

Wide-Band Enhancement of TV Images for the Visually Impaired

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Abstract

Purpose: The effect of a novel wide-band image enhancement on the perception of TV images by patients with AMD was studied by measuring their preferred enhancement levels and their perceived quality of such individually enhanced images compared to the originals and to arbitrarily enhanced images.

Methods:

Visually relevant bar and edge features were located in the images using a dual-polarity edge detector based on a vision model¹. The contrast of the pixels of such features was enhanced, scaled according to the strength of the edge, and then added to the original image. Images (static) were randomly grabbed from cable TV channels and grouped into five major content categories. Patients selected their preferred enhancement level by moving a mouse over a graphics tablet. Ten images enhanced at 10 levels, the original, and 4 levels of image degradation were used. The median individual selection was used to enhance images for a second procedure. Patients compared the quality of 50 test images with individually-selected enhancement to that of the original images, the same images processed using an alternate arbitrary enhancement level, and degraded images. Data were analyzed using a signal detection approach.

Results: Visually-impaired patients (n=35) could distinguish the wide-band enhanced images and preferred them over the original and degraded images. Most patients preferred a moderate level of wide-band enhancement. They reported preferring natural-looking images and thus rejected visible artifacts of the enhancement at higher levels. Preference was not correlated with visual acuity ($r=0.07$, $p=0.75$). Comparison of the enhanced images to the originals by 23 of the patients revealed that there was a slight preference for enhancement of multiple face images (Area under ROC= 0.60 ± 0.04) compared to other content categories. Perceived image quality was high and statistically significant for only 22% of these patients.

Discussion: Possible reasons for the limited increase in perceived image quality are presented and possible improvements are suggested.

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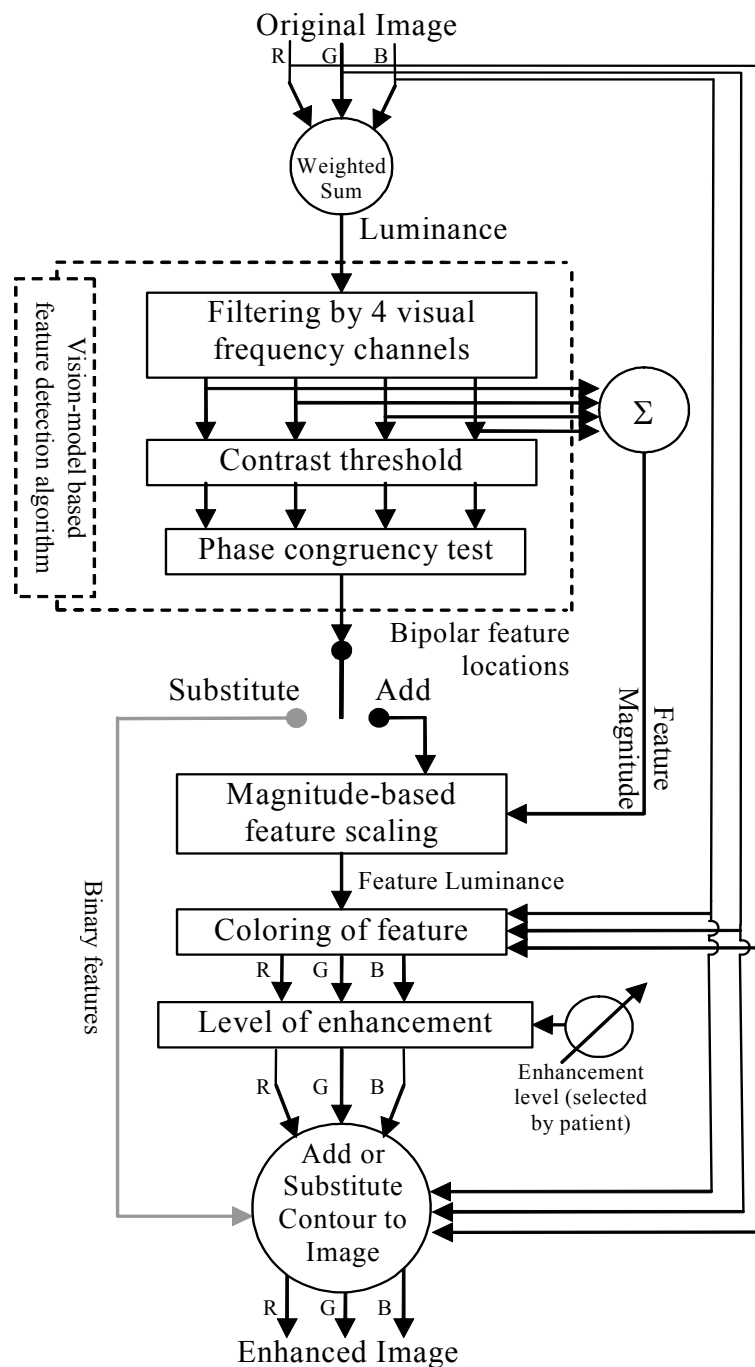
Background

