these data, a d’ index of sensitivity was computed for each participant and each condition.

Statistical Analysis

Analyses of variance were conducted on the d’ index of sensitivity. The factors were group (patients with AMD vs. normally sighted controls), two exposure durations (300 vs. 3000 ms), and four background conditions (isolated object, scene, structured background, nonstructured background).

Correlations between performance (sensitivity index) and clinical parameters (logMAR visual acuity and the largest diameter of the lesion) were performed by using Pearson’s correlation coefficient (r) and the matching significance of the correlation (P). Statistical significance is reported as P < 0.05. All data were analyzed using statistical software (Statistica version 8; StatSoft, Maisons-Alfort, France).

RESULTS

Results are presented in Figure 2 for sensitivity and Table 3 for target detection (hits and false alarms).

Effect of Group

A significant main effect of group was observed with a higher sensitivity for controls than for patients with AMD (d’ = 4 vs. 2.64 F₁,₅₂ = 40; P < 0.001).

Effect of Exposure Duration

The increase in exposure duration increased sensitivity (3.58 vs. 3.07 F₁,₅₂ = 36.5; P < 0.001). The group interacted significantly with exposure duration (F₁,₅₂ = 24.2; P < 0.001). As can be seen from Figure 2, sensitivity for target
The effect of background condition was significant (Effect of Background patients (d’ = 2.86; nonstructured background, d’ = 2.70) than when it was in a scene (d’ = 2.49). The effect of the background condition was significant in the patient group (F(3, 48) = 5.7; P < 0.004) but not in the control group (F < 1). The interaction between group and background just failed to reach statistical significance (F(3, 96) = 2.6; P = 0.058).

Correlations between Sensitivity and Clinical Data in AMD Participants

Correlations between sensitivity, visual acuity, and lesion size are summarized in Table 4. Significant correlations were found between sensitivity and visual acuity in all background conditions, both at 300 ms and at 3000 ms. The correlation between sensitivity and visual acuity was lower when the target was in a scene (r = 0.52; P < 0.01; df = 15) than when it was isolated (r = 0.76; P < 0.01; df = 15) or separated by a white rectangle from either a structured background (r = 0.62; P < 0.01; df = 15) or a nonstructured background (r = 0.78; P < 0.01; df = 15). The relation between sensitivity and visual acuity was also stronger in all background conditions when the exposure time was longer. Sensitivity correlated significantly with lesion size in all background conditions when the exposure duration was long (3000 ms) but was significant only with the scene background when the exposure duration was short (300 ms).

**DISCUSSION**

The main results can be summarized as follows: Performance was lower for patients with AMD than for controls at both exposure times. With the exception of the photographs of real-world scenes at short exposure time, target detection was well above chance (>70% correct) for patients with AMD. Correlations were found between visual acuity, lesion size, and sensitivity in all conditions at long exposure time and in the 'scene' condition at short exposure time. Patients with AMD were able to detect the target with more efficiency when it was separated from the background than when it was located in a scene. Background condition did not significantly affect performance in normally sighted controls except for the nonstructured background condition in which the number of false alarms was higher than in the other background conditions for

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**Table 3. Percentages of Correct Detections (Hits) and False Alarms of Patients with AMD and Controls in the Different Background Conditions and the Two Exposure Times**

<table>
<thead>
<tr>
<th></th>
<th>Isolated</th>
<th>Structured</th>
<th>Non-structured</th>
<th>Scene</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>300 ms</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patients</td>
<td>70 ± 23</td>
<td>3.3 ± 0.7</td>
<td>1.6 ± 0.3</td>
<td>62 ± 23</td>
</tr>
<tr>
<td>False alarms</td>
<td>3.3 ± 0.7</td>
<td>1.2 ± 0.3</td>
<td>0.6 ± 0.2</td>
<td>1.6 ± 0.3</td>
</tr>
<tr>
<td><strong>3000 ms</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patients</td>
<td>74.5 ± 19.7</td>
<td>2.1 ± 0.5</td>
<td>70.8 ± 20.1</td>
<td>70.8 ± 20.1</td>
</tr>
<tr>
<td>False alarms</td>
<td>5.6 ± 0.2</td>
<td>3.6 ± 0.3</td>
<td>3.6 ± 0.2</td>
<td>3.6 ± 0.2</td>
</tr>
</tbody>
</table>

Values are mean ± SD.
both groups of participants (Table 3). However, the number of false alarms was, on average, very low for both groups. Performance for patients with AMD improved with the increase in exposure time but remained lower than for normally sighted controls.

As expected, performance was lower in patients with AMD than in controls because of central vision impairment. Decreased visual acuity and larger lesion size were associated with low performance in terms of sensitivity on target detection. This relation likely occurred because the task involved detailed processing: the discrimination of an object from its background.

In contrast to controls, results improved significantly in patients with AMD when targets were separated from their background than when targets were in scenes (Fig. 2, Table 3). This effect was more pronounced when the exposure time did not allow exploration (300 ms), but the same tendency was present when exploration was possible (3000 ms). This result replicates previous data6 and elaborates on them by showing that the target object does not have to be completely isolated on a white background. A white space surrounding the object is sufficient enough to improve its detection and to facilitate figure/ground discrimination. Patient performance increased by 17.5% in terms of sensitivity when the object was separated from its background by a white space. The detrimental effect of scene background (without a white space surrounding the object) likely reflected impaired figure/ground segregation in patients with AMD. Higher sensitivity to crowding does not allow exploration (300 ms), but the same tendency was present when targets were in scenes was still above chance in patients with AMD. Object detection is correlated with visual acuity and with lesion size. Performance is improved when the exposure time is longer and when the target is isolated from the background. The results of the present study may have practical applications in the rehabilitation of the spatial environment of elderly persons with low vision.

### Acknowledgments

The authors thank Christabel Sabtala and Emmanuelle Boloix for building the images, Sarah Fauque for working with the participants, and Steven Ola for checking the English of the manuscript.

### References


### Table 4. Relations among Visual Acuity, Lesion Size, and Sensitivity Index (d’) for Each Background Condition and Exposure Time

<table>
<thead>
<tr>
<th>Condition</th>
<th>Exposure Time</th>
<th>LogMAR VA</th>
<th>Lesion Size</th>
<th>LogMAR VA</th>
<th>Lesion Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isolated</td>
<td>300 ms</td>
<td>0.76*</td>
<td>NS</td>
<td>0.81†</td>
<td>0.51*</td>
</tr>
<tr>
<td>Structure</td>
<td>300 ms</td>
<td>0.52†</td>
<td>0.53*</td>
<td>0.77†</td>
<td>0.47*</td>
</tr>
<tr>
<td>Scene</td>
<td>3000 ms</td>
<td>0.62†</td>
<td>NS</td>
<td>0.82†</td>
<td>0.59*</td>
</tr>
<tr>
<td>Nonstructured</td>
<td>3000 ms</td>
<td>0.78*</td>
<td>NS</td>
<td>0.84†</td>
<td>0.56*</td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level (df = 15).
† Correlation is significant at the 0.01 level (df = 15).


