15.4: People with Visual Impairment Prefer TV Viewing Using a Contrast Enhancement Consumer Product

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Abstract
A device that uses technology previously tested for those with visual impairment to improve video clarity has recently been implemented in a product marketed for home theater viewers with normal sight. We found it to benefit viewers with visual impairment, even with the settings aimed at normally-sighted users, suggesting that the higher enhancement capabilities not accessible from the user interface may benefit this population even more.

1. Background

1.1 Introduction
In the US there are about 3 million people with vision impairment, and their numbers are increasing steadily with the aging of the population [1]. They watch TV regularly, and for a similar extent of time as those without impairment [2]. *Central field* loss (*CFL)*, where the central retina is damaged by macular degeneration, diabetic retinopathy, and other diseases, has a particularly disabling effect on visual perception. The natural *retinal locus* of high resolution vision (the fovea) is damaged such that patients have to learn to use another part of their retina for fixation (the *preferred* retinal locus) [3], and there are blind areas in the central visual field. The loss of visual resolution usually worsens as the disease progresses, and a new, more eccentric, retinal location is used to examine details. A simulation of vision with CFL may be seen at: http://www.eri.harvard.edu/faculty/peli/lab/videos/videos.htm

When asked what they miss in the TV picture, the answers our patients give are similar. They cannot see the details or expressions on people's faces (sometimes to the point of failing to identify who is who in the scene) and they cannot read text on screen. Some report difficulty following a storyline when they fail to identify a character.

Many CFL patients use magnification to increase the size of the image on the retina. This can directly compensate for the loss of resolution, but at the expense of the wide field of vision. Magnification of a TV picture can often help, as the success of telescopes and magnifying devices such as 'MaxTV' [4] have shown. However, context may be lost if such devices magnify only a part of the TV image and objects of interest in the surrounding area are no longer visible. Magnification may also be achieved by sitting closer to the TV, increasing the size of the TV screen, or via electronic zooming of the displayed images (which we have proposed and implemented [5]). The only alternative to magnification that has been suggested is to increase contrast via image processing [6].

1.2 Contrast Enhancement
The human visual system is sensitive to a range of spatial frequencies. An average normally-sighted person can easily see spatial frequencies up to about 25 c/deg, with a peak in sensitivity between 2 and 4 c/deg. However, high (>4 c/deg) and low (<2 c/deg) frequencies require greater levels of contrast to be seen than mid-range frequencies. Individuals with visual impairment require higher levels of contrast to see most stimuli, up to a critical frequency at which no level of presented contrast is sufficient for the stimuli to be seen by them [7]. This frequency varies according to the severity of impairment. In the population we study, most patients can not detect sinusoidal grating stimuli at frequencies above 4 to 8 c/deg at any contrast [7]. This loss in contrast sensitivity can therefore be thought of as having a low-pass filtering effect (though it is strictly a nonlinear, threshold, effect).

Contrast enhancement of images and video has been proposed as a method to make these media more visible to patients with visual impairment [8]. Local, adaptive contrast enhancement [6] has been shown to be of benefit to these patients in recognizing faces from static images [9], and more recently from videos using an implementation of the same algorithm in a real time video device (CE-3000) developed by DigiVision [10].

1.3 Hardware
DigiVision has manufactured a number of flexible devices that perform adaptive enhancement in real time [11]. Several studies using these devices in our lab have shown that patients prefer the enhanced video over the original [10]. These devices were used in medical and military image enhancement applications, but have never been marketed to the visually-impaired public.

Recently, DigiVision launched the DV-1000 CMOS chip. It performs the same real time processing as earlier, far larger systems. It can process digital video, treating it with 4:4:4 luminance/chrominance processing, and up to 1080p HDTV resolution. It is designed to be integrated with consumer devices such as TVs and video cameras. The size of the convolution kernel (which determines the spatial frequencies being enhanced) can be varied from 3.4% (5.2% in 1080p mode) to 19.6% (14.6% in 1080p mode) of screen size. A number of other parameters can be varied, including the enhancement gain (including fractional values resulting in blur), and the maximum/minimum luminance values to which enhancement should be applied. These latter two controls are provided to prevent the loss of detail caused by enhancement saturation at the low and high end (known as black and white ‘crush’.) The enhancement can be applied to any rectangular region of the picture.