- People with vision impairments watch TV with their families²
- Video access will become even more important
- Image enhancement for people with visual impairments was first proposed by Peli and Peli³
- Narrow-band contrast enhancement (Adaptive Enhancement) significantly and substantially increased face recognition for visually-impaired people⁴
- Peripheral vision is better with wide-band stimuli than with narrow-band stimuli in some visual recognition tasks. An enhancement method implementing a wide-band approach should be tested

Study Outline

- We computed a line drawing (outline, cartoon, or feature map) of the visual features in the image. We superimposed the line drawing on the original image
- This study evaluated the perceived benefit to 35 people with central vision impairments when viewing static TV images

Wide-band Algorithm



- Bipolar features generated from luminance signal¹
- Magnitude of features computed
- Feature pixel values are added (or subtracted) to original pixel if feature above threshold of all 4 bands
- Scaled features approximately maintain the RGB ratio
- Individually-selected enhancement level multiplies the feature magnitude before being added to the original

Methods

Images

- Single video frames were randomly digitized from cable TV
- 127 of the 200 images contained little or no apparent motion
- Images were categorized into *Face*, *Figure*, *Text*, *Busy Scene* and *Other*
- 100 images were arbitrarily divided and patients viewed only one of the two sets of 50 images

Procedure 1 - Determination of preferred wide-band enhancement level

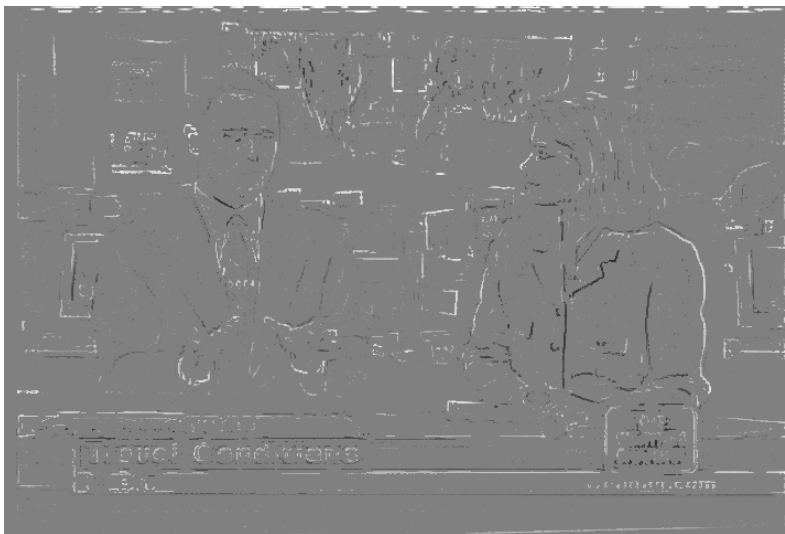
- By moving the mouse up and down on a blank graphics tablet, patients progressively changed which of 15 pre-calculated levels of the image was displayed (see panel 6)
- This selected the level they “liked the picture the best, where it was clearest and where they got the most detail from the picture”
- 10 images (each shown twice)

