From Color To Emotion

Ideas and Explorations

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How do colors affect human emotions? This question is the target of the ideas and explorations that follow.

We will need, in time, to clarify what we mean by "color" and by "emotion." But for now we use these terms with their intuitive meanings. We will explore the relationship between color and emotion with visual examples, and hope that these guide us toward clarifications that help answer our question.

Kinds of Connections

The connections between colors and emotions probably have at least three sources: evolution, culture, and personal experience.

First, there are evolutionary connections that were forged by natural selection during the Pleistocene and before. Objects and events critical to survival are often associated with characteristic colors: the blue of water, brown of a bear, green of leaves, amber of sunrise and sunset, and red of fruits and some berries. A color associated to such a critical object or event would come to be associated as well with the emotion it evokes. Such a color might, in some cases, be diagnostic of a critical event and therefore evoke an emotion, and an adaptive response, prior to the actual event. A glimpse of a large patch of furry brown from the corner of the eye might, for instance, be enough to trigger the emotions and adaptive responses appropriate to an encounter with a bear, and thereby reduce the probability that such an encounter actually happens. A pool of water that is murky blue might trigger an emotion of disgust, and avoidance of a potentially harmful drink. These connections are probably universal for *Homo sapiens*, in the sense that they vary little, on average, across cultures. There will, of course, be the normal variations among individuals due to mutations, and there might be interesting variations between genders due to gender-specific selection pressures (e.g., Arthur et al., 2007, report that women give more emotional descriptions to colors than do men).

Second, there are cultural connections that are forged by culture-specific associations of colors to people, places, objects or emotionally charged events. The red and yellow of a bullfighter's cape might trigger special emotions in Spanish culture. The reds and greens of Christmas, and the blacks and oranges of Halloween might trigger culture-specific emotions. The colors of terrain, plants or animals that are unique to a region might develop culture-specific emotions. The delicate pinks of the Japanese cherry tree might have special emotional connections for the Japanese, the pale reds of the Arizona painted desert for the indigenous Indians, the bright blues of the blue poison dart frog for those in the Sipaliwini savanna of southern Suriname.

Third, there are personal connections created by idiosyncratic personal experiences. A British toddler might, for instance, witness his mother shriek at the sight of a banana spider which, though not indigenous to England was accidentally imported to London by a freighter ship. Such a toddler might connect fear with the speckled brownish-yellow color of the spider's abdomen, a connection that could last a lifetime.

Our focus here is on the evolutionary connections between colors and emotions. These are the most widely shared connections, and are probably the themes for which the cultural and personal connections are variations.

The Standard Theory of Color

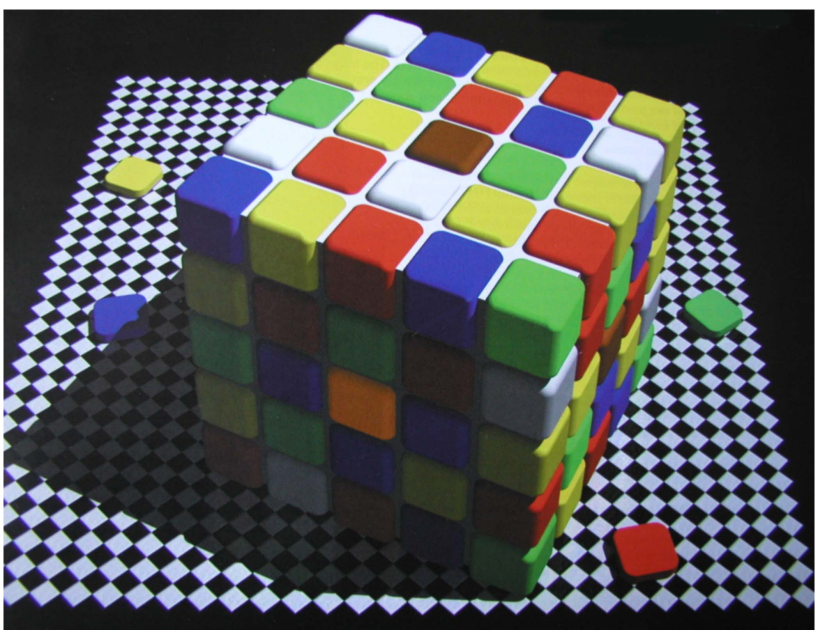
The research to date on color and emotion has studied, almost exclusively, rectangular patches of uniform color (e.g., Arthur et al., 2007; Gao & Xin, 2006; Gao et al., 2007; Ou et al., 2004a, 2004b). Such stimuli may be ill suited for the study of the evolutionary connections between color and emotions, since they rarely occur in nature. The colors in nature typically appear on complex shapes, have complex variations in hue and shading, and are situated in a complex context of differently colored shapes.

