Chromatic Cognition and Human Behavior

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Abstract For humans, cognition is the processing or interpretation produced by the brain of all information captured by the five senses, based on different capacities, such as perception, imagination, reasoning or memory, and the transformation of that interpretation into fundamental knowledge for our own way of being. However, most of our reactions are still unknown, such as those concerning chromatic cognition. Recent research has been able to identify areas of the brain that are activated during the phenomenon of chromatic cognition, just as we begin to be able to measure human behavior with regard to color issues. The visible brain consists of multiple functionally specialized areas that receive their input largely from two areas of the brain known as V1 and the area around it known as V2. Through these areas the Human Being perceives the Color and these, in turn, can be more or less stimulated when we see different colors. This document presents some results of a quasi-experiment methodology still in development, using the Virtual Reality (VR), trying to verify the human brain reactions, mainly the chromatic cognition, to the different dimensions of the colors. In an earlier phase, in addition to the literature review, other methods were used, such as survey research and direct observation. It is intended to compare the results obtained with the use of these methodologies with those of the quasi-experience. This book chapter focuses on the acquisition of scientific knowledge in the area of chromatic cognition. As future results of this research, we intend to achieve a systematization of scientific knowledge reusable by all within the scope of Color/User interaction and chromatic cognition; and produce guidelines to serve as a projective tool for designers to use and apply color in design projects, as well as a reference to the use of Color for general users.

Keywords Color · Chromatic cognition · Human behavior · Virtual reality

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1 Introduction

The present book chapter focuses on the cognition of color and human perception, and its importance for design and design development. Although there are some studies in this area, they are still insipid and many of them are not very scientific, so it is considered not only a current theme, but also a pertinent one. After the use of methods such as research by inquiry, direct observation and literature review, the second phase, a quasi-experience with users using the Virtual Reality (VR), is now presented in order to verify the brain reactions to the different color dimensions, in particular the color cognition, comparing the results obtained with the previously used methods.

The waves of light affect us every minute of our lives and enter our energy system, whether we are awake, whether we are sleeping, whether we are visual or blind. Our growth, blood pressure, pulse, temperature, muscle activity, immune system, etc., are all affected by the rays of light. The colored rays affect not only our bodies but also our emotions, dispositions and mental faculties.

As highly colored beings, our forms are made of vibrant, ever-changing colors, and the Human Being responds actively or passively to the chromatic impulses in everything we do. We all have a personal relationship with Color. Often, we give ourselves an instinctive color treatment, just choosing clothes of a certain color or placing certain colors around us, in our homes, gardens or in the work environment. Most of our reactions, however, are unconscious and only when we begin to use color in an informed way can we take advantage of this extraordinary vital force to improve the quality of life and our well-being (Moreira da Silva and 2016). The Human Being, during its evolution, created psychological and physiological reactions to the color, although in many cases they can not be controlled nor explained objectively; however, make color a necessary medium for information, communication and understanding of the environment. Color has the function of attracting attention, transmitting information, adding emotions and stimulating illusions (Gamito et al. 2009).

By understanding the effects of physiological and psychological color, we can select the best colors for our clothes, for our home and work environments. There are not many studies on the subject, and even those are merely descriptive of a period or time. So far, there has never been an attempt to understand the global phenomenon. This article presents a research project, which aims to understand the correlation between human statements when they see different colors, using research methodologies by inquiry and direct observation, and the areas of the brain that are activated when humans see a specific color using artificial cognitive systems.

The main objectives of the research project are the acquisition of scientific knowledge in the area that can serve as a projective tool for designers, as well as contributing, through the dissemination of its results, as a reference to the use of color for general users.

Throughout the project, a qualitative and quantitative, interventionist and non-interventionist methodology was used, with user-centered research, with participatory design, using the survey, direct observation and quasi-experience, supported by mechanical means, in the laboratory, using artificial cognitive systems and virtual reality.

