Psychophysical and Psychophysiological Measurement of Image Emotion[1]

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Abstract

While emotional responses to images are highly influenced by image content, the effects of image attributes on emotion is less established. Understanding and modelling of these effects will enable us to design imaging devices and software for better user experience. In this paper, the relationship between the image characteristics and the emotional responses was investigated. Eight generic images as well as two personal photos were used as the experimental stimuli, manipulated in terms of image colourfulness and lightness contrast. Two experimental techniques, including psychophysical and psycho-physiological methods, were used to measure the emotional responses. In the psychophysical assessment, each observer rated the images in terms of pleasant/unpleasant, exciting/calming, natural/unnatural, appealing/unappealing and like/dislike. The experimental results show that image colourfulness and lightness contrast have a consistent influence on the observers' responses. The observer responses were found to be significantly affected by the image subject, and in particular by whether or not there is personal relationship of the observer to the image. In the psycho-physiological assessment, each observer's skin conductance and the heart rate variation were recorded, showing significant differences between generic images and personal photos.

Introduction

Most consumer photos serve emotional functions as well as informational ones. We keep pictures of our kids in the wallet not only because we need to remember how they look but also because we enjoy looking at them. Recent studies have shown that the emotional aspects of an image may play a more significant role in image appeal than its technical qualities, especially in consumer images [1]. If we know how to influence the viewer's emotional responses to images, we can upgrade the existing imaging devices, which are aimed mainly at maximising the information, seen in the image: lighten the shadows, sharpen the details, increase the contrast, etc [2-5].

So far most of the image quality research focused on the cognitive image content, with few studies relating image colour statistics to emotion [2,3]. All studies in this area were conducted using "generic" test images, to which the observers have no personal relation. In consumer imaging industry, however, the images are never generic – the customers print their family photos to which they have personal attachment. In the present study, the following questions are to be answered:

1) How do we modify an image's colour characteristics in order to enhance its emotional impact?

2) Are image emotion models derived on the basis of generic images applicable to personal ones?

The present work aims to provide initial answers to both questions. To do this, both "standard", generic experimental images (called "common images" in this article) as well as observer's personal "family album" photographs were used as the stimuli, manipulated in terms of image colour and contrast. Psychophysical and psycho-physiological methods [6,7] were used to measure emotional responses of the observers.

Experimental Set-up

Image selection and manipulation

Twenty-nine observers, 20 Chinese and 9 British, participated in the visual assessments. Each observer viewed images manipulated by lightness contrast and colourfulness. The source images included eight *common images* (see Figure 1), which were viewed by all observers, and two *personal images* depicting subjects of personal value to observers, e.g. family members or friends. The personal images were viewed only by the observers who provided them.

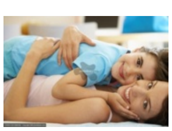
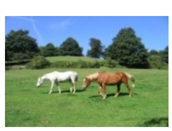
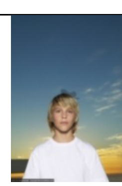
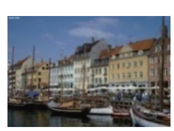
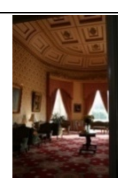
Positive		Neutral				Negative	
						IAPS image 9340*	IAPS image 2095*
Family	Horses	Outdoor	Harbour	Indoor	Fruits	Rubbish	Baby

***Figure 1** The eight "common images" were divided into 3 categories, positive, neutral and negative, according to image subject and the IPAS ratings. *: The IAPS negative images are not shown here due to the IAPS terms of use. [9]*

All images were selected according to the following guidelines: (a) the images should cover a wide range of *pleasure* values according to the International Affective Picture System (IAPS) [9], (b) the images should cover a wide variety of scenes such as sky, grass and human skins, and (c) the images should cover a reasonably wide range of colours in terms of hue, lightness and chroma. Regarding guideline (a), image subjects were divided into three groups, positive, negative and neutral, according to visual ratings of image *pleasure* reported by the IAPS. For instance, family and natural scenes were considered positive images, neutral faces and objects considered neutral, photos of a crying baby and rubbish considered negative.

