8.2: Factors Affecting Image Quality Preferences

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Abstract
Image quality plays a key role in consumer purchasing decisions. In this study we manipulated image quality of videos using a consumer product that enhances digital video images in real time. Videos were presented on two HDTVs, enhanced by varying amounts and subjects made pairwise comparisons. Our results showed two distinct preference groups ("Sharp" and "Smooth") in our study subjects. Preferences for enhancement depended on the video content, particularly the presence or absence of a human face.

1. Introduction
Image quality is consistently noted as one of the predominant factors in consumers' purchasing decisions [1]. Image quality can be evaluated subjectively (such as perceptual appreciation) or objectively (such as computational image measurements of the physical attributes of the image, like spatial frequency, and the display, like monitor resolution). Computational image quality metrics are also used to predict subjective image quality because measurements involving human subjects are laborious [2]. However, progress in computational image quality metrics requires a detailed understanding of perceived image quality.

Subjective image quality evaluation differs between areas such as medical imaging [3] and consumer products (e.g., cameras and video displays) [4]. Diagnostic imaging requires sufficient visible information for accurate detection (as of a tumor), whereas image quality for consumer products should satisfy aesthetic needs [5]. Attention to image quality in terms of available information as well as aesthetic appreciation is required for evaluation of image enhancement techniques for patients with visual impairments [6]. Image enhancement techniques have been developed to serve as vision rehabilitation aids for patients with visual impairments [7-11]. Both static image enhancement [9, 11-13] and video enhancements [14-16] have been reported to be preferred by patients with visual impairments.

While some progress has been made in the assessment of the image quality of static images, there has been little progress in the assessment of video quality. Before further computational progress can be achieved, particularly for video quality, much work on the measurement of subjective image quality is required [17]. Subjective evaluation of preference is also much harder in video due to its transient and variable nature.

In a recent study, Fullerton and Peli [16] evaluated video enhancement preferences of patients with visual impairments and of normally-sighted subjects. Videos were enhanced using a commercially available device marketed for normally-sighted individuals. Patients with visual impairments preferred any amount of enhancement over the original video, whereas normally-sighted subjects preferred only the least amount of enhancement ("Low"). Fullerton and Peli speculated that the normally-sighted subjects may have preferred less enhancement because they were too close to the TV (3', to match the viewing distance of the patients with visual impairments) and because videos were presented on standard-definition TV (SDTV), which has limited high spatial frequencies that can be enhanced [16]. Each enhancement level was compared only to the un-enhanced original video. Thus, there was no information about relative preferences among different enhancement levels, nor was there a test of the statistical significance of differences among the levels.

Our primary research interest is in developing tools to assess image enhancement preference and performance benefits for patients with visual impairments. While such tools will be useful for our work on image enhancement for low vision patients, it will also serve much wider needs in image compression and general image quality evaluation. In the current study we improved testing and analysis for measurement of video image quality preference. We found that normally-sighted individuals can be categorized into at least two different groups in terms of their preferences for image enhancement. Preferences varied greatly for one of the groups, based on the presence of human face content in the videos.

2. Methods
Forty normally-sighted subjects (visual acuity 20/25 or better) between the ages of 20 and 83y (median age 31y) consented to participate. All aspects of the study adhered to the tenets of the Declaration of Helsinki. Participants were unaware that image quality was being assessed, as they were told that they were control subjects in a study for a vision rehabilitation device. This created an application-independent environment that is considered desirable for image quality evaluation [1].

Subjects viewed high definition (HD) video segments, each up to 30s, on two adjacent 42" HDTVs (VIZIO VO42L FHDTV10A, Irvine, CA), at an angle of 148° between them, and from a viewing distance of 7'. The two HDTVs had consecutive serial numbers and were closely matched in their spectral and luminance properties. The source video was duplicated using an HDMI splitter (HSP12 HDMI Splitter-1-in 2-out, ConnectGear, Inc., Fremont, CA) and then were processed independently by two PureAV RazorVision devices (Belkin International, Inc., Los Angeles, CA) that were each connected to one of the HDTVs (Figure 1). Subjects made pairwise comparisons (e.g., right TV with Low enhancement versus left TV with High enhancement) to indicate their preference (two alternative forced choice). Four enhancement levels (Off, Low, Medium and High) by presentation side (Left/Right) gave 16 (4x4) pairwise combinations. Preference for each combination was measured four times, resulting in 64 trials per subject. For each subject, 64 HD videos were randomly selected from a pool of 76 HD videos. Videos were downloaded from Apple websites (http://www.apple.com/trailers/, and http://www.apple.com/quicktime/guide/hd/) and were edited down to 30s video segments using QuickTime 7 Pro.