Procedure 2 - Perceived image quality

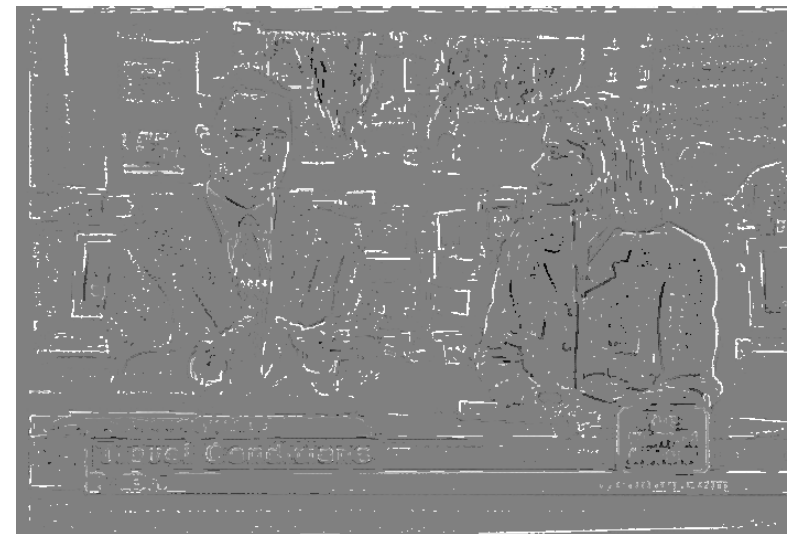
- 50 images from each set of
 - (1) originals
 - (2) images processed with the individually-selected enhancement level (based on procedure 1)
 - (3) images processed with a second (arbitrary) wide-band enhancement level
 - (4) degraded images (adaptive enhancement with $K=0.37$)
- By moving the mouse, the patients rated the quality of each test image as compared to the original image. Guide words on the tablet were:
 - “better”, “slightly better”, “typical”, “slightly worse” or “worse” (than the original image)



(a) Original Image



(c) bipolar features calculated using scale factor 255 (level 9)



(e) bipolar features calculated using scale factor 3199 (level 15)



(b) Degraded image (K=0.37, level 2)



