SPECIAL ISSUE ON FOOD COLOUR

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SOMMARIO | SUMMARY

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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"*!

Editor
Alessandro Farini *(INOA-CNR, IT)*
Anna Grazia Mignani *(IFAC-CNR, IT)*

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A Comparison of Color Schemes and Images in the Package Design of Sweets in the US and Japan

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ABSTRACT

This study compares the color schemes and design of packages of sweets in the US and Japan from the viewpoint of the cultural history of color. To visualize this comparison, color charts representing typical Japanese and American sweets packages are presented. The central aim of the comparison is to clarify cultural differences in color that characterize appetizing sweets, between the US and Japan. The research method was as follows: I purchased a total of 120 items, 20 items each of hard candy, chocolate, and chewing gum sold nationally, both in the US and Japan in 2013-14. Using ColorMunki Design of X-Rite, I measured the color scheme of these packages and listed the data in the form of color charts. These data are significant in revealing the fundamental cultural differences in the package design in these nations, a valuable insight for the field of international marketing and graphic/package design. Generally, there is a strong tendency for Japanese sweets packages to use a warm and light color scheme, whereas American ones apply a vivid multicolor scheme. Japanese sweets manufacturers produce various novelty items that promote seasonal and regional marketing, whereas American mass-produced sweets and its coloring are generally aimed at children and their dreams. Therefore, the color scheme of and the images on packages of US sweets resemble American comics.

KEYWORDS

Color Scheme, Sweets, Packaging, Color Culture

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1. INTRODUCTION

This paper compares the color schemes of the package design of sweets in the US and Japan from the the cultural studies of color perception and representation[a]. To visualize this comparison, color charts representing typical Japanese and American sweets packages are presented. The main objective of this paper is to clarify the cultural differences in color that characterize appetizing sweets between the US and Japan. Hues in the color scheme of these package designs are primarily examined. Sugita reported that colors that infants see everyday largely influence the human color perception[b]. Considering Sugita's biological experimental result [1], I hypothesized that the color scheme of the packaging of sweets can be a root cause of forming color culture since human beings habitually see packages of sweets from childhood. The result of this comparison can expose the cultural distinction in the color perspective and will be valuable in international marketing when exporting Japanese sweets. As precedence research, Birren published a series of books on color and consumer psychology [2]. Kawasome presented a paper examining the relation between food color and human appetite. Iyenger, in her book, *"Art of Choosing"*, wrote on the issue of how people choose color [3].

2. METHOD

The research method was as follows. I purchased 120 items: 20 items each of hard candy, chocolate, and chewing gum sold nationally, both in the US and Japan in 2013-14. The names of stores were *Wegmans, ACME*, and *Hudson News* in New York and New Jersey; and *100 Lawson, Aeon*, and *Okashi-no-Machioka* in Tokyo and Kanagawa. Both in the US and Japan, retail stores displayed an average of 18-30 competing products on the same shelves. (Figure 1 and 2)
Using Color Munki Design of X-Rite, I measured the color scheme of these packages and listed the data in the form of color charts. From 20 items I selected 3 representative colors[c] each: background, main subject motif, product name logotype. Figures 3-8 represent the hues of hard candy, chocolate, and chewing gums, which are frequently used.
For reference, I compare the typical colors of the sweets packages in the US and Japan in Munsell notations and RGB variables (Figure 9 and Tables 1-3).
Moreover, as an example of the cultural image influencing color, I mention American comics (Figure 10).

a - This paper is based on the presentation in AIC 2015 Tokyo: Hidaka, K. "A Comparison of Color Schemes and Images in the Package Design of Sweets in the US and Japan", Poster presentation with the proceedings, AIC 2015 Tokyo, 2015, p. 426-431. However, in this paper I have redone the color analysis, revised the text and added some figures based on the reviewers' comments.

b - Sugita experimented color perception of four monkeys by exposing them under various colored light for extensive period of time, and then he proved lighting and experience during infancy considerably change their color perception.

c - There are also some cases that only 2 colors can be seen in the design.

3. COLOR SCHEMES

3.1 HARD CANDY

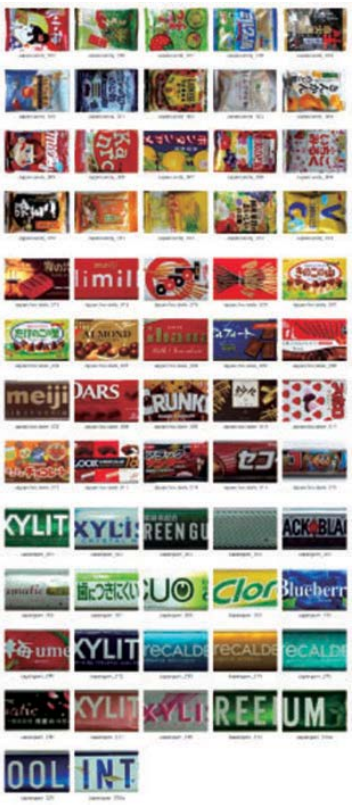
Figure 3 shows that Japanese hard candy packages tend to use warm hues, such as red to yellow and light gray; however, they use less green to purple. The use of warm hues and grayish colors gives bright and soft impression overall. Furthermore, the Japanese data show middle ranges of value and chroma.
Figure 4 shows the similarity with the Japanese data, which also use warm hues. However, there are two differences: first, there is no use of gray, and second, there is frequent use of green. The tendency of not using gray in the US hard candy packages makes it look very colorful and vivid. The US hard candy uses low value (brightness) and high chroma (vividness).

3.2 CHOCOLATE

Figure 5 shows that the colors frequently used in Japanese chocolate packages are red, brown (orange and red-purple low in value and chroma), black, and light gray. Moreover, they use gold frequently for product logos. In the data, gold appears as yellow and silver appears as gray since RGB colorimetric device does not consider metallic surface. Red, brown, black, and gold are four hues that seem to be typical colors for Japanese chocolate. In Japan, black reminds bitterness and red reminds sweetness. Additionally, brown is in between red and black; to make brown hue, people mix these two colors. Typical products such as *Glico's Pocky* and *Lotte's Ghana* milk chocolate also use red packages. The bitterer taste and more cacao ingredients the products have, the darker are the hues of the package from brown to black.
In contrast, Figure 6 displays the frequent color scheme in the US. They use brown, dark gray, yellow-green, and blue. *The Hershey* chocolate currently uses brown in red-purple hue and silver gray. American traditional chocolate snacks, such as *Milky Way* and *Reese*, use orange and green, which are not found in the Japanese color scheme.

3.2 CHEWING GUMS

Both Japanese and US chewing gums frequently use yellow-green to blue-purple and silver (gray) for their packages. These hues represent cool, refreshing sensation of menthol flavor. On the contrary, they scarcely apply orange and brown for their overall background. Figure 7 shows that the most frequent hue in Japan is silver (gray). Japanese chewing gums use metallic colors and do not apply many hues to give an impression of a cool, sharp feeling. Black is also often used to express a sharp stimulus. Moreover, Japanese have an image of healthiness in green color. A unique Japanese chewing gum flavor is



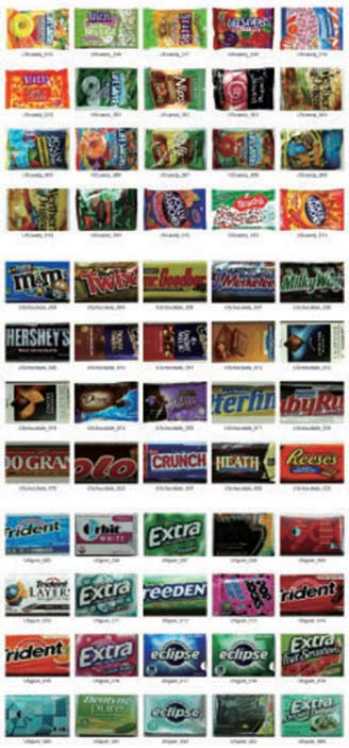


Figure 1 - Japanese Sweets (left)
Figure 2 - US Sweets (right)

Japanese plum, and its red packaging reminds one of ripe plum.

American chewing gums use more blue-green than those of Japanese. In terms of value, Japanese chewing gums use high to medium range of colors, whereas the American package applies low range of colors. Furthermore, Figure 8 shows that the use of orange in the US is more frequent than in Japan.

4. BLUE COLORED SWEETS AND PACKAGE

Quoting the article from Birren, Kawasome reported that blue food reduces appetite [4]. It seems that previous research papers have spread such stereotype to the public, especially package designers and food manufacturers. Therefore, food packages in Japan frequently use warm colors, such as red, which is confirmed in this study. However, in the US, even though *"blue"* and *"fluorescent color"* in food rarely exists naturally, this survey found that these colors are widely used in both the packaging and food.

5. RESULTS AND DISCUSSION

5.1 THE TYPICAL PACKAGING COLORS OF THE US AND JAPAN

This section compares the typical colors from the result of this survey and examines the cultural distinction. Here the term *"typical"* means that these list of colors are happening in the usual way since these are selected as the most frequent colors each nation use. Figure 9 illustrates a list of typical colors used in packages, sequenced from the first to fifth place. The left column is of the Japanese hard candy, chocolate, and chewing gum, and the right column is of the US. Comparing these three types of sweets, the divergence of hue is remarkable, particularly in chocolate.

In Japanese packages, the illustrative images of fruits, green tea, or milk are often used to inform and evoke these flavors. Accordingly, the colors of these items reflect the color of the packages. In Japan, the use of color in packages of long sellers, basic items versus seasonal, limited, or regional novelties are poles apart. The seasonal, limited ones use more drastic color schemes, whereas the long sellers do not often change the design and colors.

American package design generally applies colors in high chroma and low value. Unlike Japanese, American sweets tend to use illustrative images of contents rather than ingredients. Seasonal and limited novelties are also popular in the US, but it seems that these are rather event based, such as Halloween, Easter, and Christmas with its symbolic colors[d].

5.2 AMERICAN COMICS AND SWEETS PACKAGE

The mass-produced snacks and sweets sold in American supermarkets and convenience stores are mostly for children, and its coloring is generally aimed at children and their dreams. Professor Story of University of Minnesota pointed out a tendency to use toys and cartoon characters for food advertisement to make

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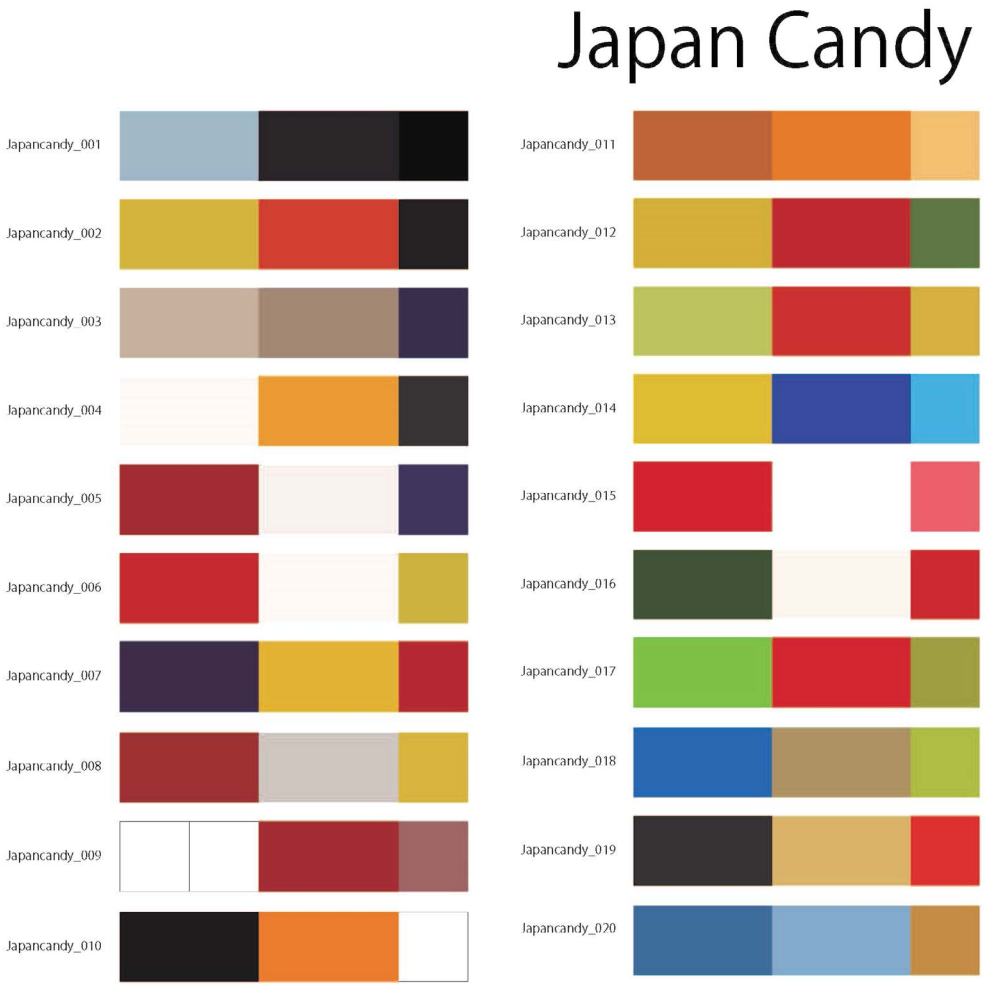