All original images were firstly converted into equal size of 1024 x 768 pixels. The image RGB were converted into XYZ using a characterisation model for a Samsung LCD TV with a peak white close to D65, and were then transformed to CAM02-UCS [11] for image manipulations. The CAM02-UCS is an approximately uniform colour space based on CIECAM02 colour appearance model [12]. The eight “common images” were divided into 3 categories, positive, neutral and negative, according to the image subject. For the neutral images, the manipulations included eight levels of lightness contrast and four levels of linear colourfulness manipulations. For the negative and positive images, four levels of lightness contrast and two levels of colourfulness linear transformation were used. Examples (the *harbour* images) of image manipulation are shown in Fig.2. The sigmoid and inverse sigmoid functions (Equations 1 to 2) were used for the lightness contrast manipulation.

Sigmoid: $$G_{output} = \frac{100}{[1/(1+p^q)]\times\left\{1+[p/(0.01\times G_{input})]^q\right\}} \quad (1)$$

InverseSigmoid:

$$G_{output} = 100 \times p \times \left[\frac{1-0.01\times G_{input}\times[1/(1+p^q)]}{0.01\times G_{input}\times[1/(1+p^q)]}\right]^{-1/q} \quad (2)$$

where G_{output} represents CAM02-UCS *J* (lightness) of each pixel.

The images were reproduced on 6" x 4" prints using a colour-calibrated HP Designjet Z3200ps printer and the HP Premium Satin Photo Paper. An ICC profile was used to characterise the printer in reference to the image XYZ as shown on the LCD TV. The profile was generated using the Monaco Profiler colour management software. Each print was presented with a 0.5 cm white frame against an A5-size black paper card as the background. The prints were presented individually in a GretagMacbeth viewing cabinet with a D65 simulator as the light source, situated in a darkened room. Each image was viewed using the 0/45 geometry.

Emotion scales

This study used both psychophysical and psycho-physiological methods to measure each observer’s emotional responses. For the psychophysical measurement, the categorical judgement method [10] was used to scale the following responses: *pleasantness, excitement, preference, appeal, and naturalness*. The *pleasantness* and *excitement* scales represented the two principal dimensions of emotion, *pleasure* and *arousal,* as proposed by Russell [8]. The other three scales have been shown in previous studies as significant measures of image quality [1-3,5]. The physiological measurement, on the other hand, included skin conductance and heart rate, which have been found to correlate closely with arousal and pleasure [6].

Experimental Procedure

In the experiment, each image was viewed for 10 seconds, and was then rated using 9-point scales in terms of *unpleasant/pleasant, calm/exciting, unnatural/natural, dislike/like and unappealing/appealing*. The images were presented in random order, including 15 repetitions for variability test. Psycho-physiological recordings, including skin conductance and heart rate, were taken throughout the experiment using Thought Technology’s ProComp 5 Infiniti and Physiology Suite software.

Rendering parameters	Examples for *harbour* image
Lightness	
Coloufulness	

Figure 2 Examples of image manipulation in terms of lightness contrast(upper row) and colourfulness (lower row).

Results and Discussion

Observer Variability

The two observer groups, British and Chinese, show the same level of inter-observer variability (i.e. accuracy) in the experimental data, with an RMS (Root Mean Squared) of 1.36 for British and 1.34 for Chinese. Among the five semantic scales, response for the *exciting/calming* was the most consistent for both observer groups (with an RMS of 1.17 for British and 1.11 for Chinese) and *naturalness* the least (with an RMS of 1.52 for British and 1.48 for Chinese). Regarding the intra-observer variability (repeatability), British data were more repeatable than Chinese data (with RMS values of 1.53 and 1.78, respectively). Among the five semantic scales, the *pleasantness* response was the most repeatable (with an RMS of 1.41 for British and 1.66 for Chinese). The least repeatable responses are *natural/unnatural* for British (1.69) and *like/dislike* for Chinese (1.89). The responses between the two observer groups (British and Chinese) showed close agreement, with a correlation coefficient of 0.76. Thus the responses for two observer groups were combined for data analysis as described later. Moreover, the responses for *unpleasant/pleasant, dislike/like, natural/unnatural and unappealing/appealing* are highly correlated, with a mean correlation coefficient of 0.86. Thus the four responses were combined into one dimension, *pleasantness,* for the following analysis.

Effects of colourfulness on image emotion

Efforts were made to investigate the impact of colour appearance attributes on emotion, in terms of the relationship between CAM02-UCS attributes (colourfulness and lightness contrast) and visual results (pleasantness and excitement). It was found that the two colour attributes had a clearer relationship with the visual results expressed by the relative difference between the original and rendered, than those of the absolute scale values. It seems that the relative difference serves as a normalisation process to minimise the image dependency problem.