Observers do report emotions to colored rectangular patches, and their reports are consistent across individuals and cultures (Gao et al., 2007). This suggests an evolutionary source. It might be, for instance, that certain colors are, by themselves and even in the simplified context of a lone rectangular patch, highly diagnostic of events or objects of critical significance in the past to *H. sapiens*. Such colors might be sufficient, even in isolation, to trigger the evolutionary appropriate emotions.

It is more likely that these results are simply irrelevant to understanding emotional responses to colors. These experiments typically ask observers to rate colors along dimensions such as *warm-cool*, *vivid-sombre*, *light-dark*, and *transparent-turbid*. The subjects might be reporting just perceptual properties of colors rather than real emotional responses such as *disgust*, *fear*, *elation*, *suspense*, *love* or *joy*.

Limitations of the Standard Theory

Most previous experiments report their data as relationships between emotions and CIE coordinates of color patches. However, there is no simple relationship between CIE coordinates and perceived colors and, a fortiori, no simple relationship between CIE coordinates and emotions. Two patches, for instance, can have identical CIE coordinates and yet can be seen as entirely different colors. One example is the image of the Rubik's cube from Dale Purves, in which the brown square on top and orange square on the side have identical CIE coordinates:

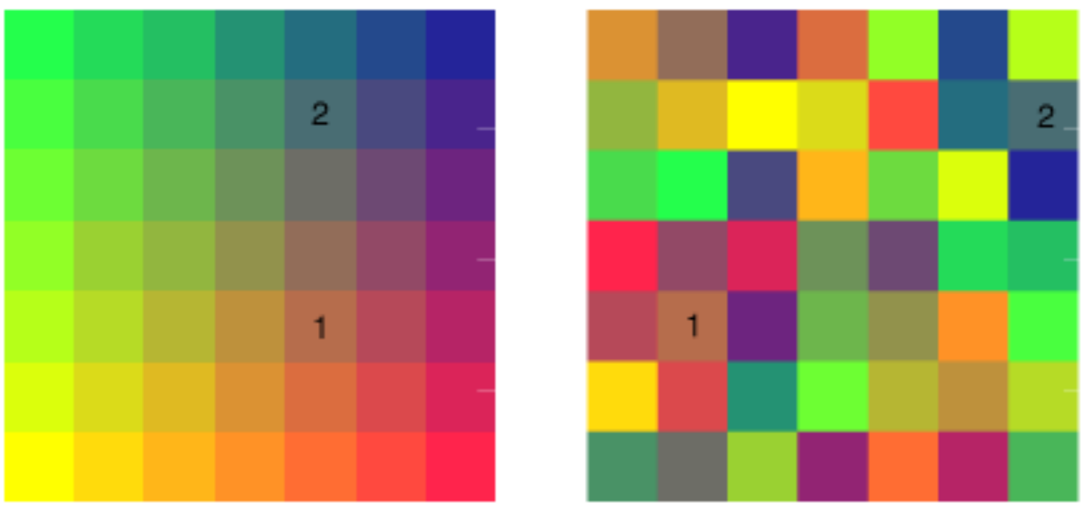


It is likely that observers would judge the brown and orange squares as quite different along "emotional" dimensions such as *warm-cool*, *vivid-sombre* and *light-dark*.

Another example where two patches of identical CIE coordinates are seen as different colors is neon color spreading:

The spaces between the blue lines on the left have identical CIE coordinates to the spaces between the blue lines on the right, yet the spaces on the left look white, and the space on the right look blue. Again it is likely that observers would judge them as quite different along standard "emotional" dimensions.