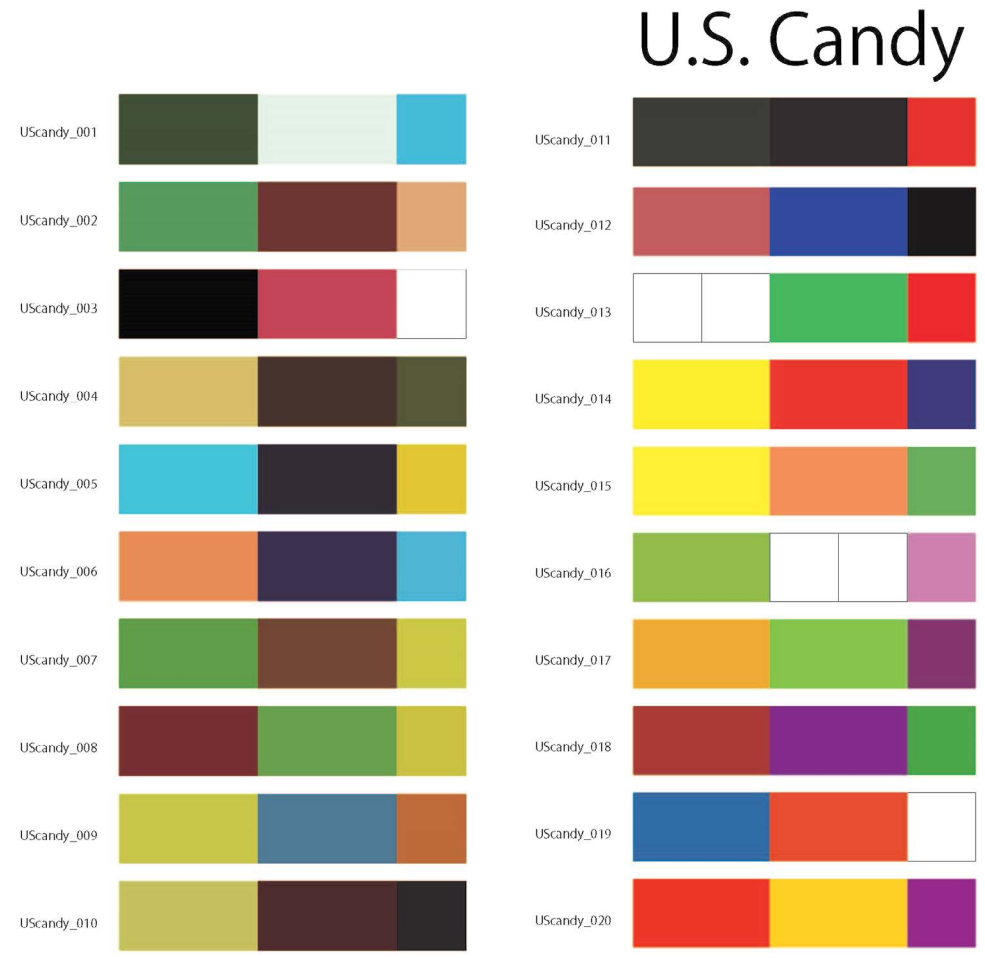

Figure 3 - Japanese Hard Candy (above)
Figure 4 - US Hard Candy

Figure 5 - Japanese Chocolate (above)
Figure 6 - US Chocolate

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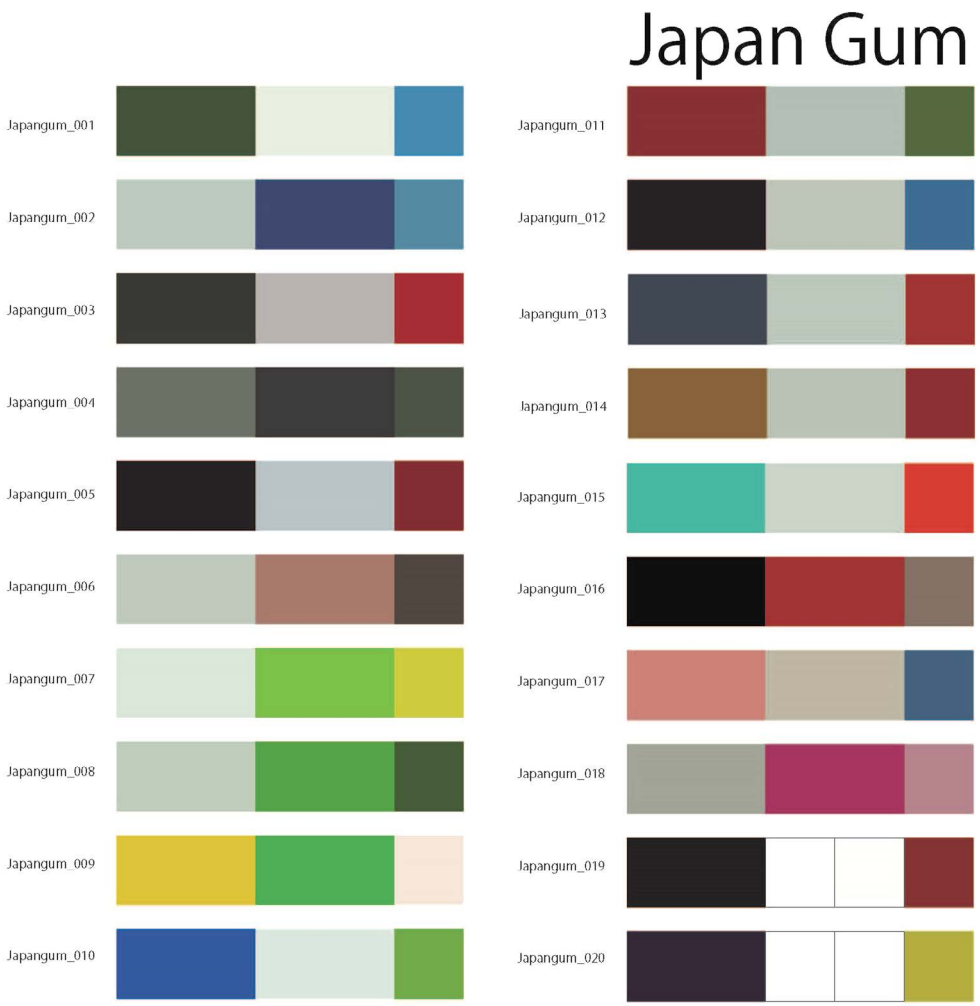

Figure 7 - Japanese Chewing Gums (above)
Figure 8 - US Chewing Gums

d - Red & green for Christmas, yellow & pink for Easter, and orange & black for Halloween.

Figure 9 - Typical Colors in Packages

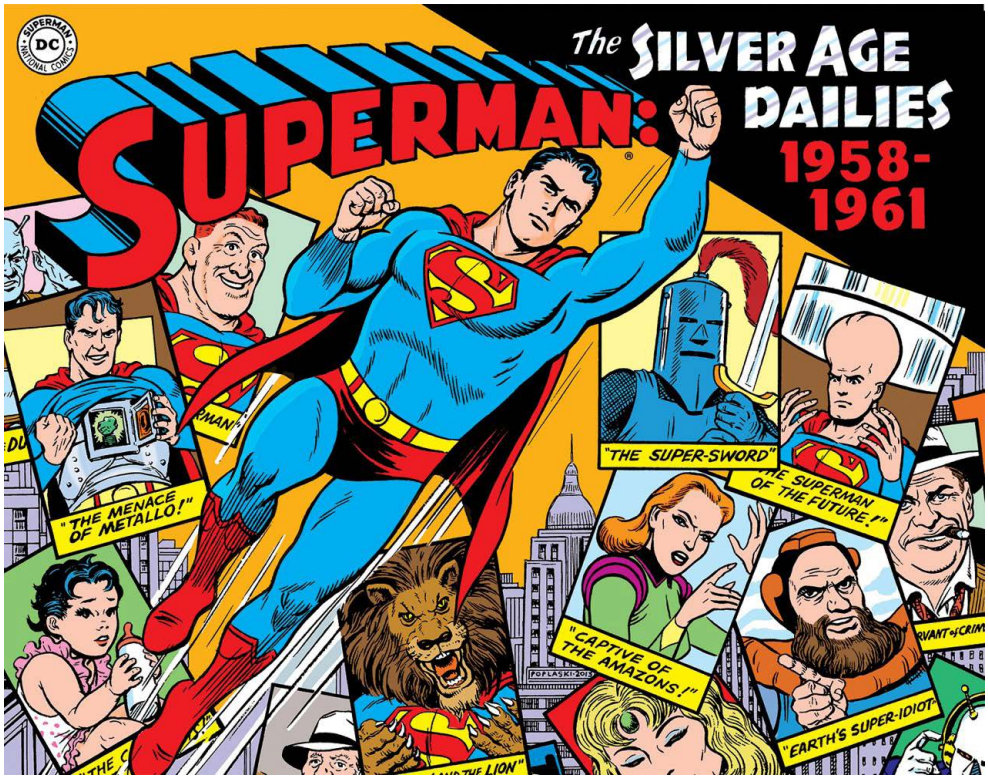

Figure 10 - "Superman: Silver Age Dailies Vol. 1: 1959-1961" the Library of American Comics, 2013, Superman TM and © DC Comics, Inc

children recognize brands [5]. In particular, *M&M, Kellogg's* cereal, and *Oreo* cookies use this marketing strategy [6].

Thus, it is predictable that the color scheme of these snacks and sweets packages resemble toys and cartoons. In Figure 10, Superman's color, which are blue, green, and red shows similarity to the one used in the US sweets. In Japan too, children purchase sweets because of bonus toys and the popular anime cartoon characters that are seen on the package. Yet, the colors of Japanese toys and cartoons may not be as vivid as those of the US.

Table 1 - Comparison of the Typical Colors of Hard Candy in Japan and the US

Japan	Munsell (HVC)	RGB	USA	Munsell (HVC)	RGB
1	6.6R 4/11	179: 57: 44	1	7.6R 4/12	195: 67: 45
2	4.9Y 6/7	187: 158: 66	2	1.9G 4/6	72: 134: 82
3	3.5YR 5/9	213: 122: 57	3	9.2R 4/10	197: 83: 46
4	N 8.0	207: 205: 199	4	4Y 7/9	234: 187: 65
5	1GY 6/7	153: 161: 60	5	1.2B 6/5	88: 161: 176

Table 2 - Comparison of the Typical Colors of Chocolate in Japan and the US

Japan	Munsell (HVC)	RGB	USA	Munsell (HVC)	RGB
1	6.2R 4/11	180: 57: 50	1	N7.0	180: 181: 159
2	8.6YR 5/5	173: 130: 72	2	0.2GY 6/7	164: 163: 59
3	6.7R 1/3	72: 35: 29	3	1YR 1/1	49: 38: 32
4	N8.0	207: 199: 195	4	7.6PB 3/8	65: 81: 142
5	N1.0	32: 28: 24	5	7.3YR 4/5	137: 96: 47

Table 3 - Comparison of the Typical Colors of Chewing Gum in Japan and the US

Japan	Munsell (HVC)	RGB	USA	Munsell (HVC)	RGB
1	5.1GY 7/1	176: 181: 168	1	9.2G 4/3	82: 129: 117
2	1.7PB 3/4	66: 96: 124	2	8GY 3/4	69: 98: 50
3	9.2GY 5/8	78: 140: 59	3	1.3P 2/2	56: 54: 74
4	3.3R 3/7	128: 50: 40	4	7.9RP 5/9	188: 93: 136
5	9GY 3/4	61: 92: 49	5	1.2GY 7/1	183: 185: 169

6. CONCLUSIONS

The packages of long seller sweets can become the evidence of perception and representation of color in every country. In Japan, warm and light colors are used in the basic long sellers, and color scheme variations are seen in seasonal, regional, and limited items. In the US, marketing to children and color scheme of American comics deeply influence the design and colors of sweets packages. Humankind forms the color culture—perception and representation by looking at these items on a daily basis since childhood.

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[6] Ibid.

Colour as a Code in Food Packaging: an Argentine Case

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ABSTRACT
Intellectual and emotional aspects of the product's image raise the concerns about its qualities; concerns about nutrient content, the ingredients, the amount of sugar, salt, fat. The product appearance induces expectations.

