Face Recognition in Age-Related Maculopathy

Mark A. Bullimore, Ian L. Bailey, and Richard T. Wacker

Patients with age-related maculopathy (ARM) complain frequently of difficulty with face recognition. The authors attempted to quantify the level of impairment by comparing face recognition with clinical tests of visual function, namely contrast sensitivity, grating acuity, letter-chart acuity, and word-reading acuity. For face recognition, we used 32 black-and-white photographs that had been cropped to remove the outline of hair so that identification was predominantly dependent on the facial features. The angular size of the faces was indicated by the equivalent viewing distance (EVD). Four male and four female models were used, and for each model, there were four photographs with different facial expressions—happy, sad, angry, and afraid. For each photograph, the subject's task was to name the model and identify the facial expression. Threshold EVD (50%) was determined for correct identity recognition and expression recognition. For eight subjects all experimental procedures were repeated at a lower luminance level. For ARM subjects, increasing task complexity (grating/letters/words) substantially decreased resolution. Face-recognition abilities were most closely related to word-reading acuity when comparisons were made either across subjects or across luminances within subjects. Contrast sensitivity was associated poorly with face-recognition thresholds. In some subjects with more advanced ARM, identity recognition was substantially poorer than expression recognition. Invest Ophthal Mol Vis Sci 32:2020–2029, 1991

Age-related maculopathy (ARM) is the largest cause of visual impairment in the United States and United Kingdom.1,2 The development of ARM leads to a loss of contrast sensitivity3 and visual acuity,4 color-vision problems,5-6 adaptation difficulties,7 and central visual field defects.8 Low vision patients rarely complain to clinicians of “reduced contrast sensitivity” or “a loss of visual acuity” but more frequently report difficulties at specific tasks, most notably with reading, face recognition, orientation, and mobility. It is appropriate to seek an understanding of which of our clinical tests best predict functional visual performance.

Several studies have investigated the relationship between functional visual performance and consulting room measures of vision in low vision patients. Marron and Bailey9 examined the visual factors that were correlated with orientation and mobility skills in a heterogeneous group of low vision patients. Linear regression analysis indicated that peak contrast sensitivity and visual fields were best correlated with orientation and mobility; visual acuity showed a poor correlation. In a more recent study, Brown et al10 compared visual fields, visual acuity, and differential velocity discrimination with mobility performance in a group of ARM patients and age-matched normals. Various indices of mobility performance were examined including total travel time, number of errors, and average speed. Their ARM subjects showed significant correlations between mobility performance and visual fields, differential velocity discrimination, and visual acuity.

Ebert et al11 assessed functional visual performance in 64 patients with macular disease, 52 of whom had ARM. The patients were tested with practical tasks such as currency discrimination, color recognition, reading a clock, and reading large print. Those with visual acuities of 20/250 or better tended to do all tasks better than those with visual acuities of 20/500 or worse. In a subsequent study, Alexander et al12 examined visual function in 100 ARM patients with visual acuities ranging from 20/100–20/1280. They compared visual acuity and contrast sensitivity with the ability to read, tell time, and distinguish colors, products, and facial expressions. Facial expression recognition was examined using four 20 × 25-cm black-and-white photographs presented at a distance of 46 cm, and the subjects had to describe the expression on each face. Their subject population was divided into three groups based on visual acuity: 20/100–20/250 (n = 36), 20/320–20/500 (n = 35), and 20/640–20/1280 (n = 29). It was found that 26% of all subjects could recognize the expressions on all four photo-
graphs, but 42% of subjects in the best visual acuity group identified all four expressions. Only 10% of the worst visual acuity group performed at this level. Similar trends were observed when the subjects were divided into three groups based on the peak contrast sensitivity.

In our study, we attempted to quantify the level of face recognition impairment in ARM subjects by comparing face-recognition ability with several clinical tests of visual function: contrast sensitivity for both gratings and edge targets, grating acuity, letter-chart acuity, and word reading acuity.

