Colour Memory

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Abstract

The aim of this study is to give an overview about the phenomenon of human colour memory: the related concepts, methodology, experimental findings and their interpretation. The concept of "cognitive colour" is defined. The characteristics of short-term and long-term colour memory are discussed, including memory colour shifts. Psycho-physical experimental methods to quantify colour memory are described and some typical memory colour results are briefly presented and interpreted.

1. Cognitive Colour

One result of visual processing is *perceived colour* with its three continuous perceptual attributes: hue, colourfulness, and brightness. After this processing stage, the colour perception can be classified into a *category* if it is required by the observer's task. Classification is related to the economy of cognition in the human brain. This economy has been of great survival value, accelerating several complex visual tasks. For these tasks, colour appearance and colour difference modelling is limited for predicting the observer's behaviour[1].

Perceived colours are represented and stored in a compressed form as cognitive colours. Cognitive colour means one item from the discrete set of colour categories. This set may depend on the observer's task, e.g., naming the set of the eleven basic colours, or the set of the colour prototypes or long-term memory colours associated with familiar objects. Cognitive colour is very important in certain specific tasks like colour coding, colour naming, Stroop effect, spatial organization of coloured visual objects, visual search, and colour memory[1]. We can define the concept of *cognitive colour space* by the discrete set of the perceived colour categories. Each category corresponds to a volume of colour space. If a perceived colour is in this volume then that perceived colour will be associated with that category. A cognitive colour can be represented by the boundaries of this volume or by a "representative item" e.g. the "centroid" item [2].

2. Colour Memory

In the visual task where the colour memory of the observer is involved, the concept of cognitive colour plays an important role. In a typical memory matching task, the observer memorizes his/her perceived colour of an "original" colour stimulus, and then, the original colour disappears. After a given time, his/her task is to reproduce his/her short-term memory colour by selecting one colour from the colour perceptions of several "actual" colour stimuli. Instead of selection, other methods can also be used (see Section 3 below). In a different kind of experiment used to quantify the long-term memory colours directly, there is no "original" colour stimulus (see Section 3 below).

In the visual experiments, the original colour stimulus and the selected "actual" colour stimulus are usually significantly and systematically different, and this is usually called a *memory colour shift*. The memory colour shift is usually directed towards a basic colour or towards a colour prototype (in other words, a long-term memory colour of a familiar object) which was similar to the original colour[3]. The reason is that the observer tends to categorize the original colour and to remember only that category, i.e., to remember a cognitive colour, e.g. a long-term memory colour. For example, it may seem more economical for the observer to remember the expression "green grass" instead of a particular colour shade of green grass. The selected "actual" colour stimulus tends to represent the cognitive colour remembered; it comes from that volume of perceptual colour space that corresponds to the cognitive colour remembered. The selected "actual" colour stimulus tends to be close to the representative item of the volume (see the end of Section 1).

If the observer happens to be a colour specialist then he/she may recall a term of a colour atlas for the original colour as soon as the colour is perceived and then he/she may remember that colour atlas term. In the author's view, this can also be considered a cognitive colour with a small volume in colour space. As the volume is very small, there is *no memory colour shift* in this case.

3. Methods to Quantify Colour Memory

We used several different psycho-physical methods to quantify colour memory. An experimental technique usually consists of two main steps: 1. the observer is given a cognitive and/or perceptual *cue* 2. he/she has to find his/her memory colour based on this cue. Four types of such cues were recognized.

1. "Abstract" cue without image context. In this case the observer is told the *name* of a familiar object (e. g. "green grass"), and then, he/she has to determine his/her *long-term* memory colour (or in other words: colour prototype[4]) corresponding to this name.

2. "Abstract cue with image context". In this case the observer can see a *greyscale picture* of a familiar object (e. g. a landscape) in which an area is left blank. Then he/she has to find out his/her *long-term* memory colour that would best fit that blank area.

3. "Memory matching cue without image context". In this case the observer can see a standalone uniform colour patch. This is the original colour i.e. the colour that he/she has to memorize. "Standalone" means that there is no image context (e.g. a photo depicting a familiar object) together with the original colour. Then, there is a time interval (e.g. 4-60 seconds) where only a uniform background is displayed. After that, he/she has to find out his/her "actual" colour perception or short-term memory colour for the original colour.

