Colour Memory Investigations on Computer

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Abstract: Colour memory plays an important role in many practical tasks related to the choice, identification and assessment of colours. The customers of colour imaging products often prefer long-term memory colours or colour prototypes of familiar objects frequently seen in the past. Colour memory is also one of the factors responsible for the phenomenon of colour constancy. These facts motivated researchers in colour science to construct different psycho-physical methods to characterise human colour memory on a computer-controlled monitor. In memory matching techniques, the remembered colour might differ from the original colour even if the viewing situation is the same. Aim of our experiments was to examine the cognitive colour effect in presence and absence of image context and to determine the "distance of emergence" of the effect related to prototypical or long-term memory colours. A further aim was to compare these results with the results of simultaneous colour matching experiments. The image context was realized by showing greyscale photo-realistic images. Results indicate that the extent of the cognitive colour effect may depend on the distance from the prototypical colour. In this work new experimental methods were designed and realized to achieve more stable and reliable experimental results.

Keywords: colour memory, memory matching

1 Introduction

Colour stimuli can be defined in terms of three tristimulus values[1]. Perceived colour is an attribute of visual perception consisting of a combination of chromatic and achromatic content. In the psychological literature, the distinction between perception and cognition has been the subject of much debate. A common distinction is that while perception refers to an immediate mapping of objects or events of the real world into the brain, cognition refers to subsequent higher-order processes of semantic and verbal classification of the perceptions[2]. The term cognitive colour may be defined as follows: the result of the colour module of early visual processing is perceived colour with its three continuous perceptual attributes, hue, colourfulness, and brightness. After the early visual processing stage, colour perceptions are classified into conceptual categories if required by the visual task. Cognitive colour means one from the discrete set of these categories. This set may depend on the visual task, e.g. the set of the eleven basic colours, or the set of the colour prototypes or long-term memory colours of familiar objects[3].

Colour memory is often required to compare an original image with its reproduction both in the laboratory and in everyday life situations, for example a woman purchasing gloves to match a hat at home, an artist in his studio mixing a colour on his palette or a photographer looking at his photo in a viewing booth and then at the reproduction of his photo on a colour monitor, or a colour inspector comparing a colour sample with a colour standard at another location. In these situations, observers memorise an original colour in a 1st viewing situation. This becomes a so-called “instant memory colour”. In traditional terminology[4], the term “memory colour” refers to colours that are recalled in association with familiar objects in long-term memory. The attribute “instant” indicates the difference between the terminology of the present work and traditional terminology. After a given time interval, observers compare their so-called “later memory colour” with an “actual colour”. The actual colour is seen in a 2nd viewing situation usually different from the 1st one. In the 2nd viewing situation, observers may modify the actual colour until it matches the later memory colour. The result of the modification of the actual colour is the "corresponding colour". In the present study the two viewing situations were identical. The difference between the original colours and the corresponding colours is completely due to memory effects[5]. The difference between later memory colour and the instant memory colour is the memory shift. Memory shifts are not related to perceptual artefacts like differences in viewing situation.

The light entering the human eye evokes a colour perception, which depends both on the colour element considered and on the viewing condition. This colour perception is subject to changes in short-term colour memory from one view to the next. Thus in one view, observers tend to remember a different colour than seen in a previous view, even if the viewing condition is the same. In short-term colour memory, shifts in hue, chroma, and lightness occur. Several authors agree that these shifts cannot be explained by sensory mechanisms or adaptation differences[6,7,8,9].

Earlier the memory matching experiments were accomplished with some kind of coloured chips, in most cases Munsell colour chips. Nowadays people use computers more often for work and amusement therefore examining the colour matching on colour monitors is important. During a colour matching experiment it is very important to ensure an equal viewing situation and within this to ensure an identical adaptation condition for the matching colours. To achieve this objective we designed and used a novel experimental set-up on a colour CRT monitor.