**Materials and Methods**

All subjects were volunteers, recruited from the Low Vision Clinic at the School of Optometry, University of California at Berkeley. They were selected at random from the clinic records, the only criterion being a clinical visual acuity of 20/40-20/400. Informed consent was obtained from all subjects after explanation of the procedure. Fifteen ARM subjects, 62-96 yr of age, participated in the study. Their visual acuities ranged from 0.27-1.17 logMAR (minimum angle of resolution) (20/37-20/300). In addition four normal subjects (age range, 62-75 yr) participated; their visual acuities ranged from -0.22-0.00 logMAR (20/12-20/20). All subjects had a full ophthalmic examination before the study. All testing was monocular with subjects using their preferred eye and wearing an appropriate refractive correction.

**Testing Face-Recognition Ability**

In designing a test of face recognition ability, many factors must be considered. Race influences face recognition ability in that whites generally recognize white faces better than they do black faces, whereas blacks recognize white and black faces equally well. In our study, the stimulus faces and the subjects were white. Since there is evidence that subjects are better at identifying faces of their own gender, equal numbers of male and female faces were used. Furthermore, subjects tend to make fewer errors with faces of their own age so we chose adults for our stimulus faces.

We used black-and-white photographs of four male and four female faces, displayed by projecting them onto a screen. The mean luminance of the projected faces was 100 cd m\(^{-2}\) (Fig. 1). The photographs were selected from “Pictures of Facial Affect” (Consulting Psychologists Press, Palo Alto, CA). For each photographic model, there were four different facial expressions: happy, sad, angry, and afraid (Fig. 2) and a photograph with a neutral expression also was available (Fig. 1). The photographs were cropped to remove the hair outline so that identification was predominantly dependent on the facial features. The faces did not have prominent jewelry, facial hair, or spectacles. In preliminary studies, six male and six female faces were used, and for each, there were two additional facial expressions: disgusted and surprised. However, we found that normally sighted subjects had difficulty reliably discriminating “angry” from “disgusted” and “afraid” from “surprised.” Furthermore, it was clear that certain face photographs were significantly more recognizable than others. Two male and two female faces were eliminated to minimize the range of recognizability across faces (similar strategies have been used previously in the design of letter charts).

Previous studies assessed face recognition abilities by either recording the percentage correct recognition at a given test distance or by varying the contrast of the projected faces and determining the threshold contrast for detection or recognition. We varied the angular subtense of the faces by altering the observation distance and the size of the projected image.

---

Fig. 1. Photographs of the four female models selected from Ekman P and Friesen WF, “Pictures of Facial Affect” (Consulting Psychologists Press, Palo Alto, CA). The male faces are not shown for copyright reasons.
The angular size of the faces was indicated by equivalent viewing distance (EVD):

\[ EVD = \text{distance at which a real face would subtend the same angle that the projected face subtends} \]

or \[ EVD = \frac{\text{observation distance}}{\text{enlargement ratio}} \]

The observation distance could be varied from 0.50–10 m, and each subject’s refractive correction was adjusted to compensate for variations in observation distance. The enlargement ratios used ranged from 0.25–2.0 with mean face luminance being kept constant at 100 cd m\(^{-2}\) by varying projector voltage and using glass neutral-density filters.

Throughout the experimental session, the subjects were able to refer to a panel with large photographs of the eight photographic models with neutral facial expressions (Fig. 1). This provided a means of reminding the subjects of the names and appearances of the photographic models. Each session commenced with a training period in which the subject was introduced to the face recognition task at a very close EVD. The subject was shown the projected photographs in a random order, asked to name the identity and describe the facial expression, and provided with feedback. Subjects usually grasped the nature of the task.
quickly, and if a subject was having difficulty with the task, the EVD was decreased. The training session also served to provide the experimenter with a coarse estimate of each subject’s threshold EVD. After the experimenter was confident that the subject had grasped the nature of the task, all 32 photographs were presented in a predetermined order to ensure that each subject had the opportunity to view each photograph at least once. The experimenter then selected an initial EVD which he believed was above threshold, and the subject was presented with 16 photographs selected at random by computer. The exposure time was controlled by an electronic shutter and limited to 10 sec. For each photograph, the subject’s task was to identify the model and name the facial expression. They had to recognize both the identity and the expression to be given credit for a photograph.