> *"Expectations govern our attitude to food and the food scene. We deduce from the appearance of the food in front of us whether it will harm us or be good for us"*, says John Hutchings.(Hutchings 2003)

The consumer searches for the attributes he considers most suitable according to his internal needs, in the products he wants to buy. It is necessary to define a target segment to propose the product that is effectively closer to the ideal of the buyer and to communicate its benefits.
This is why the packaging has a big responsibility. Emotions, memory, social patterns, are behavioral areas in which colour plays an important part. There is a message to remember, and the packaging is a message in itself; it helps to guide, motivate and encourage consumers in their purchase decision. It is imperative to choose the potential customer for the message; each target has its language, its expectations.

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1. SEGMENTATION

It is significant to consider two types of segmentation: functional segmentation and psychological one. In the functional segmentation the idea is to group consumers according to the functional advantages the consumer is looking for. When products are addressed to health conscious consumers, the packaging, associated to the product concept, can produce a functional segmentation. Packaging has a decisive influence on the consumers perception, and therefore, in the purchasing decision.
Psychological segmentation is based on the characteristics of the consumer's social class, their lifestyle, reference models, their personality, involved in the emotional satisfaction they obtain in the purchase. The psychological differential advantages are often more sustainable than the functional. Packaging must show specific signs, build confidence as much as unambiguous product identity.

2. CHANGES IN CONSUMER

Consumers, increasingly informed and demanding, have taken the lead. They show new desires, seeking harmony between quality and wellness. In the twenty-first century the will to live in a more human and less frivolous world emerged. Banality is being outdated. The importance of healthy living, honesty and revaluation of emotions are values that flourished and increasingly permeate many aspects of life. Packaging design is one of them. Information and consciousness: accompanying the suitable healthier urban living, many products are incorporating functional values as a vital part of their communication systems. Nutritional and functional information are relevant when choosing a brand or a particular variety.

3. VISUAL IDENTIFICATION

Colours are created in our brain as a perceptual tool to facilitate our visual-cognitive and visual-emotional functions. Colours are more than a physical process: they work as a signs system, a source of information decoding the world around us. In this world, the products we buy every day are present. The consumers develop their opinion about the products they see in less than 90 seconds from their first interaction with them. Between 62% and 90% of that assessment is based on the colour of the product. ((Institute for Color Research,Color Communications, Inc)
The communicative properties of a color can be defined by two categories: natural associations and psychological or cultural associations.
Research conducted by the secretariat of the Seoul International Color Expo 2004 documented the following relationships between color and marketing: 92.6 percent said that they put most importance on visual factors when purchasing products. Only 5.6 percent said that the physical feel via the sense of touch was most important. Hearing and smell each drew 0.9 percent.
Vision is the primary source for all our experiences. Current marketing research has reported that approximately 80% of what we assimilate through the senses, is visual. Color addresses one of our basic neurological needs for stimulation.
A complex semiotic process enables the understanding of products differentiation on the market. The impact of colour on the decisions about what product to buy is due to the fact that it is a symbol that reflects the image we have of ourselves, our personality.

4. THE COLOUR OF THE PRODUCT

Colour is an essential element used as a sign to represent desirables product attributes. Consumers respond to the *"total product"* that also includes their image. Successful design requires an awareness of how colors communicate meaning. Colour can provide information about the quality of a product and can also show a strong association with certain product categories. Green, for instance, is associated with natural products (Figure 1).
The marketing function of the package includes the location, because the consumer must be able to identify the type of product (dairy desserts, breakfast cereals, detergents, etc.) from a distance in the linear, and also identification, because once located the product the consumer must clearly identify the products they really want to buy within a family or brand. The packaging must show specific signs, the information that helps build confidence in the product and strengthens consumer purchasing decisions.
The graphics and colours used in the package must be consistent with the status or image or expectations it wants to satisfy and must serve to identify and locate the product. Colour improves readership. Colour can be used as a referent code system for the product. Colour coding helps to clearly identify the desire product.
In package design some actions apply to the expected typology change in order to produce a strong identification with the brand (Figure 4). We also find the opposite strategy, which is to favor the association with the category identity. Breaking the category code can be a key to differentiate a new product. In spite of the fact that some brands traditionally use green as a strong (Figure 2) identifier, green colour is used in associations with the green countryside and healthy products in most countries.

Green is related to nature, freshness, fertility, peace, hope, humidity, regeneration, growth, relaxation; is calming, curative, and balsamic, in its positive meanings.
In many countries is used to identify bio products. In some others, green is also a visual attribute related to low fat; so do pink and light blue (Figure 6 and 7).

5. DIET OR LIGHT PRODUCTS

Important changes in consumption values caused a typological substitution in the colours expected for certain products. The irruption of diet and light products and the explosive growth in value reached by the concept *"low calorie"* produced an unexpected change in the colour paradigm.
The first experiences in colour for diet products focused on white, silver and pastel colours as pink. Finally, green, associated with nature, became a strong identifier for this type of products. Then, colour is not talking about product attributes but on their feature of being *"light"* instead.
Colours meaning can also have a regional value, given by a mixture of cultural interpretations associated with some colours and their historical use.
In Spain, for instance, light products began to appear in the 80's proposed as healthy products. Begoña Hernández Salueña, from the Department of Physics of the Public University of Navarra, after consulting several dairy companies, says that there is no official code for the colours of the milk pack.
The use of colour by type of milk (blue for the whole, green for semi-skimmed and skimmed) has to do with the organization in supermarket shelves and with the communication for consumers. These colours appear having being selected by the first brand that sold these products, followed for the other brands. But several brands have recently decided to break that tradition and begun using colours more for identifying the brand than the (Figure 3) category. Central Dairy Asturiana, for example, has decided to use red for whole milk instead of blue and blue for the semi-skimmed and green for the skimmed. Pascual, uses dark blue for whole milk; light blue and pink for semi-skimmed and skimmed.

6. LIGHT PRODUCTS IN ARGENTINA

It is interesting to see how in Argentina, green colour has definitely been adopted as a category code, especially in dairy products. The low fat dairy products area at the supermarket is easily recognizable from far away in a green spot.
Gonzalo Petracchi, packaging designer for Sancor, says: The green code emerged in the argentine market around the 90s, when the changes from diet products to light ones came out in order to clarify what was being offered to consumers.
Diet products sought a cleaner and pure image, in association with reduced-calorie diets choosing a colour as blue/cyan. At the beginning of the change, diet and light were virtually synonymous, but light category products wanted to find their own individuality in a codified meaning, an identity charged with emotional values as care and health, without giving up flavor (Figure 8).
The official argentine food code and that one of Mercosur include the requirements for food labeling, in order to give the information that builds confidence, but no rule appears mentioning the use of colour as an identifier.
In argentine food code, for instance, food labeling included in chapter XVII-food or dietary regime-specifies the words to use, but not colour: Food with low lipid content will be labelled with the name of the product and the indication *"diet, reduced lipid value"* or *"diet of low fat"* and also may bear the legends *"reduced calorie or low calorie"*.

In spite of in most cases the colour code for whole fat products is blue, red is also used in Argentina as in other countries.
Green is definitively the colour code for low fat and fat free in Argentina. Some brands are recently incorporated two greens, light green and darker one; to show a different identification for no fat and low fat.
There are a few exceptions. Nestle use light blue for 0% fat powder milk and Sancor have introduced recently pink to identify 0% fat milk.
Green is the colour of security. It is also the colour of permission
Green packaging assures us to eat healthy, preventing us from getting fat, with safety, confidence and certainty. Big companies of massive consumer products invested heavily in communication to encourage the establishing of an expressive symbolic code. In the last two years, in Argentina, this code has widely spread to others categories. (9)
Celebrating the power of colour as a code in food packaging, I would like to remember what Charles Riley wrote in his book Color Codes:

> *"completely mastering color is impossible, but the power it imparts to those who dare to handle it is as profound as that of light itself"*.

He says also

> *"colour is a third Promethean gift, like language and fire"*. (Riley, 1995)

1

Figure 1- Green = Natural

2

Figure 2- Green as brand identifier

3

Figure 3 - Spain Red-Blue=Whole/ Blue-Pink= Light

4

Figure 4 - USA Red=Whole=Fat Free=Low Fat

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Figure 5 - Germany Green=Whole/ Red=Low

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Figure 6 - Italy Blue=Whole Pink=Whole Pink=Low Green=Low

7

Figure 7 - Chile Blue=Whole/ White+Blue-Blue-Green=Low Fat

8

Figure 8 - Argentina Red=Whole Green=Low/ Blue=Whole Green=Low

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Figure 9 - Argentina- Others categories using Green as light=Low fat

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Colour in Food Packaging Strategies and Rules

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ABSTRACT

Originally made to prevent diseases due to poor sanitary conditions, food packaging is much more than this. It protects and communicates information not only about the food type (organoleptic properties for consumption), but also about the company and its corporate strategy. Factories abide by strict packaging standards, focusing part of their resources to the packaging look, through psychology, marketing and budget based analysis. For a packaging to work, it has to *safeguard the product, induce shopping, being read*.

On the sale shelf, the product has to be *first seen, then chosen and finally purchased* among many competitors. Products has to catch the attention of the consumers in a small timeframe. Moreover, since the consumer buys 75% *by impetus* and only 25% *by programming*, therefore it's clear that *purchasing means getting emotional. Succeeding in selling means being able to give rise to emotions*. Colour in packaging is a wonderful salesman. It evokes emotions and is a quick, efficient and silent messenger. Its *"language"* is ubiquitous, fully understandable and cheap. It is a powerful tool of non-verbal communication, able to strongly influence the mechanism for impulse buying. Colour can attract attention in a very short time, transmitting product specific messages and creating strong brand identity.

Colour per se cannot meet all needs: the degree of saturation, brilliance and combinations between different colours change from time to time the end result. The creation of a seductive and attractive packaging is highly dependent on hue and hue combinations, context, the type of graphics and print format. The chromatic effect of a final package also depends on the material and texture. Finally every colour evokes a different emotion and every colour evokes a different food (e.g. white for milk products). The language of colour, with its rules, requires a process of research and investigation that is difficult to fully understand, nevertheless, all food companies use colour in packaging with the strategy to increase their sales.

KEYWORDS

Colour, emotion, food, packaging, strategy, sales, salesman

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1. FOOD PACKAGING

Originally conceived to prevent diseases deriving from poor sanitary conditions, food packaging means more than a mere food package. A package both protects and communicates. Upon inspection, consumers get information not only about the food type, its organoleptic properties, its beneficial properties, but also about the company and its corporate strategy. Factories abide by strict packaging standards, focusing part of their resources to the packaging look, thus creating an analysis current, perching between psychology and marketing. The final aim consists in finding the best appropriate package for food, a compromise between budget requirements and the goal to stimulate the customer to purchase.

2. TODAY'S MARKET ANALYSIS AND LARGE SCALE RETAIL STORE

To understand the issues related to food packaging, it is necessary to examine the point of sale, the place where the product is displayed – among its many competitors. The attention of the consumer must be caught – the product must be sold. No serious company, wanting to loyalize its customers and sell its products would do it without knowing the weak and strong points of its point of sale [16]. If we consider a point of sale, putting aside the place, decor, design and colours, two are the fundamentals:

- The precise location where the product is displayed (i.e. counter, shelving units, showcase)
- The light source

In a grocery store, food products are arranged following a marketing rationale.
Brand products and market leaders are placed on the upper shelves: these are popular brands, known by consumers because of ads, whereby price and quality are high. Purchasing them is not easy: one has to look up to see them, and consequently raise one's arm. Private Labels are placed on shelves at eye level, i.e. the LSRS brand. They represent a good quality/price compromise. They stand in the most favorable position for purchasing, because they are both at eye and hand level. In the lowest shelves: best price products, unknown brands, with a low quality standard and low price. Purchasing them is uncomfortable: one has to bend down. Whilst the brand and leader products have to launch an advertising campaign to keep their market share, private label and best price products do not advertise. Moreover, to get the better strategical position, localization at eye level on the shelves (approximately 135 cm high, i.e. the average height of an Italian woman), a company has to invest a lot of money [16, 20]. Food companies have to compete in a overstocked market with very tight margins, where products are surrounded by all their competitors. These difficulties are even worsened by the trend of consumers to shopping quickly and with less and less time of consumers to spend inside a point of sale. For a brand product, there is a difficulty in being *first seen, then chosen and finally purchased*.

Moreover, the food company has to take into account that

- Every food product satisfies not only a functional need (hunger, thirst), that is primary need, but also a symbolic one, which is secondary: I eat in search of gratification, I eat because of my social position, I drink to have more energies etc.
- *The first and foremost driving force of purchase is emotional* [16].

The consumer, in fact, buys something by impetus or by programming.
All research institutes agree about the data that out of four products bought, three are bought by impetus and only one by programming [16, 17]. These figures, 75% by impetus and only 25% by programming, vary slightly depending on the Point of Sale , but it is clear that *purchasing means getting emotional.*
At the mall, one does not read the label, but looks at the package!
Succeeding in selling means being able to give rise to emotions.

3. PACKAGING: FROM MERE PACKAGE TO REAL COMMUNICATOR

EFFICIENT PACKAGING AND WINNING PACKAGING

For a packaging to work, it has to include three features [20]. These are:

- It must adequately safeguard the product
- It must induce shopping
- It must be read.