2 Colors Code

> The code is a system of principles that bestows a certain value on certain siamas. Value is mentioned and does not mean, in order to give a more general character, because meaning is used only in relation to communication between human beings; In the case of human communication, the receiver has a voluntary act of comparing message and code and decodes it. (Eco 1967)

This type of message is visual and the signals must correspond to the perceptual needs themselves, which belong to human beings. Therefore, the system of principles must give a certain value to certain signals to become a code and that certain value has a significant basis. In terms of Color, particularly color/space language, the organization of codes follows general rules that are strictly linked to the possibility of manipulation of color language, to the limits and differential thresholds of perceptual ability in general, whether signals or visual field and the categories of meaning that are embraced by the language of color, as analyzed before, according to the color/space signs that are the color communication, and those that communicate by color, or with characters of simple signs, overlapping or supersigned signals. Thus chromatic codes are organized as having the repertoires of color/space signals as the basis, programmed according to categories and shade or shade classes, and depend on the range of signal repertoires of the individuals participating in the communicative process, consideration of the environment and the context of common experience. Primary and primary color/space codes are organized according to requests for harmonic tone types, boundary extension, and levels of differentiation between shadows or tones.

By these codes, which are applicable to the programming of languages for all the fields of the project, one can define the types of chromatic harmonization that, from a group of color/space signals, constitute a new signal indicator of a certain communicative situation characterized as a message by total quality and by the amount of visual vibrations between tones it transmits. Based on the formation of signal repertoires, the overlapping color/space codes for designating communicational intentions of something more than color/space are defined according to the context request. These codes follow the common communicative structure of the languages applied to them, besides the chromatic reference given by the previous code, the qualification established by the communicative structure. The selections of units of interest in the coding are applied to the repertoires of signals and, for the set, a system of rules is established for the transmission of the message (Moreira da Silva and 2016).

3 Neuroscience of Color

In order to approach Color, one must understand the brain and how the nervous system works. Neuroscience studies the nervous system, particularly with regard to Human Beings. This field is significant for the study of Color because it allows an understanding (as much as medical science allows) of the process involved between the arrival of the light wave and the physical reactions that result in the interior of the human body. Chromatic vision results from a very complex process in which the nervous system compares the intensity of light at various wavelengths through specific interactions that are known to be different from those needed to produce the perception of other properties of the universe visual.

It is known that people only see Color when light and chromatic signals that reach the eye reach the brain. The structure of the eye is not at all simple. The very structure of the retina is very complex and acts as the function of the first level of light interpretation. As the color of a given wavelength reaches the retina, all photoreceptors capable of responding do so. The combination of responsive receptors allows the brain to interpret the exact color of light. For example, if light with a wavelength of 600 nm (nonometers) reaches the retina, 30% of the green photoreceptors respond together with 55% or 64% of the red receptors. From this information, the brain will calculate that the color in question is orange. The reason there are two possible red responses is because 60% of the population has the amino acid at position 180 of the opsin protein, while the rest have alanine at that position. Therefore, although they all describe red and their variations in the same way, it is likely that there may be a difference in color perception.

From the retina, visual information passes to the optic nerve, joining the optic chiasm. Here, images are organized so that the information one or both eyes see on the left side of the vision is directed to the left half of the brain and vice versa. With the help of both eyes focused on the same object, the Human Being can perceive depth and distance, while each eye produces a slightly different image of the same object. The visual cortex of the brain completes the task of organizing visual information, which began in the retina. As mentioned earlier, processes in the brain are poorly understood, although the brief description above reflects current medical studies (Moreira da Silva 2016).

> The visual system is adapted to obtain maximum information with a minimum of effort: what is not required immediately, or can be considered as acquired, can be considered redundant, the eye has evolved to see the world in immutable colors regardless of the unpredictable, shifting and uneven lighting. (Lancaster 1996)

Graham (1997) undertook studies in cats to determine the role of various areas of the brain (only a small survey was conducted on humans). Five areas were identified within the cat's brain, which control the perception of: form; movement; color; and coordination of form and movement; and coordination of movement and color. The perception of shape is therefore very important for cats, with movement and color, respectively, in second and third places.

Once visual information has reached the human brain, it is interpreted through the various elements present in this structure. The Human Being has several types of memory that correspond to various brain locations. It is assumed that memories of specific functions, with more or less identified locations, correspond to the cortical location. Although both sides of the brain are involved in mental functions, it is known that each side has its specific functions. The cerebral cortex contains 90% of all nerve cells, and receives and interprets the sensory impulses. The brain contains the voluntary and conscious process, with the right side controlling the imagination and the left side controlling the logic. The thalamus deciphers sight, hearing, taste, and touch; the hypothalamus regulates blood pressure and body temperature, translating emotions into physical (physiological) responses. The pituitary gland is the largest endocrine gland in the body, controlling all other glands; the cerebellum is responsible for muscle coordination; and direct training regulates emotion. All these glands are interrelated and related in the response to visual stimuli. Questions about the role of striated cortex, the first visual area of the superior mammalian brain in color perception, have recently been restarted (Johnson 2001).

