Impacts of Package Colour on Preferred Image Colour, Contrast and Sharpness: Taking Package Design of Orange Juice as an Example

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Abstract

Due to the effects of colour harmony, preference of a foreground image varies with the background colour. This is an important issue in graphic design of packages as foreground images and background colours are two salient features. Graphic design of an orange juice package was examined as an example in present study to find out the relationship between the background colour of the package (i.e. package colour) and the foreground image in terms of colour, contrast and sharpness. A psychophysical experiment was conducted using 30 package colours as the variables, with which the observer's task was to achieve a satisfactory package appearance by adjusting colour, contrast and sharpness of an orange image as the foreground. Considering observers' Areas of Interests (AOI) while adjusting the image of orange, the results showed that to achieve a satisfactory packaging design, the higher the values of lightness/chroma for a package colour, the higher values of lightness/chroma were required for the orange image. In the case of image contrast, two distinct trends were found for the relationship between image contrast and the ΔE_{N0} *of package colour (i.e. CIELAB colour difference between the package colour and black). The first trend can be illustrated by a positive accelerated increasing function in the case of reddish-yellow package colours and the second trend was a negative accelerated increasing function for non-reddish-yellow package colours. With regard to sharpness, package colours were found to have little impact on sharpness of the orange image.*

1. Introduction

Package appearance is considered a 'salesman on the shelf'. A primary vehicle for communication and branding [1], package design can influence consumers' purchase decision making. Fruit juice is considered one of the "low involvement products" as defined by Harris [2]. Colour and graphics in fruit juice packages, two key elements of total appearance in a package design [3], have a strong impact on marketing communications and consumer decision-making. This is because the evaluation of product quality is sometimes ignored for low involvement products, whereas graphics and colour become more critical [4].

In the procedure of packaging graphic design, designers have to consider if the appearance of each visual element can harmonise. According to our previous study [5], the change of the package colour can lead to the change of both colour harmony in the design and consumer expectations about the product; consumers may expect a high quality orange juice and willing to purchase it if the package appears harmonious. Based on these results, the present study aims to investigate the interactions between package colour and the appearance of main image in the packaging graphic design, in terms of consumers' preferences, i.e. to find out the preferences of a foreground image for different package colour as the background. To achieve this, the colour, contrast and sharpness of the main image in the package were studied against different package colours.

2. Experimental Design

The purpose of this study was to investigate the relationship between package colours and the appearance of orange images in terms of colour, contrast and sharpness. The latter two attributes (i.e. contrast and sharpness) represent the spatial aspect of image quality. In the experiment, observers were asked to adjust colour, contrast and sharpness of an orange image as the foreground for 30 package colours as the background conditions, using Adobe Photoshop 7.0. The adjustments were done by the criterion of satisfaction of the appearance of the whole package design.

2.1 Stimuli preparation

The experimental stimuli were sampled using modified photographs of orange juice packages; we removed the brand logo and amended the product name and other product information, but retained the main image in the package (i.e. oranges). As shown in figure 1(a), a default stimulus, two carton-packed orange juices, is allocated in front of a neutral surround with L* of 50. We then generated 30 images for use in the experiment by manipulating the package colour, as illustrated in Figs. 1 (a) and (b). Figure 2 shows distribution of the 30 package colours in CIELAB colour space. Note that in each image, the lightness difference of the front side against the top side is identical to that in any other image. The techniques of colour processing here were based on Gonzalez and Woods' study [6].

(a) (b)

Figure 1. Examples of experimental stimuli: (a) default stimulus – white package and (b) a green package.

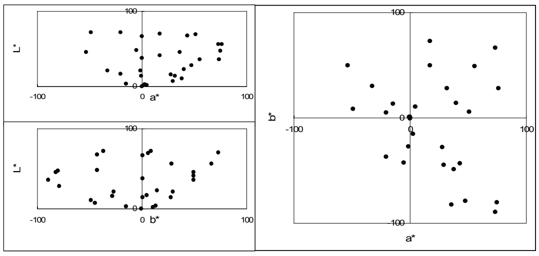


Figure 2. The distribution of the 30 package colours.

2.2 Observers

Seven males and 7 females, including 5 British and 9 Eastern Asians with normal colour vision, participated in this experiment. They were either postgraduate students or staff members at the University of Leeds and their average age was 28, ranging from 22 to 30.

2.3 Experimental Procedure

The experiment contained 2 tests. The first test was image colour adjustment in terms of hue, saturation and lightness in Photoshop. The second test was the adjustment of contrast and sharpness, using the functions of contrast and Unsharp Mask in Photoshop. At the end of each test, observers were asked to indicate the areas of interest (AOI) in the orange image, where they tended to focus on when doing the adjustment. Note that the AOI method is intended to identify which part(s) of image was used for visual assessment. There is a great interest for scientists and engineers in the field of imaging industry to understand this.

