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IMAGE ENHANCEMENT IMPROVES FACE RECOGNITION

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Image enhancement has been proposed as a potential aid for the visually impaired (1). Digital image enhancement may be used to improve visibility of video images and printed pictures. We demonstrated its value with optically simulated cataracts (1). Use of enhancement filters based on the patient's contrast sensitivity function was shown to modestly reduce magnification demands for reading of patients with central scotoma (2). However, the value of image enhancement in recognizing and perceiving gray scale images has not been demonstrated. If improvement is noted, these techniques may be implemented in various ways. Television programs can be enhanced either at a central broadcasting location or the patient's receiver, or a portable system may be used with a head-mounted, closed-circuit TV system to aid mobility (3).

Difficulty with face recognition is a frequent early complaint of many patients with macular disease (4). Faces can be recognized both when low pass filtered to a large degree (5) or high pass filtered (6,7). Since most image enhancement techniques are in the form of high pass filtering, this study evaluated improvement in face recognition with the adaptive enhancement algorithm (1). To evaluate actual face recognition rather than the ability to discriminate among test faces, we tested patient ability to recognize celebrities.

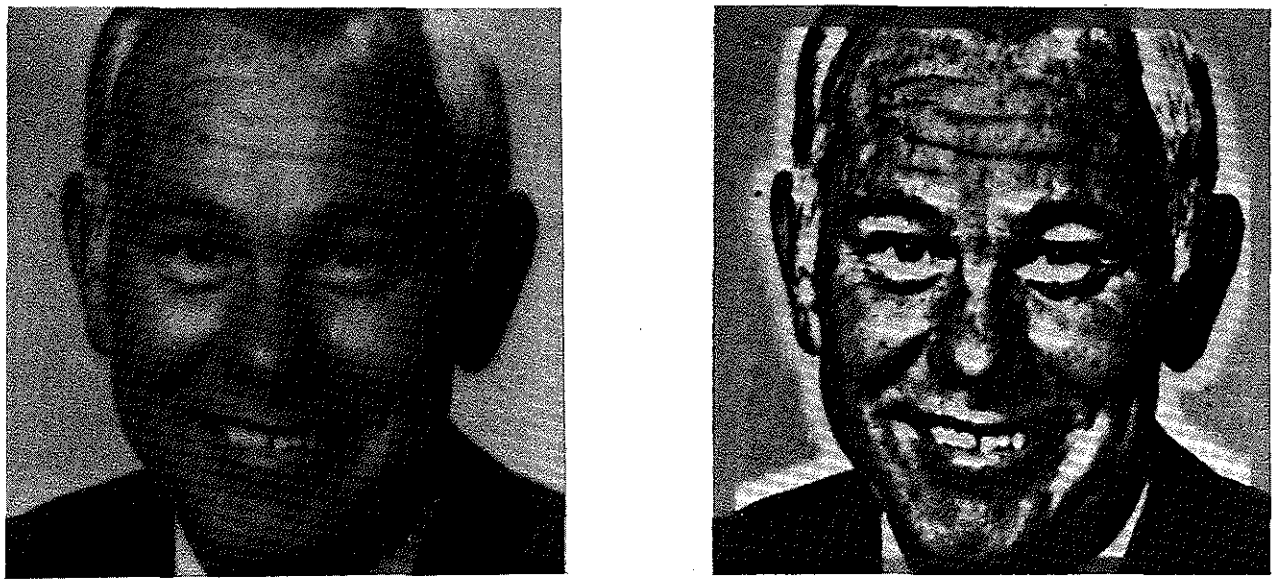
Methods

Photographs of 50 celebrities and 40 unfamiliar people were used. The celebrities' photographs were expected to be familiar to most patients in our population (Americans over the age of 60). Transparencies of celebrities and unfamiliar faces were digitized at a resolution of 256 x 256 and at 256 gray levels. Illumination was adjusted by eye to obtain maximum dynamic range and clear visibility of all images when digitized.

The 17 patients selected had central visual loss due to macular disease in one eye resulting in acuity of ≤20/70. Preference was given to patients with good vision in one eye (>20/40). Thus, familiarity with the celebrities could be verified. Occasional patients were included who did not meet the last criteria.

Images were enhanced with an adaptive enhancement algorithm (1). The same parameters were used for processing all the images. Images, presented to the subject sitting in a lighted room on a 60-Hz non-interlace video monitor, were shown from a distance of two meters, and their size

on the display was adjusted to 4° (Fig. 1). Original and enhanced images were intermixed and presented in random order by the computer. Subjects indicated their level of confidence in recognizing the face in the picture as belonging to a celebrity by assigning a rating of from one to six. A rating of one meant that the subject was positive the face belonged to a celebrity; six meant that the patient did not recognize the face.



a b

Fig. 1. Example of an image used in the study. (a) An original picture of Johnny Carson. (b) The same image enhanced. Each image span 4^{o} x 4^{o} when presented to the patient.

Patients' responses were used to calculate receiver operating curves (ROCs) for original and enhanced images, respectively. Because the same faces were presented in both forms, the responses for each face were assumed to be correlated requiring a correlated ROC (8) analysis. The area under the ROC (A_z) was taken as a measure of recognition. If the enhancement improved patient recognition, the area under the ROC for the enhanced image should be larger than for the original image.