The end-product manufacturer may restrict or organize these features in certain ways, to make the device specific for an application. DigiVision gives suggested presets for TV use.

In one application, Belkin has integrated the device into a new product in their PureAV® line. The product, RazorVision, is designed to be used as a simple in-line cable, with 3 enhancement pre-sets – 'Low', 'Medium' and 'High'. Supplied only with HDMI/DVI connectors, the device is clearly aimed at the HD-viewer market, and has not been marketed to those with visual

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impairments. DigiVision supplied us with a basic device with settings similar to those used in the Belkin model. Examples of the effect of enhancement settings are shown in Figure 1. Promotional material can be found on the Belkin website: http://www.pureav.com/razorvision/

The device's large kernel size allows an enhancement of moderate spatial frequencies that may be useful to people with these impairments at the seating distances they use at home (Section 2.2). The purpose of this study was to investigate whether people with CFL could perceive any benefit from using the device at the three preset levels included in the Belkin RazorVision product.

a

b

c

d

Figure 1. Examples of the video processing of the DigiVision device used in the study. **a.** No enhancement **b.** 'Low' **c.** 'Medium' **d.** 'High' enhancement

2. Methods

2.1 Experimental Setup

The DigiVision device we used featured analog S-Video input and output using analog to digital circuitry surrounding the DV-1000. The external controls were identical to the Belkin RazorVision device. The DV-1000 control software allows computer-based control over the level of enhancement applied, and also allows full control over the internal parameters (which were not modified in the current study).

We presented a sequence of six short video clips selected to represent various types of programs seen on TV [12]. Subjects were seated 3’ from and centered between two identical TVs (approximately 3’6” diagonally from the center of any one TV). The videos were taken from DVDs, and played using the VLC media player (www.videolan.org). Sixteen times during the sequence, subjects were asked which TV picture looked 'clearer' to them (see Figure 2). Each TV received the processed video (processed using the DigiVision DV-1000 device) for half of these presentations, according to one row from a table counterbalanced for 8 presentations with 24 subjects, which was repeated twice. The table also controlled processing enhancement level, with 4 presentations of each level ('bypass', 'low', 'medium' and 'high') per subject. It was important to test the no enhancement 'bypass' mode in case any effect of processing was present. The sequence of videos was started at a video determined by subject number; e.g., the sequences for subjects 1 and 8 began at video number 1. Not all subjects saw all of the videos, as the sequence length varied depending on individual response time.

The alternation of the processed image presentation was achieved using an Extron® MMX 42 SVA RCA video switching unit (Extron Electronics, Anaheim CA). This switcher accepts up to 4 S-Video+audio inputs, and can switch any of these to one or both of two S-Video+audio outputs. The device can be controlled via an RS-232 serial cable or with front-panel controls.

The TVs were identical in so much as they were both of the same model, bought at the same time and from the same store. They did not come from the same batch number, so we cannot be sure of equal manufacturing specifications, but they were adjusted using the controls until the picture display was subjectively equivalent, using both moving video and static test pattern generator signals.

A custom software program enabled the experimenter to record the subject's choice of clearer image, as well as starting video playback at the correct video, controlling the video switch for correct output and sending the appropriate key presses to the DigiVision control software to select the correct enhancement level.

Audio was provided to the subjects at a low level, so that they would concentrate on the picture rather than the segments of storyline being presented. This was a difficult change in viewing habit for some subjects, who often use audio to help deduce what is taking place in the program.

2.2 Subjects

22 subjects (mean age 61; range 19-87) having mean visual acuity 0.82 logMAR (20/132 Snellen, range 20/46 – 20/609) took part in the experiment. Twenty of them had CFL. Subjects were recruited from our database of participants from previous studies, and from ophthalmology clinics in the Boston area. They estimated the amount of TV they watched per day at 2.8 hours (range 0-7.5), using a mean home sitting distance of 5’ 5” (range 2”– 18’), and TVs of mean size 29” (range 12-52”).