Image colourfulness was computed using CAM02-UCS [11]. The difference between median colourfulness in manipulated and original images was computed and plotted against the difference of mean scale values for image *pleasantness* and *excitement*, as shown in Figures 3 and 4.

Figures 3 (a)-(d) show the change in the *pleasantness* response (i.e. the difference in the *pleasantness* response between a manipulated image and its original) plotted against the change in the median colourfulness of each image, together with a best fit curve illustrating the trend, for the four image types, neutral, negative, positive and personal, respectively. The change in image *pleasantness* was described as a function of the change in median colourfulness (M). The trend was modelled using the *Log Normal Distribution* as given in the following:

$$\Delta Pleasantness\ (\Delta M) = k_0 + \frac{k_1}{\sigma\sqrt{2\pi}(k_2\Delta M - k_3)} e^{\frac{-[\ln(k_2\Delta M - k_3) - \mu]^2}{2\sigma^2}} \quad (3)$$

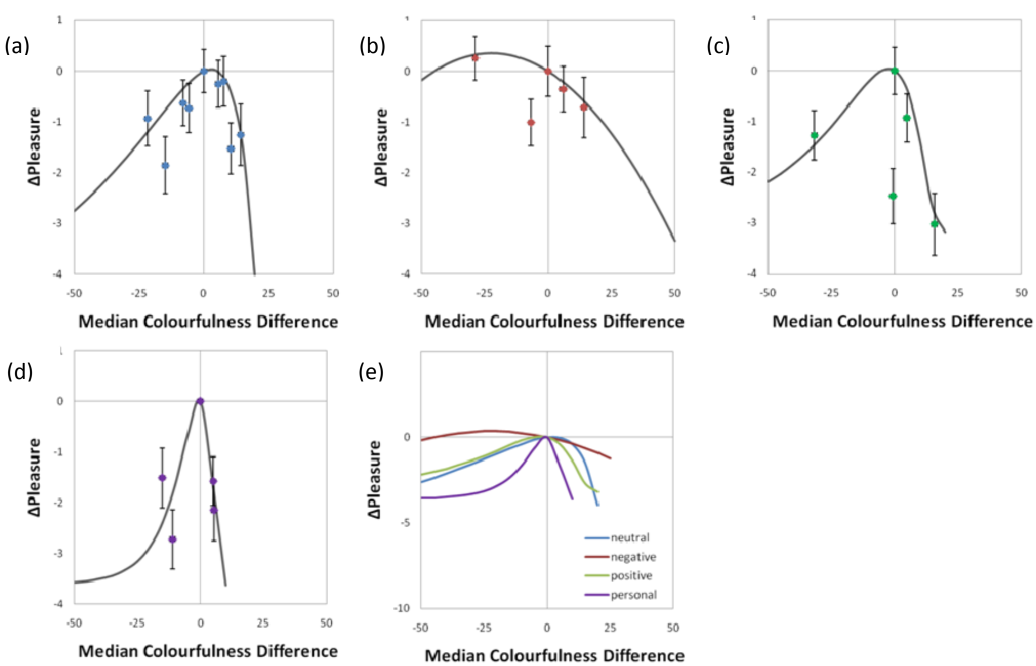


Figure 3 *Change in pleasantness plotted against change in image colourfulness for (a) neutral images, (b) negative images, (c) positive images, (d) personal images and (e) the best fit models for all subjects. The error bars show the 95% confidence interval.*

Coefficients σ, μ, k_0 to k_3 were determined by the Solver tool in Microsoft Excel to make the curve best describe the trend for each data set. To compare the trends between the four image types, all the best fit curves for the four types are presented in Figure 3(e).

The diagrams show different trends for the four types of images. The most significant difference is that the *pleasantness* response for negative images seems to remain unchanged, or even show somewhat increase in the response, when the image colourfulness is reduced to become lower than that for the original image. For the other three image types, however, any significant changes in image colourfulness seem to result in lower pleasantness response (i.e. the observer felt less pleasant). This suggests that while over-enhanced and over-reduced image colourfulness can lead to lower pleasantness response for both positive and neutral images, the decrease in image colourfulness does not influence the pleasantness response to negative images, which have been low in the first place before any manipulations.

As shown in Figure 3(e), the pleasantness response for personal images show the sharpest fall as image colourfulness changes, either increase or decrease, suggesting that the observers were more sensitive to changes in image colourfulness for their personal photos than for the common, generic images. The positive images and the neutral images show similar trends in terms of the change in pleasantness response as a function of the change in image colourfulness.

