SPECIAL ISSUE ON FOOD COLOUR

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SOMMARIO | SUMMARY

Special Issue on Food Colour

Editorial

2015 was a very important year for food culture because in Milan took place the Universal Exposition Expo 2015. Expo 2015 was held under the theme *Feeding the Planet, Energy for Life*. It was very natural, for an international journal based in Italy to dedicate a special issue to the relationship between food and colour.

As editors of this special issue, we took into consideration the statement of the famous gastronome Savarin: *"Tell me what you eat, and I'll tell you who you are"*, since the many color hues related to food are indeed an expression of culture, in addition to being nutritional and health aspects.

We could imagine that food is a huge topic, and obviously we know very well that colour is also an interdisciplinary topic. What we could not forecast is the incredible extent of the subjects belonging to the overlap between food and colour. In this special issue, only to give same examples, you can find papers about tea, packaging, lighting, music.

Finding referees for so many different topics was not easy, because we need in a referee the same overlap in expertise present in the papers. For this reason, the preparation of this special issue was not fast as we would have liked and we want to apologize with all the authors. We want also to thank Maurizio Rossi, editor in chief of this journal, for his proposal to us to be editors of this special issue, and Veronica Marchiafava, journal secretariat, for her patience, continuous commitment, and great help. Without Veronica this special issue would not exist.

And now enjoy the read, or, probably better for this special issue, *"bon appetit"*!

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Food Perception Without Colors

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ABSTRACT
If we are going to discuss the importance of color in food we cannot overlook that part of the world population has not trichromatic vision – with reference to those who see colors differently or who don't see any colors at all.
In this article I try to put myself in the shoes of someone who don't see any colors of food or who cannot see them properly. I shall try to see through the eyes of a person unable to perceive colors – an anomalous trichromacy — exploring and describing, when possible, the numerous visual-perceptive problems. These people have a limited access to the meanings mediated by colors in our society.

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1. COLOR IN NORMAL VISION AND ITS IMPORTANCE IN FOOD PERCEPTION

Color has important consequences on appearance, packaging and consumption of food that can be coherently studied/addressed only in the case of people with trichromatic vision - people who perceive colors properly.
Color is related to food in many ways – from production to sales, display to purchase, quality control to actual consumption. The color of a food is usually considered one of the main factors that decide how a consumer, specially a person with trichromatic vision, takes into account when assessing its quality, and it is a very important spoilage indicator in food preservation at home, and in the quality of control during the food industry processes: the color food changes in the presence of bioactive compounds. Sant'Anna, Deyse Gurak, Damasceno Ferreira, and Tessaro, in their review of studies *Tracking bioactive compounds with colour changes in foods* describe (2013) describe with the Cielab parameters and colorimetric instrumentation, how the change of colors food tracks bioactive components [1].
However, there are many psychological aspects tied to the color of food too. Fergus M. Clydesdale, in his study entitled *Color as a factor in food* choice (1993), note that the color of a food influences a person's perception of which one they will enjoy compared to another. Color plays a key role in the selection of food, even influencing its flavor: the visual perception of color, when there is too much in a food, can even replace sugar. It influences judgments on the intensity of the taste, on the amounts of sweetness and pleasantness, so it becomes a decisive factor governing food preferences. [2]

2. INTRODUCTION TO NORMAL COLOR VISION MECHANISMS

Colors are the visual perceptive sensations resulting from the electro-photo-chemical activity generated by a light signal (photon) which enters the eye and is picked up by the retinal photoreceptors (retinal nerve cells), absorbed and processed photo-chemically to convert it to electrical impulses that are sent to the brain. At each frequency in the visible spectrum of electromagnetic radiation, certain wavelengths and intensities are associated with the visualization of a given color. [3.4] The resulting colors are not due only to the reflection of a certain photon on nearby objects or surroundings, but to the light rays which, as Isaac Newton demonstrated, are ever-present in the air throughout our planet [a] [5].
Color has been described as the result of processes taking place in our eyes and brain – a quality of our visual-perceptive sensation, though the result also depends on the physical properties of the source lighting the bodies we see [6].
However, color vision and perception in poor or good light depend on two main factors: first of all the integrity and health of cones the retinal nerve cells, where the cones receive electromagnetic signals from the frequencies in the visible spectrum; these establish the main condition for colors to be perceived by the human visual system. The second factor is that there must be no lesions in the brain areas responsible for visual-perceptive function, where the electric impulses generated by the retinal cells arrive [7].