3. Data Analysis

Photoshop scores of hue, saturation, lightness, contrast and sharpness cannot be used directly in the data analysis because we do not know exactly what algorithms are used in Photoshop. Thus, the image colour, contrast and sharpness needed to be firstly defined.

Image colour was determined by calculating average CIELAB values of all pixels in the image using the average of 14 observers' AOIs as a weight matrix. The weight matrix, denoted by F, was calculated by the following equation:

$$F = \frac{\sum_{i=1}^{n} F_i}{n} \quad (1)$$

where F is the weight matrix, F_i is a matrix of the i^{th} observer's result of AOI with the focused area denoted by 1, otherwise 0 (as illustrated in Figures. 3(a)-(c)); n is the number of observers in this experiment.

(a) (b) (c)

Figure 3. (a) The image of oranges (b) an observer's AOI (as shown in white parts) (c) the average of 14 observers' AOI(s) (weight matrix)

Unlike uniform colour patches, the colours in an image vary from pixel to pixel. If the image colours were only calculated by averaging colours of all pixels in the image considered, it is considered that this average image colour cannot represent what observers see. Using a weight matrix based on AOIs in calculating image colours, a more reasonable result in terms of image colours can be produced.

A local contrast algorithm was used to define image contrast. The algorithm is given by equation (2).

$$C_{local} = \left(\sum_{i=1}^{m} \sum_{j=1}^{n} \Delta E_{ij} \right) \Big/ mn \quad (2)$$

where ΔE_{ij} is the average CIELAB colour difference of the pixel (i, j) against its eight neighbors.

The AOIs for the contrast adjustment was averaged as the weighting matrix and was then used in calculating image contrast. The contrast-adjusted orange images were pre-processed using the average AOI and then the local contrast values were calculated. Figure 4 shows the procedure of how the image contrast was defined.

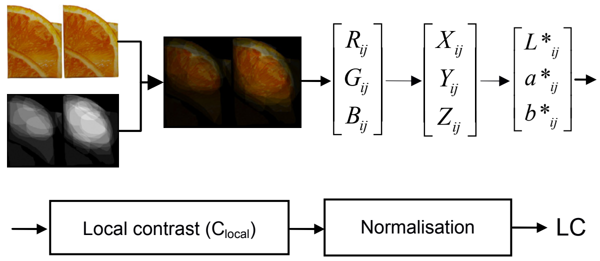


Figure 4. A flow chart of how image contrast was defined

Considering the AOI in the sharpness adjustment, same method (i.e. pre-processing orange images using average AOI as the weighting matrix) was conducted before the sharpness calculation. The image sharpness was defined as follows: (1) Conduct Fourier Transform for 3 channels R, G and B of the pre-processed orange images. (2) In the frequency domain for each channel, average the values of digital counts of all pixels timed by the distance against the centre of the channel. (3) Average the values of the 3 channels determined from (2) and then normalise it. Figure 5 illustrates this entire procedure.

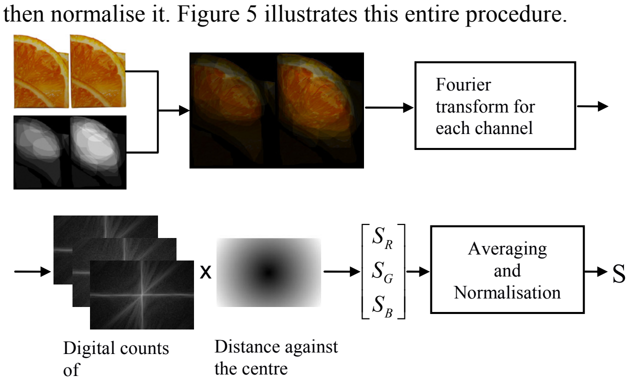


Figure 5. A flow chart of how image sharpness was defined

4. Results

4.1 The Averaged Area of Interests

We first compared the results of AOIs for the adjustments of colour, contrast and sharpness, as illustrated in Figures 6 (a)-(d) and Figures (a)-(c). Figure 6(a) shows the original orange image. Figures 6(b) to 6(d) show averaged AOIs for colour, contrast and sharpness, respectively. These results appears that the AOIs for the three adjustments were somewhat similar. To do the comparisons in a more precise fashion, we illustrated contour maps of averaged

AOIs for colour, contrast and sharpness, as shown in Figures 7 (a)-(c) respectively. The areas inside each contour show the AOIs where at least 50% of the observers pay attention during the visual assessments. The contour maps in Figure 7 reveal that observers tended to pay attention on the flesh of oranges, which occupy the largest area of the image (as shown in Figures 7(a)-(c)). When comparing the results between colour, contrast and sharpness, we found that a large part of the orange image was needed for the contrast adjustment while only a few specific areas in the image were focused on for the sharpness adjustments.