2 Method

Built upon our earlier experiments a new experimental method were created. The most important advantage of the “method of deciding” (described below) is that very similar viewing conditions can be ensured for the "original" colour and the "decision" colour[10]. All visual experiments have been carried out on a well-calibrated and characterised colour monitor in a dark room. Each of our 10 colour normal observers participated in three series called simultaneous (S), geometric (G), and photo (P) series. In the S series, the observer saw two colour patches of 2º viewing angle on a grey background. The observer had to tell a yes or no answer about whether the two patches were of the same perceived colour. One of the two colour patches was called "colour centre" and the other was called "decision colour". In the G series, the observer saw only one colour patch (the "original" colour). He/she had to memorize the original colour in 4 seconds. After a 4 seconds delay he/she saw the "decision" colour for 4 seconds, and had to tell a yes or no answer about whether the original colour and the decision colour were remembered and perceived the same. The P series was similar to the G series except that there was a photo-realistic greyscale image (see in Figure 1) depicting a familiar object around the original colour and the decision colour, which was intended to represent an image context known to influence the performance of human colour memory[10].

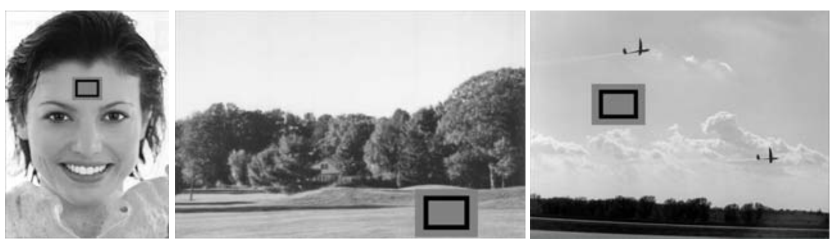


Figure 1

Photo-realistic greyscale images used in the P series

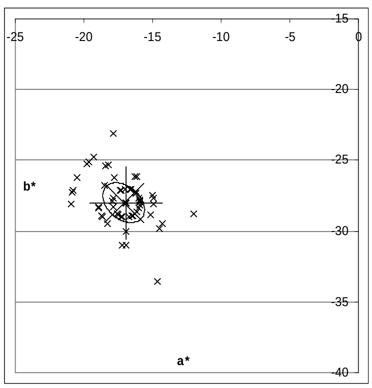
Three fixed original colour stimuli (Caucasian skin, green grass and blue sky) were used in all series as colour centres or original colours. They resulted from our previous experiments[10,11] as colour memory prototypes (in other words: prototypical colours) and thus we expected *no* significant shift between the original colours and the mean memory colours[10]. 50 decision colours per series were randomly selected from the ΔE_{ab}^{*}=20 neighbourhood of the original colours (or colour centres) by ensuring ΔL^{*}=0 between the decision colour and the original colour (or colour centre). The decision colour was allowed to be the same as the original colour (or colour centre).

3 Results

Figure 2 shows a result of the three experiments described above, for the case of the “green grass” colour, as an example. These CIELAB *a*-b** diagrams contain all "yes, the same" answers of all observers for green grass colour and for the S, G, and P series. The original colour (or colour centre) is depicted by a large plus sign, the mean decision colour of the "yes, the same" subset of 10(11, 12) observers x 50 decision colours is depicted by a smaller cross sign. The "yes, the same" subset is depicted by small crosses. The variability ellipse of latter subset is also shown. The mean and standard deviation values of CIELAB values *a*, b*,* C_{ab}, and *h* are presented.