Cells in the striatum cortex are excited by light from a distribution of wavelengths and inhibited by light from another distribution, falling into a small region of space. Adjacent or surrounding regions show the opposite pattern of responses. The cells therefore respond optimally to the edges with a specific chromatic contrast that crosses the center and surrounds the regions of their spatial receptive fields. These findings suggest that specific color processing begins earlier in the visual system than previously thought. The first mechanisms of constancy of color, our ability to recognize the colors of objects, irrespective of the color of the light that illuminates them, may occur in the striated cortex. If so, people without striated cortex, like some older people, will lose color contrast processing.

So, the visible brain consists of multiple functionally specialized areas (Fig. 1) that receive their input largely from V1 and the area surrounding it, known as V2. These are currently the most thoroughly charted visual areas, but not the only ones. These are the areas where we perceive color and can be more or less stimulated when we see different colors.

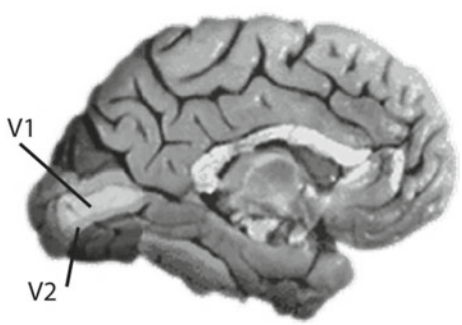

Fig. 1 Brain scheme, with V1 and V2 areas signed

4 Cognition and Artificial Cognitive Systems

Artificial cognitive systems are an emerging field. Cognition anticipates the need for action and develops the ability to predict the outcome of these actions. The field of artificial cognitive systems has the ultimate goal of creating computer systems that can interact with humans. It involves self-nomy, learning and development, memory and prospecting, knowledge and representation, as well as social cognition. This happens on the basis of a characterization of cognitive systems as systems that exhibit adaptive, anticipated and proactive behavior orientated behaviors (Vernon 2014).

Cognition implies an ability to understand how things can be and take this into account in determining how to act (Berthoz 2000). A cognitive system exhibits an effective behavior through perception, action, deliberation, communication and through an individual or social interaction with the environment. The characteristic of a cognitive system is that it can function effectively in circumstances that were not explicitly planned when the system was designed. That is, it has some degree of elasticity and is resilient in the face of the unexpected (Vernon 2006).

> Mental states are always based on real or imagined physical states, and problem space operators always expand into primitive capacities with executable actions. (Langley 2005)

For cognitive systems, cognition is representative in a strong and particular sense: it involves the manipulation of explicit symbolic representations of the state and behavior of the external world to facilitate proper, adaptive, anticipatory, and effective interaction and the storage of the knowledge gained from that experience to argue even more effectively in the future (Hollnagel and Woods 1999).

5 Development of an Experimental Part (Quasi-experience)

This research project has already achieved important results, going beyond the review of the literature on the research topic in question, mainly due to the empirical phase of the project, or applied research. Through recent research, we know which areas of the brain are activated, as well as we can measure the behavior of Human Beings with respect to Color-related issues. Thus, user experimentation is underway with the aim of if the brain reactions to the different dimensions of the color were verified, comparing the results of this experimental phase with those obtained by the other methods previously used.

So, and because we are developing an experiment with humans, we decided to use the quasi-experience methodology.

Quasi-experimental research is a research that resembles experimental research but is not true experimental research, i.e., doesn't corresponds entirely to experimental research requirements. Although the independent variable is manipulated, participants are not randomly assigned to conditions or orders of conditions (Cook and

Campbell 1979). Because the independent variable is manipulated before the dependent variable is measured, quasi-experience eliminates the directionality problem. But because participants are not randomly assigned—making it likely that there are other differences between conditions—quasi-experimental research does not eliminate the problem of confounding variables. In terms of internal validity, therefore, quasi-experiments are generally somewhere between correlational studies and true experiments. Quasi-experience is an empirical interventional study used to estimate the causal impact of an intervention on target population without random assignment, most likely to be conducted in field settings in which random assignment is difficult or impossible, or when we are working with humans or animals. This type of research is often performed in cases where a control group cannot be created or random selection cannot be performed.

