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The Influence of Color on Recognition Memory for Cultural Landscapes

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Abstract

Introduction. Color is an important factor influencing success in scene recognition memory. It has been experimentally proven that the mechanisms for color participation in the perception of natural and anthropogenic landscapes are fundamentally different. We continued to study the impact of color on visual memory and provide the first experimental evidence for the role of color in memorizing scenes containing natural and anthropogenic components (cultural landscapes). **Methods.** The study sample comprised 154 subjects (45 males) aged 18-66 years (mean age = 24.88, SD = 9.28). A continuous recognition task was used to simulate the process of how people see and recognize images in the real world. First (at the encoding step), participants were shown a sequence of 36 color and black-and-white photographs of various types of cultural landscapes on a computer monitor. Experimental stimuli followed each other in a random order with an exposure of 64, 128, 300, or 2000 ms; the interval between presentations was 7000 ms. Then (at the recognition step) the same 36 photographs were presented with the equal number of duplicate stimuli. Half of the stimuli were the same as in the memorization stage; for the second half, the color conditions were changed. Participants had to determine the images that had already been shown in the first stage of the experiment and those they had seen for the first time. **Results**. Color plays an important role in the encoding phase in designed and naturally evolved landscapes. On the contrary, in associative landscapes color is important in the recognition phase as a part of the representation of complex images in episodic memory. **Discussion.** The results showed that the patterns of recognition of cultural landscapes differed from the reception of both natural and anthropogenic landscapes and were related to the degree of cultural development of the original natural environment.

Keywords

color perception, experiment, cultural landscape, continuous recognition, visual memory, recognition memory, color vision

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Introduction

In everyday life, people continuously recognize hundreds of images replacing each other (Kostina, Filippova, Allahverdov, & Allahverdov, 2022). We only need to look quickly to remember what a room, street, or entire city skyline looks like (Thorpe, Fize, & Marlot, 1996; Oliva & Torralba, 2006; Motoyoshi et al., 2007; Whitney & Yamanashi Leib, 2018). In recent decades, experiments have shown that scenes are encoded in our memory at the same speed as individual items (Oliva & Schyns, 2000; Joye, Steg, Ünal, & Pals, 2016). However, in comparison to simple forms, the mechanism of scene perception is fundamentally different. In most cases, we do not have time to recognize and identify the individual objects of the image, and we perceive the entire scene by focusing on its special spatial characteristics and visual properties (Steeves et al., 2004; Brady & Alvarez, 2011; Sekimoto & Motoyoshi, 2022).

Color is one of the important factors that impact memory for scenes, as demonstrated by extensive experimental data (Gegenfurtner & Rieger, 2000; Wichmann, Sharpe & Gegenfurtner, 2002; Spence, Wong, Rusan & Rastegar, 2006; Griber & Sukhova, 2020). First, in the encoding phase, color helps the visual system quickly segment complex images, understand the composition, define the boundaries of individual objects and facilitate their identification and semantic labeling. Memory researchers propose to call this possible color advantage *sensory facilitation* (Wichmann et al., 2002), as it is characteristic of early visual processing and has nothing to do with representing scenes in memory. Later, in the recognition phase, color is a part of the representation of complex images in episodic memory and provides *cognitive facilitation* in the recognition process (Gegenfurtner & Rieger, 2000, p. 807).

Research findings show (Kardan et al., 2015; Taniyama, Suzuki, Kondo, Minami & Nakauchi, 2023) that the role of color in the perception of natural and anthropogenic landscapes is quite different. Color greatly facilitates the recognition and designation of natural landscapes (forest and desert landscapes, sea coasts and canyons, mountains and cliffs) (Oliva & Schyns, 2000), but has a significant reduction in the impact of artificial objects on landscape perception (interiors of residential buildings, university campuses, railway stations, airports and city streets) (Wichmann et al., 2002, p. 514). The rate of naming natural scenes decreases when they are presented in unnatural colors or without colors, but does not change at all when the same phenomenon occurs in non-natural landscapes (Oliva & Schyns, 2000).