If the subject scored above 75% correct at the initial EVD, then the EVD was increased by 0.15-log units (\(\sqrt{2}\)), and 16 additional photographs were presented. The EVD was increased in 0.15-log unit steps until the subject gave two consecutive scores below 50%. If the subject scored below 75% correct at the initial EVD, then the EVD was decreased by 0.3 log units (two times), and 16 additional photographs were presented. If the subject continued to score below 75%, then the EVD was reduced further up to a minimum EVD of \(-0.6\) log m (25 cm) which we believed was the closest distance at which face recognition might occur in a real-life situation. Two subjects were unable to attain a score of 75%, even at the shortest EVD and were, therefore, excluded from the results. For each subject, a threshold EVD (50% probability of seeing) was determined by applying probit analysis.

**Clinical Tests of Vision**

In addition to face recognition, contrast sensitivity was measured for gratings and edge targets and visual acuity for gratings, letters, and words.

**Contrast sensitivity:** Contrast sensitivity was measured using a Joyce Electronics oscilloscope (Cambridge, UK) interfaced to a Gemini microcomputer. The screen had a mean luminance of 100 cd m\(^{-2}\) and was masked by a surround of the same mean luminance to present a 13.6° central test field to the subject. Four spatial frequencies were used: 0.4, 1.25, 4.0, and 12.5 cycles/degree. A two-alternative forced-choice procedure was used with the gratings presented either on the right or left half of the screen. The border between the patterned half of the screen and the blank half was smoothed by a Gaussian function. A correct response from the subject led to the contrast being reduced by 0.1 log units. After an incorrect response, the contrast was increased by 0.3 log units. Each spatial frequency was tested independently to reduce the effects of spatial frequency uncertainty. All trials began with the grating at 100% contrast, and the trial ended when the subject had made eight incorrect responses. The subjects would be presented with 30–50 stimuli in any given spatial frequency. Contrast thresholds for an edge target were also determined, using the same protocol, and the subject’s task was to state which half of the screen was darker. Threshold contrast (50% probability of seeing) was determined by probit analysis. The display luminance could be varied by the use of glass neutral-density filters.

**Grating acuity:** Grating acuity was measured using a moire fringe apparatus. Two square-wave gratings on celluloid film (133 lines/cm) were mounted on two sheets of clear plexiglass that could be rotated with respect to each other. This gave a moire interference grating pattern whose spatial frequency was dependent on the angle between the square-wave gratings. The luminance profile across the interference grating had a triangular wave form. The gratings were viewed against a large light box, and the mean luminance of the gratings was 100 cd m\(^{-2}\). The subject was positioned 1 m from the grating display which subtended 14.5°. The initial spatial frequency was 0.3 cycles/degree (logMAR, 2.0), and the experimenter made the gratings narrower until the subject reported that the grating pattern could no longer be perceived. The experimenter recorded a vernier scale reading from the knob used to adjust grating spatial frequency, and the reading was then converted to a logMAR value. The spatial frequency was then decreased until the subject reported that a grating pattern could be seen again, and this value was recorded. Threshold was determined from the mean of three ascending and three descending measurements.

**Letter-chart acuity:** This was measured using Bailey-Lovie charts. The charts were printed on transparent plexiglass and viewed against a large light box (75 X 80 cm), and the background luminance of the chart was adjusted to 100 cd m\(^{-2}\). Letter-chart acuity scores were expressed as logMAR, and credit was given for every letter read correctly. There were five letters per row, and the size difference between successive rows was 0.10 log units. Therefore each letter was assigned a value of 0.02 log units.