(d) features from (c) added to original image



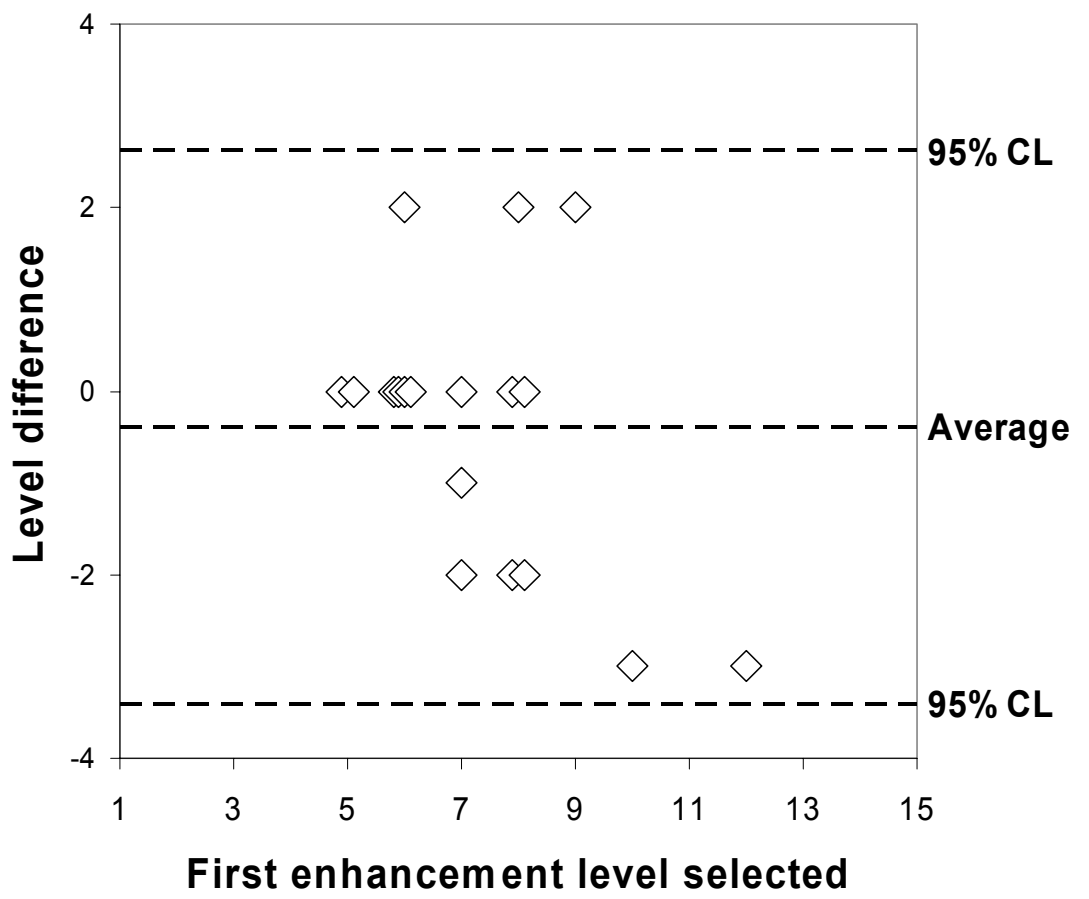
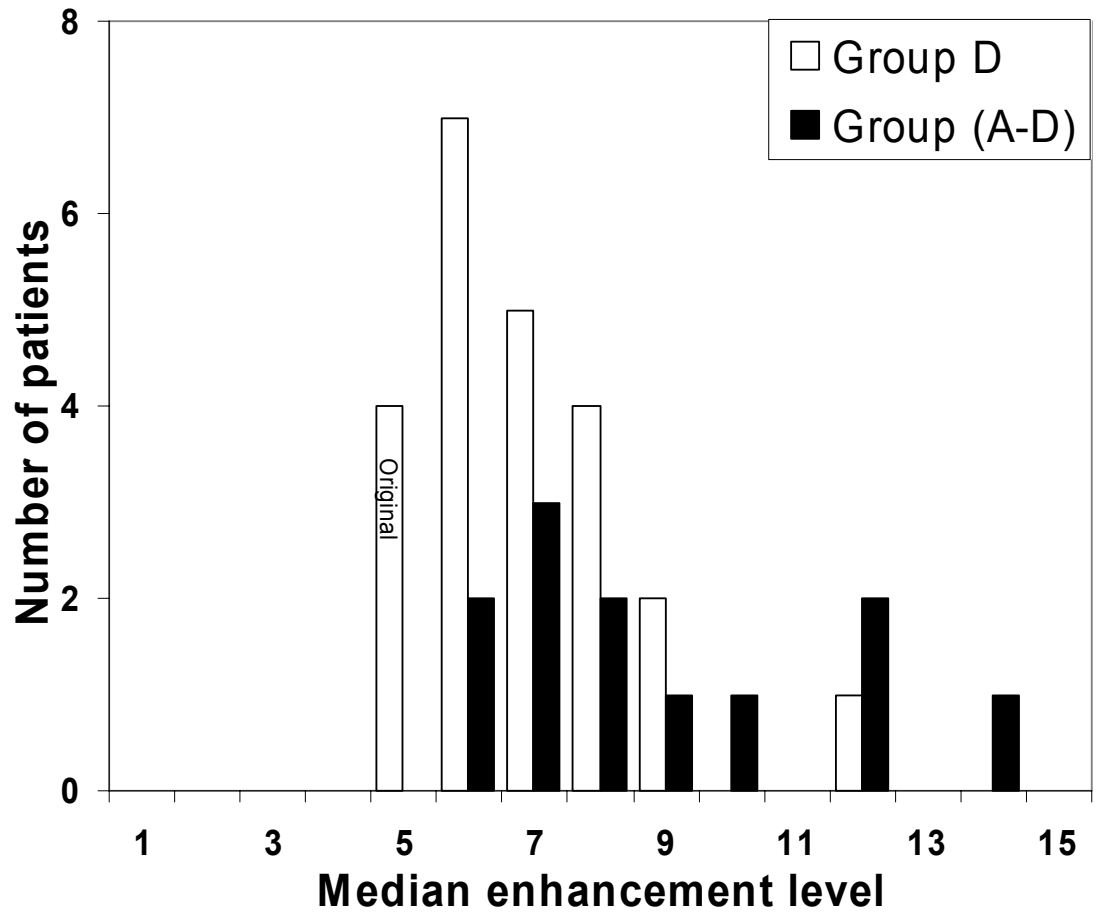
(f) features from (e) added to original image

Enhancement Levels and Subject Groups

Level No.	K (degraded) or Scale Factor (enhanced)
1	K=0.2
2	K=0.37
3	K=0.50
4	K=0.70
5	Original
6	63
7	127
8	191
9	255
10	319
11	511
12	767
13	1023
14	1535
15	3199

Group	n	Age [years] Median (range)	VA [Log MAR] Median (range)	Documented CFL	Definition
A	35	70.0 (19.2-86.0)	0.89 (0.52-2.00)	27	Patients who completed procedure 1
B	18	68.6 (27.3-86.0)	0.95 (0.74-1.30)	14	Subset of group A who repeated procedure 1
C	25	69.1 (19.2-86.0)	0.88 (0.52-1.30)	20	Subset of group A who evaluated image set "B" in procedure 1
D	23	69.1 (19.2-86.0)	0.86 (0.66-2.00)	17	Subset of group A who completed procedure 2
E	5	60.7 (19.2-70.0)	0.94 (0.73-1.13)	3	Responders. Subset of group D who significantly liked the enhanced images