4. "Memory matching cue with image context". Similar to the above but in this case, the uniform original colour patch is displayed within a (greyscale) photo-realistic image. This image is intended to provide the image context for memory matching. E.g. if the image is a landscape and the uniform original colour patch is in a "grass area" of the landscape then this will suggest remembering the word "grass".

We used three types of methods to find out the memory colour. The first method is a "method of adjustment", and the second and the third method are "constant stimulus" methods[5].

1. "*Matching*" the memory colour on a colour output device (a visual colorimeter or a colour monitor) by adjusting the hue, the chroma, and the lightness of the "actual" colour. Strengths of this method: all colours can be matched within the colour gamut, and, the same viewing condition can be ensured by using greyscale images. Weakness of this method: it may be difficult for the observer.

2. "*Selecting*" the memory colour from several constant colour patches. Strength of this method is that it is easy to do. Weakness of this method is that there is a perceptual difference between the viewing situations of memorizing and selecting (latter viewing situation consists of several colour patches to select from). An additional weakness is that the number of the constant patches and hence the colour gamut to select from is limited.

3. "*Deciding*" whether a just presented colour patch (the "actual" colour or “decision” colour) is the memory colour or it is not (yes/no answer). This is very easy to do for the observer but the subsequent presentation of many different colour patches may confuse the observer and influence his/her memory colour.

4. Memory Colour Results

Six *long-term memory colours*, skin (both Caucasian and Oriental), green grass, blue sky, deciduous foliage, orange and banana, were quantified in the CIELAB colour space, in the viewing situation of a self-luminous colour monitor, for two different observer groups, Koreans and Hungarians[6]. In this experiment, a combination of the following methods was applied (see Section 3): “abstract” cue without image context with "selecting" the memory colour from several constant colour patches and then also with "matching" the memory colour, and finally, “abstract” cue with image context together with "matching" the memory colour. The final quantification of the six long-term memory colours was based on averaging the results[6] of these methods, see Figure 1. Significant differences were found between the Korean and the Hungarian long-term memory colours[6], e.g. although Oriental skin and Caucasian skin had similar chroma, Oriental skin contained somewhat more yellow hue, and Caucasian skin was found to be significantly lighter than Oriental skin. Literature data [7, 8] were different from our experimental findings possibly mainly due to the viewing conditions differences. Literature data were obtained by using reflecting stimuli and not self-luminous stimuli as in the present study and this seems to influence the recall of long-term memory colours significantly.