2.3 Analysis

Low-vision patients, and particularly those with CFL, may have a side bias [13]. The patient may have one eye that is much better, resulting in favoring images on one side (especially at the short viewing distance). With the preferred retinal locus on one side of the central blind area in about 75% of CFL patients, there might be a preference to one side as well. Such bias could mask the effect of the enhancement we are investigating. Although the balanced presentation of all conditions on both screens prevents the bias from causing a false result, it does not prevent the masking of the actual effect of the enhancement. To reduce this masking (systemic noise) effect, we identified the patients with strong side preferences. This was done using the binomial test for small samples (16 trials per subject) to examine the difference of observed proportion from that expected (50%) [14]. We found 4 subjects with a strong preference for one side over the other (75% in all cases, $p=0.028$). The data from these subjects were removed from subsequent analyses. The highest side-preference shown by the remaining subjects was 69%, in 4 subjects (ns, $p=0.067$).

The remaining data were pooled across all subjects and presentation side, and analyzed using the proportion of presentations preferred. The chi-square test was applied. The value of Cramer's V, which can give a measure of the strength of the association, was also obtained. Cramer's V values close to 1.0 are considered strong. These two tests were carried out using SPSS version 10 (SPSS Inc., Chicago, IL). The result for the 'bypass' no-enhancement case was compared to the expected 50% and was tested using the binomial test for large sample sizes [14].

Figure 2. A visually-impaired subject choosing the enhanced video on the left screen. Note the short seating distance.

3. Results

Figure 3 shows that the patients with impaired vision had a clear preference for enhancement. The chi-square test confirmed that this effect was significant (chi-square=31.4 with 3 dof., $p<0.001$). The Cramer's V statistic was 0.3, indicating moderate strength of association between enhancement level and proportion of presentations preferred. This result was also highly significant ($p<0.001$). Note that for the bypass case, the processed image was selected only 38% of the time (with 50% the expected value). This difference, which was significant ($p=0.01$), might indicate that the bypass setting on the device actually reduces the clarity of the video slightly. This might be a result of the analog-to-digital conversion circuitry surrounding the DV-1000 chip.

4. Discussion

Our results show that patients with a wide range of central visual impairment are able to see the effect of the DigiVision device from the shorter than normal distance they use for viewing. They show a clear preference for the enhancement, even at the levels set for people with normal sight. A similar device could easily be developed for people who are visually impaired, by providing higher levels of enhancement – and possibly enhancing different (lower) spatial frequencies.

It is possible, with the use of the parameter controls accessible only through the computer interface of the DV-1000, to evaluate other settings which might provide even more benefit for those with contrast sensitivity loss. At some higher level of enhancement one would expect that the benefit will disappear due to the negative effects of the distortions caused by the enhancement [15]. However, newer high dynamic range displays may offer a solution for this limitation. We are planning follow-up studies which will explore the value of the wider range of parameters available to people with visual impairments, with standard displays as well high dynamic range displays, and will attempt to identify the useful range of enhancement.

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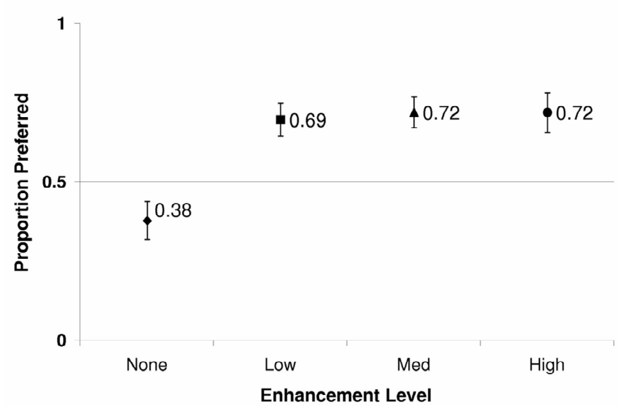

Figure 3. The overall proportion of processed presentations that were preferred by 22 subjects for each enhancement level, including the 'No Enhancement' bypass level. This bypass level is different than the 50% level expected ($p = 0.01$). This result might indicate a slight degradation of the image by the device when in bypass mode. Error bars show ±standard error of the mean computed over the subjects.

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