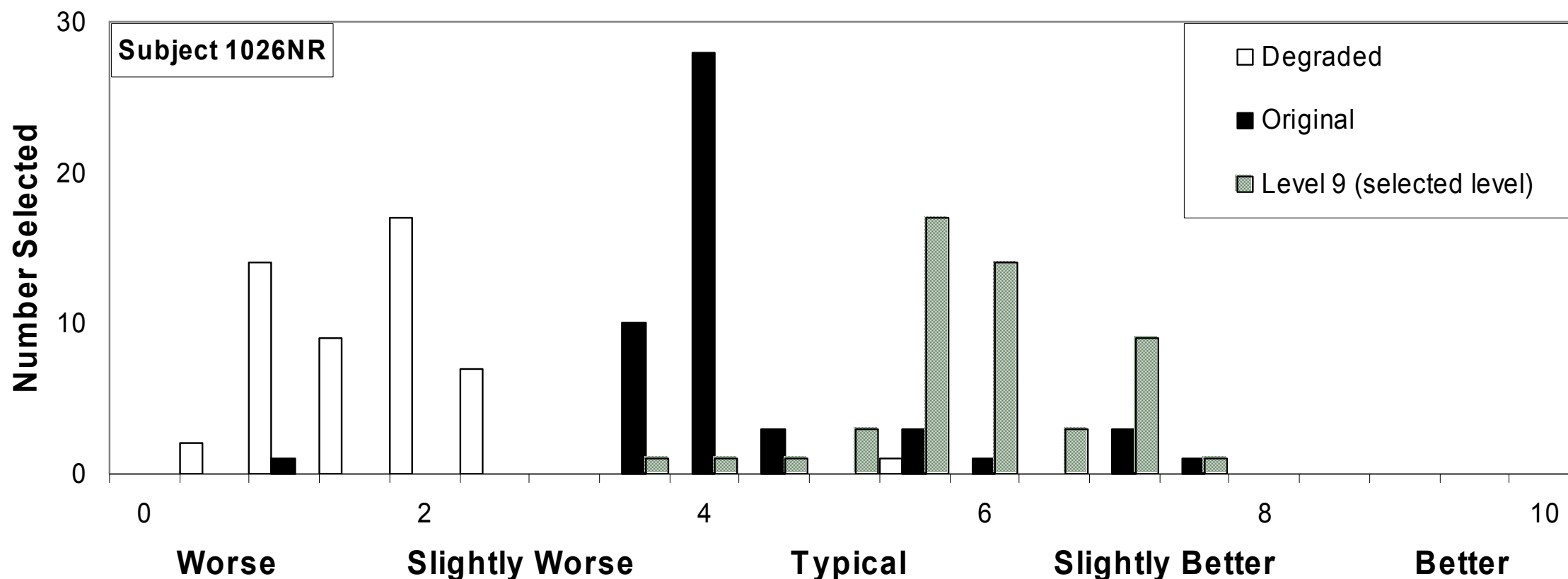
Selected Enhancement Levels and Repeatability



In procedure 1, most patients preferred a moderate level of enhancement. No patient preferred any of the degraded levels. The patients in Group A who did not complete Procedure 2 (Group A-D) selected a median 1 level higher than the patients in Group D (who completed Procedure 2) ($p=0.02$).

Difference between enhancement levels selected on two repetitions of procedure 1 (Group B) was not significant ($p=0.27$). Half the patients selected the same level. Note, overlapped symbols were shifted slightly horizontally to make them visible