According to researchers, this can be explained by the fact that natural and anthropogenic landscapes have fundamental differences in spatial characteristics, visual characteristics, and dominant colors (Field, 1987; Burton & Moorhead, 1987; Frey, Honey & König, 2008). Natural landscapes usually have large areas with uneven contours, which are colored in the typical, almost identical colors. On the contrary, in artificially created landscapes, vertical and horizontal lines dominate and there are no such zones. Unlike natural objects, artificial objects have clear, long, and regular boundaries, and are characterized by greater chromatic variability, which is generally observed at a small spatial scale (Oliva & Schyns, 2000). For example, city color consists of a large number of dynamically changing elements, including pedestrian clothing, moving vehicles, goods in store windows, street lighting elements, and signs located along the street (Grieber, 2017; 2021; 2022).

The color information of natural and anthropogenetic scenes is involved in visual memory in different ways (Oliva & Schyns, 2000; Steeves et al., 2004). Short-term viewing generally does not use small-scale spatial information, and recognition is based mainly on large-scale data. This means that in anthropogenetic landscapes, color is not used as a signal. However, it plays an important role in natural scenes.

We continued to study the influence of color on visual memory ***and experimentally investigated how people memorize and recognize cultural landscapes.*** These landscapes, which we live in most of our lives, combine natural and anthropogenic elements and are the result of conscious and deliberate human activities to meet their practical needs (Lavrenova, 2021).

Our ***hypothesis*** is that the mechanisms by which color is involved in the perception of cultural landscapes can differ from the recognition of natural and anthropogenic landscapes. In addition, the recognition pattern can be associated with the degree of cultural development of the initial natural environment. Thus, in designed, naturally evolved, and associated landscapes the role of color may differ (Vedenin & Kuleshova, 2004).

Methods

Participants

The study sample comprised 154 subjects (45 men, 109 women) aged 18-66 years (mean age = 24.88, SD = 9.28). All participants had normal color vision and normal or corrected to normal visual acuity.

Stimuli

To create the stimuli, we selected 72 photographs from three different categories:

1. Designed cultural landscapes included images of landscape architecture, noble estates, mosaics on the facades of city buildings, city sculpture, traffic flows, festively decorated streets, city advertising, industrial landscapes, and residential quarters.
2. Naturally evolved cultural landscapes included photographs of cultivated fields, rice terraces, views of villages in central Russia, northern towns, panoramas of cities, and historical centers.
3. Associative cultural landscapes included photographs of memorable places, places of creativity, sacred places, and battlefields.

Photographs were selected from the *McGill Calibrated Color Images Database* (Olmos & Kingdom, 2004) and other open color image databases. All selected images were reduced to a resolution of 1024 x 768 pixels. Figure 1 shows example images for each category.

A 32-inch *Dell S3221QS* monitor with a vertical refresh rate of 60 Hz was used to demonstrate the stimuli. The participants sat at an 80 cm distance from the screen, which provided a visual angle of about 28 x 21 degrees.

Each image was represented in one of the two representation conditions – in color or in black-and-white (gray scale). For black-and-white images, the intensity of the red, green, and blue luminophores was at the same value for each pixel. Thus, the brightness of each pixel was the same in the color and black-and-white representation conditions. Black-and-white images are shown in Figures 2 and 4.

Figure 1

Examples of experimental stimuli with different types of cultural landscapes: (a) designed; (b) naturally evolved; (c) associative

(a)

(b)

(c)

Experimental procedure

The experiment used a continuous recognition procedure that simulated how people see and recognize images in the real world (Potter, 1976; Wichmann et al., 2002).