**Word reading acuity:** This was assessed using Bailey-Lovie word reading charts. The charts were printed on transparent film and viewed against a large light box, and the background luminance of 100 cd m\(^{-2}\) was used. Word reading acuity scores were expressed as logMAR, giving credit for every word read correctly.

**Variation of face recognition with luminance:** Inter-subject comparisons of face recognition ability could
be influenced by cultural, educational, or various psychologic factors, and this could mask the relationships between visually related face recognition ability and the clinical tests of vision. In eight subjects (five ARM and three normal), all experimental procedures were repeated at a second luminance level (1 cd m\(^{-2}\)) to establish whether individual subjects showed parallel changes in face recognition ability and clinical tests when performance was reduced by decreasing the task luminance. With each luminance reduction at least 5 min was allowed to ensure adequate adaptation to the lower luminance level.

**Results**

The mean visual acuity values for the ARM (n = 13) and normal (n = 4) subjects are shown in Figure 3. In the normal subjects, mean visual acuity values were similar for all targets. In the ARM subjects, however, visual acuity deteriorated with increasing task complexity, ie, grating/letter/word, consistent with previous findings.\(^4\)\(^2\) The mean face recognition thresholds (EVD) for both subject groups are also shown in Figure 3. For normal subjects, this was 1.26 (±0.15) log m (≈18 m); the mean value for the ARM group was 0.16 (±0.38) log m (≈1.5 m). The difference in mean face recognition threshold values between the two groups was most similar in magnitude to the difference in mean word-reading acuity values.

Face recognition thresholds were plotted as a function of grating acuity, letter-chart acuity, and word reading acuity for both normal and ARM subjects (Fig. 4). They also were plotted as a function of edge-contrast threshold (Fig. 4). Plotting contrast thresholds for 0.4, 1.25, and 4.0 cycles/degree gave similar results. Edge-contrast thresholds correlated well with contrast thresholds for both 0.4 and 1.25 cycles/degree (r = 0.91 and 0.87, respectively). When edge-contrast thresholds were plotted against the minimum contrast threshold for the gratings, the correlation coefficient improved (r = 0.93). One of the 13 ARM subjects was unable to see the 4-cycles/degree grating, and 9 of the 13 could not see the 12.5-cycles/degree grating.

Best-fit linear regression lines are plotted (bold lines) in Figure 4, and the correlation coefficients and regression equations are summarized in Table 1. Face recognition thresholds correlated poorly with measures of contrast sensitivity. Table 1 shows, however, that face recognition thresholds correlated better with measures of visual acuity and that the correlation was stronger for word reading acuity than for letter-chart acuity. Furthermore, the slope of the best-fit line was close to unity, which implies that halving the word reading acuity would be accompanied by halving of the threshold face recognition EVD.

**The Influence of Luminance on Face Recognition**

Reducing the luminance of the face recognition task from 100 to 1 cd m\(^{-2}\) invariably produced a reduction in face-recognition ability. This is shown graphically in Figure 4, where the thin lines represent individual changes in the relationship between face recognition threshold and the corresponding acuity or contrast thresholds. The lines that represent intrasubject...
Fig. 4. Face recognition as a function of contrast threshold, grating acuity, letter chart acuity, and word reading acuity. Solid squares represent the normal subjects, open squares represent the ARM subjects. Best fit regression lines (bold solid lines) are shown and 45° lines (dashed lines) are provided for reference. Best fit regression equations and correlation coefficients are given for all subjects (correlation coefficients are also given for the ARM subjects only). The thin lines represent the change in face recognition threshold and the corresponding acuity or contrast thresholds when the mean luminance is reduced from 100 to 1 cd m⁻².

