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# Memory Color

Christoph Witzel* and Karl Gegenfurtner
Department of Psychology, Giessen University, Giessen, Germany

## Synonyms

Canonical color; Diagnostic color

## Definition

A memory color is the typical color of an object that an observer acquires through their experience with that object. For example, most people know that a ripe banana is typically yellow; this knowledge about the typical color constitutes a memory color.

## Conceptual Clarifications

A memory color is an observer's knowledge of a typical object color. The typicality of the memorized color implies that the observer considers the memory color to be representative or "canonical" for the range of colors, in which the respective object occurs. In this way, it determines the observer's expectation about an object's color based on her or his prior knowledge. For example, an observer that is only familiar with the yellowish color shades of the ripe common bananas (i.e. Cavendish bananas) would be surprised to encounter a Red Dacca banana because it is not in line with this observer memory color.

The concept of memory color is historically closely related to the idea of a memory color effect on color appearance. Moreover, it partly overlaps with the notion of "color diagnosticity". Finally, it ultimately refers to the same phenomenon as "canonical color," though with different emphases and connotations. This section will clarify these conceptual relationships.

### Memory Color Effect

The notion of a "memory color" was coined by Ewald Hering in 1878 [1]. He associated it with the idea that knowledge about typical colors affects the perception of the actual color of given objects (e.g., [2]). However, the fact that an observer knows about the typical colors of certain objects (i.e. memory colors) does not necessarily imply that this knowledge influences the way they see the actual object colors. For this reason, it is sensible to disentangle the concept of a memory color from the idea of a memory color effect on color appearance. Hence not all research on memory color is about the memory color effect.

### Color Diagnosticity

Like memory colors, color diagnosticity refers to the association between an object and its typical color. An object is color diagnostic when it only occurs in a particular range of color shades, and this

*Email: cwitzel@daad-alumni.de

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range of shades may be summarized by a typical color as the best example of this object's colors (objective color diagnosticity). For example, ripe bananas occur in a limited range of yellowish shapes, and this range may be summarized by a yellow that is typical for ripe bananas. In contrast, cars are not color diagnostic (or color neutral) in an objective sense because they occur in arbitrary colors. However, in order for an object to be color diagnostic for a particular observer, the observer needs to know what the range of color shades are, and what the most typical colors are (subjective color diagnosticity). This knowledge consists of memory colors, and hence, the memory color for an object constitutes its subjective color diagnosticity. In most cases, it may be assumed that subjective color diagnosticity converges towards objective color diagnosticity through experience, so that memory colors approach the most common or typical color of an object. However, the objective co-occurrences of objects and colors and the subjective knowledge about them are not a priori the same.

### Canonical and Typical Color

While the term "memory color" has been employed in psychophysics, the alternative term "canonical color" is primarily used in developmental research [3, 4]. Here, the research questions are more focused on the developmental order than on the subjective nature of memory colors. Hence, in these studies the term "canonical color" is often used in a way that abstracts from the difference between subjective and objective color diagnosticity and refers directly to the color-object association determined by the experimenter. However, since these studies concern the object-color association of the observers and not the regularities in the environment, the term "canonical color" is ultimately interchangeable with the one of "memory color". While "memory color" emphasizes the psychological, subjective aspect of perception and memorization, "canonical color" highlights the convergence to a shared knowledge that reflects the statistics of the environment.

The notion of "typical" or "prototypical object color" seems to merely refer to the physical occurrence of object colors. However, the idea of typicality requires – at least implicitly – an assumption about a representation of the range of actually occurring object colors through a typical color. For example, the typical color may be represented by the mean of all occurring colors, by the color that occurs in most cases (mode), by the color that is "purest" (i.e., maximally saturated), or simply by a whole region of colors (exemplar-based typicality). So, the mere idea of typicality refers to a real or virtual observer (i.e., a human being or a simulating algorithm) that integrates the single exemplars encountered hitherto into a typical representation. For this reason, it is difficult to dissociate the notion of typical object color from the integration process done by the real or virtual observer and hence from their memory colors.

## Methods to Determine Memory Colors

Since memory colors imply a relationship between objects and colors, the assessment of memory colors needs to take three constitutive determinants into consideration. Firstly, memory colors require familiarity with the respective objects. Secondly, they require an idea about the range of colors that are typical. Finally, memory colors are determined by the link between the object and its typical color, which constitutes the color diagnosticity of the object.