Results

In all cases, patients demonstrated better recognition with the enhanced images than with the original, untouched digitized images (Fig. 2). The difference between the two areas under the ROC curves indicated a statistically significant increase in recognition for 8/17 patients ($p<0.05$). In addition, in response to questions and often spontaneously, patients

reported that the enhanced images were significantly clearer, sharper, and easier to see.

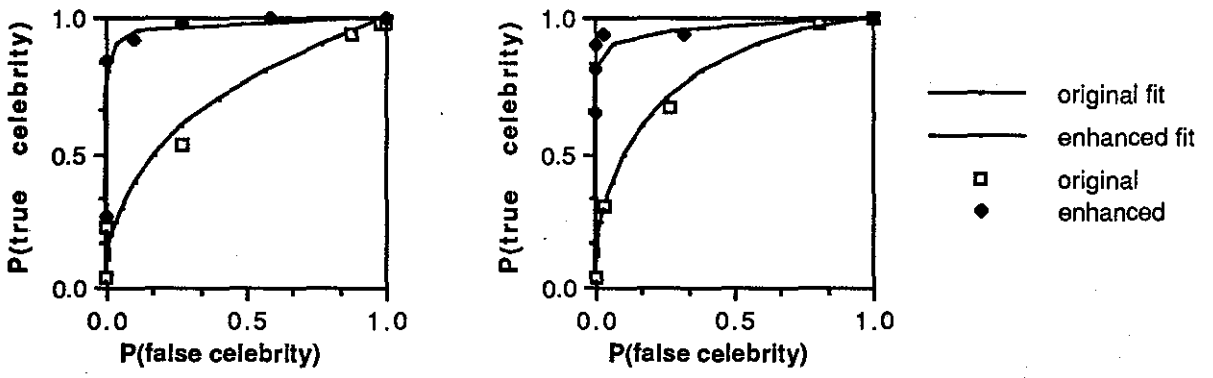


Fig. 2. Receiver operating curves for two patients comparing recognition with the adaptive enhancement to the performance with the original images. (a) Right eye of a 68-year-old man with foveal cyst (visual acuity 20/70). The area difference is significant (p = 0.0001). b) Left eye of a 67-year-old woman with age-related maculopathy (visual acuity 20/100). The difference between the areas under the curve is significant (p = 0.001).

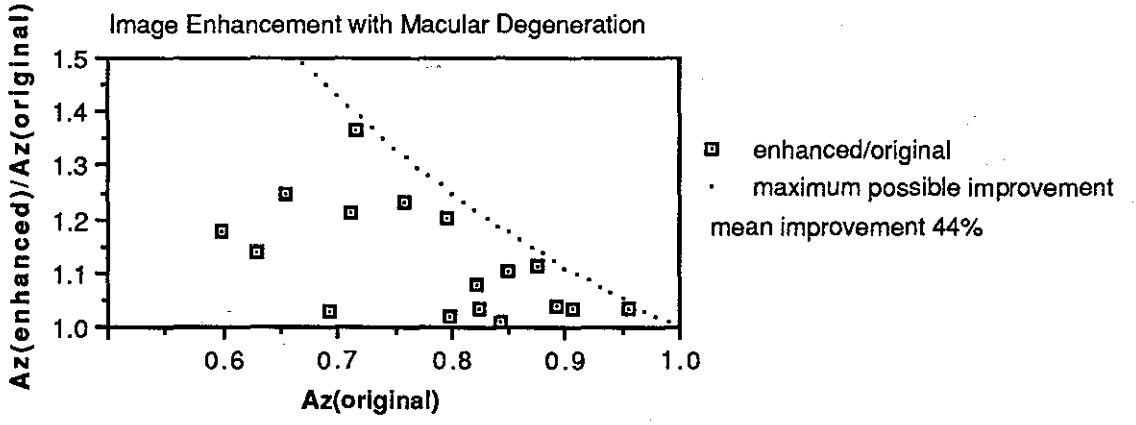


Fig. 3. Improvement in recognition for all patients tested. Square data points, representing improvement with the adaptive enhancement, compared with the maximal possible improvement for each patient's level of performance without enhancement (dotted line). All patient's improved, with some reaching a level close to the maximum possible improvement.

The level of improvement measured as the ratio of the areas under the curves ($A_z[enhanced]\,/A_z[original]$) varied from patient to patient. This improvement was negatively correlated with the area under the curve for the original image (however, it was not correlated with visual acuity) Fig. 3. Thus, great improvement can be attained only by patients whose performance was sufficiently degraded by macular disease. When we normalized the measure of improvement by calculating *gain* as the ratio of improvement and maximal possible improvement:

$$gain = \frac{A_z(enhanced) - A_z(original)}{1 - A_z(original)} \qquad (1)$$

we found that the mean *gain* was 44% of the maximal possible improvement. For many patients, improvement with adaptive enhancement was close to the maximum possible, and the gain was not significantly correlated with initial performance.

Discussion

Image enhancement can provide a measurable, statistically significant improvement in face recognition for the visually impaired. For many, improvement is substantial and approaches the maximum possible. The technique presented here for evaluating the gain attained by image enhancement also provides a tool for comparing different enhancement algorithms. We currently are evaluating enhancement with the adaptive thresholding technique (3) both for patients with macular disease and media opacities. In the future, we will compare the results using these techniques with those obtained using filters based on patients' contrast sensitivity functions.

Acknowledgments

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