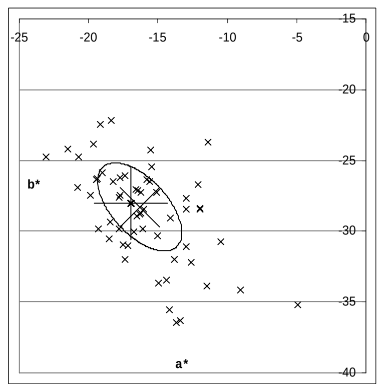
Simultaneous

Sky



	*a**	*b**	C_{ab}	*h*
Mean	16.5	10.0	19.4	30.4
STD	2.3	2.0	2.2	10.1

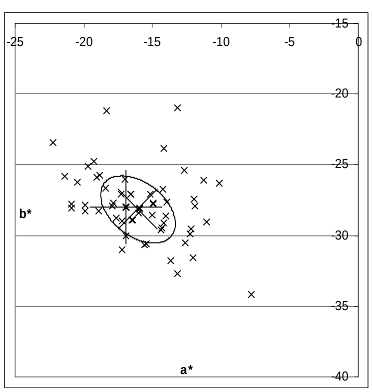
Geometrical



	*a**	*b**	C_{ab}	*h*
Mean	17.3	9.8	20.0	29.5
STD	2.5	2.7	2.8	7.1

Photo

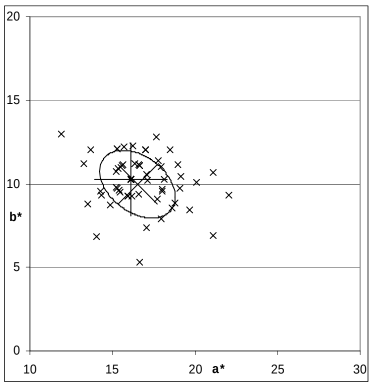
Sky

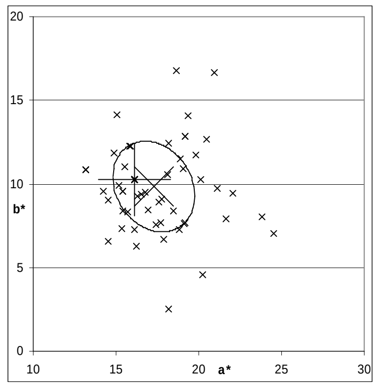


	*a**	*b**	C_{ab}	*h*
Mean	16.7	10.4	19.9	31.8
STD	2.4	2.9	2.8	7.2

Simultaneous **Geometrical**

Skin



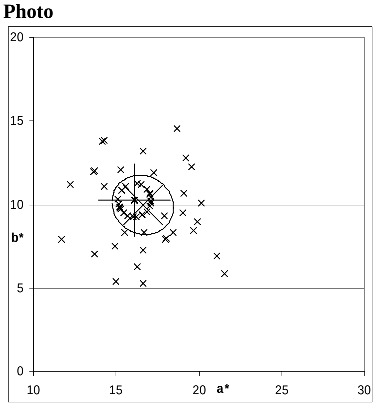


	*a**	*b**	C_{ab}	*h*
Mean	16.5	10.0	19.4	30.4
STD	2.3	2.0	2.2	10.1

	*a**	*b**	C_{ab}	*h*
Mean	17.3	9.8	20.0	29.52
STD	2.5	2.7	2.8	7.05

Photo

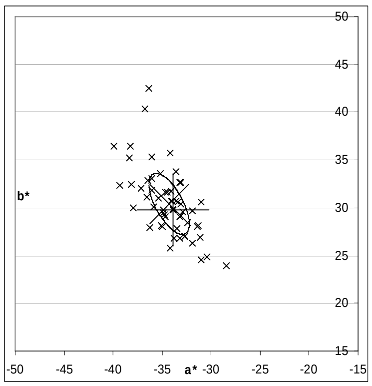
Skin



	*a**	*b**	C_{ab}	*h*
Mean	16.7	10.4	19.9	31.8
STD	2.4	2.9	2.8	7.2

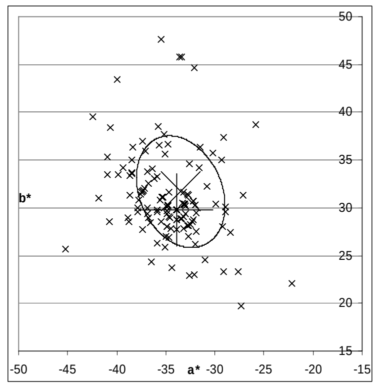
Grass.