These features, skillfully combined by creative and advertising agencies may lead to successful result. If we consider only the graphical aspect, in applying this rule we simply represent the product by way of a picture or a sketch on the box containing the product (i.e. putting an orange on an orange juice tetra-brick). This kind of packaging has a limit, though: it satisfies

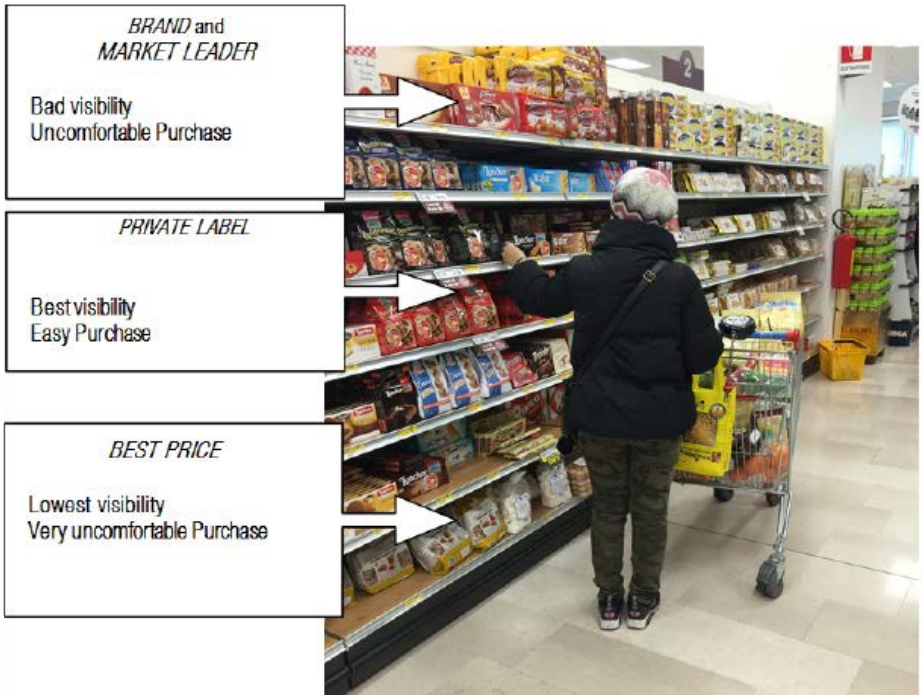

Figure 1 - Shelves Layout in Large Scale Retail with Brands, Market Leaders, Private Labels and Best Prices

only the primary need of the consumer, (hunger, thirst) but not his secondary needs [15, 19].
To satisfy all the requirements, the packaging has to stimulate not only the eye, but also other senses [1, 2, 3]. Multisensorial messages evoke emotions, beneficial and pleasurable feelings during food consumption. Moreover, it has to stand out among all competitors, express a strong personality and a special plus: appeal [7,13].
A fourth feature is then necessary, that is being seducting and charming: it must be "catching"!

3.1. THE BARILLA CASE

One of the first food companies to understand the need to use the term appetite as an ad on its box has been Barilla, the Italian pasta leader and popular brand name all over the world.
In 1969, Barilla started a *re-styling* operation of its packaging, known as *"appetizing in the box"*. The pasta box of 1956, a square shaped cardboard box chosen by the company, resulted in a market survey as being felt masculine, cold, industrial and dull, unable to provoke emotions, too outdated in a world of communications. The restyling was committed to Lippincott&Margulies, an international company specialised in visual communications. Barilla decided to keep the colour blue, perceived as the company colour, which had been chosen by Pietro Barilla, founder of Barilla in 1877, who started with his first pasta shop in Parma, since the colour reminded of the so called "sugar paper" once used to wrap up the loose spaghetti. The 1956 box, light blue with a bulk of spaghetti on it, was hence restyled. The new feature consisted in reminding the appetite, showing pasta at the moment of its cooking process [7].
The Barilla package, as displayed nowadays in a point of sale, has undergone another restyling around how the product is presented, which is shown at the very moment of its consumption, and not, as it was before, during the cooking, so to further evoke its appetizing properties. The light blue becomes a dark blue, a more refined and exquisite colour. Pasta has been therefore *"refined"* from a large consumption Italian main course to an exclusive and refined food product.

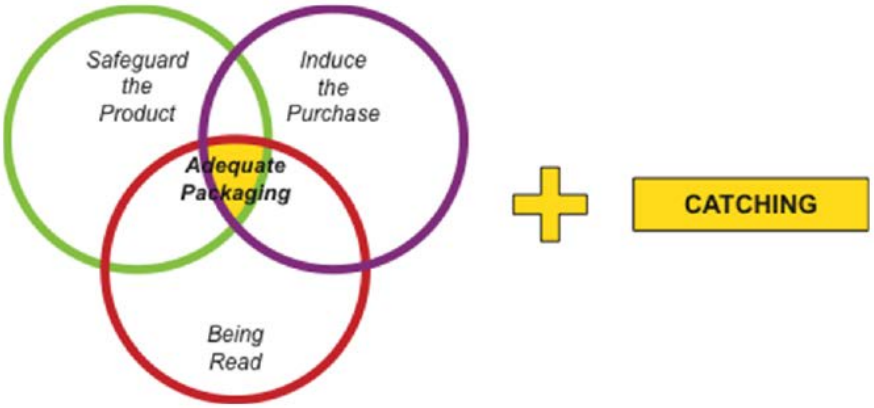

Figure 2 - A winning packaging has to be "catching"

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This new message has been supported by a massive advertising campaign all over the world. At the time, many famous testimonials like Alberto Tomba and Steffi Graf appeared in the ads, sitting in a luxury restaurant and ordering a nice Barilla maccheroni dish instead of exclusive courses like caviar [7, 18, 19].
Although minor changes have been introduced from time to time in the pasta packaging, according to the outcome of periodic marketing surveys [21], the Barilla food company has always relied on two traditional features of its brand:

- the Blue chromatic code
- the cardboard box

Moreover, Barilla has never substantially modified the traditional image of the fork with a spaghetti knot, originally launched in 1985. In this picture pasta appears already deeped in sauce, ready to be tasted.
The addition of a plastic window to the main side of the pasta package, originally used only in the foreign markets to provide a visual definition of the pasta type (not always known), is consistent with the food packaging strategy currently dominating in western countries: to show the content for its immediate identification and emphasize the manufacturer transparency and corporate integrity. One may observe:

- Barilla is the market leader and owns the colour code.
- The best strategy for consumer goods - mass market goods - is appetite recall – displaying the scope on the package [15, 19].

Colour: Inspiring and preempting flavour

Several studies prove the great power of colours on consumers, inspiring and preempting the perceived flavor [8- 12].
Ernest Dichter's Test (1964) envisages the following steps:

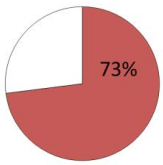
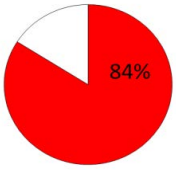
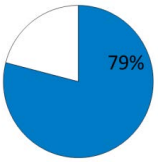
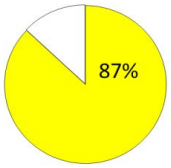
- The same coffee poured into 4 cups
- Behind every cup were standing 4 different tin cans, in four different colours: brown, red, blue, yellow
- A considerable sample of people were asked to depict the perceived flavour of all cups

3.2. MARKET LEADER/PREMIUM PRODUCT THE LAVAZZA/PELLINI CASE

In 1964, the Dichter's Test was made. In 1970 Lavazza comes out with the Qualità Rossa which soon becomes the most sold coffee [13, 14].
Lavazza's choice is red, the colour conveying at best a rich and full flavour to consumers, adding the image of a hot coffee cup on the packaging.
Usually, a company wanting to launch a brand and acquire a market share from a competitor,

Figure 3 - Barilla cardboard box of 1956 showing the product, center: 1969 picture of pasta while cooking, right: 1985 pasta ready- to –eat

Figure 4 - A 2016 Barilla typical spaghetti package

Tin can colour			
BROWN	RED	BLUE	YELLOW
			
Answer Percentage and Taster Comment			
			
too strong note	richer note	lighter note	too sweet note

has to differentiate itself. In this particular case, two were the options:

- Getting rid of the image recalling the function - which will be only sensed or
- Breaking with the habits and use a completely unusual colour.

Lavazza and Pellini coffee brands are the best example of different strategies to gain market shares and increase sales [19].
Pellini's packaging choice was almost imposed by the fact that they were obliged to design a new package opposed to that of Lavazza [18]. To differentiate itself, Pellini broke with the habits launching its product on the market (100%) Arabic) with a new packaging, following three innovative rules:

- No drawings of a cup
- Colour code change: red has been changed by dark brown, almost black (a "noble" colour which recalls the colour of a roasted coffee bean)
- No vacuum-sealed package: instead, a cylindrical tin can labeled: - 100% Arabic – to highlight the value of the product (a tin can is definitely more valuable than a bag).

This packaging has made possible Pellini's market repositioning so to address a different market segment, a *"niche"*, and increasing thus its sale price [13].
From consumer good, Pellini became a premium product, an exclusive and high quality brand, supported by a polished image. Illy had a similar approach with its elegant silver tin can [18].

4. COLOUR IN PACKAGING

Colour: a quick, efficient and silent messenger.
Moreover its *"language"* is ubiquitous, fully understandable and cheap!
Because of these features it is a powerful and extraordinary tool of non-verbal communication, able to strongly influence the mechanism for impulse buying. Colour could be defined as *"the*

Figure 5 - Pellini comes out on the market employing the breaking strategy

silent salesman" for its ability to attract attention in a very short time, transmitting product specific messages and creating strong brand identity [9]. If colour can *"conquer"* the eye in a second, the reaction that everyone has towards a specific colour is based on sensorial, emotional and cultural perceptions.

It's important to understand that a colour per se cannot meet all needs: the degree of saturation, brilliance and combinations between different colours change from time to time the end result. The creation of a seductive and attractive packaging is highly dependent on hue and the selection of its combinations, its context, the type of graphics and print format. The chromatic effect of a final package will also depend on the material, its nature and texture [13].

Understanding the language of colour requires a process of research and investigation that is difficult to fully complete.

4.1 FIRST ASSUMPTION: ALL COLOURS ARE ALLOWED IN NUTRITIONAL PACKAGING

In this area wrong colours do not exist. It sounds surprising but this is due to the extremely broad number of competitors active in the market and faster and faster and emotions-based selecting criteria. It's very hard to obtain and hold market shares and any tools and means are allowed [19].

4.2 SECOND ASSUMPTION: ANY HUE IS USEFUL PROVIDED THAT IT'S PROPERLY UTILIZED

Notwithstanding the unique features of an item (texture, shape etc.), its printing and graphic format and its marketing characteristics (target, end user, purchasing mechanism etc.), it's important to remember that the message conveyed by a colour depends on individual, social and cultural values. Many studies have been carried out on this topic: some have shown that people with light eyes and hair are attracted by packaging with light and soft hues while those with a darker complexion prefer darker and more intense colour shades [19].

Indeed, Johannes Itten was the first to observe that people tend to select colour shades similar to their face hues while studying individual reactions to *"Armocromia"* (Colour Harmony) at the Weimar Bauhaus [4]. In this respect, food industry has to implement different strategies based on the specific market they work in. Changes and adaptations of product packaging, shape and colour are common to meet country specific expectation. Minor modifications are often sufficient (i.e.: Barilla has introduced in its pasta packages a small window to show its

Figure 6 - From a study of J. Itten: People with light coloured face prefer light and soft colours and the same is true for people with dark shades who prefer darker and strong colour contrasts

content) or, sometimes, it's necessary to change recipes or ingredients (salts, spices, sugar etc.). Since 1941, we know that in western countries adults prefer blue (Universal Colour Score, Hans Eysenk,1941) [6, 10] while in Japan white is the favourite colour [15].

5. HOW TO IDENTIFY A PACKAGING COLOUR

To facilitate the choice of a colour code some criteria exist that help identifying the hue more appropriate for a given food. In a situation where any colour is allowed, two rules are more relevant:

5.1. THE RULE OF COHERENCE

Based on intuition and common sense, the *"coherence"* rule is similar to the criterion used to strengthen a food/beverage colour.

The *"coherence"* rule is reliable because it doesn't depend on social and cultural values. Since the early Sixties, its applications has enable the manufacturing of easy to interpret and sell items. At present, it represents a good starting point but it's not sufficient (18).

According to this rule the consumer is immediately informed and at the same time reassured on the food content.

5.2. THE RULE OF COLOUR INDUCED MESSAGING

Colours may stimulate perceptions and convey messages based on people experiences, models, social-cultural values and living environment.

Table 2 shows the main colours and food they are associated to.

Although this rule helps in developing packages, it needs, as in the case of the coherence criterion, additional approaches.