Figures 4 (a)-(d) show the change in the *excitement* response plotted against the change in image colourfulness. The change in image *excitement* was described as a function of the change in median colourfulness (M). This trend was modelled using the *Boltzmann Cumulative Distribution* as shown in the following:

$$\Delta Excitement\,(\Delta M) = k_0 + (k_1 - k_0) \times \left(1 + e^{\frac{(\Delta M - k_2)}{\alpha}}\right)^{-1} \quad (4)$$

Coefficients α and k_0 to k_2 were determined by the Solver tool in Microsoft Excel to make the curve best describe the trend for each data set. The diagrams show that the increase in image colourfulness leads to higher image excitement for all the three types of common images: neutral, negative and positive. Figure 4 (d) shows that for personal images, the excitement response seems to become lower whether the image colourfulness is increased or decreased. This result implies that observers were so conservative in changing in their personal photos that they may even feel less excited when seeing the photos being enhanced by increasing the colourfulness.

Effects of lightness contrast on image emotion

Image lightness contrast was determined by the 95th percentile of lightness value (*J* in CAM02-UCS) minus its 5th percentile value, in proportion to the entire range of lightness for the image. As shown in Figures 5 (a)-(d), over-modifications in lightness contrast, whether increased or decreased, all result in lower pleasantness response. Figure 5 (e) shows that such changes seem to be more significant for personal photos than for common images. Figures 6(a)-(d) show that increase in lightness contrast corresponds to increase in excitement response for all common images. For personal images, however, any over-modifications in lightness contrast lead to weaker excitement response, i.e. the observers felt less excited at their personal photos when the lightness contrast is either over-enhanced or over-reduced.

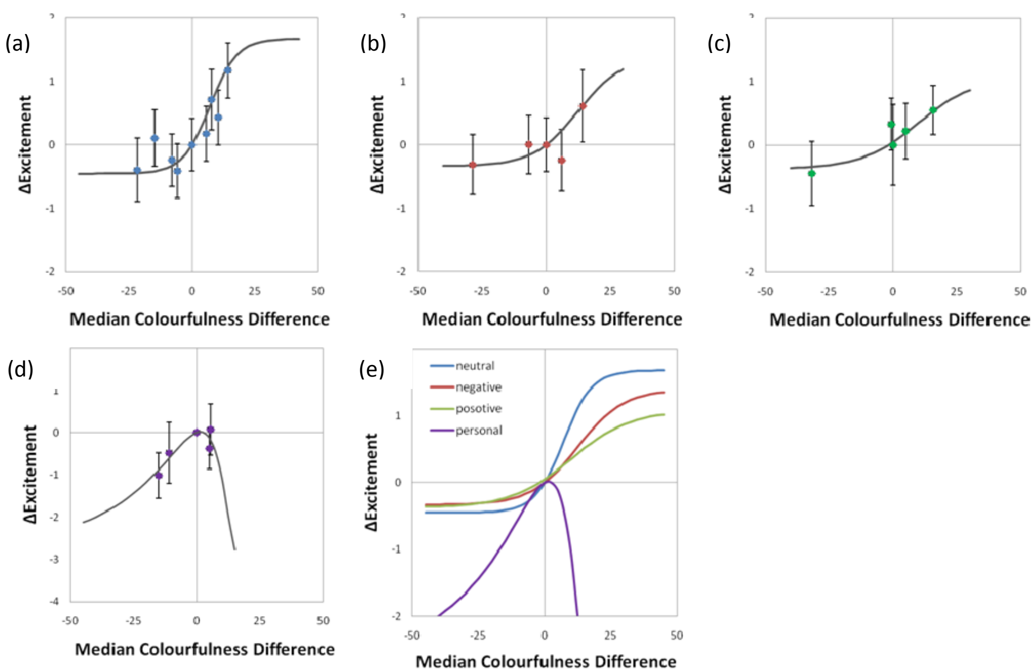


Figure 4 *Change in excitement plotted against change in image colourfulness with 95% confidence interval for (a) neutral images, (b) negative images, (c) positive images, (d) personal images and (e) the best fit models for all subjects.*