### Object Recognition

In order to measure an observer's memory colors for an object, the observer must be able to recognize the object. This does not only require that the observer is familiar with the respective

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kind of object; it also depends on how well the exemplar used for the measurement can be identified as the respective kind of object. In particular, many measurements of memory colors use two-dimensional images, and the question arises whether the pictorial representations are recognizable and representative. For example, outline shapes of fruits, such as oranges or carrots, are barely recognizable even though people are highly familiar with these objects (cf. [2]). As a consequence, the measurement of memory colors may be affected by particularities of the image sampling. For this reason, many studies use image databases that also provide familiarity indices for the images, such as the Snodgrass line drawings (e.g., [5]).

### Color Typicality

In order to assess the range and typicality of colors associated with an object, color adjustment or rating techniques may be used. In the former, observers adjust the color of the objects to the typical color, and the distribution of these adjustments informs about the nature and the precision of the typical color (cf. e.g., [6]). In rating tasks observer evaluate how well a particular color matches the typical color of an object [7].

### Color Diagnosticity

For most studies, the most important measurement is the assessment of the strength of the object-color association, i.e. the color diagnosticity. A fundamental distinction can be made between techniques that refer to conceptual measures and those that measure color diagnosticity perceptually. A typical conceptual measure involves verbal elicitation. Observers are asked to name the most important object features, and color diagnosticity is assessed by the priority with which color is named among these features. Other techniques require observers to rate how important color is to describe the object. Some studies have also used indices such as the Nelson word association norms to assess color diagnosticity [5]. The problem of these techniques may consist of how well these conceptual measures may be transferred to the particular instances used as stimuli. For example, the verbal name of red cabbage may well be associated with the color red. Nevertheless, a grayscale (i.e., achromatic) image of red cabbage is not unambiguous enough to refer to its typical color.

A perceptual approach consists of showing the respective objects (mostly their images) without color and asking the observer to indicate their typical color. The accuracy and speed of the answer gives insight into the strength of the object-color association. In particular, the speed may also reflect the automaticity of the memory color knowledge. Moreover, this technique also ascertains the validity of the measures for the particular stimuli. This, however, is also the drawback of this technique, since measurements cannot directly be generalized to all instances of the respective objects [2].

## Characteristics of Memory Colors

Memory colors may be characterized by how typicality is represented in memory and when and how the first object-color associations develop during childhood. Finally, memory colors have also been used as references to measure color constancy and the subjective appreciation of the quality of the illuminant.

### Typicality

Memory colors consist of the most typical color that is associated with the respective object and a region of tolerance, within which concrete colors may still be accepted as instances of the memory

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color. The most typical memory colors tend to exaggerate the actual hue of the color-diagnostic objects. This implies that memory colors are oversaturated for objects that typically have chromatic colors, such as a banana, and undersaturated for objects that are typically achromatic, such as a cauliflower. Moreover, the regions of tolerance are wider for variations in saturation than in hue, implying that memory colors are more clearly defined in hue than in saturation [7].

### Development

Preschool children (up to 5 years) may still have difficulties, when they are asked to identify the appropriate color for very common color-diagnostic objects (e.g., [3]). Some approaches assessed object-color knowledge through their effects on perceptual performance (also see section "The Memory Color Effect"). Interference effects that reveal memory color knowledge have been found at the age of 3.5 years with an object Stroop paradigm [8], and for 2–3 year old children in a free-looking paradigm (e.g., [9]). A study that used a simple preferential-looking procedure has even found some evidence that infants possess memory colors as early as at the age of 6 months [4].

### Constancy

Memory colors also provide a reference for perceived colors. For this reason, memory colors may be used to measure color constancy under different illuminations; however, these measurements are coarse due to the overall variability of memory color estimations [6]. At the same time, there is some evidence that observers prefer illuminations that produce the colors of color-diagnostic objects as similar as possible to the observer's memory colors [10].

## Effects of Memory Colors

Through memory colors, object and color identification interact in several ways. These interaction effects will be summarized below; but see [2, p. 15] for more references.

### Object Recognition

Firstly, there is ample evidence that memory colors promote object and scene recognition. In particular, color-diagnostic objects and scenes are identified more easily when seen in their typical colors (for a review see [11]).

### Priming and Cueing Effects

Secondly, color-diagnostic objects automatically elicit the respective memory color and vice versa. In particular, so-called object Stroop tasks have shown that colors are identified more rapidly when seen on the respective color-diagnostic object (e.g., [12]). In turn, priming paradigms revealed that colors facilitate the identification of the labels for color-diagnostic objects (e.g., [13]). Finally, mentioning color-diagnostic objects verbally directs gaze automatically towards their memory colors. Similar to cueing, this implies an orientation of overt attention towards memory colors (e.g., [5]).