Table 1. Best fit regression lines and correlation coefficients for face recognition as a function of contrast threshold, grating acuity, letter chart acuity and word reading acuity

<table>
<thead>
<tr>
<th>Regression line</th>
<th>r(n + arm)</th>
<th>r(arm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contrast threshold</td>
<td>y = -1.80 - 1.29x</td>
<td>0.79*</td>
</tr>
<tr>
<td>Grating acuity</td>
<td>y = 1.18 - 1.79x</td>
<td>0.76*</td>
</tr>
<tr>
<td>Letter chart acuity</td>
<td>y = 1.11 - 1.26x</td>
<td>0.87*</td>
</tr>
<tr>
<td>Word reading acuity</td>
<td>y = 1.36 - 1.16x</td>
<td>0.96*</td>
</tr>
</tbody>
</table>

Correlation coefficients are given for all subjects (n + arm) and for the ARM subjects only (arm).

* P < 0.001.
† P < 0.05.
‡ P > 0.05.

Discussion

Our results suggest that word reading acuity is the best predictor of face recognition ability. First, face recognition thresholds most highly correlated with word reading acuity (r = 0.95). Second, the plot of subject variations were most similar in slope to the inter-subject regression lines (bold lines) for letter-chart and word reading acuity (Fig. 4). The approximately proportional relationship between word reading acuity and face recognition threshold that was evident across the subject pool was also seen in individual subjects when performance was changed by reducing task luminance.

Our results suggest that word reading acuity is the best predictor of face recognition ability. First, face recognition thresholds most highly correlated with word reading acuity (r = 0.95). Second, the plot of subject variations were most similar in slope to the inter-subject regression lines (bold lines) for letter-chart and word reading acuity (Fig. 4). The approximately proportional relationship between word reading acuity and face recognition threshold that was evident across the subject pool was also seen in individual subjects when performance was changed by reducing task luminance.

Discussion

Our results suggest that word reading acuity is the best predictor of face recognition ability. First, face recognition thresholds most highly correlated with word reading acuity (r = 0.95). Second, the plot of subject variations were most similar in slope to the inter-subject regression lines (bold lines) for letter-chart and word reading acuity (Fig. 4). The approximately proportional relationship between word reading acuity and face recognition threshold that was evident across the subject pool was also seen in individual subjects when performance was changed by reducing task luminance.

Discussion

Our results suggest that word reading acuity is the best predictor of face recognition ability. First, face recognition thresholds most highly correlated with word reading acuity (r = 0.95). Second, the plot of subject variations were most similar in slope to the inter-subject regression lines (bold lines) for letter-chart and word reading acuity (Fig. 4). The approximately proportional relationship between word reading acuity and face recognition threshold that was evident across the subject pool was also seen in individual subjects when performance was changed by reducing task luminance.
face recognition threshold against word reading acuity had a near 45° slope (Fig. 4, Table 1). Third, a change in luminance produced changes of similar magnitude in face recognition threshold and word reading acuity as evidenced by the thin lines in Figure 4 showing slopes that are approximately 45°. This latter finding was particularly noteworthy because inter-subject data for face recognition could be influenced by various cultural, educational, or psychologic factors and mental abilities. The regression equation (Table 1) could be used in the clinical setting to predict face-recognition performance from word-reading acuity values.

The close relationship between face recognition ability and word reading acuity suggests that face recognition may be thought of as a complex resolution task. Compared with normally sighted subjects, ARM patients showed a strong decrease in visual resolution with increasing task complexity (Fig. 3), but there were considerable individual differences. For a subject with a word reading acuity which was substantially poorer than letter-chart acuity, poor face recognition abilities would also be predicted. Inspection of Figure 3 shows that there was a reasonable correlation between face recognition threshold and letter-chart acuity. Most subjects fell very close to the unit ratio line (shown as a dashed line), but the correlation coefficient was lowered by four data points that fell to the left. When face recognition threshold was plotted against word reading acuity, however, the data points for three of these subjects were much closer to those of the remaining observers. This led to the improved correlation and suggests that these three subjects were very sensitive to the effects of spatial complexity. The mean difference between letter-chart and word reading acuities for these three subjects was 0.48 compared with 0.20 for the other ten ARM subjects (mean for all ARM subjects, 0.27). Contrast sensitivity and grating acuity are both tasks that lack spatial complexity, and they are the poorest predictors of face recognition ability. It would be interesting to examine the relationship between face recognition thresholds and contrast thresholds for a more spatially complex task such as the Pelli-Robson chart.