On the basis of his studies on nutritional advertising (1949), Max Lüscher states that food which has to be perceived as natural and fresh requires red, yellow or warm hues to be seen as *"living"*[5].

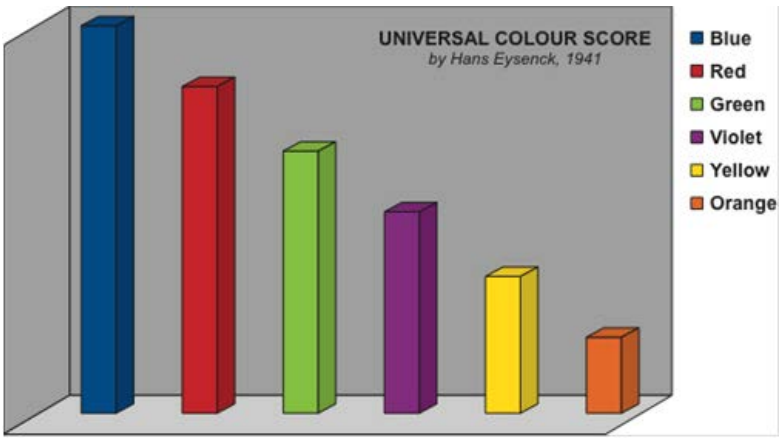


Figure 7- This graph describes western adults favourite colours among the six major ones

Using these rules, manufacturers try to offer consumers a product capable also to induce emotions.

5.3. THE RULES OF MARKET LEADERSHIP

As mentioned, the choice of a colour for a food package is based on corporate strategies that take into account market characteristics, competitors, target, positioning and market leaders. In the food industry sector, the colour selected by the leader set the rule and a colour code. The *"Barilla blues"* is a typical example.

When a food company plans to launch a product already introduced by the market leader, it has two options:

-to align (me too)

-to react (break the rule)

In the first case it will attempt to imitate the leader packaging colour and graphic, this would look appropriate but would lack attractiveness and originality. The *"me too"* strategy is typical of Private Labels [15, 19].

The second options requires the development of tactics based on totally different products features, including colours so as to induce new visual identity (i.e.: red vs blue, white vs black).

Coca Cola, the unchallenged market leader, has chosen red as its colour code. In this case the colour has multiple meaning: indeed ice blue would have been more appropriate for a

FOOD	FOOD COLOUR	PACKAGING COLOUR
Milk e dairy products (yogurt, etc)	White	White
Water	transparent, colourless	transparent, colourless
Bakery products/pasta	Light Yellow shades	Warm Light Yellow
Eggs and eggs derived products/egg powder	Strong Yellow	Yellow
Egg pasta/egg noodle	Yellow	Bright Yellow
Grain products	Light Brown shades	Light Brown, Yellow Cake, Yellow/Orange
Mozzarella/ fresh cheese	White	White
Coffee	Dark Brown	Dark Brown/ Black
Fresh vegetables (salad)	Green	Green, Warm Green, Yellow-Green

Table 1- "The rule of Coherence". The colour of the packaging is reminiscent of content

Table 2- The rule of colour induced messaging

COLOUR	MESSAGE CONVEYED TO CONSUMER	FOOD
Blue in its lighter shades: Light Blue, Sky Blue	reassuring, harmless fresh refreshing undemanding, light **reminiscent of water, air, sky**	milk and dairy products fresh cheese water ice cream fish frozen food decaffeinated coffee products for children (when purchase decision makers is the mother)
Yellow: warm and light shades, orange shade	warm fragrant friable freshly baked **reminiscent of grain, yolk**	bakery products breakfast products pasta egg noodles
Green	fresh refreshing genuine no additives / preservatives reassuring **reminiscent of nature**	fresh vegetables salads

refreshing drink. However, Coca Cola contains caffeine to energize consumers likely to be young and dynamic. Coca Cola is not only a refreshing drink but, chromatically speaking, supports a *"sparkling"* and active life style. The product, its packaging and colour share the same message: they are coherent and thus believable. Pepsi Cola, its major competitor, has been forced to break the rule adopting the opposite blue colour [13, 20].

6. THE STRATEGIC UTILIZATION OF COLOURS

6.1. COLOUR AS A PRODUCT DIFFERENTIATOR

Based on its strong symbolic value, a colour code can better identify different types of products in the food industry [17]. Colour is a food labeling tool (Table 3).

8

Figure 8 - According to "the rule of colour messaging" the packaging of decaffeinated coffee is often blue or light blue

9

Figure 9 - The align strategy is usually used by Private Labels to imitate Market Leaders. Here Esselunga aligns to Barilla

10

Figure 10 - Applying the breaking strategy Pepsi Cola enters the market using the blue colour

6.2. COLOUR TO IDENTIFY DIFFERENT VARIETIES OF THE SAME PRODUCTS

A colour code, rather than specific shapes and/or graphics, serve to differentiate among variations of the same products, being more recognizable by consumers. Hues are changed so as to represent chemical or physical features (taste etc.). Some examples are reported on table 4 [19].

Common people adopt highly represented colours as colour codes, as shown in specific food products: in the case of *"owen"* products, red means salty and blue bland while for sauces, spices and dressing red means tasty, hot vs blue which indicates mild, healthier. Even for mineral water red and blue means strong or light sparkling [18].

TYPE OF PRODUCT	COLOUR	CONVEYED MESSAGE
Premium Products	"Noble" colours: Golden, Silver, Black, Dark Green, Dark Blue, Dark Brown	**nobility and finesse**
Best Price Products	Red, Orange	**induce to stop, stimulate purchase and appetite**
Bio Products	Green	**freshness, genuinity, no additives**
Light Products	same colour of the basic product but in its lighter shades	**the package colour, identical to the basic product, is only "lightened":** **the product appears lighter and low-calorie**

Table 3 - Colour as a food differentiator

FOOD	PACKAGING COLOUR	EVOKED MESSAGE
Basic Product		
Milk		
pasteurized whole milk	Light Blue	freshness
pasteurized skimmed milk	Light Red	lightness
Basic Product		
Crackers		
salted crackers	Red	tasty, flavourful
unsalted crackers	Blue	healthier
flavored crackers	Green	aromatic
whole grain crackers	Light Brown	content high -fiber

Table 4 - Using colour to identify basic products and its extension line products

Figure 11 - Colour codes acquired over time: red for salted/hot/sparkling and blue for unsalted/mild/still

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ABSTRACT

Coloured lighting is a vital factor for plant growth, inducing both photosynthesis, phototropism and photomorphogenesis. Detailed experimental studies on the photobiology of plant have already shown the importance of creating proper lighting receipts for different species, growth and developmental stages in order to obtain a good plant productivity and nutritional quality formation.

LEDs, nowadays, are a good tool for creating the proper lighting receipts composed by different narrow spectral power distribution combined for specific plants. Small dimension, long operating lifetime, great efficiency, digitally controllable features and optically controllable performances are also useful aspects for plants' lighting system development not only for laboratorial research experimentation, for aero-spatial and industrial food production but also in other filed such as domestic applications.

In this domain, the research aimed at defining requirements and features of a lighting fixture for food growing that could be prototyped in an easy and economical way. The requirements were derived firstly from a scientific literature review about agriculture and food science in order to define the preferred characteristics of lighting for food growing in terms of quantity, spectral power distribution, spatial distribution, direction, temporal distribution. More than this a a qualitative survey was performed in order to derive further product' specifications in terms of end-users' interests in the functionalities, dimensions, price and interface features of the system.

Finally, the solutions were further developed in two prototypes that meet the following requirements: mixing between the different channels, ability to create relations of flow between the channels, the overall dimensions. The prototypes were meant as design probes for evaluating the usability and the impact of the product before proceeding to the detailed design.

KEYWORDS

coloured lighting, spectral power distribution, LED lighting, horticultural lighting

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1. INTRODUCTION

Lighting and particularly coloured lighting is a vital factor that contributes to plant growth inducing both photosynthesis, phototropism and photo-morphogenesis. Detailed experimental studies on the photobiology of plants have already shown the importance of creating lighting receipts specific for different species' growth and development in order to obtain a good plant productivity and nutritional quality formation. LEDs, nowadays, represent a good solution for creating the proper lighting receipts composed by different narrow wavelength specifically combined for every plant. Small dimensions, long operating lifetime, great efficiency, digitally controllable features and optically controllable performances are also useful aspects for an horticultural – centric lighting not only for laboratorial research experimentations, for aero-spatial and industrial food production but also for educational, medicinal and therapeutic scopes [1-2-3]. More than this, domestic food farming is currently an increasing trend derived by both the emergent interest in eating healthy, genuine, km-0 and origin controlled food combined with a raising necessity of nature reconciliation through sustainable behaviours and responsible choices [4]. In this regard, an LEDs lighting system for home farming can be a possible solution especially in domestic environment lacking natural lighting or good climatic conditions, with limited or absent natural spaces as gardens, terraces and balconies.

2. RESEARCH AIM

The research scope is defining requirements and features of a lighting system for food growing in domestic environments, by investigating and proposing a practical and ready to make designed solution considering not only technological problems but also user oriented issues. If the hypothesis is that LEDs are creating the opportunity for an energy efficient, reliable and qualitative superior system for domestic gardening, this papers would like to contribute with a series of guidelines and a designed proposal for the realization of an easy, economic, efficient, functional prototype that could be used for experimental research scopes.
For reference, I compare the typical colors of the sweets packages in the US and Japan in Munsell notations and RGB variables (Figure 9 and Tables 1-3).

3. RESEARCH METHODOLOGY

The requirements of the proposed Domestic Horticultural – Centric Lighting system were derived firstly from a scientific literature review about agriculture and food science in order to define the preferred characteristics of lighting for food growing in terms of quantity, spectral power distribution, spatial distribution, temporal distribution and direction. A quantitative - qualitative survey was performed in order to derive further lighting system specifications in terms of end-users' interests and attitudes in using an LEDs based system for domestic cultivation. More than this, the aim was to gather insights in terms of desired features to better define a domestic horticultural-centric LEDs based lighting system.

4. LIGHTING REQUIREMENTS FOR PLANTS

According to the literature review, plants require light throughout their whole life-span from germination to flowering and seed production. Quality, quantity and duration are the most relevant parameters of growing light influencing in different way the plant performance [6]:

- *Light Quantity (Irradiance)* is the main parameter which affects photosynthesis, a photochemical reaction within the chloroplasts of plant cells in which light energy is used to convert atmospheric CO2 into carbohydrate;
- *Light Quality (SPD - Spectral Power Distribution)* of the radiation: this aspect regards which portion of the light emission is in the Blue, Green, Red or other visible or invisible wavelength regions. These can be defined as *"primary colours"* and their mixture defines different SPD (lighting receipts) specific for each plant. For photosynthesis, plants have the maximum response for Red and Blue light. Light spectral distribution also has an effect on plant shape, development and flowering (photomorphogenesis).
- *Light duration (photoperiod)* is related to the developmental responses of plants to the relative lengths of light and dark periods and mainly affects flowering. Plants are very selective in absorbing the proper wavelength according to their requirements. The most important part of electromagnetic spectrum is called PAR (photosynthetically active radiation) which spread from 400 to 700 nm.

The fundamental problem to solve in the LEDs lighting engine design is to model different SPD (it means to identify the proper number and the driving current of the *"primary coloured LEDs"*) to optimize the plant growth in an efficient way: the

main idea is that a controlled and engineered SPD would be much more beneficial for the plants rather than white light because it would allow to better control the flowering time, the high photosynthetic efficiency, the low heat stress in a more efficient and performance oriented way. The visible spectrum can be subdivided in several bands and each of them has a defined role in plant's growing and photosynthesis process [7]:

- *380–400 nm (ultraviolet A/visible light)*: the process of light absorption by plant pigments (chlorophylls and carotenoids) begins;
- *400–520 nm (visible light: violet, blue and green bands)*: peak absorption by chlorophylls occurs in this range and has a strong influence on vegetative growth and photosynthesis;
- *520–610 nm (visible light: green, yellow and orange bands)*: this range is less absorbed by the plant pigments and has less influence on vegetative growth and photosynthesis [8];
- *610–720 nm (visible light: red bands)*: a large amount of absorption occurs at this range, strongly affecting the vegetative growth, photosynthesis, flowering and budding;
- *720–1000 nm (far-red/infrared)*: germination and flowering is influenced by this range but little absorption occurs at this band.

The selection of the *"primary colours"* (in first approximation, good candidates are Red, Green-Yellow, Blue-Violet) is important to photosynthesis. In addition to this, it is also important to consider the relative proportion or *"Red:Blue"* - *"Red:Green:Blue"* ratios. Many studies [5] investigate the best mix of primary light sources to match them with the peaks of the absorbance curve of the plants [An example is reported in Figure 2].