One last example is due to Jan Koenderink:



The 49 patches on the left and the 49 patches on the right are in fact the same set of patches, with their positions rearranged. Yet the colors seen on the left are dramatically different from the colors seen on the right. For the set of patches on the left each patch looks darker on the left side and lighter on the right side. But for the set of patches on the right each patch has uniform brightness. The set on the left appears to be illuminated by several colored lights, while the set on the right appears to be illuminated by a single white light. There are browns and tans on the right, but not on the left. The patches appear to be perfectly flat on the right, but slightly curved on the left. Again we see that identical CIE coordinates do not guarantee identical colors or identical emotions. Colors, shapes, shading and lighting are perceived together in a coordinated perception that relies for its origin on a sophisticated analysis not just of local CIE values but also of a much broader image context.

How much context is required for color to trigger specific evolutionary emotions? We can approach this question in a manner typical of science, by looking for minimally complex contexts that still reliably trigger emotions. One way to do this is to take an image that clearly evokes an emotion, successively blur it to greater degrees, and observe how the emotional reaction changes as the information in the image is successively reduced.

We will begin with a concrete example. To make sure your emotional reactions to the images are as unbiased as possible, we'll start with the most blurred image, and look at successively sharper versions. Here is the most blurred image of the sequence:

Take a moment, as you look at this image, to introspect for any clear emotional reactions.

This image is almost perfectly uniform in CIE coordinates, and so resembles the stimuli that are typical of most prior experiments on color and emotion. It appears red and warm (which, we think, is just a perceptual description), but beyond that it does evoke a clear emotional reaction.

Here is the next image, slightly less blurred:

Our reaction to this image is more complex than to the prior image. There are hints of 3D shape, shading and perhaps even surface gloss. We're unsure whether to reactive positively or negatively to the image, and so we search the image looking for clues to help decide how to react. With the ambiguity comes a sense of urgency to resolve the ambiguity and to take an emotional stance.

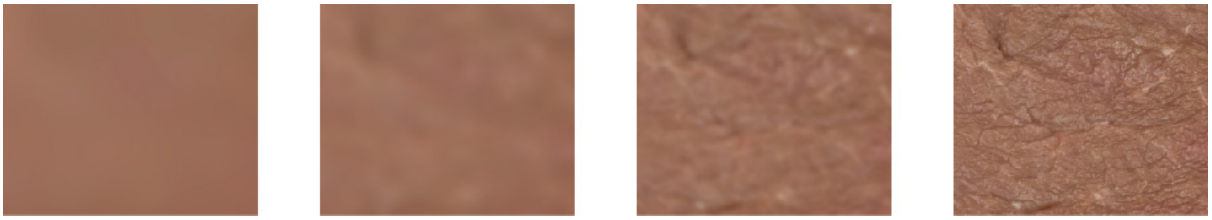
The next image reduces the blur further:

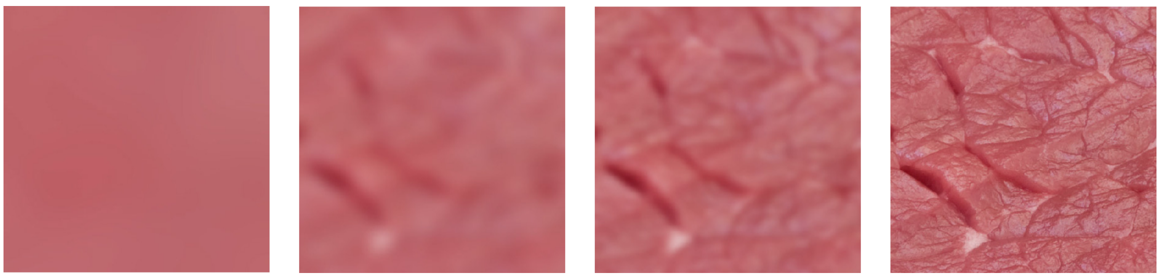
There is still no clear emotional reaction. The image is still ambiguous and we find ourselves again trying to resolve the ambiguity. The next two images successively reduce the blur. You can check for yourself how this affects your emotional reaction.