Are Contrast and Contrast Sensitivity Important in Face Recognition?

Our results led us to question the relationship between contrast sensitivity and face recognition. It has been proposed that contrast sensitivity is a good predictor of face recognition abilities, but the evidence rests on experiments in which the stimulus variable was the contrast of the faces presented. Although this may be interesting in a research or theoretic context, in real life, the recognizability of faces mainly changes due to alterations in angular subtense and luminance.

Owsley et al compared contrast thresholds for the detection and discrimination of "real-world" targets with visual acuity and contrast thresholds for spatial frequencies 0.5-22.8 cycles/degree. They studied 93 subjects 20-77 yr of age and their real-world targets included faces, road signs, and everyday objects, such as bicycles and coffee cups. They found that when age was omitted as an independent variable, contrast thresholds for 6 cycles/degree was the best predictor of contrast thresholds for face discrimination (r = 0.42). Contrast thresholds for 0.5 and 3.0 cycles/degree were the best predictors of contrast thresholds for face detection (r = 0.44). They concluded that contrast sensitivity predicts whether patients are likely to have difficulty in seeing visual targets typical of everyday experience. Conversely, Rubin and Schuchard were unable to demonstrate any strong relationship between contrast sensitivity and face recognition abilities in low-vision patients. Pairs of faces were presented, each subtending 13.5 to 8.1° at the patient's eye (EVD, ~ 0.4-0.6 m), and the subject's task was to determine whether the faces belonged to the same or different individuals. They found that face recognition performance correlated poorly with both letter-chart acuity (r = 0.07) and contrast sensitivity (r < 0.20).

Fiorentini et al examined the relative contribution of high and low spatial frequencies in face recognition. The subjects had to discriminate between the faces of nine men presented at an EVD of about 5 m. The faces were low-pass or high-pass filtered in the spatial frequency domain, with spatial frequency being defined in terms of cycles/face width (cycles/fw). They found that face recognition was much less accurate for images that contained only spatial frequencies up to 5 cycles/fw (equivalent to around 3 cycles/degree) than for images that contained only spatial frequencies higher than 5 cycles/fw.
Peli et al\textsuperscript{22} assessed the influence of image contrast enhancement on face recognition in 17 patients with macular disease. They selected photographs of 50 celebrities and 40 unfamiliar people; these were displayed on a monochrome video monitor. The images were enhanced using an adaptive enhancement algorithm, and the faces subtended 4° at the patient's eye (EVD, \(\sim 1.25\) m). Original and enhanced images were presented randomly, and the subjects had to say whether the face presented was a celebrity or not. These authors found that image enhancement significantly improved face recognition in 8 of 17 subjects.

The findings of Fiorentini et al\textsuperscript{21}\textsuperscript{21} and Owsey and Sloane\textsuperscript{35}\textsuperscript{35} suggest that higher spatial frequencies are important in face discrimination. However, the actual range of spatial frequencies which best predicts recognition will depend on the angular subtense of the observed face. Our study used size as a variable for face recognition. The results suggest that visual acuity, or specifically word-reading acuity, is the best predictor of face-recognition ability and, despite methodologic differences, this was similar to the findings of these other reports.\textsuperscript{19,25}\textsuperscript{19,25} Contrast remains an important parameter in face recognition;\textsuperscript{20}\textsuperscript{20} increasing the contrast of selected spatial frequencies improves face recognition from a given distance. It is important to differentiate between contrast thresholds and suprathreshold contrast perception. Hess and Bradley\textsuperscript{32}\textsuperscript{32} found that suprathreshold contrast perception was normal in amblyopic patients despite elevated contrast thresholds. Other workers have shown that, in normal subjects, suprathreshold contrast discrimination was relatively unaffected by luminance and retinal eccentricity when normalized for contrast-threshold differences, even though contrast thresholds were elevated.\textsuperscript{35,34}\textsuperscript{35,34} Recently contrast discrimination has been reported to be independent of both visual acuity and contrast thresholds in a range of ocular pathologies.\textsuperscript{35}\textsuperscript{35}