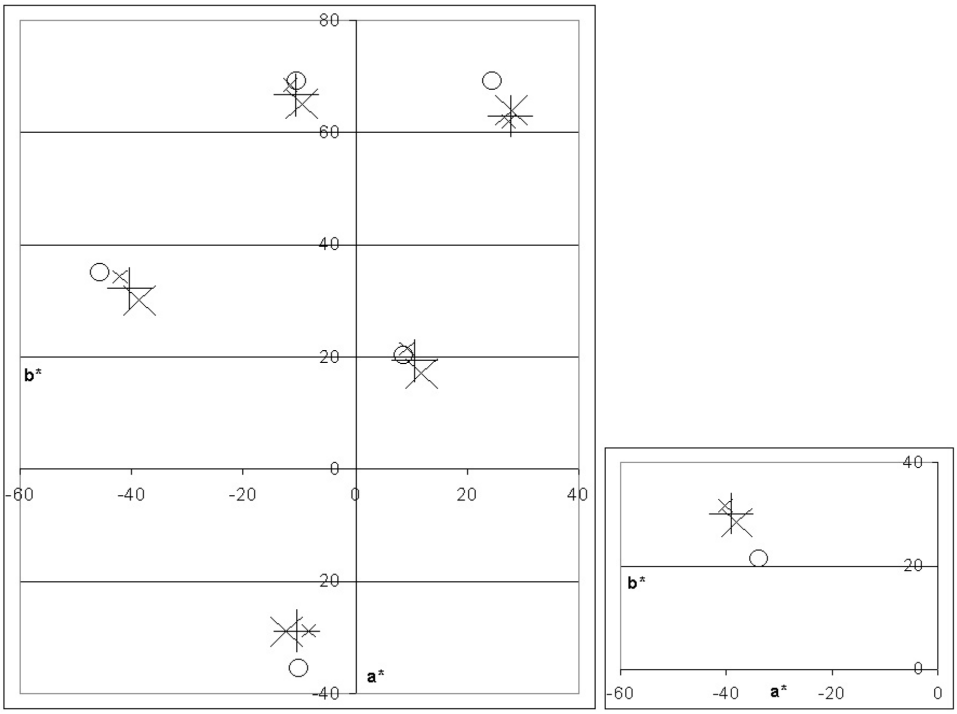

Figure 1. *Korean and Hungarian long-term memory colours[6] in CIELAB a*-b* diagrams. Open circles: Korean, small crosses: Hungarian (first experimental series), large crosses: Hungarian (second experimental series), plus signs: Hungarian (average of the two series). Foliage is shown in a separate diagram on the right. Long-term memory colours in the left diagram (clockwise from the green grass colour on the left side): green grass, banana, orange, skin (both Caucasian and Oriental), blue sky (at the bottom).*

Concerning the *short-term memory colours* and the *memory colour shifts*, an interesting tendency was found by plotting the hue component of the memory colour shift (see Section 2, the hue shift can be expressed e.g. in CIELAB hue angle differences Δh_{ab}) as a function of the hue of the different original colours (h_{abO}) for the different types of object (e.g. sky, skin or grass) separately. In our previous studies, blue sky, Caucasian skin, and plant colours were investigated[3, 9]. An example is shown in Figure 2. Similar tendencies were found for chroma and lightness as for hue. The tendency was the existence of "constant" hue, chroma, and lightness intervals. The concept of “constant” intervals is defined in the following way: If the original colour is in the “constant” interval then there is no significant hue, chroma, or lightness shift [3, 9]. Considering only one type of object (e.g. blue sky or Caucasian skin or plant), the memory colour shifts were *systematic* in the sense that they were *directed toward the constant intervals*. The reason for this finding was claimed to be that the mean values of the constant intervals were “representative items”[1] (see the end of Section 1) and they represented long-term memory colours [3]. In these studies[3, 9], the “memory matching cue with and without image context” was used together with the method of “matching” (see Section 3).

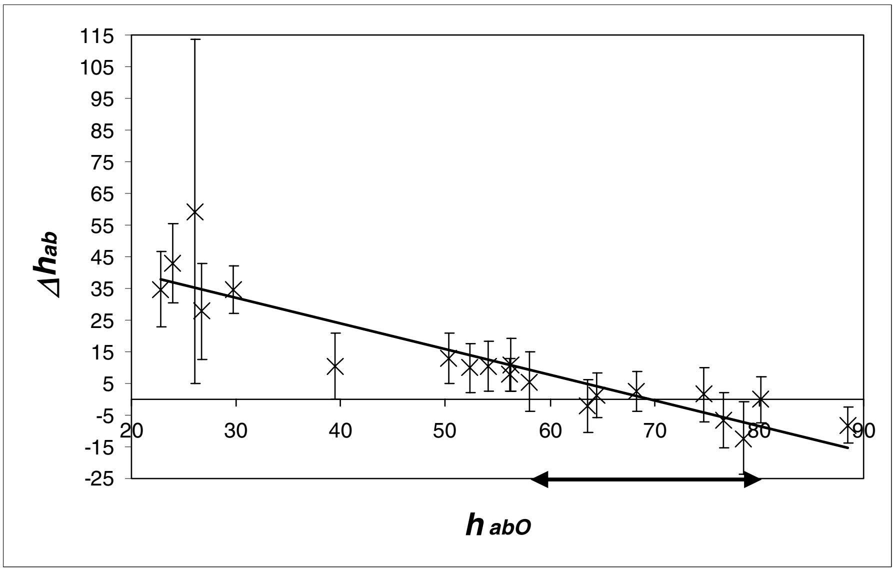

Figure 2. *Hue component of the memory colour shift, expressed in CIELAB hue angle difference Δh_{ab}, as a function of the hue of the different original colours (h_{abO}) for Caucasian skin. Result[3, 9] of the method of "memory matching cue with image context" and "matching"(see Section 3).The arrows show the "constant" hue interval of Caucasian skin (see text).*