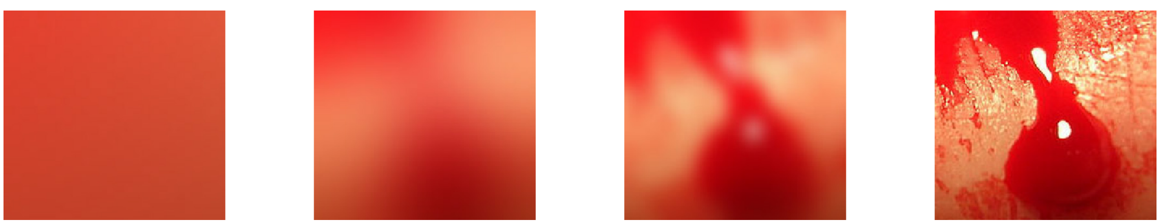
Finally, below is the unblurred image. To this we have a clear and positive emotional reaction. This is obviously part of a ripe, healthy strawberry, and we would like to eat it. Compare this with the previous image. Although it is clearly a strawberry, we can't tell if we want to eat it or not. It might be overripe or unhealthy; we're just not sure. It's the fine detail in the image below that tells us that this is the taut, shiny surface of a ripe, healthy strawberry, and that finally triggers the positive gustatory emotional reactions.

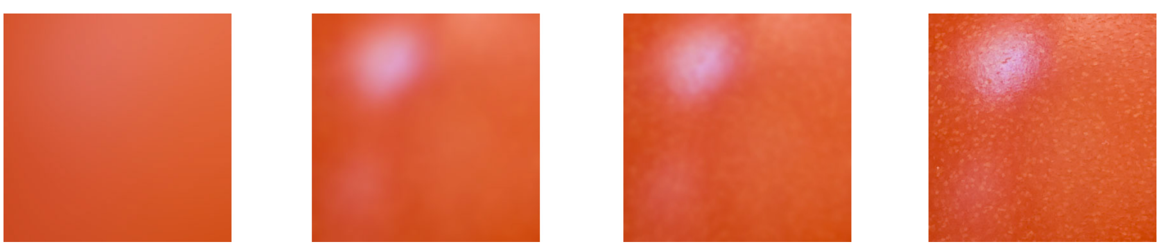
One key point to note is that all the images in this strawberry sequence are related by Gaussian blurring, and so they all have about the same *average* CIE coordinates. Yet the emotional reaction varies substantially from one image to another. There is much more to the emotional reaction to colors than simply average CIE coordinates

Here are a few more sequences of images. Studying such examples can lead to new ideas about how color details trigger specific emotions.









Chromatures: A New Concept of Color

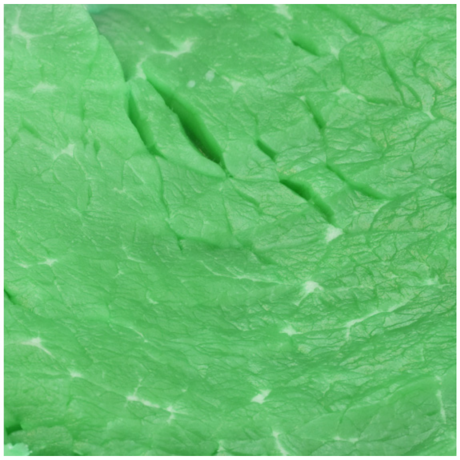
It appears then that the standard concept of color, as represented by a set of CIE coordinates, is inadequate for building a scientific theory of color-emotion connections. A richer concept is needed. Remarkably, no appropriate concept is currently available. *Texture* usefully highlights the spatial inhomogeneity that is needed, but does not highlight the chromatic aspects of this inhomogeneity, and is often used for achromatic patterns. *Chiaroscuro* refers to achromatic changes in shading that promote a perception of relief. *Image fragments* were introduced by Ullman et al. (2001, also Davies & Hoffman, 2003), but the applications are primarily achromatic, and can include image regions much larger than we want here. *Color* has a well-entrenched meaning; it would be a fool's errand to try to change this meaning.