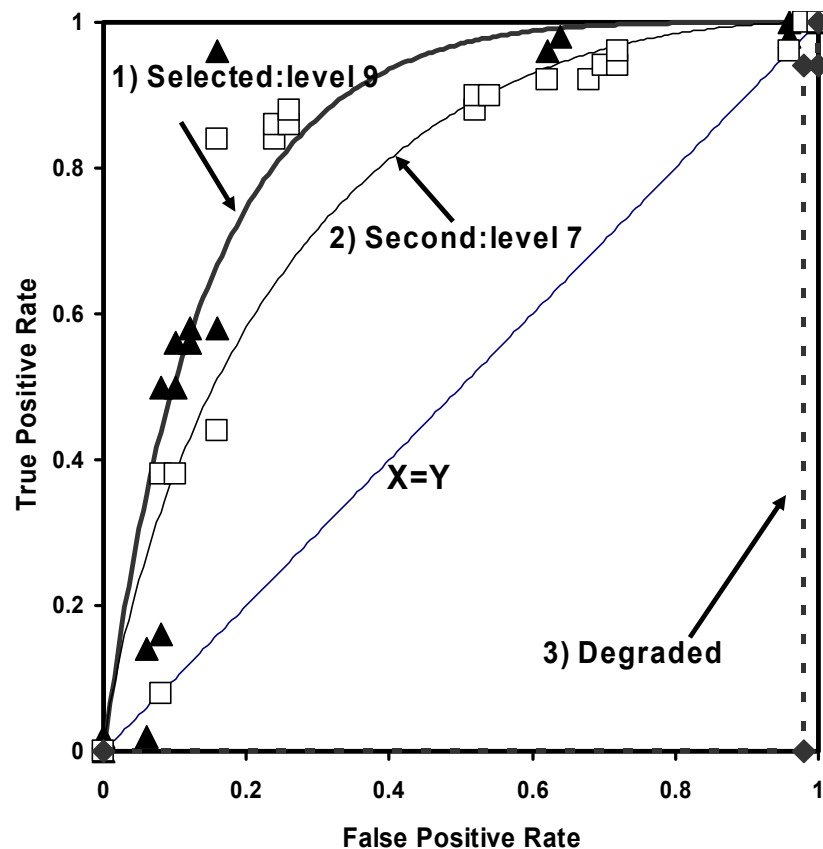
Frequency Distributions of Perceived Image Quality



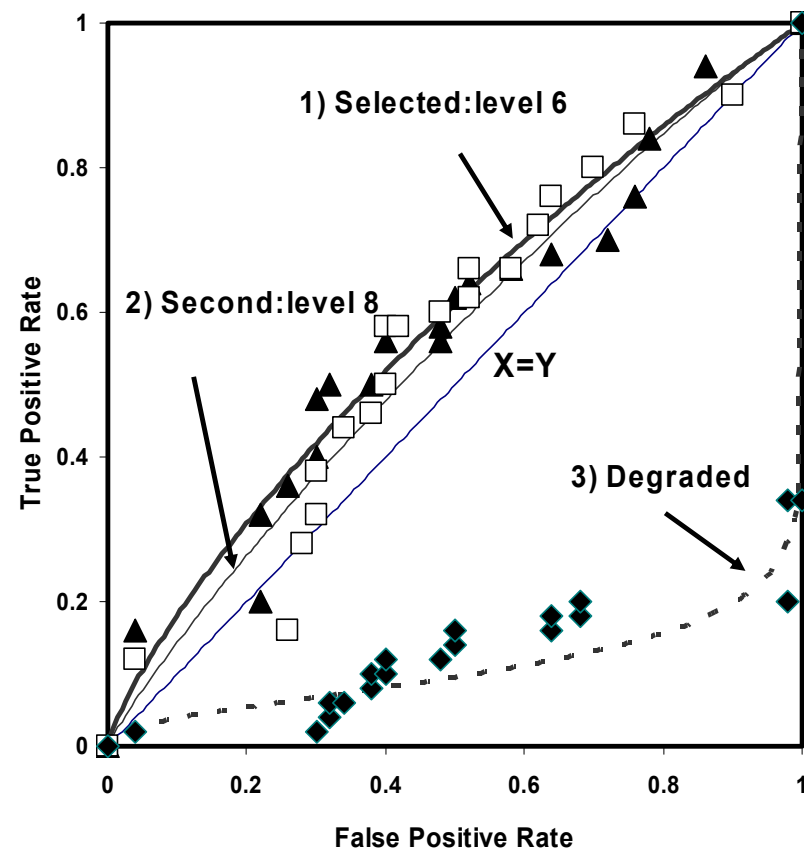
Frequency distributions of the perceived image quality scores (Procedure 2). This patient clearly preferred the individually-selected (level 9) wide-band enhancement (and thus has distributions that were clearly separated). The same data were used to construct two of the ROC curves shown in Panel 9 (left). For the purposes of illustration, bins are 0.5 units wide, but the ROC analysis does not involve binning. For simplicity, the second wide-band enhancement image set is not shown.

ROC Curves

ROC data and fitted curves for two patients. Each ROC curve is a comparison between the perceived image quality of that set of images and the set of original images⁵. The dashed lines hugging the lower right corner are the fits to the filled diamond symbols (the degraded images).