In a recent study[10], among other methods, the method of decision (see Section 3) was applied, in 3 conditions: "memory matching cue without image context", "memory matching cue with image context", and, as a reference condition, simultaneous colour matching was also applied. The original colours were long-term memory colours taken from our previous experiments (blue sky, green grass, and Caucasian skin)[3, 9]. The aim of this study was to prove that these original colours were real long-term memory colours and to compare the accuracy of simultaneous and memory matching. The accuracy of matching, expressed by the size of the variability ellipses of the "yes" answers of the method of decision, was best for the case of simultaneous matching, worse for the memory matching experiment with image context, and worst for the case of the absence of image context. Figure 3 shows an example. In the image context experiment, in the presence of the photo-realistic greyscale image depicting a familiar object around the original colour and also the "decision" colour, the tendency to categorize the original colour was strong. Therefore, observers remembered the colour category only i.e. they remembered a cognitive colour. The three original colours turned out to be real long-term memory colours because the memory shifts were not significant and the original colours were always well within the variability ellipses of the "yes" answers of the method of decision.

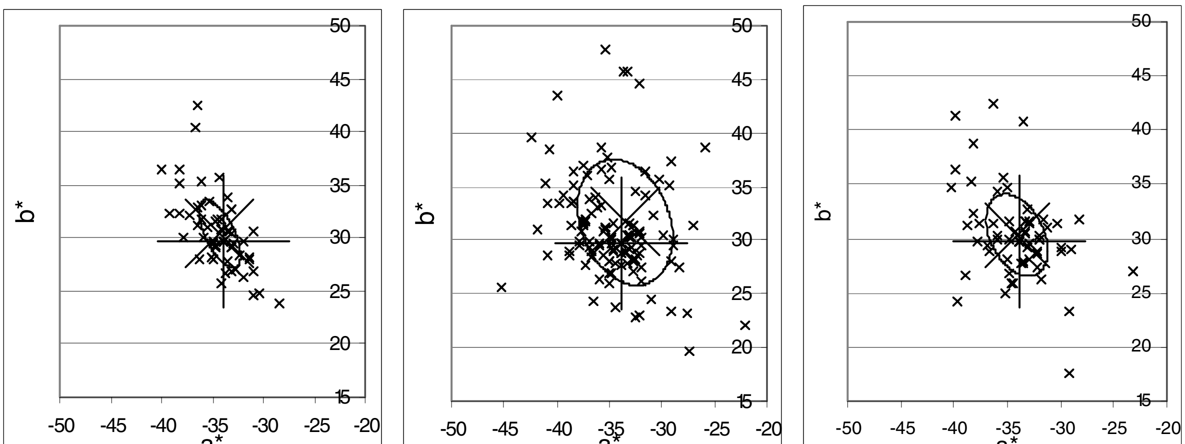

Figure 3. *Variability ellipses of "green grass" in CIELAB a*-b* diagrams. Method of decision (see Section 3). Original colour: large "+" sign, average "decision" colour of the "yes, the same" answers: large "x" sign, all "yes, the same" answers: small "x" signs. Left diagram: simultaneous colour matching, middle diagram: memory matching without image context, right diagram: memory matching experiment with image context.*

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Author Biography

Peter Bodrogi received his MSc degree as a research physicist from the Eötvös Loránd University, Budapest, Hungary, in 1993 and his PhD degree in information technology from the Pannon University in 1999 with a thesis on the psychophysical investigation of human colour image memory effects on computer controlled monitors. He is currently an associate professor with the Pannon University, and is responsible for the education of photonics, lighting engineering, and computer ergonomics for information technology students. He participated in several industrial research and development projects in the fields of optics, lighting engineering, and information technology, as a researcher and as project manager. His research interests are photometry, colorimetry, visual psychophysics, and the optical and lighting engineering aspects of information technology, including the design and testing of colour displays.