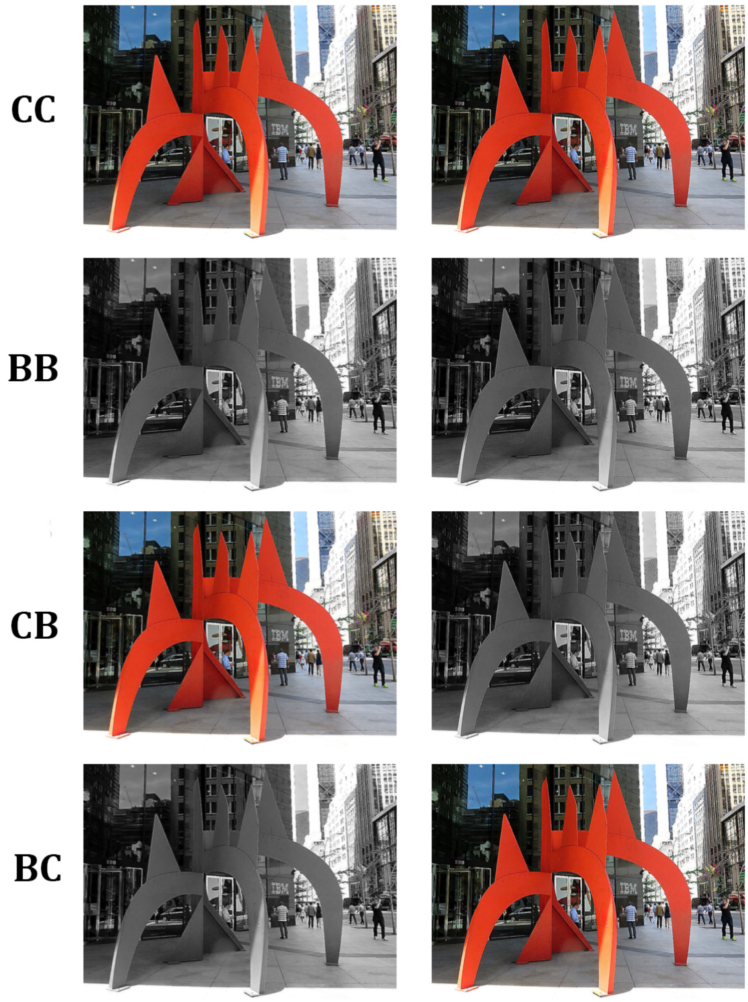
First, in the encoding phase, participants were randomly shown a sequence of 36 alternating photographs of different types of cultural landscapes. Each image appeared on the screen in color or in a corresponding black-and-white mode at different speeds (64, 128, 300, or 2000 ms), but with the same interval between stimuli (7000 ms).

After this, in the recognition phase, participants were shown the same 36 photographs mixed with the same number of duplicate stimuli and asked to identify which of the images they saw in the first stage of the experiment. Half of the images we asked to remember in color were shown in black-and-white. The second half of images were shown unchanged (both times in color).

Thus, the experimental design was a 2x2 design, which was traditionally used in natural and anthropogenic landscape studies (see, e.g., Gegenfurtner & Rieger, 2000; Wichmann et al., 2002; Spence et al., 2006). The scheme included two levels of encoding (color / black-and-white) and two levels of recognition (color / black-and-white) and resulted in four possible combinations of color conditions (Figure 2): color images at both stages (CC condition), black-and-white images at both stages (BB condition), a color image at the encoding stage and a black-and-white image at the recognition stage (CB condition), a black-and-white image at the memorization stage and a color image at the recognition stage (BC condition).

Figure 2

Four combinations of color conditions: color images at both stages (CC condition), black-and-white images at both stages (BB condition), a color image at the encoding stage and a black-and-white image at the recognition stage (CB condition), a black-and-white image at the encoding stage and a color image at the recognition stage (BC condition).