So we propose to introduce a new concept that we can call *chromature* (obtained by combining *chroma* and *texture*). A chromature is a small colored image patch, typically subtending just a few degrees of visual angle, typically not comprehending an entire object, and typically inhomogeneous in hue, saturation and brightness. Chromature includes color as the special case in which the patch is entirely homogeneous. The image patches we examined above are all examples of chromatures. Whereas the space of (aperture) colors is usually taken to be three dimensional, the space of chromatures is much larger: the set of n-pixel chromatures forms a 3^n dimensional space.

We propose, then, that the connections between colors and emotions are few and weak, but that the connections between chromatures and emotions are many and strong.

We propose also that chromatures can evoke strong emotions even in the absence of object recognition. Some of the least-blurred chromatures presented above have sufficient information to reliably recognize the object, and one could certainly argue that it is no surprise that there are emotional reactions to objects. But we propose that object recognition is not necessary for a chromature to evoke a strong emotional reaction.

However, changes in chromatures can alter the emotions evoked by objects. Consider the these two images of meat, for instance:



The image on the left has a normal chromature and evokes a normal emotional reaction. The image on the right has an abnormal chromature, and no longer evokes the normal emotions. Notice that the difference between the images is not a simple change of a single color, but is instead a systematic change of many RGB values (of various shades of red) into many other RGB values (of various shades of green). So it is more precise and correct to call the difference a change of chromature rather than a change of color.

We would expect that the emotional consequence of a chromature change to an object is quite specific to the object involved. The change from red to green in the meat above leads to a strong negative emotion, but a similar change of chromatures in a grape does not:

The evolutionary reason is clear. Natural selection shaped our emotions to be adaptive responses to specific events and objects of critical importance. The visual properties of these objects, and the natural variations in their chromatures, are idiosyncratic: A chromature change that indicates bad meat does not necessarily indicate a bad grape. So we should expect that there are few, if any, general rules about how chromature changes alter emotional reactions to objects. Instead, we shall have to look case by case. In each case, it will be interesting to find the simplest characterizations of chromature changes that reliably alter the emotional reaction, and then to understand what selective pressures were responsible. For instance, a chromature change that makes the skin of a strawberry look wilted rather than taut, and rotten rather than ripe, is a change that has consequences for health, and therefore natural selection can shape us to attend to such chromature changes and to find them disgusting. Notice that this enterprise is starkly different from, and more demanding than, the standard enterprise of trying to assign a unique emotion to the specific CIE coordinates of a color, independent of the context in which that color appears.

One example of this new kind of enterprise is the study of facial attractiveness by Jones et al. (2004). They found that observers' ratings of the apparent health of small skin patches correlated highly with their ratings of attractiveness of faces. Here are two examples of the healthier skin patches:

Here are two examples of the less healthy skin patches:

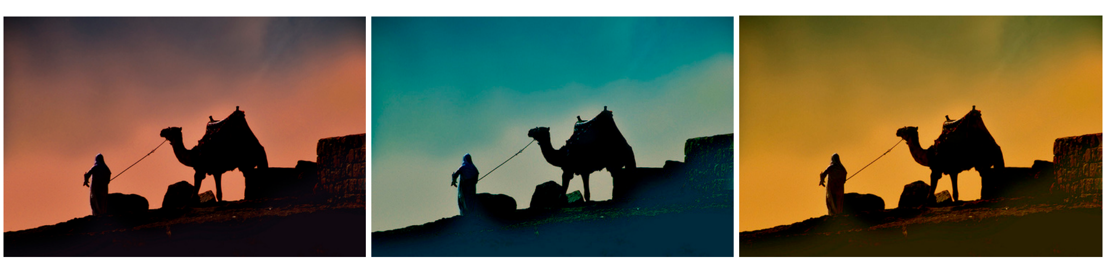
 

These patches are prototypical examples of chromatures. In the context of a face, the mottled chromatures lead to negative emotional reactions and the homogeneous chromatures to a positive emotional reaction. An illustration of this effect is the following image from Fink et al. (2006):

However, in a different context the emotional reactions could be reversed. If, for instance, we texture mapped these chromatures onto a stucco wall, the more mottled chromatures might lead to more pleasing walls.