a - The radiations referred in the visible spectrum, corresponding to electro-magnetic radiation between 380 nm (violet) and 780 nm (red);

3. VARIETIES OF HUMAN COLOR VISION

Human beings see colors in a variety of ways; most people have trichromatic vision, so-called normal color vision. In ophthalmology, the trichromatic vision or trichromatism describes the human color vision based on three kind of receptor protein through cone receptors that absorb short, medium and longer wavelengths light (blue, green and red) of the visual spectrum [8].
Nevertheless there are other forms of human color vision too. There are some people in the world who have a different *"readability"* of physical reality due to functional/physiological or anatomical anomalies of their body, congenital alterations or caused by traumatic events [9]. Their experiences of the world are the result of sensations associable to an uncommon knowledge.
People with different color vision are defined anomalous trichromatic, so-called also color blindness. They have congenital or acquired color vision characterized by an another sensitivity to the colors and they don't clearly distinguish the colors of the visible spectrum.
The anomalous trichromatic people are defined by the receptive problems of one kind of cones, due to the absence of one of three photo-pigments [10]. The cones contain three specific photo-pigments sensitive to wavelengths of electromagnetic radiation: eritrolabe is sensitive to red, clorolabe is sensitive to green and cianolabe is sensitive to blue. The cones, control the reception of the wavelengths, absorb the maximum luminous intensity of the three primary colors (red, green, blue). The classification of color vision alterations arises from the following conditions:

- Protanopia is the red blind = absence

of eritrolabe;
• Tritanopia is the blue blind = absence of cianolabe;
• Deuteranopia is the green blind = absence of clorolabe;
• Protanomaly is red weak sensitivity;
• Deuteranomaly is green weak sensitivity;
• Tritanomaly is blue weak sensitivity;
• Tetrachromacy are people, specifically women, who see a four-dimensional space of colors, they have an extra photo-pigment, with which they distinguish among mixture of spectral colors [11].

Other people have monochromacy or achromatopsia, these color vision alterations or color blindness are related to functional anomalies on two cones or the complete atrophization of cones. In the visual process these conditions generate heavy problems to distinguish two or three primary colors: respectively monochromacy is the partial achromatopsia and the vision in greyscale is a complete achromatopsia.
The complete achromatopsia is distinguished in retinal achromatopsia due to retinal congenital anomalies and in cerebral achromatopsia in this case is an acquired achromatopsia caused by anomalies in visual cortex area. different cases are cited in the literature and compared, for example the artist Jonathan I. whose life narrated by Oliver Sacks [12] and that of the patient of dr. Antonio Damasio [13].
The incidence of people color blindness is different and varied among the ethnicity of the different geographical regions of the world and the color blindness is genetically trasmitted. In the U.S.A., approximately one person in 33.000 is achromate [14].

4. COLOR VISION ANOMALIES AND DIFFICULTY IN FOOD PERCEPTION

It is extremely interesting to study people with an achromatic visual perception, especially if the topic is tackled from different angles. Since complete achromates cannot distinguish colors they fail to see why they are useful, or why society has attributed such value to them throughout history. The ways colors are used by society still influence the visual perception of those who cannot see the color, or only see it partially or differently. Every day these people find themselves faced with visual-perceptive barriers resulting from inappropriate use of color – not advantageous for everyone.
People with achromatopsia have not been much studied as well as the study of their attitudes that require a systematic deep analysis of their needs in everyday life, if we are to design different ways of using color so that its message is accessible to everyone.
On this topic Ludwig Wittgenstein noted that

> *"We speak of "colour-blindness" and call it a defect. But there could easily be several differing abilities, none of which is clearly interior to the other* [15]. *And remember, too, that a man may go through life without his colour-blindness being noticed, until some a special occasion brings it to light."*