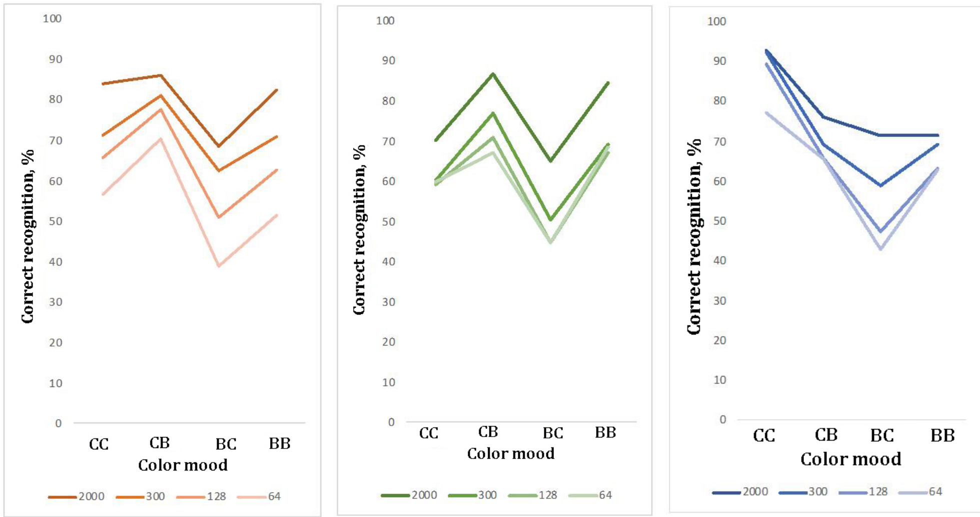
Results

Patterns of recognition of different types of cultural landscapes

For each type of cultural landscape, we identified specific recognition patterns that were consistently repeated at different exposure durations (Figure 3).

Figure 3

Patterns of recognition of different types of cultural landscape: (a) designed; (b) naturally evolved; (c) associative



(a) (b) (c)

As we expected, recognition of images from different categories was significantly correlated with presentation length (F = 13.78158, p <.00001). However, even with a very short-term exposure (64 ms), the number of correctly recognized images was quite large (59 %), indicating the high speed at which we process complex visual images. When the presentation duration was increased to 2000 ms, the success of image recognition was maximum and reached 78 %.

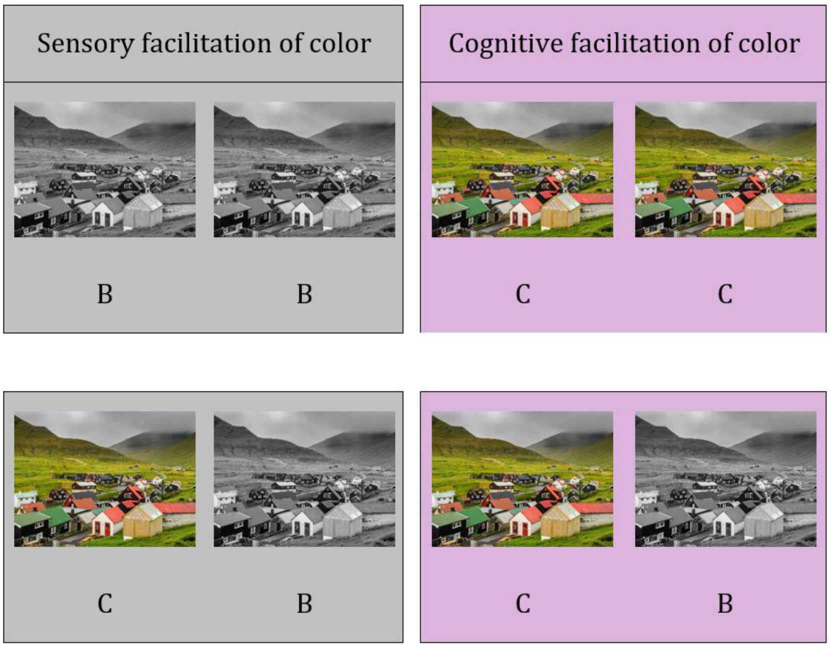
Sensory vs. cognitive facilitations of color

The analysis paid particular attention to the differences between BB and CB conditions, as well as between CC and CB conditions. Based on previous research (see Gegenfurtner & Rieger, 2000), we believed that color did not affect decision-making if photos were initially presented in color and then shown in black-and-white (CB condition). It plays a certain role only during memorization – in the processes of image segmentation and determination of the boundaries of the figure and the background. Thus, the differences between BB and CB conditions (Figure 4, left) indicate the importance of colors at the information encoding stage (sensory facilitation). If color only plays an important role at cognitive level, there will be no difference between BB and CB conditions.

On the contrary, since the encoding conditions for the CC and CB stimuli (Fig. 4, right) are the same (in both cases the photograph was presented in color), any differences between the two groups arise during the process of comparing the target image with its memory representation. Consequently, the advantage is explained by the fact that color relates to this representation as an additional attribute and provides cognitive facilitation.