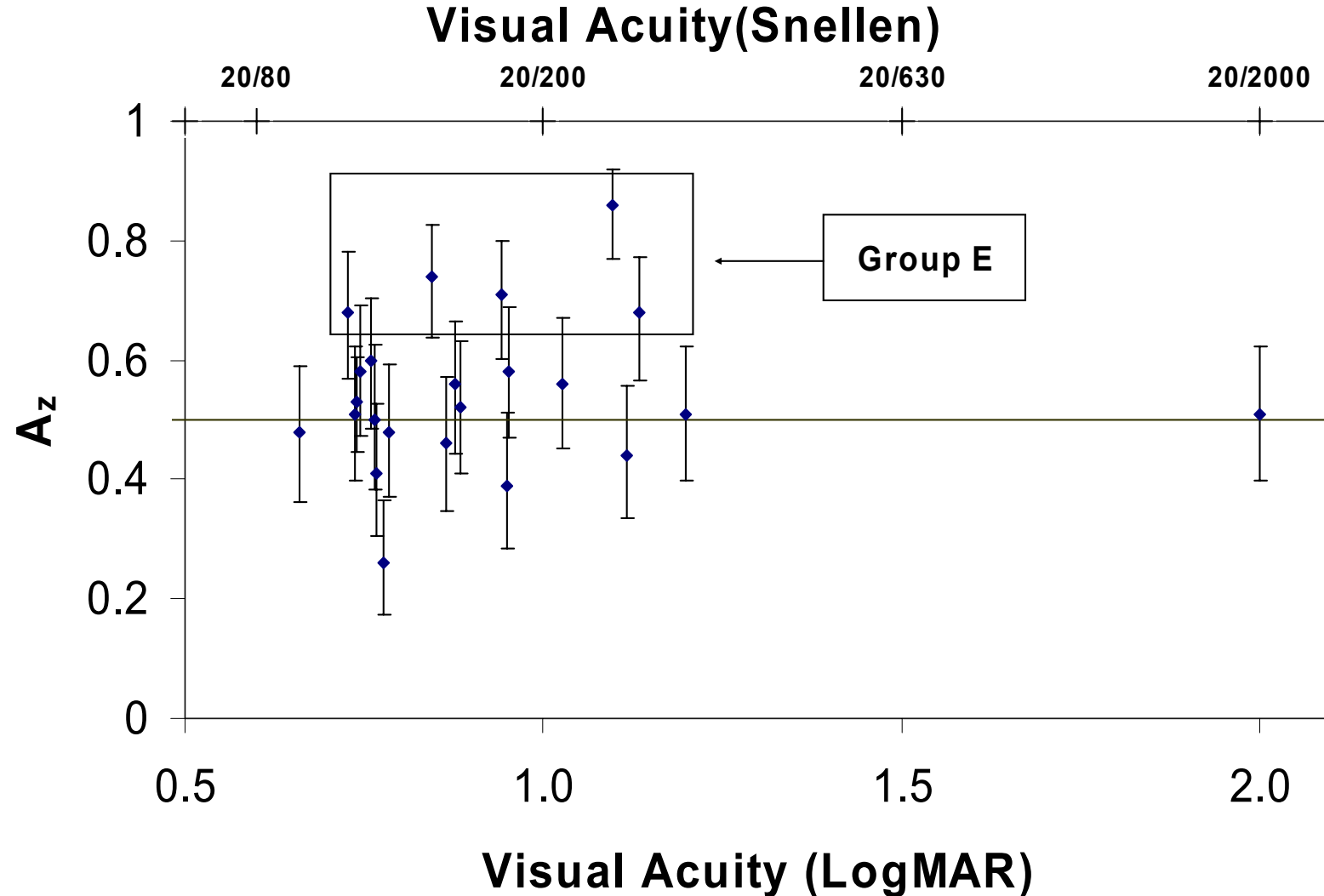


A 43-year-old patient (VA 20/250) who clearly favored the wide-band enhancement and clearly rejected the degraded image. The curves (1) and (3) were constructed from data presented in Panel 8.



An example in which the area under the ROC curve (A_z) was only slightly larger than 0.5 for both enhancement levels. A 69-year-old patient (VA 20/180). The degraded level was clearly rejected.