> Quasi-experimental research is similar to experimental research in that there is manipulation of an independent variable. It differs from experimental research because either there is no control group, no random selection, no random assignment, and/or no active manipulation. (Abraham and MacDonald 2011)

In a quasi-experience research, the researcher lacks control over the assignment to conditions and/or does not manipulate the causal variable of interest. When we have access to a relatively large number of people who have or will receive a particular type of social work intervention, and we try to figure out what the effects of that intervention may been, then quasi-experience research can be an excellent approach, as it is in the present case.

To be aware of the seen color, one must interact directly with a person's brain, intercepting information at source and translating it into a cognitive color map. In this phase of our research, we are using the Virtual Reality (VR), trying to verify the human brain reactions, mainly the chromatic cognition, to the different dimensions of the colors.

In the present research project, to achieve this, we had to use a brain-computer interface using electroencephalography (EEG) and virtual reality. Our brain absorbs all kind of information, being constantly active, compacting and re-connecting existing data, and integrating everything into a consistent base. It shapes how we see our environment, filters or highlights objects and information most relevant to us. It creates its own knowledge based on our thoughts, emotions, desires and experiences, ultimately driving our behavior. The human brain consists of billions of cells, half of which are neurons, half of which help and facilitate neurons activity. The neurons are densely interconnected via synapses, which act as gateways of inhibitory or excitatory activity. Any synaptic activity generates a subtle electrical impulse referred to as a postsynaptic potential, which can be measured on the head surface.

EEG or Electroencephalography is the physiological method of choice to record the electrical activity generated by the brain via electrodes placed on the scalp surface. It is the process of recording a person's brain waves through electrodes attached directly to the skull. For faster application, electrodes are mounted in elastic caps similar to bathing caps, ensuring that the data can be collected from identical scalp positions across all respondents.

The EEG has the potential to unlock a truly immersive Virtual Reality (VR) by capturing a person's brainwaves while they are in the world of VR, and translating those moving signals from the participants. So, it measures electrical activity generated by the synchronized activity of thousands of neurons, providing excellent time resolution, allowing you to detect activity within cortical areas, even at sub-second timescales.

Therefore, it is relatively easy to detect electrical impulses emanating from a brain. However, the signal is sometimes so cloudy that it is difficult to decode the data. EEG has proven to be effective in detecting general brain phenomena, such as areas of the brain activated when people see a specific color.

6 Conclusions

Until now, during the quasi-experimental phase, we have worked with a group of 43 volunteers aged 23–41 years; and another group of 52 volunteers aged between 45 and 67 years. A helmet, similar to an elastic cap, was used to provide the feeling of Color using immersive virtual reality (Fig. 2). Nowadays, virtual reality helmets have become lighter, more comfortable and with clearer images. However, we had to spend some time to test and adapt the users to the use of the helmet, as well as to the immersive reality, especially the second group. All selected volunteers present normal vision. Some members of the second group evidenced the existence of a more aged vision. However, they clearly distinguished the different used colors. During the experiment, we always used the same color (through the Pantone reference system, for analog and digital support), which we used previously during the research-by-survey phase.

During experimental development, 11% of the first group found that they were color-blind: although they were seeing different colors, they activated the same location of the brain in the striated cortex. In the second group, only 4% were color blind. The results also evidence that regardless of which group they belonged to, 87% of the

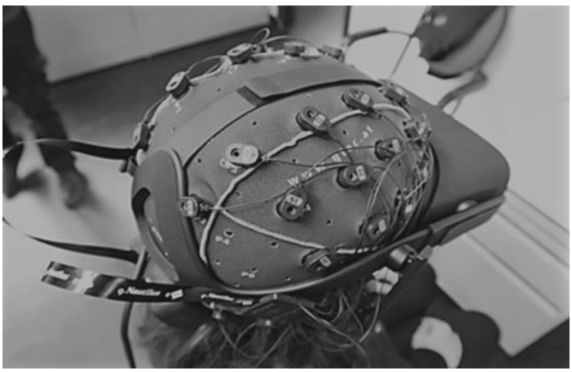

Fig. 2 Helmet used during the quasi-experiment, using immersive virtual reality

volunteers activated the same area of the brain when they saw a specific color. The achieved findings are already very significant data that can contribute to a greater knowledge in the scope of the perception and the chromatic cognition in the Human Beings.

The current project aims the acquisition of scientific knowledge in the area that can be used as a projective tool for designers, besides contributing as a reference for the use of color and for other investigations in areas related to color and the advancement of artificial cognitive systems.

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