### Color Memory

Moreover, there is also some evidence that memory colors influence color memory. When memorizing the actual color of color-diagnostic objects, this memorized color seems to be shifted towards the object's memory color [14].

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### Color Categorization

Memory colors also serve as references in color naming. There is evidence that the category membership of ambiguous colors close to the category boundary may be changed by showing the colors on different color-diagnostic objects. For example, a color that is halfway between orange and yellow will be classified rather as orange (or yellow) depending on whether it has been seen on a carrot (or a banana, respectively) (e.g., [15, 16]).

### Color Constancy

Finally, memory colors support color constancy. When the colors in a scene change due to a change of the illumination, knowledge about the original color helps to estimate the color change that is due to the illumination. However, according to available evidence the contribution of memory colors to color constancy is small compared to the contribution of low-level mechanisms such as adaptation (e.g., [17]; but see[18]).

## The Memory Color Effect

According to the classical idea of a "memory color effect" memory colors directly influence the appearance of the actual color of the objects. Familiarity with the object-color association implies an expectation about the color of a concrete exemplar of an object, and this expectation shapes the perception of its actual color. In this way, memory color effects indicate that color appearance depends on the object, on which the color is shown, as well as on the experience and the prior knowledge of the observer. For example, an observer may know that bananas are yellow. Does this knowledge influence how this observer sees the actual color of a banana? Or can she or he perceive and appreciate the actual color independently of their prior knowledge?

### History

Although the precise idea about memory color effects was introduced by Hering [1], the idea that prior experiences with objects in the environment influences the way an observer perceives their colors has already been formulated by Hermann von Helmholtz in 1867. During the twentieth century several studies pursued Hering's original idea that memory colors affect the perception of the objects' actual colors. Most of these investigations have shown that observers overestimate the saturation of the object colors when the hue corresponds to the typical color of the objects. However, there were also other studies that could not replicate this effect. Moreover, these earlier studies could not unambiguously show that memory colors really affect perception rather than biasing memory retrieval and judgment (for further references, see [2]).

### Recent Developments

More recent studies used a broad range of methods and techniques to approach this question. They could confirm that observers overestimate the proportion of the objects' typical hue, when judging the colors of color-diagnostic objects. For example, observers would judge a banana to be more yellow than it actually is (e.g., [15]; for further references, see [2]).

One of these approaches could even show that a color-diagnostic object may automatically bring about the impression of its typical color [19]. In this case, a banana should still appear to be yellow even if it is completely grey. In this approach, participants had to adjust the colors of the objects so that they look grey to them. Now, if the object alone induces the impression of its typical color then the observers have to counteract this impression in order to see the object so that it looks subjectively

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grey to them. And indeed, the participants of these studies shifted the color adjustment towards the color opposite to the typical color. For example, they adjusted the banana slightly towards blue because blue is the opponent color to yellow. They did this, even though they had only to match the color of the object to the color of the background. This implies that they really saw the banana as yellow or at least slightly yellowish when it was actually grey.

### State of the Art

Follow-up studies that also used the achromatic adjustment method showed that images with less perceptual information, such as outline shapes, yield weaker memory color effects. This explains why some of the classical studies that used outline shapes yielded inconsistent findings. Moreover, these follow-up studies showed that the memory color effect is robust to dramatic changes of the illumination [6].

All of these studies used fruits and vegetables as stimuli. The colors of these objects do not cover the whole color space and the chromatic distributions of these objects are all based on natural surfaces. For example, there are no fruits and vegetables that occur in a very colorful blue or purple. Another follow-up study used artificial, man-made objects, such as a Smurf cartoon character, a Nivea lotion tin, and a German mailbox. The results of this study revealed memory color effects for these artificial objects that had all kinds of chromatic distributions. This study also showed that the memory color effect occurred most strongly along the daylight axes, along which observers are least certain about their color judgment [2].

## Outlook: The Role of Memory Colors

In everyday life, people use colors to identify objects in their environment. However, the link between colors and the surface properties of objects is not as simple and direct as everyday life experience might suggest. For example, the light reaching the retina intermingles contributions from illumination and surface properties. Memory colors reinforce the association between colors and particular objects, namely, color-diagnostic objects. In this way, memory colors may increase the reliability of object identification and hence support the functional role of color as an object attribute. For future research, the question arises of whether memory colors play a constitutive role in color appearance and communication, leading to a functional adaptation of the observer's color identification to their physical and social environment.

## Cross-References


- ▶ Chromatic Contrast Sensitivity
- ▶ Color Vision, Opponent Theory
- ▶ Colors, Subjective
- ▶ Fechner's Colors and Behnam's Top
- ▶ Stroop and Reverse-Stroop Interference

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