Figure 4

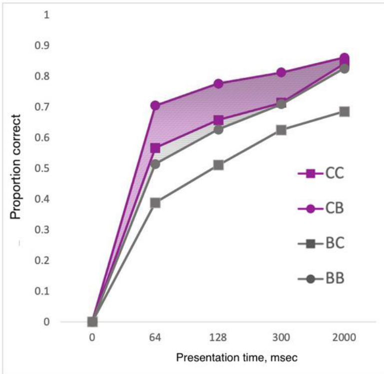
Sensory and cognitive facilitations of color: difference between the BB and CB conditions (left), and the CC and CB conditions (right)



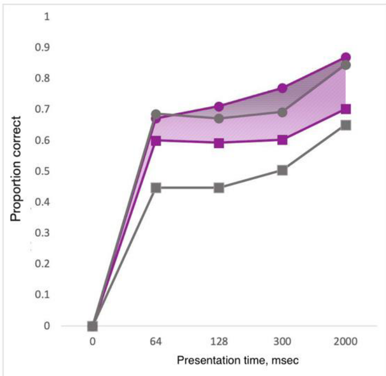
The analysis showed qualitative differences in the way we memorize images of different types of cultural landscapes. Designed landscapes are created purposefully, characterized by a certain thoughtful planning composition, and include a large number of various kinds of anthropogenic elements created on the site of natural formations. Here, color provides a sensory facilitation and plays an important role at the encoding stage (differences between the BB and CB conditions (t(306) = 4.9252, p = .000001) are indicated by gray shading in Figure 5-a). On the contrary, in associative landscapes, where the cultural component is often presented not in material form, but in mental form, based on the association of the object with a cultural phenomenon, color provides a cognitive facilitation and is important exclusively in the process of recognition (differences between the CC and CB conditions ((t (306) = 4.1612, p = .000041) are indicated by pink shading in Figure 5-c). Moreover, both in designed and naturally evolved rural, historical, and industrial cultural landscapes (Figures 5-a and 5-b) there is an unexpected 'shift' in the CB condition compared to the CC condition (t(306) = 4.7751, p = .000001), which indicates that the color added to the initially black-and-white photographs in the process of comparing the target image with its representation in memory represents a kind of cognitive obstacle and prevents us from memorizing.

Figure 5

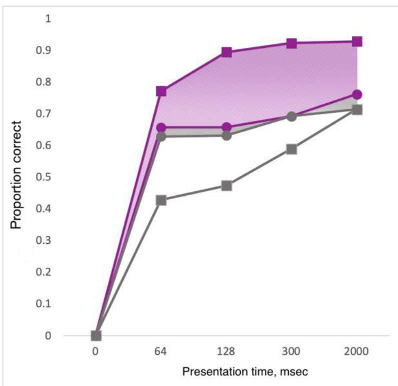
Correlation of the proportion of correctly recognized images of various types of cultural landscapes with exposure duration; sensory facilitation of color (difference between the BB and CB conditions) is indicated by gray shading; cognitive facilitation of color (difference between the CC and CB conditions) is indicated by pink shading.



(a) designed



(b) naturally evolved



(c) associative

Discussion

The comparison of recognition patterns of various types of cultural landscapes in our experiment (Figure 3) with the configurations generated by the linear model that is used in analysis of variance in I. Spence and his colleagues (Spence, 2006, p. 3) confirms that the shapes of the curves, rather than the absolute success rates, are significant for various types of cultural landscapes.

In recognition patterns of designed and naturally evolved landscapes, an asymmetry effect is clearly visible, similar to that of M. Pezdek and colleagues (Pezdek et al., 1988) described several decades ago in their study on the way people memorize different types of drawings. As in our experiment, the authors used a 2x2 experimental design. However, the changing condition was not color, but the complexity of the image. Thus, participants had to memorize several pictures and then to recognize them. The performance of recognizing images, which at the recognition stage had a simpler form than during memorization, was significantly higher than in cases where the stimuli initially had a simpler form than during recognition. The experimenters explained this by the fact that in a more complex image the new details change it to such an extent that it does not correspond to the memory representation. In our case, the same thing happened with color. Participants were unable to recognize color photographs that they had memorized as black-and-white (BC condition). On the contrary, they successfully identified black-and-white images that they had previously seen in color (CB condition).