Simultaneous



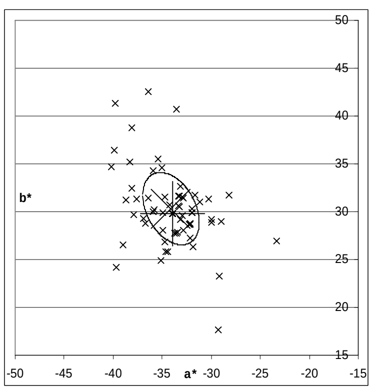
	*a**	*b**	C_{ab}	*h*
Mean	-34.3	30.4	45.8	138.5
STD	2.1	3.2	3.4	2.1

Geometrical



	*a**	*b**	C_{ab}	*h*
Mean	-34.5	31.0	46.5	138.2
STD	3.4	4.5	4.4	4.1

Photo



	*a**	*b**	C_{ab}	*h*
Mean	-34.3	30.4	45.8	138.5
STD	3.5	4.0	4.3	3.8

Figure 2

Variability ellipses for sky, skin and grass. The original colour is depicted by a large plus sign, the mean decision colour of the “yes, the same” subset of 10 observers x 50 decision colours is depicted by a big cross. The “yes, the same” subset is depicted by small crosses. The mean and standard deviation values are presented.

In Figure 2 the *a**, *b** diagrams contain all "yes, the same" answers of all observers for a given familiar object (sky, Caucasian skin and grass) and for a given experiment (simultaneous, geometrical and photo). In Figures the original colour (or colour centre) is depicted by a large plus sign, the mean decision colour of the "yes, the same" subset of 10 observers x 50 decision colours is depicted by a big cross. The "yes, the same" subset is depicted by small crosses. The variability ellipse of latter subset is also shown. Standard deviations (STDs) of the $a*$ and $b*$ values of the "yes, the same" subset are listed in tables below the diagrams.

As can be seen from Figure 2, the scatter of the yes answers is largest for the deciding colour patch experiment; it is smaller for the deciding photo experiment and smallest for the simultaneous series except for Caucasian skin colours where the photo experiment has the smallest scatter. The reduced scatter of the deciding photo experiment may be a cognitive colour effect: as already mentioned all 3 original colours chosen resulted from previous experiments as colour prototypes. In the photo experiment, in the presence of the photo-realistic greyscale image depicting a familiar object around the original colour and the decision colour, the tendency to categorize the original colour may be extremely strong. Therefore, observers tend to remember a category only i.e. to remember a cognitive colour. Observers may remember the expression “Caucasian skin” and accept or not accept the decision colour as "Caucasian skin" long-term memory colour. The tendency seems to be weaker for the case of the deciding colour patch series hence scatters tend to increase.

In previous experiments, the “original” colour stimulus and the selected “actual” colour stimulus were significantly and systematically different. The memory colour shift was usually directed towards a basic colour or a colour prototype. In the present series, the original colour was a colour prototype, and, as expected, memory shifts were statistically not significant. The original colour (or the colour centre) is well within the variability ellipses in Figure 2.

The effect of presenting or not presenting the visual context of a photo-realistic greyscale image has turned out to be significant. As expected, the mean short-term memory colour was not significantly different from the original colour.

Conclusions

From the results of the experiments the following main inference can be drawn: the original colours can be regarded as prototypical colours because they are located inside the variability ellipses which were created to be analogous to the MacAdam[12] variability ellipses. These variability ellipses denote the accuracy of remembering so the original colour is a prototypical colour if it is located inside the ellipsis.

The variability ellipses of memory colours can be defined as follows: if the original colour is inside this ellipsis then the memory colour is still considered as prototypical but if the original colour is located outside this area then a cognitive effect can be observed during the memory matching. This cognitive effect also begins to act inside the area of the ellipsis and the appearance of the effect is continuous.

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