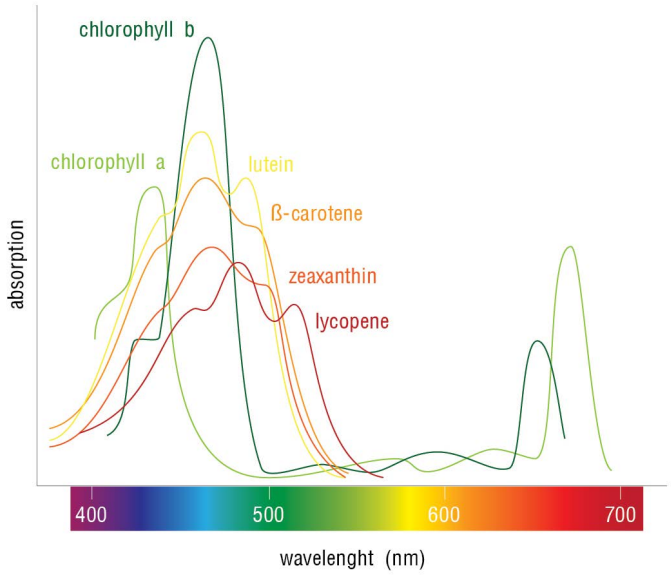


Figure 1 - Absorption spectrum of chlorophyll and other photosynthetic pigments. Adapted from Margherita Giacomozzi thesis "Cibele, Light for Food"

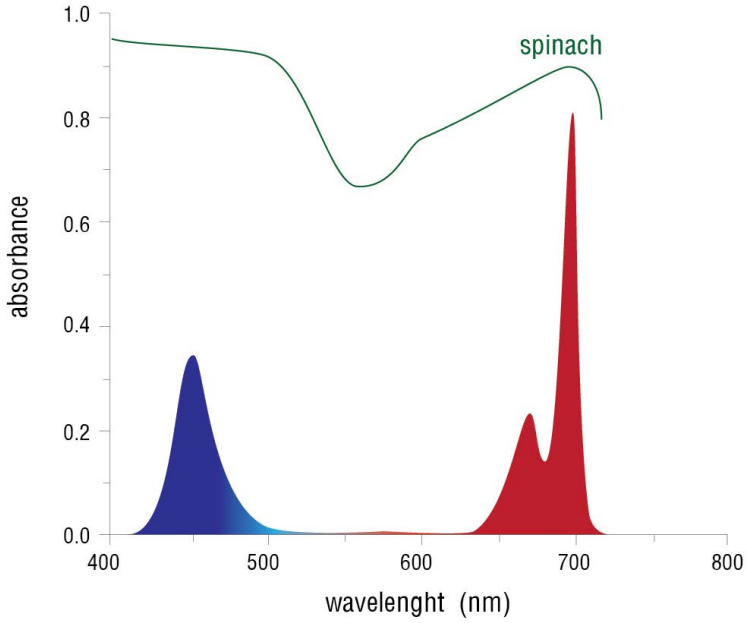


Figure 2 - Comparison between the SPD of three different LEDs and the absorbance spectra for the Spinach plant. Adapted from Margherita Giacomozzi thesis "Cibele, Light for Food"

DOI: 10.23738/ccsj.i52016.04

5. USERS' REQUIREMENTS FOR DOMESTIC HORTICULTURAL-CENTRIC LIGHTING

5.1. PARTICIPANTS

For this study, 63 respondents (38.3% male - 61,7% female) took part in the survey. The age of participants can be divided in two categories: 24-34 years old (68,3%), 35-47 years old, (31.6%). Half of the participant was living in North Italy (50%) and the other half was spread in Europe (The Netherlands 8.3%, UK 5.0%, Spain 3.3%, Austria 1,7%, Belgium 1.7%, Germany 1.7%, Switzerland 1,7%,), east and far east (China 16.7%, Turkey 3.3%, South Korea 3.3%) and USA (3.3%).
The survey was directed to people interested in the growing - farming at home topic: the majority of the participants were architects, designers and engineers (34%) followed by educators, teachers and professors (17%), researcher (10%), psychologists and sociologists (7%).

5.2. USERS' ATTITUDES TOWARD DOMESTIC HORTICULTURAL-CENTRIC LIGHTING

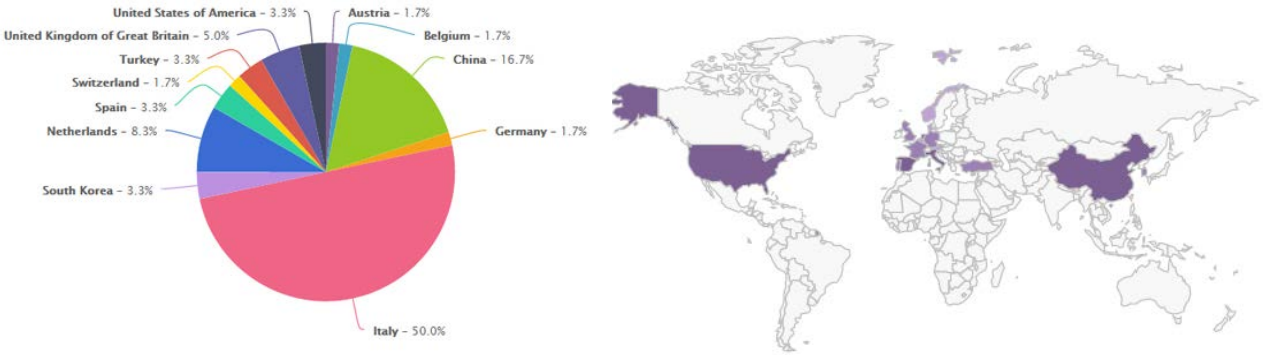


Figure 3 - Participants' distribution in the world

From the survey, a strong majority of the participants (71.5% rating equal or greater than 6) affirmed that they were inclined in eating genuine food intending self-grown, km-0, pesticide-free (ave. 7.3; std. dev. 2.8 on a 0 - 10 scale). In addition to this, the 65.6% were positively in favour and willing to cultivate fruits or vegetables in their home with an indoor growing system (ave. 6.2; std.dev. 2.5 on a 0 - 10 scale). Despite of this, the 52.5% were not particularly skilled in gardening and cultivating (ave. 4.3; std.dev. 2.7 on a 0 - 10 scale). This preliminary results shows some insights about the latent need of providing systems for gardening and food growing that help and support users with on-time information and feedback for better farming outcomes.

The 48,2% were interested in using an LEDs based system for cultivating indoor (ave. 5.8; std.dev. 2.6 on a 0 - 10 scale), primarily because of the lack of spaces such as garden and balconies (41.3%), and consequently because of poor natural lighting and bad weather conditions in winter. In addition to this, people were interested in using an LEDs based lighting system for ensuring the growth of food for their own consumption (39,7%), also appreciating the opportunity of cultivating (and eating) some species off season (33.3%) and considering the interesting possibility of experimenting and learning (25.4%). Other consideration regarded the educative and therapeutic purpose of horticulture at home (36.5%) that helps in stimulating children, adults and elderly people in their physical (exercise, sensory, stress release) psychological (accomplishment, confidence, biophilia hypothesis, connection with nature), intellectual (observation, experimenting, creativity, curiosity) and social skills (community, sharing).
Finally, LEDs were recognized as a more efficient technology for indoor growing compared to traditional lighting systems not only in terms of lower energy consumption but also in terms of the lighting quality provided that responds more precisely to plants' needs, thus defining a more productive growing system.

6. REQUIREMENTS FOR AN LEDS LIGHTING SYSTEM FOR DOMESTIC FOOD GROWING

From the scientific literature review and the survey, some requirements for a domestic horticultural-centric LEDs lighting system were defined. In particular, the research investigated features like dimensions, location and integration of the system in the domestic environment. In addition to this, the typologies of cultivation were explored and related to the proper lighting in terms of quantity, quality and duration for producing a congruous amount of species (not intensive industrial production), with particular interest in the efficiency of the LED based lighting system combined with good flavours, aromas and nutrients of the food. The exploration focused also on the homely feeling

of the system considering the aesthetics, pleasantness, interest and domestic suitability. Considering the not professional users, the investigation focused also on the perceived functionality and the overall simplicity of the system (installation, use, cleaning/maintenance, control and management). [9]

6.1 DOMESTIC INTEGRATION: DIMENSION AND LOCATION PREFERENCE

The space required, considered available and useful for a domestic farming system was preferentially (49.1%) a *thin, vertical volume* (approx. 0.3 x 0.3 x 1.6 m) and a *cubic compact volume* (31.6%) (approx. 0.8 x 0.8 x 0.8 m) (Figure 4). This dimensions shows both to have an appropriate capacity for cultivating a proper amount of food and to be also compatible and harmonious with the other domestic furniture, fitting the system into the limited domestic space available. In relation to this, in condense high-rise apartment buildings the preferred room and location where to place the system were on the kitchen countertop (45%) or the pavement in any other available space of the house (38.3%), especially in the living and dining room. In other situations, such as villas and wider spaces, people suggested the use of a specific room such as a winter garden (20%), an old annex of the house or the basement / garage.

6.2 TYPOLOGY OF CULTIVATION AND LIGHTING NEEDS

From the survey the most interesting cultivation were:

- *vegetables* (73.3%) (Spinach, Swiss chard, Artichoke, Zucchini, Cabbage, Eggplant, Lettuce, tomatoes, cauliflower, fennel, celery, cardi, dandelion, broccoli head, endive, peppers, cucumbers, chicory, broccoli, turnip, pumpkin, leek);
- *spices and aromatic / medicinal plants* (61.7%) (cumin, marjoram, thyme, chives, oregano, basil, mint, parsley, rosemary, sage)
- *small-medium fruit plants* (51.7%) (strawberries, blueberries, raspberries, blackberries, currants).

Considering this list of desiderata, the lighting needs were derived from the scientific literature review and the lighting receipts (lighting quantity, quality and duration) were identified in order to be suitable and adaptable to the majority of plants by mixing the wavelength in an appropriate way and trying to limit the amount of different LEDs channels (primary colours) in order to reduce the overall costs. In Table 1, a summary of the typology of cultivation and related lighting receipts was provided with examples.

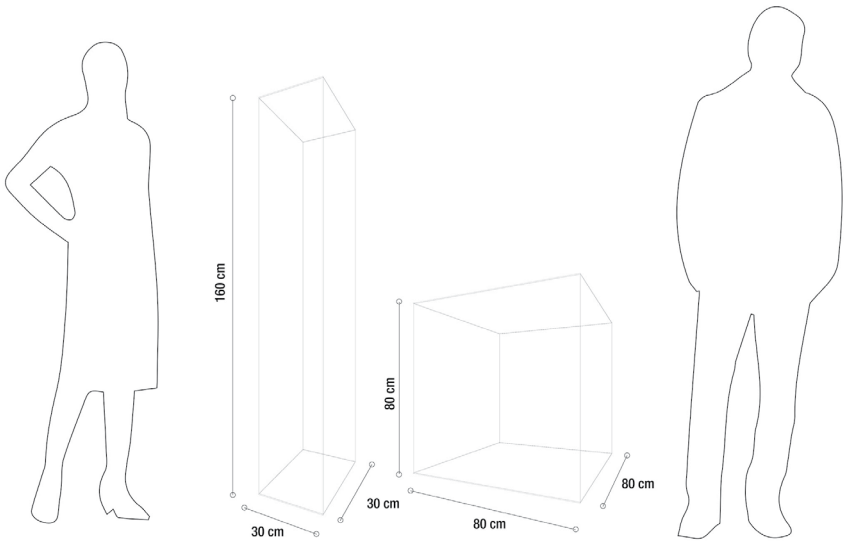


Figure 4 - Domestic integration: dimensions preference

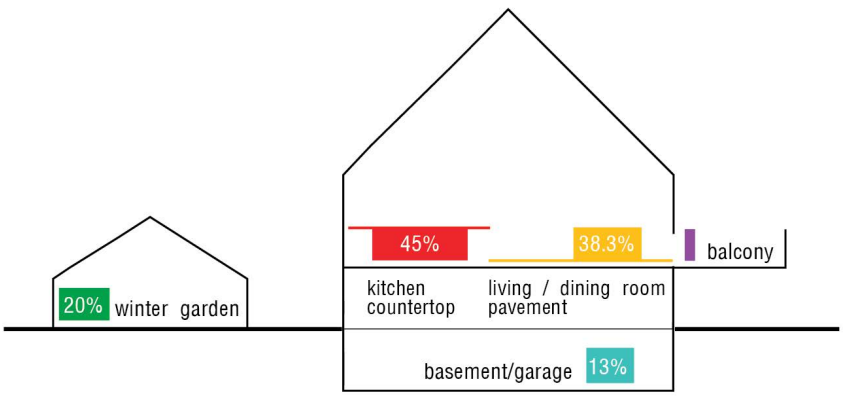
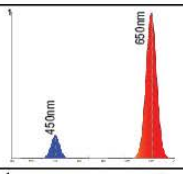
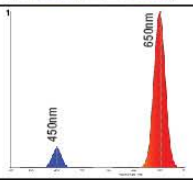
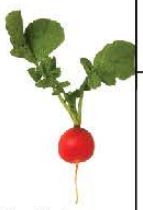
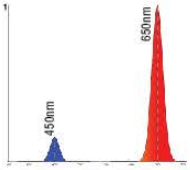
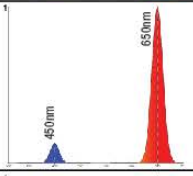
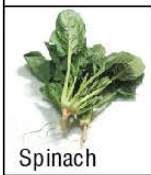
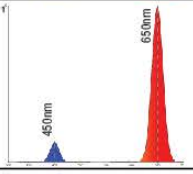
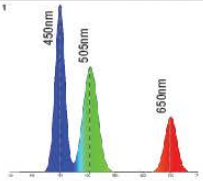
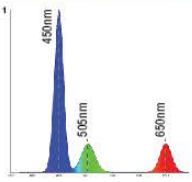
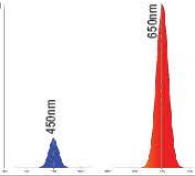
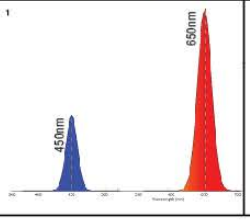