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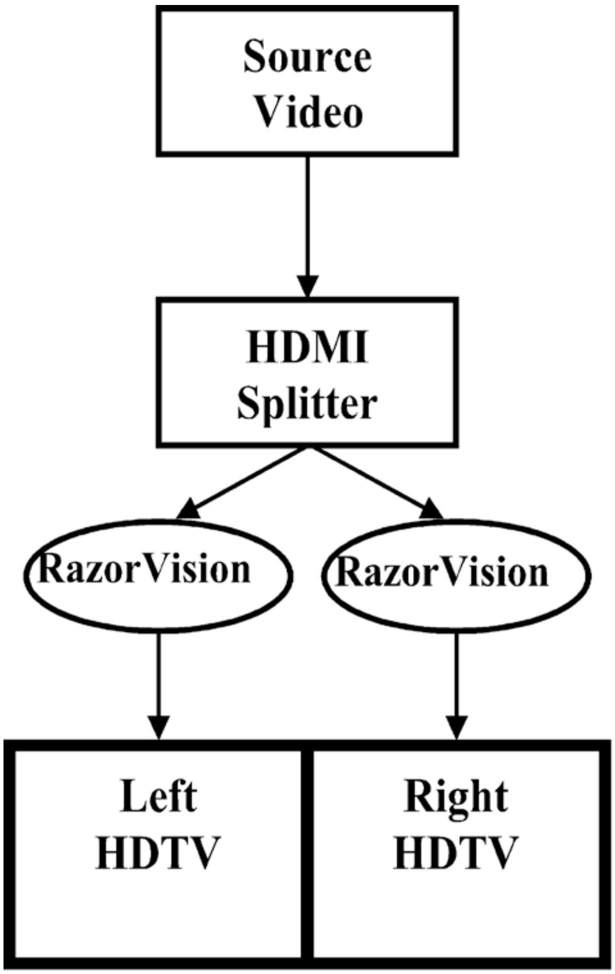


Figure 1: Experimental set up used in the study. The two HDTVs were side by side and angled (148°) so that the center of each HDTV was perpendicular to the subject. This arrangement facilitated the pairwise comparisons, as the two HD videos were shown as close as possible.

Preferences were represented in tables. An example for all subjects is shown in Table 1. The tables represented enhancement levels and presentation side in columns, and preferences for each trial were recorded in the rows. As there was no significant effect of side, the preference tables were collapsed for side. Enhancement levels not compared in a trial were indicated by zeros. An identity vector, (*e*), used as the response variable for (binary) logistic regression, was randomly assigned a value of 1 or 0. If *e* was 0, the signs of the item responses in that trial were reversed. Thus, the preferred level is indicated as 1 if *e* =1 and -1 if *e* =0. Logistic regression was performed using the method described by Lipovetsky and Conklin [18]. The obtained regression coefficients were normalized to range from 0 to 1 and were used to construct a Thurstone-like perceptual scale [18, 19]. The perceptual scale orders preferences from least (0) to most (1) preferred. The significance levels associated with coefficients indicated whether preferences for two enhancement levels are significantly different. The statistical analysis is described in detail elsewhere [20].

Pilot testing indicated that some subjects preferred natural or smoother-looking videos while others preferred a brighter and sharper appearance for the videos. Thus, at the end of the 64 trials in the main study, subjects were asked to describe their preference criteria. The reported preference criteria also depended on the video content (*i.e.*, presence of human faces). The videos were therefore classified for its content. For that classification, 4 naïve subjects, who did not participate in the preference study, rated all 76 videos for four types of content: faces, human figures, nature, and man-made objects. The distinction between "faces" and "human figures" was that if the video's primary focus was of a human face then subjects rated the video high on the "face" scale, if, on the other hand, the video's primary focus was of people without an emphasis on faces (e.g., pedestrians) then subjects rated the video high for "human figures". Each rating scale ranged from 0 to 5 (0 = content absent and 5 = always present). Subjects were asked to watch the videos casually, as if they were at home. They were encouraged to recollect "key elements" from the scene. Key elements were described as scenes or content that helped them to understand the video or that they would use to describe the video to someone who had not seen it. Ratings were averaged across the four raters. Videos were classified as "face" if they averaged 3 or higher on the face content scale, and "non-face" if they averaged 2 or lower on the face scale. Of the 76 videos, 36 (47%) were classified as face and 27 (36%) were classified as non-face. The remaining 13 videos were not classified as either and were not included in the *post-hoc* analysis of the effect of video content.