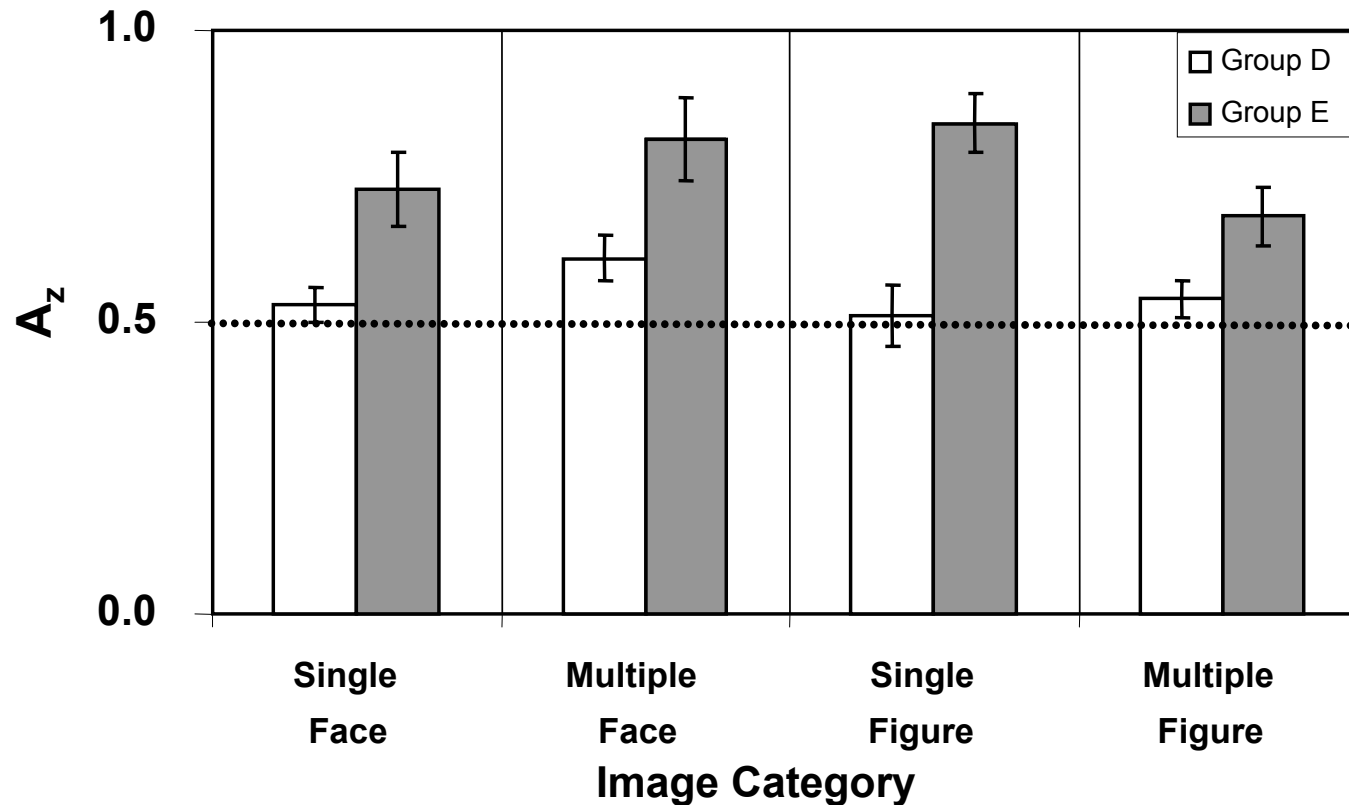
Perceived Image Quality Was Not Correlated With Visual Acuity



Perceived image quality with the individually-selected enhancement (A_z) was not correlated with visual acuity (Group D). Error bars show the asymmetric 95% confidence intervals.

For five patients (Group E), the lower bound of the A_z confidence interval was greater than 0.5 and those were grouped for additional analyses.

Results Based on Image Category and Face Width



Average A_z by image category. For Group D, while all show a mean A_z more than 0.5 (dotted line), the multiple-face category had the highest perceived image quality and it was the only one that was significantly different from 0.5 (original). For Group E, the A_z values were significantly higher than 0.5 for all four image categories. Error bars represent SEM.

Category	Number of Images	Average Face Width
Single face	19	8.6°
Multiple faces	9	4.4°
Single figure	7	4.1°
Multiple figures	9	2.5°

The average face width in 44 images of four sub-categories. Face width was the ear-to-ear visual angle computed for the average observation distance of 39 inches.

Conclusions

- Patients preferred natural images
- Wide-band enhancement was beneficial for 1 in 5 patients
- Possible reasons for this result
 - Blur adaptation
 - Longer period needed to appreciate enhancement
 - Need better algorithm (we have some ideas, will be glad to hear yours)

References

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