People with achromatopsia cannot identify food, or any other visible thing, on the basis of its color. This limitation depends on their different types of achromatopsia, they see the world from at least three different visual-perceptive viewpoints: the complete achromates can only see things in greyscale, while partial achromates have monochromatic vision of either in red scale or in blue scale [16].
Complete and partial achromatopsia are due to a lack of the ability to see or perceive respectively three or two primary colors and the colors formed when they are combined[b]. Both achromatopsia are not progressive, and are caused by congenital malformations or degenerative changes to the cells of the retina.
The diagnosis is based on an anomaly detected in a photopic electroretinogram (ERG) which in a person with achromatopsia shows the absence or reduction of the ability to distinguish colors. Moreover are used also test with Ishihara tables and Osterberg charts, and the test of colored crayons, grids green and red to match the color of pastel used and estimate the percentage of the corresponding color [17].
However, the achromates may also suffer other visual problems: they may have low visual acuity (from 1/20 to 2/10), photophobia, an horizontal nystagmus – which is an involuntary oscillation of the eyes - or squinting, taking the form of continually screwing up one's eyes to avoid bright light, and a central scotoma.
They generally have problems focusing details and their sight is often interrupted by white flashes when too much light hits their eyes, so they are constantly worried by a lack of information about their surroundings, that can sometimes disorient them.
This conditions are not true when the achromate has an acquired achromatopsia caused by anomalies or trauma in visual cortex area (cerebral achromatopsia).
It is certainly not easy to live in a world without color, seeing it only in greyscale and experiencing all its aspects – practical and functional as well as cultural – without being able to rely on the messages it conveys, especially because nowadays color has meanings for all the world's cultures, often serving as a common language

b - See the information of The Associazione Acromati Italiani Onlus at the website http://www.acromatopsia.it. Reference is made in particular to visual perception problems involving color vision. In the USA one person in 12 has some sort of problem and there is a strong imbalance towards males (8%) compared with only 0,4% of females.

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[18]. Just think what sensory expressions are used to describe all the features of food, for example in the contest of wine drinking, the use of wine color vocabulary (ruby-red) to describe the characteristics of types of wine [19]. What semantic approach to the terminology and perception of food can a person use if they can't see colors? Adjectives that everyone can grasp may have to be selected so as to provide sensory experiences to ensure social integration and inclusion.

Every day the media carries messages that are mostly designed and produced in colors intended for people with trichromatic vision, and when an image is presented as colorless there is usually a reason – a predefined meaning. Thus in all cultures colors form an expressive visual code, as a content that adds detail and information to the surroundings, improving people's perceptive and descriptive quality; they are signs and symbols that raise the quality of human reality and experience [20].

5. COMPENSATIONS GIVEN BY TEXTURE, SHAPES, AND CROSS-MODAL PERCEPTION

People with trichromatic vision can see every things better, but as achromates have not got this visual aid they have to *'develop'* their own visual perception strategies to make up for this different view of reality. Not having enough visual elements to deal with everyday life, achromates have to compensate the lack of color with other codes of expression. They undoubtedly use other sensory channels in the attempt to educate their visual perception abilities by identifying other typical visual *'markers'*. These may include *'tonal vibrations'* for certain color mixes, or special sensitivity to texture, which even though seen only in greyscale, or monochromatically, can still provide sensory information useful for building up alternative ways of orienting their visual perception more appropriately.

People who see colors know and remember how certain colors are associated with certain objects, or with reality in general. The achromate, however, has to associate things with shapes and textures *'visualized'* only in greys, and therefore has no experience of the multiple cultural messages conveyed by color.

But to get back to the main topic, it is precisely because color supplies so much perceptive and visual information that one wonders what achromates really see when they look at food. What relationship have they got with food? What effects does this lack of color perception have on their nutrition? These are the first questions that arise at the very start of a study on the color needs of people who have to live without color.

This raises many problems not just involving the appearance of food, where seeing only in greyscale certainly does not make it easy for an achromate to immediately recognize and identify an item. There are other practical questions, such as how can a color-blind person visually check the quality of a food, to see whether it is altered or contaminated. It clearly appears that checking the quality of a food is largely based on the visual-perceptive assessment of its color as an effective and practical *'tool'* for an immediate estimate of its bioactive ingredients[c] [21]. But this cannot work for an achromate, who can only base his judgment on texture as his *'tool'*.

The texture facilitation in food perception regarding primarily the people with an high or medium visual acuity that allows a fine perception of the elaborate features of texture food. In this conditions the perception of texture food could be compensated for lack or absence of color. The people with acquired achromatopsia (cerebral achromatopsia) could exploit this perceptive compensation. This facilitation doesn't apply to people with partial or complete achromatopsia where their visual acuity is low.