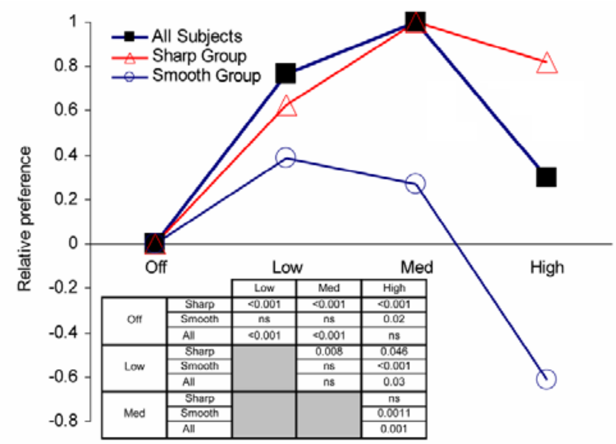
Table 1: Preference table example for all 40 subjects with the preferred level shown in bold in each row.

SUBJECT	TRIAL	OFF		LOW		MEDIUM		HIGH		IDENTITY VECTOR (e)
		LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	LEFT	RIGHT	
1	1	0	0	0	1	**-1**	0	0	0	0
1	2	**1**	0	0	0	0	-1	0	0	1
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
1	64	0	0	0	0	**1**	0	0	-1	1
2	1	0	0	0	0	0	**-1**	1	0	0
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
40	63	-1	0	0	**1**	0	0	0	0	1
40	64	1	0	0	**-1**	0	0	0	0	0

3. Results

Subjects were classified as "Sharp" or "Smooth", based on their self-reported preference criteria. Of the 40 subjects, 27 reported liking a smoother appearance, especially for human faces, and preferred brighter images for nature scenes. These subjects were classified as *Smooth*. Twelve subjects reported preferring brighter and clearer images irrespective of video content. They were classified as *Sharp*. One subject reported preferring lower contrast and had no preference for enhanced details in either nature scenes or scenes with faces. This subject was not assigned to either group but was included for the overall analysis. The preference scales obtained for each group and for all subjects pooled together are shown in Figure 2, where the three preference scales have been normalized so that the Off enhancement level was set to zero (simple translation of the scales). Statistical significance of differences between each enhancement level pair is shown in the inset table in Figure 2.

The *Sharp* group significantly preferred all levels of enhancement to Off, and also significantly preferred Medium enhancement to Low. No other enhancement levels significantly differed from each other. The *Smooth* group significantly preferred Off, Low, and Medium to High, with preferences for Off, Low, and Medium not significantly different from each other.



		Low	Med	High
Off	Sharp	<0.001	<0.001	<0.001
	Smooth	ns	ns	0.02
	All	<0.001	<0.001	ns
Low	Sharp		0.008	0.046
	Smooth		ns	<0.001
	All		ns	0.03
Med	Sharp			ns
	Smooth			0.0011
	All			0.001

Figure 2: Relative preferences for the four enhancement levels (Off, Low, Medium and High) plotted for *Sharp (n=12)* and *Smooth (n=27)* groups and for all 40 subjects. Higher values on the relative preference scale denote greater preference. Off /original video is set to zero for each group to facilitate comparison. The inset table shows the statistical significance for each of the paired comparisons (ns: not significant, p >0.2).

As the *Smooth* group's reported preference criteria depended on video content (*i.e.*, presence of human faces), we hypothesized that the *Smooth* group would prefer higher enhancement levels for non-face videos and lower enhancement levels for face videos. We conducted a *post-hoc* analysis of preference data for the *Sharp* and *Smooth* groups separately for face and non-face videos. As shown in Figure 3, the *Smooth* group's preferences clearly differed for face and non-face videos, whereas video content minimally affected the *Sharp* group's preferences.