Figure 5 - Domestic integration: location preference

Table 1 - Typology of cultivation and related lighting receipts (quality, quantity, duration)

In comparison to the lighting receipts found in the literature review as reference (refer to Table 1), the authors selected one value of the peak position for each spectral band in order to develop the experimental lighting prototype characterized by extreme simplicity and reduced costs, adaptable to the domestic environment (avoiding dangerous UV or NIR

Type	Nomenclature	PROTOTYPE LED light source Dominant Wavelength (nm)	REFERENCE Light source Dominant Wavelength (nm)	Ratio Red:Blue %Red: %Green: %Blue	PAR (400 - 700 nm) µmol*photons*m^{-2}*s^{-1}	Photoperiod (light/dark) Hours	Spectral power distribution	Reference
 Lettuce	Lactuca sativa	450,650	450,635	8:1	200	18/6		[11]
	-	450,650	470,660, 670,680,690	10:1	250	18/6		[12]
 Radish	Raphanus sativus	450,650	450,635	8:1	200	18/6		[11]
	-	450,650	470,660, 670,680,690	10:1	250	18/6		[12]
 Spinach	-	450,650	470,660, 670,680,690	10:1	250	16/8		[12]
 Cucumber	Cucumis sativus Moskovskii Teplichnyi	450 505 650	450 - 500 500 - 600 600 - 700	17.5%: 40%: 42.5%	424	14/10		[13]
 Tomato	Starfire	450 505 650	450 - 500 500 - 600 600 - 700	15%: 17.5%: 67.5%	409	16/8		[13]
	Fragaria Ananassa Duch	450,650	455,640	7:1	200	16/8		[14]
 Strawberry	Fragaria vesca	450,650	450,630	3:1	100	16/8		[15]

spectral emissions), flexible to be used to grow different species (Table 2). In addition to this, particular care was given to the lighting uniformity which is stated as an important feature both for instantaneous and photoperiod lighting by the *"Lighting systems for agricultural"* standard published by ASABE (American Society of Agricultural and Biological Engineers). [10]

LED Colour	Dominant Wavelength (nm)	Spectral bandwidth at 50% $I_{rel\ max}$ (nm)
RED	650	25
GREEN	505	30
BLUE	450	20

Table 2 - Primary LED colour for horticulture light source

6.3 FUNCTIONALITY + SIMPLICITY + DOMESTICITY

People were confronted with three proposed solutions and some guidelines and insights were derived [16]. In particular, the main desired features were:

- *simplicity:* in terms of use, installation, cleaning/maintenance
- *domesticity:* compatibility with the domestic environment in terms of dimensions and location;
- *aesthetics:* pleasantness and interest
- *functionality:* in terms of effectiveness in food production
- *intelligence of the solution:* in terms of flexibility, modularity and upgradability
- *control and management:* simplicity in use and maintenance; flexibility in terms of information provided, adaptability to different cultivation; self-explanatory and helpful in providing knowledge.

The comparison and assessment made by the participants conduced to a reasoned selection of two different solutions that are specific for two different user targets, for two different kind of domestic cultivation and also show different features.

7. LEDS BASED DOMESTIC HORTICULTURAL – CENTRIC LIGHTING PROPOSAL

The solutions were further developed in two prototypes that meet the following requirements:

- mixing between the different channels;
- ability to create relations of flow between the channels;
- the overall dimensions;

The prototypes work as design probe useful for evaluating the usability and the impact of the product before proceeding to the detailed design.

7.1 DOMESTIC HORTICULTURAL LAMPSHADE

This solution [Figure 6] hides the intelligence and the lighting performance into a designed lighting fixture which is both decorative and functional: it can be used for experimenting a small scale cultivation and for helping not so *"green-fingered"* users in taking care of their plants (especially in winter time). More than this, when the user is not interested in using it for cultivation, it can be reversed in a normal lighting fixture or it can create particular lighting atmospheres in the domestic environment. This solution is suitable for *"naïve"* cultivators and amateurs.

The prototype achieves two different functions: light for plants growing and light for illumination of the environments. For this reason the device uses both a RGB LED strip and a strip with warm white LEDs (3000K). It allows to adjust its height in order to better adapt to different plants and also to different levels of growth in an efficient way (Figure 7).
It is composed by the following part:

- RGB LED strip with 26 light diodes in SMD (Surface-Mount Device) package;
- warm white with whit 48 light diodes in SMD package;
- reflector in high diffusive material (MCPET – Microcellular PET) composed by a mixing chamber for blending the different colours and a central diffuser that scatter the light emitted directly from the LED source;
- plastic box with a round shape that includes all the other optical part and light source;
- a plastic transparent diffuser with a high coefficient of transmission;
- A constant voltage LED driver: the current intensity is set by a resistor on PCB (Printed Circuit Board) and the different ratios between the channels is achieved by PWM (Pulse-width modulation) technique.

7.2 DOMESTIC HORTICULTURAL CABINET

This solution [Figure 8] integrates the intelligence and lighting performances in a lighting engine designed to hack and re-adapt a cabinet system that can be placed in storage rooms hidden from the domestic environment or in a dining /

living room integrated with other functions. It is a modular, upgradable, flexible solution, suitable for cultivating different species and farming a reasonable amount of food. The prototype is composed by the following part:

- RGB LED strip with 8 light diode in SMD package;
- Reflector in high diffusive material (MCPET);
- Plastic box with a rectangular shape that includes all the other optical part and the light source;
- A plastic transparent diffuser with a high coefficient of transmission;
- A constant voltage led driver: the current intensity is set by a resistor on PCB and the different ratios between the channels is achieved by PWM technique.

As shown in the Figure 9, the prototype has been realized in a single module. The lighting appearance depends of the different lighting receipts realized by setting the different ratios between the Blue and Red channel as described in Table 1.

8. CONCLUSIONS

This paper focused on setting the requirements, envisioning some insights, proposing some guidelines and defining LEDs prototypes of Domestic Horticultural-Centric Lighting design based both on the scientific review and on users' feedbacks, assessment and elicited observations. The released final prototype has been designed and built to be tested in a real environment. The survey was conducted on a reduced amount of subjects, but it can be hypothesized that the results can foreshadow emerging needs that in the future will be of interest to the broad masses of users.

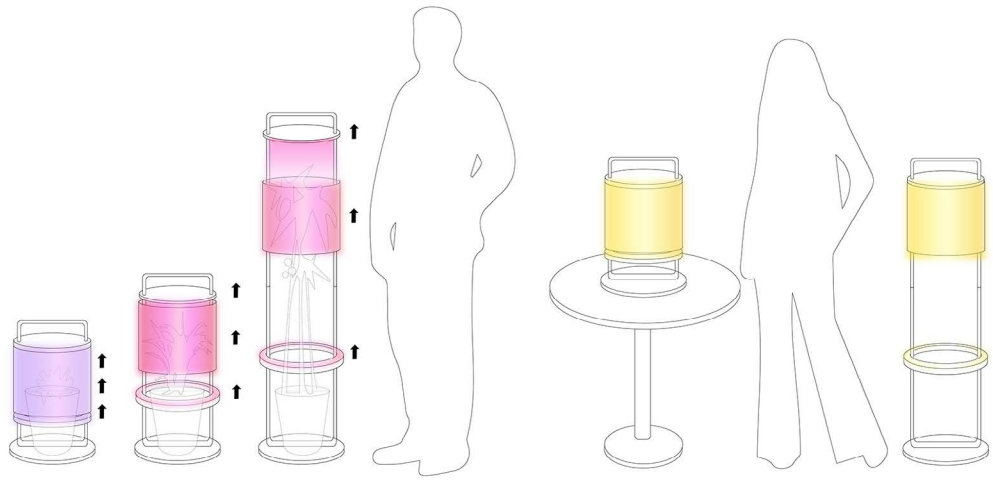


Figure 6 - The Domestic Hortic Lampshade: a double func horticultural / decorative lig system

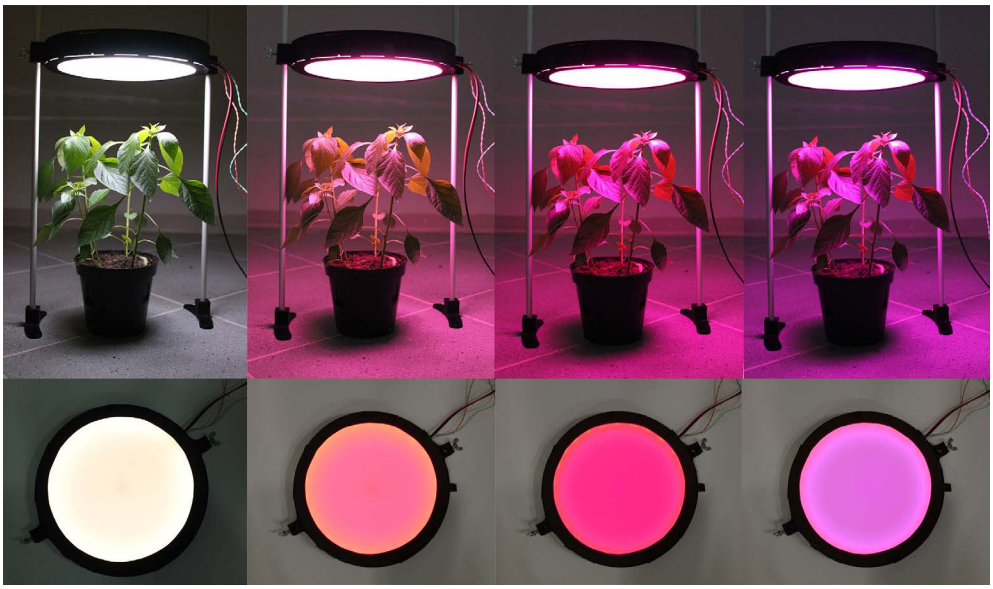


Figure 7 – The flexible Lighting Engine Prototype of the Domestic Horticultural Lampshade

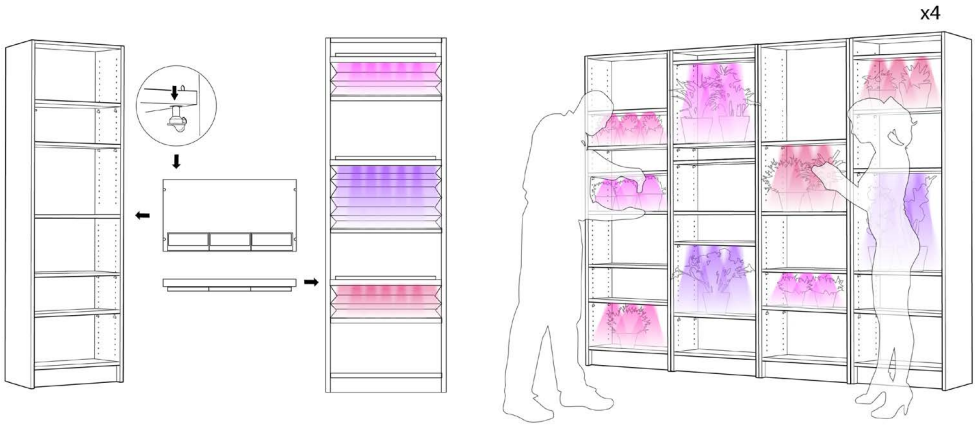


Figure 8 - The Domestic Horticultural Cabinet: modular scalable furniture hacked with an horticultural lighting engine

Figure 9 - The modular Lighting Engine Prototype of the Domestic Horticultural Cabinet

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Tea versus celadon: some chromatic interactions

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ABSTRACT

The tea as well as the stoneware named celadon in Occident, are inventions originate from China. The triad established by the "Elements" tea, celadon and jade is emblematic in the culture of the Middle Kingdom and encompasses numerous symbolic. The existing synergy between these three materials is, finally, based on imitation (*mimèsis*) developed by Aristotle in his celebrated book *Poetic* [1]. Thus, based on this schematic triad, chromatic effects are appearing and disappearing. Sometimes recreating landscape sensation, sometimes recreating material substance (jade). User takes up a lot of space in this relationship which combines both utilitarian tool and edible substrate. He is the one who will help to create poetic (*poiètikè*) dimension into these two items.