An interesting study by Katsunori Okajima, Junya Ueda and Charles Spence investigated the effects of vision of texture on the perception of food. They maintain that color and shape of a food influence the perception of its flavor and combine in the formation of the taste; they also note, however, that the texture of a food is important, contributing to the perception of the food. These researchers have developed an Augmented Reality (AR) system which can change visualization of the texture of a food in real time; one can see how textures influence the perception of aroma and flavor. Their findings indicate that the perception of a food can be affected by changes in light intensity and texture is unrelated to any color change; when it does not suggest any particular attribute for the food, it may reflect more complex individual experiences relating to the responses of the various sensorial areas [22].

Vision of textures therefore play a large role in the perception of food, especially if they are combined with shapes and colors, which are the main visual features explaining people's associations and preferences in the perception of flavor and aroma [23]. Clearly, for people who cannot see colors shape and textures provide the main visual information for identification. Consequently the sensations and visual perceptions of achromates cannot be based on known associations tested directly through the sensorial experience of people who see in color. Since how an individual relates to food differs depending on the person's physical and genetic features, how do achromates relate to food without the interference of the color code, which

is believed to be fundamental in the recognition, attraction and differentiation of what we eat and drink? How does visual perception in greyscale affect the achromate's sensorial and physiological systems? Just think how our physiological signals of hunger and desire for food are influenced by its color. Then too, sensory perception of the colors of food affects our appetite and the stimulation of gastric juices [24]. But if a person lacks the sensorial perception of food colors does the stimulation of gastric juices always rely on the visual channel? Very probably the olfactory route compensates to a large extent.

Verhagen and Engelen, using functional magnetic resonance bioimaging, have thoroughly investigated the neurocognitive basis of sensorial integration in humans, especially food perception [25]. This perception involves multiple signals that enter the body through different sensorial channels, creating combinations of sensations as they cross it [26]. These processes have been amply studied in connection with synesthetic perception in humans [27].

6. OPEN ISSUES (EMOTIONS, RESEARCH TO BE DONE, ETC.)

From the psychological viewpoint we must not underestimate how colors relate to emotion [28]. One wonders, therefore, whether an achromate reacts emotionally to the sight of food. It seems likely that these people's emotions when faced with food are aroused not through the visual channel but through the olfactory channel. So it is smell that evoke the emotions and pleasure associated with food in an achromate more than a person with trichromatic vision.

Even so, the lack of visual perception of color still has certain effects on a person's perception of tastes and odors. How is the color of food related to its flavor and smell? Interesting among the many studies of these aspects is research by Chen, Jianshe, Eaton, and Louise on the perception of creaminess in food by people with trichromatic vision [29]. These results illustrate the importance of extending these studies to achromates and people with other color vision anomalies to find out how seeing something creamy in greyscale is related to its taste, or its smell, bearing in mind that too is associated/ translated into the gradations of grey of the image.

If the room is lit well enough, an achromate can identify a food on the basis of its shape and texture, either in greyscale or in the scale of red or blue, though the outlines may seem blurred and hard to distinguish clearly, and so do the textures, unless the person uses some sort of magnifying equipment. Quite probably an achromate cannot recognizes a food immediately, and has many difficulties because of his multiple visual impairments.

A person with trichromatic vision would be sensorially disoriented to have to appreciate the smell and taste of a food only from the perception of greyscale. Equally disorienting is the sensory combination of the tactile perception of materials that a person can visually associate only with colorless texture, or of sounds with no chromatic correspondence [30].

Antonio Damasio in his book The Feeling of what Happens. Body and Emotion in the Making of Consciousness:

> *"… a man's identity is rooted in his body… we know the world through the senses of our body…"* [31]

The mechanisms of sensations produced in humans by stimuli detected by sight, smell, taste, hearing and touch act in an integrated multimodal fashion even in people who are color-blind. However, their perceptive experience seems more complex though at the same time simpler, relying on subtle nuances or visual *'vibrations'* that are not immediately perceptible to a person with normal color vision.

Ernst Mach in his widely-known *The Analysis of Sensations*, believes that

> *"…it is not our bodies that generate sensations but the complexes of sensations that form bodies. It is not the things but the colors, sounds, pressures, spaces and times – which we normally call sensations – that are the real elements of the universe".*

To some extent I share these concepts as the complexes of sensations form bodies but only to the extent that the bodies have no difficulty receiving the stimuli that generate them – what he calls the real elements of the universe [32]. The perceptive modalities of an achromate, however, are certainly more complex: from the visual-perceptive viewpoint in the greyscale are something less than all the colors, and some gradations of color look much the same when translated into gradations of grey as it is only the *'color tone'* that makes the difference. However, it is the intersensorial result of parallel perceptions and the compensations through other sensory channels that *'form the bodies'* of achromates.