4. Discussion

The aim of our study was to measure normally-sighted subjects' preferences for HD video enhancement. The subjects in our study watched an assorted collection of videos that was representative of broadcast television and movie content. A consumer product marketed to normally-sighted individuals for HDTV image enhancement was used. Image quality was manipulated by using the three available enhancement levels of the consumer device. The pairwise comparison methodology that has recently been used in display research [4, 21] was adapted and analyzed using binary logistic regression [18] to evaluate preferences.

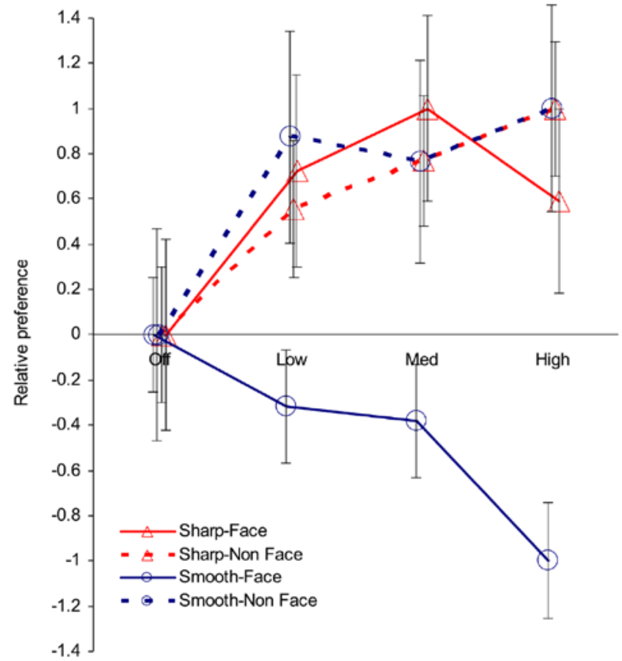


Figure 3: Enhancement preferences of *Smooth* and *Sharp* groups for face and non-face videos. Preference scaling is the same as in Figure 2. Video content with face was not preferred (values below zero) with any enhancement level by the *Smooth* group (blue solid line). 95% confidence interval is shown in the y-error bars.

Engeldrum [1] made a distinction between judgments and preferences, where, if asked "which video/image has better quality", subjects are presumed to make a judgment, whereas, if subjects are asked "which video/image do you like", subjects are presumed to make a preference decision. It is possible that different outcomes will be obtained from these two different instructions, but this has not been clearly demonstrated in this area of research. We measured preferences in our study. We found two preference patterns. One group of subjects ("Sharp") preferred higher enhancement regardless of video content, whereas another group ("Smooth") preferred higher enhancement for videos without human faces and distinctly preferred no enhancement for videos with faces (Figure 3). Video content, particularly the presence of faces, played a key role in differentiating these two groups.

In Fullerton and Peli's study [16] of the same enhancement device, the normally-sighted subjects preferred less video enhancement. Besides factors like the short viewing distance and use of SDTV, it is also possible that their subjects had Smooth-type relative preferences. We [20] reanalyzed Fullerton and Peli's data using logistic regression. There were more participants with Smooth preferences (6/12) than Sharp-type preferences (2/12). The remaining 4 participants could not be classified. Those proportions of smooth-type (0.50) and sharp-type (0.17) preferences are not significantly different from our study (0.68 and 0.30, Fisher exact test, p=0.55). Only a partial dataset was available from their study, as subjects did not make all possible pairwise comparisons. We [20] found that having a constrained set of comparison affected the relative preference function. This provided some explanation of the apparent difference in the relative preference outcomes of the two studies that used the same device. Also, it suggested that care must be taken when all possible comparisons are not made. Another recent study [22] reported that patients with visual impairments preferred lower enhancement levels for human faces than non-face static images. It is possible that the preference type is maintained after vision impairment.

Visual preferences can greatly influence a consumer's purchasing decision. Preferences may relate to objective image quality, but may differ, for example, visibility of minor skin blemishes may indicate superior image quality from computational measurements but may not be preferred by a group of customers. In conclusion, individual preferences and video content should be carefully considered in image quality evaluation and in computational metrics that are used to predict subjective responses.

5. Acknowledgements

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