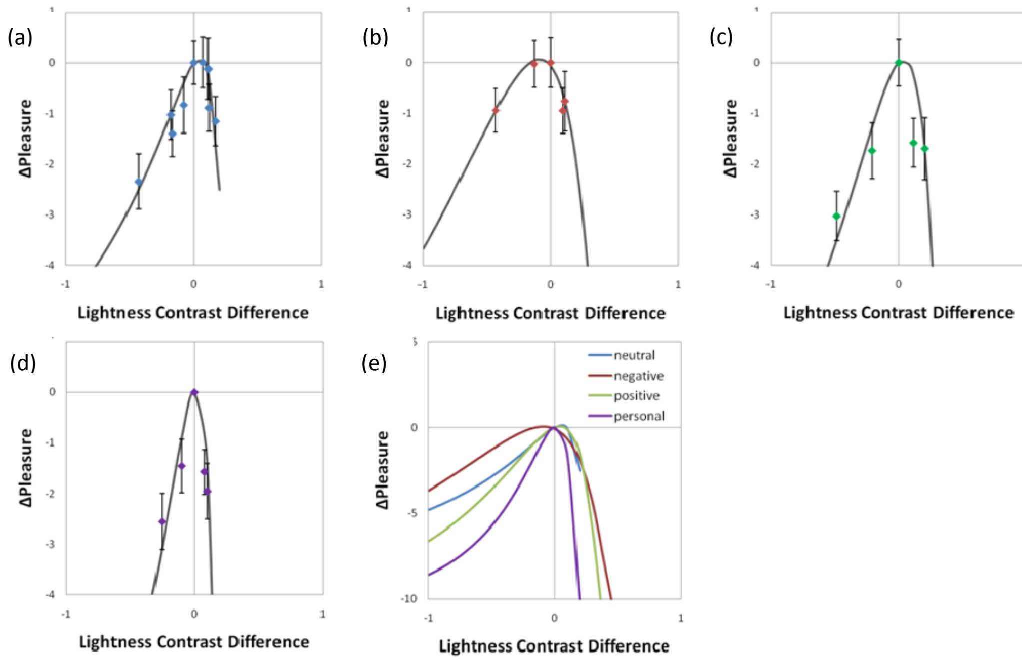


Figure 5 *Change in pleasantness plotted against change in image contrast with 95% confidence interval for (a) neutral images, (b) negative images, (c) positive images, (d) personal images and (e) the best fit models for all subjects.*

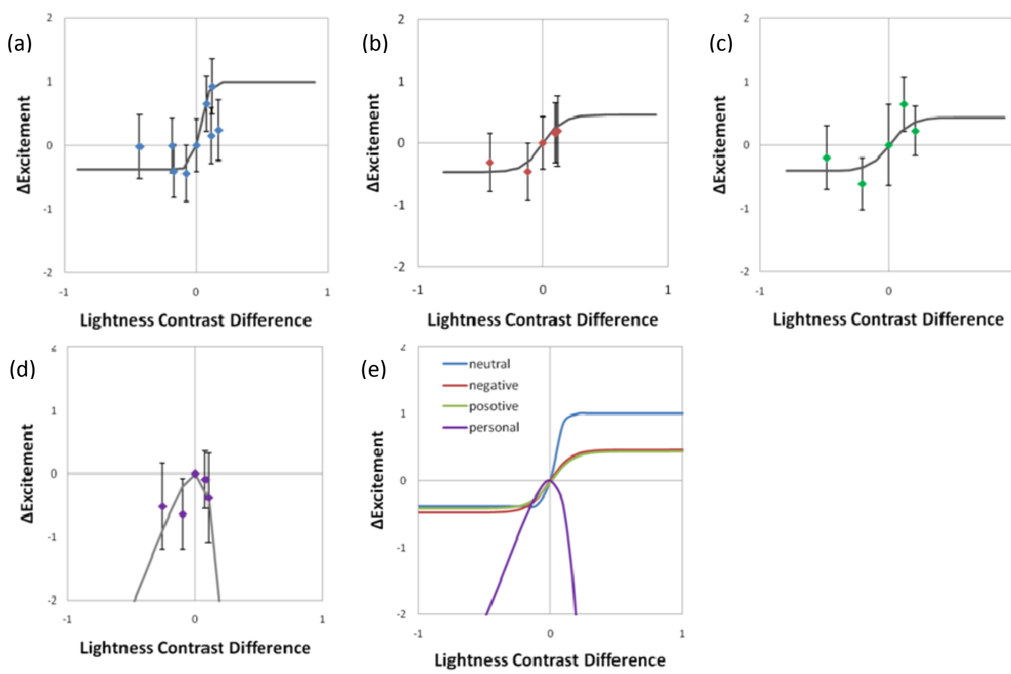


Figure 6 *Change in excitement plotted against change in image contrast for (a) neutral images, (b) negative images, (c) positive images, (d) personal images and (e) the best fit models for all subjects. The error bars show the 95% confidence interval.*