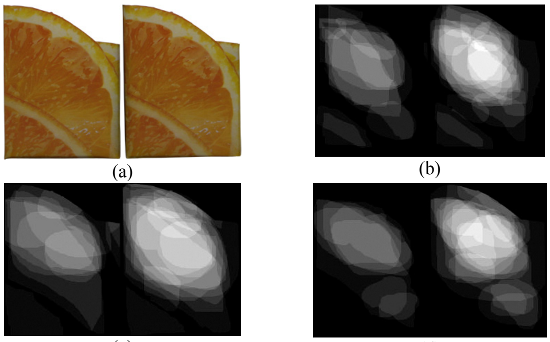

(a) (b) (c) (d)

Figure 6. (a) Original image of oranges. (b) Averaged AOIs of the image for colour adjustment. (c) Averaged AOIs for contrast adjustment. (d) Averaged AOIs for sharpness adjustment.

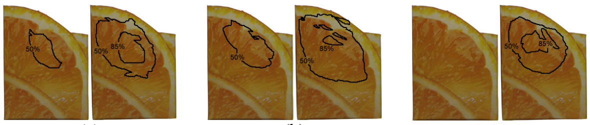

(a) (b) (c)

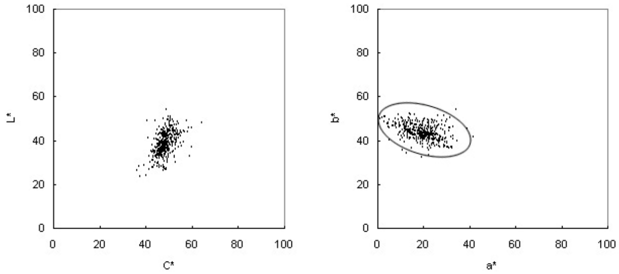
Figure 7. Contour maps of averaged AOIs for over 50% of observers during (a) colour adjustment, (b) contrast adjustment and (c) sharpness adjustment.

4.2 Preferred orange colours

In the experiment, the orange colours were adjusted to produce the most satisfying appearance of the entire package design. The adjustment results show a range of satisfying orange colours, which can be illustrated using an ellipsoid in CIELAB colour space. Figures 8 (a) and (b) show the distribution of the 420 visual results of orange image colours in CIELAB colour space. The diagrams indicate that the lightness of orange images approximately ranged from 25 to 50, with chroma approximately ranging from 40 to 60 and hue from 45° to 90°. A systematic pattern was found: to achieve a satisfactory packaging design, the higher the values of lightness/chroma for a package colour, the higher values of lightness/chroma were required for the orange image. This means that package colours with high lightness and chroma required image colours with high lightness and chroma to please the viewers. Figures 9 (a) and (b) show the relations between package colours and image colours in terms of lightness and chroma. A linear model linking package colours and preferred image colours for orange image was then developed on the basis of the pattern found above:

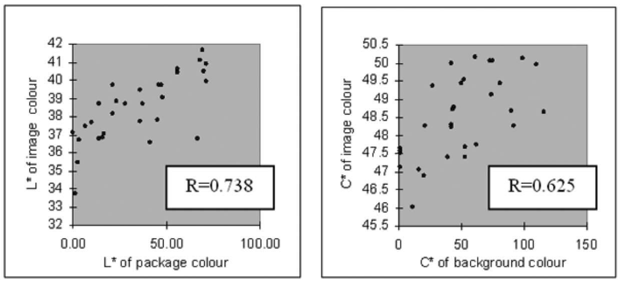
$$\begin{bmatrix} L^*_{og} \\ a^*_{og} \\ b^*_{og} \end{bmatrix} = \begin{bmatrix} 0.0945 & 0.0654 & 45.286 \\ 0.01705 & 0.0069 & 26.457 \\ 0.025 & 0.009 & 50.337 \end{bmatrix} \begin{bmatrix} L^*_{bg} \\ C^*_{bg} \\ 1 \end{bmatrix} \quad (2)$$

where L^*_{og}, a^*_{og} and b^*_{og} are mean CIELAB values of the orange image. L^*_{bg} and C^*_{bg} are lightness and Chroma of background colour in CIELAB space.