The first studies on compensations through other sensory channels dated back to the historical observations of Aristotele in *De Anima* where he alleged the existence of parallelism between the grave sound frequency perception and the refraction of light, in the Medieval Age with the first conceptualization of synaesthesic

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phenomenon through to the Eighteenth Century. In 1704 Isaac Newton in *Opics* asserted the correspondence between the colors of the light spectrum and the musical scale through a mathematical relation between the seven colors of the light spectrum and the sound frequencies on which the musical scale was based. The concept of the cross-modal perception and the intersensorial perceptive strategies changed in the different ages until today with the modern studies on synesthesia and the neural plasticity and new development [33].

The synesthesia defined from the intersensorial relations and synesthetic evocations is a modality of exploration approach to the physical world used by everybody and the compensative needs of achromates have a major weight than people with normal vision.

Sensations, like perceptions, are faculties that imply the presence of an human body [34], but we know very little about how a human body is formed when it cannot feel certain sensations, or even evoke them. What are the sensations that form that body? How can they be reinforced? It would be extremely interesting to understand what happens to the human body and how it responds from the neuro-psycho-physiological viewpoint when it receives – or does not receive – the electromagnetic signals from its surroundings; this would help us understand the meaning of the intersensoriality, parallel perceptions and the synesthetic approach implicit in humans [35].

Each of these areas would be a worthwhile field for research and study with the aim of helping extend our knowledge of the perceptive strategies of achromates and people with other color visual defects, so that in the future we might be able to propose solutions to enable them to overcome their visual-perceptive obstacles.

Our aim here is to arouse the reader's awareness of the numerous problems in the life of those who do not see things in full trichromatic detail, and whose everyday life, therefore is dotted with obstacles that could probably be dismantled if we knew more and paid more attention to their needs. Achromates live their lives, expressing themselves linguistically and communicating sensations and perceptions without being able to make any reference to color. We need to study what roles color plays in their perceptive and neuro-psycho-physiological mechanisms.

Color is an information code which is not just a matter of culture, but is a signal people use, a stimulus to which the neuro-psycho-physiology of the human body reacts automatically.

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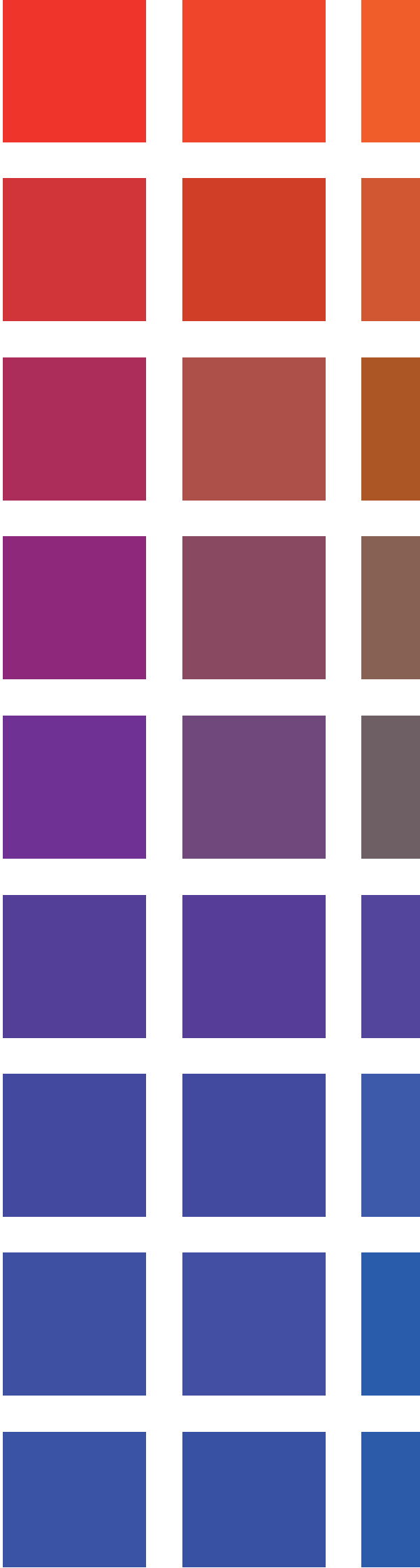

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