It is possible that, provided the contrast of the important spatial components of our face targets is above a certain critical level, then the major limiting parameter in face recognition will be visual acuity. It would appear that the contrast of these spatial components can be as low as 10%. We examined subjects with retinitis pigmentosa whose peak log contrast sensitivity is approximately 1.0 (threshold contrast, 10%) and found these subjects were still capable of reasonable face recognition (at EVDs up to 2 m). Of the two ARM subjects we studied who were unable to recognize faces at any distance, one had very poor contrast sensitivity (\(\sim 0.70\)) but relatively good letter-chart acuity (0.40), and the other had moderate contrast sensitivity (\(\sim 1.55\)) and poor letter-chart acuity (1.15). It seems reasonable to conclude, therefore, that when either visual acuity or contrast sensitivity falls below a certain level, then face recognition becomes impossible. In addition contrast sensitivity may be more important to other aspects of functional visual performance, such as mobility.\textsuperscript{9}\textsuperscript{9}

**Comparison of Identity Recognition and Expression Recognition**

The face-recognition thresholds discussed thus far relate to the correct identification of both identity and expression. We questioned whether there were any marked differences between identity recognition and expression recognition. For normal subjects threshold EVD is very similar for identity and expression recognition. For some of the ARM subjects, however, as threshold EVD was approached, the decline in performance was due predominantly to difficulties with identity recognition. Threshold EVDs were calculated independently, therefore, for identity recognition and expression recognition. Figure 5 shows a comparison of identity and expression thresholds for 13 ARM subjects, and the mean values for the normal subjects \((n = 4)\). The subjects are ranked in order of their identity thresholds. For the normals and those ARM subjects with better face-recognition abilities, identity thresholds and expression thresholds were similar. For those subjects with poorer face recognition abilities, however, expression thresholds were significantly better than their identity thresholds. In seven subjects, the expression threshold exceeded the identity threshold by more than 0.25 log units (1.8 times). In general, the ARM subjects were able to identify all faces provided the EVD was substantially closer than threshold. This indicates that their performance was not peculiarly affected by visual memory abilities.

Our results support the concept that face recognition, or more specifically identity recognition, is a complex resolution task. Expression recognition can, however, be thought of as being a less complex task than identity recognition. If, for example, the subject has to determine the expression of "Happy Frances" (Fig. 2), it might be sufficient to perceive only her mouth and/or her teeth. Such recognition of a single critical feature could be thought of as being a simpler resolution or detection task. To determine the identity of this face, the subject would have to integrate a large amount of complex visual information to discriminate "Frances" from the other characters (Fig. 1). The difference between expression threshold and identity threshold correlated poorly \((r < 0.51)\) with all measures of contrast sensitivity and visual acuity but correlated reasonably \((r = 0.72)\) with the difference between letter-chart and word-reading acuities. This may occur because both word-reading acuity and
identity recognition require more integration of spatial information than letter-chart acuity and expression recognition, respectively.

It is important to consider the ramifications of identity recognition being more severely impaired than expression recognition in advanced ARM. In our study, identity recognition was dependent solely on facial features. In reality, voice, gait, body shape, clothing, and other features may all aid identity recognition, and the visually handicapped individual may come to rely more heavily on auditory and gross visual cues. Furthermore, an ability to discriminate expressions might often be more important since much of our social interaction takes place with people with whom we are very familiar or whose identity has already been established.

Key words: face recognition, age-related maculopathy, visual acuity, contrast sensitivity, low vision

Acknowledgments

The authors thank Elisabeth Dungan, Amanda Hall, Debra Orel-Bixler, and Kaye Pruitt for experimental assistance and Stanley Klein for valuable advice and software relating to probit analysis.

References