The extent to which a chromature's emotional import is context sensitive will depend on how detailed and unambiguous the chromature is. Less detail will, in general, lead to greater ambiguity, and therefore to greater context sensitivity. More detail will, in general, more completely indicate a specific evolutionary context, and thus lead to a more specific emotional reaction. This idea can be formalized using the mathematics of Bayesian inference (Knill & Richards, 1996) and mutual information (Ullman et al., 2001; Davies & Hoffman, 2003).

Changing the entire color balance of an image can change its emotional impact. Below on the left is a photograph by Pete Foley. A color shift toward blue, as in the middle image makes the scene feel more like a cool evening. A shift toward yellow, as in the right image makes the scene feel hotter and less inviting. We might be particularly sensitive, both visually and emotionally, to chromature changes in the sky, as these can indicate weather and temperature conditions that could be critical for survival. Excessive heat, cold, wind, dust or rain can kill, particularly in a hunter-gatherer world without indoor heating or air conditioning. It is likely that the evolutionary roots of our emotional reactions to the ambient light go far back, even prior to vertebrate evolution: Plants have sophisticated mechanisms for sensing and evaluating the ambient light, allowing them to adjust their metabolic rates and pathogen defenses accordingly (Karpinski et al., 2003).



Dynamic Chromatures

Visual motion can alter the colors we experience (Hoffman, 1998; 2003). An interactive example of this can be seen online here:

http://www.cogsci.uci.edu/~ddhoff/Colordiskexp.html

Our discussion of color and emotion has so far considered only static images. But since motion can alter the colors we experience, it is likely that motion also alters the emotions we experience to colors. For instance, in the interactive "Active Space" environment created by Crawford (http://embodied.uci.edu/projects/active-space) dancers respond to a large, often colorful, display in front of them, and the display, in turn, changes in response to the dancers' movements. A key aspect of the dance creativity that emerges from this interaction is the emotion experienced by a dancer while viewing the display. This emotion is a response to the colors and shapes on the display, but also, one expects, to the way these colors and shapes move and interact with the dancer's movement.

So we are led to consider the connections between dynamic chromatures and emotions. A few examples quickly demonstrate that motion can powerfully alter one's emotional reaction to a chromature. For instance, in this video we can compare our emotional reaction to a static chromature of water versus a dynamic one:

http://www.fotosearch.com/UNF001/u15167378/

Here we can compare our reactions to static and swaying grass (download is a bit slow):

http://www.istockphoto.com/stock-video-10021985-long-grass-moving-in-the-wind.php

http://footage.shutterstock.com/video.html?id=118282

And here are time-lapse movies of clouds:

http://www.youtube.com/watch?v=pq9vf-OIM8o&feature=related

We are interested, then, in understanding the evolutionary connections between dynamic chromatures and emotions. We expect that the connections are many, specific and powerful, because motion carries much information of critical importance to adaptive behavior. Indeed, motion is the primary cue that our visual system uses to guide visual attention and to control eye movements. A small flicker, or movement, in the corner of the eye is enough to grab our attention. The adaptive significance of this is obvious. What is less obvious are the more detailed analyses of chromature motion that the visual system no doubt uses to quickly determine its emotional and behavioral response. These are of central interest to us here, and will require careful study and experiment. Water, for instance, can move in a variety of ways, and each different way might have a different emotional impact. Slow lapping waves might be calming and pleasurable, while larger, faster spraying waves might be arousing and stressful. Gently swaying grass might be pleasurable, while grass that appears to move due to the creeping of an unseen animal might trigger fight or flight emotions.

Our efforts here can be informed by neurophysiology. It is a reasonable hypothesis, for instance, that our reactions to chromatures, both static and dynamic, is highly correlated with the activity of neurons in visual areas V4 and V8. The receptive fields of neurons in V4 are large, complex, and respond to moving patterns of color, i.e., to dynamic chromatures (Ferrera & Maunsell, 2005; Pollen et al. 2002; Steven et al., 2006; Tolias et al., 2001).

Experiments

We have proposed, using arguments and visual demonstrations, that chromatures, both static and dynamic, provide a framework for exploring the relationships between colors and emotions that is richer and more nuanced than the standard notion of color as a set of CIE coordinates. We now outline a series of experiments to test this proposal.