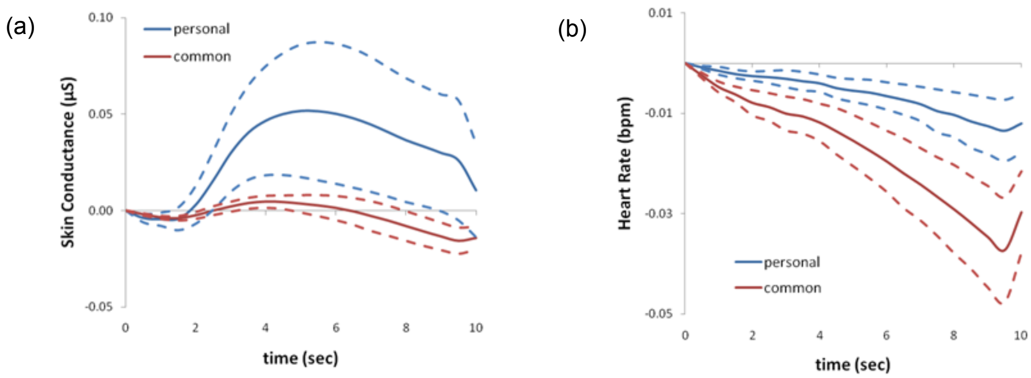


***Figure 7** Comparisons of (a) mean skin conductance and (b) heart rate variation for personal images (blue lines) and for common images (red lines). The dashed lines indicate the 95% confidence intervals.*

Effects of personal relation to the image on emotional responses

The psycho-physiological responses show significant differences between the common images and personal photos. Figure 7(a) shows the skin conductance, with the blue lines representing responses for personal images and the red lines common images. The graph indicates that the skin conductance has higher readings for personal images than for common images. It has been shown that the higher reading of skin conductance, the higher arousal (i.e. the viewer feels more aroused) [6]. This means that the personal images elicited significantly stronger emotional responses in terms of arousal than did the common images.

Figure 7(b) shows results for the heart rate variation, also indicating significant differences between personal images and common images. It has been shown that the lower reading of heart rate, the lower pleasure (i.e. the viewer feels less pleasant) [6]. The higher values of heart rate for the personal photos indicate that the personal photos were significantly more pleasant than common images to see for the viewer (who provided them for the experiment).

Conclusion

The relationship between colour attributes of images (colourfulness and contrast) and the emotional impacts of images regarding the two principal dimensions of emotion, *pleasantness* and *excitement,* were explored in this study using both generic images and personal photos as the stimuli. The experimental results demonstrate that the emotional responses resulting from variation in colour characteristics is highly dependent on image content. For generic images, the change in image pleasantness was found to decrease as the colourfulness or the lightness contrast of images were over-enhanced or over-reduced. The results agree well with a previous study which investigated the relationship between images colourfulness, image contrast and image preference. [2,5]

The change in pleasantness response to images that have negative content is rather small, illustrating the very interesting fact that no colour enhancement can make an unpleasant image become pleasant.

Image excitement, another major construct of emotion [8], was found to increase when either the image's colourfulness or lightness contrast increases. The experimental results show that such trend applies only to generic images. For personal photos, however, the observers seem to felt less excited at the manipulated images anyway, either the photos are enhanced or they are reduced in terms of image colourfulness and lightness contrast.

The experimental results show that the change in the pleasant response to personal images results in much sharper fall than those of generic ones, indicating that we are much more sensitive to the quality change in images to which we have personal emotional attachment. Figures 7(a)-(b) demonstrate that this effect may be even more significant in terms of psycho-physiological responses, as there is a large difference in terms of skin conductance and heart rate between generic images and personal photos.

The results show that the choice of images is highly application-dependant. We recommend that the future research in image perception should consider different approaches regarding the use of generic or personal images. If the application is processing technique oriented, generic image should be used. If the application is consumer-centred, however, personal photos should be used and more conservative constraints should be applied. The reason for separating the two approaches is that the two types of images have different patterns in emotions elicited, as demonstrated in the present study.

Note that the images (those before manipulations) used in this study included those having high colour fidelity of the original scenes, with the relative colorimetric intent. Such requirements should also apply to images for use in further verifications or applications of the findings presented here.

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Author Biography

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