(a) (b)

Figure 8. The distribution of 420 results of image colours in CIELAB colour space: (a) L*-C* plane and (b) a*-b* plane. The ellipse in (b) represents the 95% confidence ellipse of the 420 orange image colours.



(a) (b)

Figure 9. The relationships between image colours and package colours: (a) relation of L* and (b) relation of C*.

4.3 Preferred image contrast

In the case of image contrast, the experimental results show two distinct trends for the relationship between image contrast and the ΔE_{N0} for package colour (i.e. CIELAB colour difference between the package colour and black). The first trend can be illustrated by a positive accelerated increasing function in the case of reddish-yellow package colours; the second trend was a negative accelerated increasing function for non-reddish-yellow package colours. This suggests that the hue of a package colour has a huge influence on image contrast, especially so if the package colour has a high chroma value. For example, an image of orange would need a higher contrast if the image is surrounded by a similar hue (slightly yellowish or reddish) as the package colour. Figure 10 shows the relation between image contrast results and ΔE_{N0} of package colour in which crosses denote the data of orange package colours (0°≤h<90°) and circles the data of non-orange package colours (90°≤h<360°). Based on these findings, it is suggested that hue and ΔE_{N0} of package colours are the key parameters in quantifying such a relationship and that hue of the package colour determines which relations hold between image contrast and ΔE_{N0}. Following these results, a numeral model was developed:

$$PLC = \begin{cases} 8\times10^{-6}\times(\Delta E_{N0})^2 - 10^{-4}\times\Delta E_{N0} + 0.2874 & \text{for } 0° \le h < 90° \\ 0.0234\ln(\Delta E_{N0}) + 0.2141 & \text{for } 90° \le h < 360° \end{cases} \quad (3)$$

where

$$\Delta E_{N0} = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}$$

ΔL^*, Δa^* and Δb^* are differences of L^*, a^* and b^* between the given package colour and black in CIELAB colour space. h denotes hue of the package colour. This model determines predicted image contrast (*PLC*) to the extent of 79.9%, as shown in Figure 11.

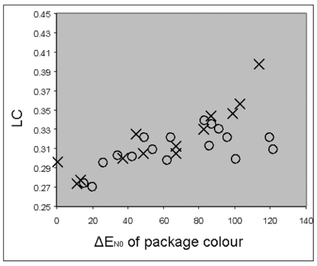


Figure 10. The relation between contrast results (LC) and ΔE_{N0} of package colour. Cross: the data of orange package colours (0°≤h<90°). Circle: means the data of non-orange package colours (90°≤h<360°)

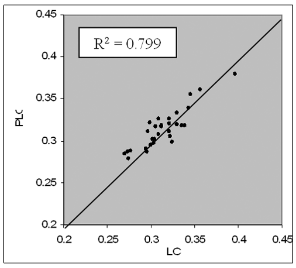


Figure 11. The relation of image contrast (LC) with the predicted image contrast (PLC)

4.4 Preferred image sharpness

Package colour (as the background) was found to have little impact on preferred image sharpness (as the foreground). The first reason was that the correlations of sharpness values (S) against lightness, chroma, hue and ΔE_{N0} ranged from 0.102 to 0.555, indicating somewhat poor correlation. Secondly, we found that the variance of sharpness scores between different observers was significantly larger than the variance of sharpness scores between different package colours ($p = 0.025$).

Considering the image difference between the images with maximal and minimal preferred sharpness values, the image difference (in terms of colour) ΔE^* is 2.13, which was not considered a large difference. Note that the image difference values were calculated by averaging colour difference ΔE^*_{ab} for each pixel in one image compared with another image. The results suggest that although observers had different preferences of image sharpness for different package colours, we did not find a clear link between the preferences and the package colours.

5. Conclusions

This study aims to clarify the relations between preferences of the appearance (in terms of colour, contrast and sharpness) of a foreground image in a package design and the package colour (as the background to that image). In the case of image colour, it was found that lightness, chroma and ΔE_{N0} of the image colours are correlated closely with package colours. This finding suggests that package colours with high lightness and chroma would need the image to also have high lightness and chroma in order to achieve a satisfactory package design. In addition, the preferred image colours were found to distribute in a narrow, ellipsoid-shape boundary in CIELAB space. A linear model of the interaction between image colour and package colour was developed on the basis of the findings.

For image contrast, it was found that the relationship between image contrast and ΔE_{N0} of package colour had two distinct trends. The relationship followed a positive accelerated increasing function in the case of reddish-yellow package colours, but it followed a negative accelerated increasing function in the case of non-reddish-yellow package colours. This relation of hue – ΔE_{N0} interaction against image contrast values was then quantified as a numeral model. For image sharpness, however, package colour was found to have little impact on the sharpness of the orange image.

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