The first experiment tests the hypothesis that the emotion evoked by a color can change if the context around the color changes but the CIE coordinates of the color does not. The stimuli are Rubik's cubes like the one shown above on page 2. On each trial the observer is asked to rate their emotional reaction to the color of the top central square and to the color of the front central square. The ratings of emotions will be done just as in earlier published experiments (e.g., Gao and Xin, 2006). The key manipulation is that the two central squares will have identical CIE coordinates. But because they appear in different contexts (one appears to be lit, the other in shadow) their colors appear to be different. We predict that the emotional reaction to the same color (same CIE coordinates) will be different in the lit context than in the shadow context. This will demonstrate that the standard procedure of associating a specific emotion to a specific set of CIE coordinates is inadequate. In consequence a new, more nuanced, notion of color is needed to capture the connections with emotions. Chromature is a good candidate.

The second experiment tests the hypothesis that different chromatures can have, on average, identical CIE coordinates and yet differ in the emotions that they evoke. The stimuli are chromatures like those shown on page 7, some of which are related by Gaussian blurring. On each trial a chromature is shown and the subject presses a button, from 0 to 9, to indicate how much they like it. Eye movements, pupil dilations, blinks, and facial EMG are recorded. The stimulus on each trial is selected at random from the several Gaussian blur sequences available, so that the subject does not, in general, see two chromatures from one sequence on adjacent trials. We predict that the emotional reaction will vary across chromatures that have, on average, identical CIE coordinates. In particular, it is likely that the emotional reaction will be stronger and more specific to chromatures containing higher spatial frequencies.

The third experiment tests the same hypothesis as the second, but with stimuli motivated by the meat and grape figures shown on pages 8 and 9. The key point of those figures is that the same green which evokes a negative emotion to a meat chromature can evoke a positive emotion to a grape chromature. The stimuli in this experiment will be lots of pairs of images of this type, each image of a pair having the same average CIE coordinates as the other member of the pair. As in the second experiment, on each trial a chromature is shown and the subject presses a button, from 0 to 9, to indicate how much they like it. Eye movements, pupil dilations, blinks, and facial EMG are recorded.

The fourth experiment tests the hypothesis that a dynamic chromature can evoke different emotions than static images of the same chromature. On each trial the subject views a short video clip of a dynamic chromature (say, moving water waves, grass blowing in the breeze) or a static frame (or several static frames placed side by side) taken from a dynamic chromature. The subject presses a button, from 0 to 9, to indicate how much they like it. Eye movements, pupil dilations, blinks, and facial EMG are recorded.

The fifth experiment tests the hypothesis that two dynamic chromatures of the same subject (say, grass blowing in the breeze) can evoke different emotions if only the movements differ (say, the grass blows softly versus wildly). On each trial the subject views a dynamic chromature, and the same measurements as before are recorded.

The sixth experiment tests the hypothesis that the emotional reaction to a small dynamic chromature extracted from a movie of a dancer correlates highly with the emotional reaction to the whole movie. The motivation here is similar to that of the experiments and figures shown on pages 9 and 10, in which a small patch of skin evoked an emotional reaction that correlated highly with the emotional reaction to the entire face. This would show that natural selection has shaped us to be able to infer reproductive fitness from short dynamic chromatures (recall Brown et al., 2005; Bates, 2007 on the correlation of dance prowess and fluctuating asymmetries).

Summary

Most research on color and emotion looks for connections between specific CIE coordinates and specific emotions. We propose that this is too narrow a notion of color to properly understand connections between color and emotion, and that the richer concept of chromature is appropriate for guiding scientific research in this area. We have motivated this proposal with several visual examples, and outlined a series of experiments that can more rigorously test it. The concept of chromature is likely to provide a powerful framework for designing experiments that explore the emotional impact of graphics, marketing, and product designs. In the area of dance, dynamic chromature is likely to provide conceptual tools and empirical results that can take the description of dance beyond standard Laban movement into a language that more richly and accurately captures dance movements, dance proficiency, and the visual processes that underlie our emotional reactions to dance performances.

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