The effect described may be due to the fact that color is involved in the memorization process indirectly. This is demonstrated in particular by previous research that people rarely know whether they have seen a particular image in color or in black-and-white (Suzuki & Takahashi, 1997). In a color image, we tend to memorize not the color itself, but some important encoding characteristics that color improves, thus facilitating memorization. On the contrary, if color is added only at the stage of recognition, it changes the image so much that it prevents us from recognizing a scene we saw in black-and-white.

This effect is not observed in natural landscapes, where color mainly performs a diagnostic function (Oliva & Schyns, 2000). Natural landscapes tend to have unique colors. Thus, canyons are mostly red and orange, forests – green, sea coasts – blue, and deserts – yellow. The projections of images of these landscapes occupy separate, non-overlapping zones in the a*b* plane of the CIELab color space. Consequently, chromatic information is distinct (diagnostic) for them. Even when they are seen in black-and-white, the color of natural objects can be predicted with high probability. In cultural landscapes, color is much less predictable and can radically change the image of the area and affect its mental representation.

In associative landscapes, higher recognition rates corresponded to conditions under which the images were the same at the stages of memorization and recognition (CC and BB conditions). The high recognition rate of CC type stimuli indicated the important role of color during both encoding and recognition processes. In the BB condition, color was not involved in the determination of boundaries and the segmentation of the image during encoding. However, the presence of exactly the same information about shape and brightness during memorization and recognition was more important than the possible enhancement of encoding processes that color could provide. Thus, recognition performance was directly related to compliance with the principle of encoding specificity, which states that the performance of memorization and recognition increases when the same information that is available at encoding is also available at retrieval (Tulving & Thomson, 1973). It was not the presence of color, but rather the quality of correspondence between the initial image shown and the image to be recognized, which was fundamental.

With a very short-term presentation (64 ms), in the CC condition, the recognition performance was noticeably lower than with longer-term exposures (128, 300, and 2000 ms). Based on previous research (Spence et al., 2006), this may be due to the fact that shape and color are processed in different cortical areas. For color to improve memory, these properties must be synchronized. Although linking color and shape occurs quickly, the process still takes some time. Therefore, for very short-term exposures, when shape and color processing have not yet had time to synchronize, the response pattern will differ from those obtained with longer-term exposures.

At the same time, the general correlation between the proportion of correctly recognized images and the duration of their presentation, also noted in previous studies of the mechanisms of memorizing complex images (Gegenfurtner & Rieger, 2000; Wichmann et al., 2002; Spence et al., 2006), can be explained by the fact that longer-term exposure increases the number of gaze fixations and their duration, resulting in more detail information being encoded (Potter, Staub, Rado, & O'Connor, 2002).

Conclusion

Our experiment confirmed that the mechanism of color participation in the perception of cultural landscapes differs from the reception of both natural scenes and anthropogenic landscapes and correlates with the degree of cultural development of the initial natural environment.

First, color significantly reduced the recognition performance of designed and natural landscapes, which participants memorized as black-and-white. Conversely, performance at identifying black-and-white images that were in color at the encoding stage increases. A similar effect of recognition asymmetry is not observed in natural landscapes, where in most cases color performs a diagnostic function and is easily predictable.

Secondly, the recognition performance of associative landscapes is directly related to compliance with the principle of encoding specificity, which states that memorization efficiency increases when the images are the same in the stages of encoding and retrieval (both times are shown in color or, conversely, in black-and-white).

Thirdly, comparing the recognition performance patterns of different types of cultural landscapes with the configurations generated by the linear model that is used in analysis of variance confirms that the shapes of the curves, rather than the absolute success rates, are significant for cultural landscapes. Color provides a notable sensory facilitation in designed landscapes and is less significant in naturally evolved ones. On the contrary, in associative landscapes, it is important only in the recognition phase as a part of the representation of complex images in episodic memory.

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Conflicts of Interest Information

The author has no conflict of interest to declare.