Over a first phase, it's important to contextualize the origin of this practice which remains, otherwise, very current in Chinese tradition. Then, we will discuss components accountable for intensify the variable character existing between tea and celadon. The latter will, naturally, bring us to the question of interaction of color. That's why, the experimental and emblematic approach of the artist-painter and teacher, Josef Albers, will be develop in a third section. We will finish by describing how usage scenarios might be innovative through the poetic scope.

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1. ORIGINS AND HISTORICAL CONTEXT

The art of tea as well as ceramics called celadon are very strongly tied in Chinese culture. Such a practice and aesthetic choice will have a direct impact on many other Asian cultures, for instance Japan will make use of celadon for the Tea Ceremony as G. St. G. M. Gompertz [2] points out in the foreword to his book *Chinese Celadon Wares*:

> *Perhaps there is no province of Chinese ceramics in which Japanese views require more careful consideration than that of celadon. For this is a class of wares in which the Japanese have taken great aesthetic pleasure from the time it first became known to them in the eighth or ninth century, and their appreciation has been sharpened by long tradition and systematic training in the Tea Ceremony.* (p 17)

Such a practice was developed during the Tang Dynasty (618-907) for several reasons.

First and foremost, in the second half of the 8th century, economic crisis lead the Empire to find material and aesthetic alternatives. It's in this way that celadon or *qing cí* enters into the home of a new clientele. Monks, rich and aristocratic families or civil servants are no longer rich enough to offer themselves rare material as jade. For want of anything better, people pour tea in small stoneware bowls. *Qing cí* is rapidly becoming in a manner of speaking an alternative material because it incorporates some of the aspects of the semi-precious stone (jade) while being less expensive.
However, even though the production of celadon remains a cheaper option than the production of objects in jade, this doesn't necessarily weaken its poetic and aesthetic richness.
Qing ci's tea bowls are much appreciated by Chinese poets from Tang Dynasty for their finesse and perfection. G. St. G. M. Gompertz even said that Yue tea bowls *"were considered preferable to all others."* Chinese writer Lu Yü greatly valued their merits in his treatise the Classic of Tea as Gompertz remarked:

Figure 1 - Green tea in a cup of Chinese celadon, Beijing, 2012

"(…) The famous "Tea Classic" of the T'ang writer Lu Yü rates them [celadon or qing cí] more highly than the silvery-white wares of Hsing-chou." (p 35)

Danielle Elisseeff explains as well that this taste lies in the fact that these monochrome ceramics are *"all at once slightly shiny but not glitzy."*[3]
Beyond the form and purity of the object, this attachment is due to its chromatic *«power»*. As we all know, jade and celadon have always been intrinsically linked particularly because of their chromatic affiliation since both belong, initially, to different shades of green. Gompertz's allegations confirm the origin of this ability:

"(…) the color resemble dice or jade and was thus considered superior to any other, or it was thought to enhance the beauty of the tea by deepening its green tone instead of changing this to red or black." (p 35-36)

This remark was also made by Michel Culas who explains that Lu Yü:

"praised Yuezhou's green porcelains from Henan because its "enhanced the color of tea".(p 124) [4]

Put another way, in addition to look jade-like, the scholars find that enamel's color matches perfectly with green tea. Celadon's tea bowls bring out the color intensity of the tea (the word *«deepening»* come from the same root as the word *«deep»* which means *«profound»* or *«intense»*). Indeed, through tea, there is well and truly a highlighting of each elements.

2. AN INTANGIBLE CHROMATIC «VIBRANCE»

We also know that the complexity of celadon lies in his variety of colors: it can be green, blue-green, sky blue, blue lavender, grey, grey green, green-yellow, green-brown, etc. In other words, it can take a wide range of colors that makes it even more interesting and intangible.
Although the object can have a multitude of different enamels, the delicate decoction, especially during the Tang Dynasty, was itself complex and subject to « multifaceted chromaticity ». Tea of the poor people was for example conceived with willow leaves or poplar leaves. Michel Culas gives details of the recipe and the ingredients:

Sous les Tang, on mettait à infuser les feuilles de thé dans un pot en y ajoutant du gingembre, de la datte, de la menthe, des pelures d'orange, de l'oignon ou du poireau et même du sel. Le thé était alors servi dans de petites coupes (chawan) de céladon transparent ou de porcelaine blanche. (p149)

This said, it is not simply a matter of *«tea»*, it is also a blend of aromatic herbs, spices or condiments and sometimes, dry fruits. Each of these elements were more likely to color the water in different way. This contributes to develop the elusive nature of the tint which could only blossom by the combination of these two substances (water and stone).
Water, which can be regarded as a coloring element, was also of importance. The poet Lu Yü could easily distinguish *"simple"* waterfall from spring water, a very valuable water. Paul Butel, in his book History of Tea, states that [5]:

Les légendes sur Lu Yu sont nombreuses. Citons un talent presque miraculeux à distinguer de subtiles différences entre diverses sortes d'eaux utilisées pour préparer le thé dont il devait apprécier la pureté relative. Un tel talent était un élément important de l'art d'un maître du thé.

Celadon tea cups were also employed to drink wine, thereby creating new color patterns, new types of combinatorial color... The latter recalling perhaps a trend that would later become, under Mongol domination (1279-1368), very popular in the Chinese ceramic Art named tobi-seiji. It is a green enamel flecked with reddish or purplish spots.
If the use of tea enables a chromatic harmony very close to tone-on-tone, the synergy which acts between enamel and fluid is a product of a discordance or a dissonance. A successful chromatic balance that could be compared to the notion of *"tonos"* describes by Pliny the Elder [6]:

(…) The art of painting at last became developed, in the invention of light and shade, the alternating contrast of the colours serving to heighten the effect of each. At a later period, again, lustre was added, a thing altogether different from light. The gradation between lustre and light on the one hand and shade on the other, was called "tonos"; while the blending of the various tints and their passing into one another, was known as "harmoge". (p 234-235)

This tone or *"tonos"* is, according to Pliny the Elder, the interstice which standing midway between the brightness and darkness. This rift is apparent by opposing values (light/gloomy) as much as complementary hues (yellow/purple) or contrast of saturation (pale/bright).

In the case of wine and *celadon*, the strained relationship between opposite tone allows improvement of each color. This might be thought of as a seeking of harmony by contrast theory as Johannes Itten was able to try out in his work *The Art of Color*. [7]
In the course of the Tang Dynasty, there are several principles of fermentation of grapes but there is also wine made by fermenting grains. Thus the awareness of various tints obtained through fermentation could provide us more meaningful level of information about the chromatic effects resulting of the association of *celadon* and liquid.

3. CHROMATIC INTERACTIONS

These chromatic interactions between fluid and material-container, invite us to get closer to the experiences developed by Josef Albers. Indeed, in his work Interaction of Color [8], the former Master of the Bauhaus mentions two typologies of effects. It is throught these effects that color be viewed like a *"volume color"* or like *"film color"*. In addition, identify these effects from the question of the use, summarizes, after all, the premise explains by Josef Albers at the beginning of his work, that:

> *«In order to use color effectively it is necessary to recognize that color deceives continually.»* (p 1)

In the case of the connection which that exists between tea and celadon, the principle of "volume color" appears to be particularly suitable, due to the fact that it is question of the color in three dimensions. In order to strengthen this idea, Josef Albers also uses the locution "surface color" to define the *"volume color"*. This color is attached to the object like a *"skin"*, it is a coating which is naturally intrinsic to it. Albers also gives the example lemon peel which is yellow.
To illustrate this phenomenon, Josef Albers took as an example coffee and then tea (two fluids more or less opaque):

> *«In the same way, tea will look lighter in a spoon than in a cup. Here we are dealing with volume color, which exists and is perceived in 3-dimensional fluids.»* (p 45)

Strangely, while Albers *"classifies"* tea in the register of colors so-called *"volume"*, the Chinese reality is quite the opposite. The choice of tea in small celadon bowls allowed, according to the Chinese poet Lu Yü, to *"enhance the color of the tea"*.
Although there is this notion of interaction (the container in celadon comes to glorify the natural color of tea by a camaieu of bright green), the principle of transparence, near from the definition of *"film color"*, is also mentioned in this sober declaration. For if we look at the verb *"to enhance"* from a chromatic point of view, even more particularly a *"pictorial"* point of view, it means: *"Execute lights, to lighten a color"*, sometimes there is even talk of *«to add color (…). »*, indeed to «*Emphasize by using a strongly contrasted color.»* [9]
Finally, these three effects are inherent to the relationship which exists between tea and celadon. Firstly, the *"water"* Element comes to bring brightness and luminosity to the green enamel, the first tint is delicately transformed by an understated filter (in this case, we also speak about *"color-light"*). Next, the coloured water created indubitably a new color. The fact of *"enhance"* the initial tint of tea leads to the unreal fabrication and to the creation of a third color. We could make reference to one of experiences realized by Josef Albers entitled: *"VI. 1 color appears as 2 – looking like the reversed grounds."* At last, the third comment is about wine use instead of tea, in this case, *"enhance"* effect occurs by contrast and by *"tonos"* sensation.
So, interaction which comes through between tea and celadon is infinitely more complex than what we are tempted to reduce it to. Actually, it is a mixture where celadon becomes an *"ingredient"*, and where it is an integral part of the recipe. In this case, the relationship which exists between tea and celadon is situated mid-way between *"film color"* and *"volume color"*. That is to say, it's a third way. And, a third typology which it ought to define.
This third typology follows these untranslatable ideas widely developed by Barbara Cassin. Guy Lecerf dealt with more specially this problem by a chromatic point of view. Borrowing the term of *"plateau"* from Gilles Deleuze, the author of *Le coloris comme experience poétique* determines three reference spaces: couleur, coloration and coloris. [10] Each one of these spaces is linked to specific applications and uses. By manipulating what Guy Lecerf terms *"modalités chromatiques"*, it is possible to create usage scenarios between tea and celadon.

4. USER AND IMAGINARY

This notion of action is even more present in this case. Indeed, surely it is about a chromatic relationship between tea and celadon, however a third factor must be taken into consideration: the user.
Historical and cultural context (Tang Dynasty), reminds us that the user is firstly an artist. It is about a poet, a philosopher; in other words a sensitive individual doted of a strong poetic perception. It is the Chinese poets, the first ones,

Figure 2 - Experiences with five different types of Asian teas

who praised the beauty of *celadon* in their poems. It is also Lu Yü, himself poet, who developed a treaty on the art *"to drink well"* the tea.
Ceramics in *celadon* of Yue awakened more particularly Chinese poets' astonishment. They praised the enamel looking for to describe the elusive nature of these ceramics. Lu Guimeng evoked for example in its poem *"Mì Sè Yuè Qì" ["Secret color of Yue's productions"]*, unattainable and almost mystical dimension of Yue's productions [Bushell's translation]:

> *The misty scenery of late autumn appear when the Yüeh kilns are thrown open:*
> *The thousand peaks have been despoiled of their bright colour for the decoration of the bowls.*
> *Let us take them out at midnight to collect the falling dew,*
> *Or fill up the cups with wine in emulation of Chi Chung-san.*

The triadic relationship which is established between tea, *celadon* and jade, also awakens all five sense. If it is mainly the sense of the view which is highlighted through these poems, musicality along with tactility contribute to give to the tea an additional sensitive dimension. Indeed, view and hearing are highlighted through celadon itself.

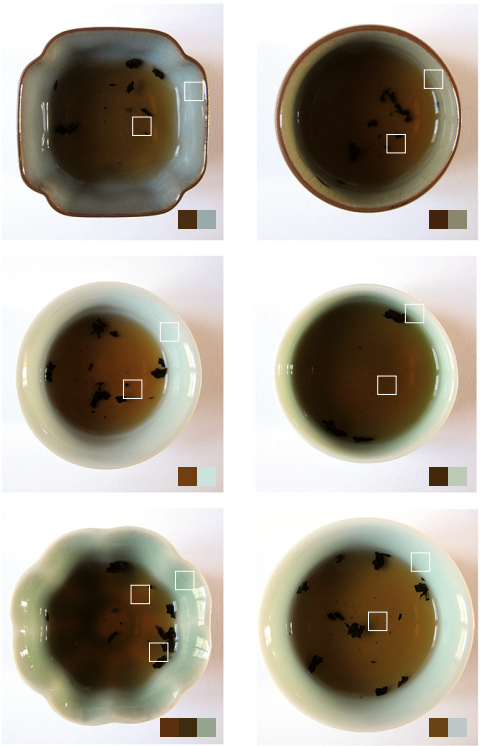
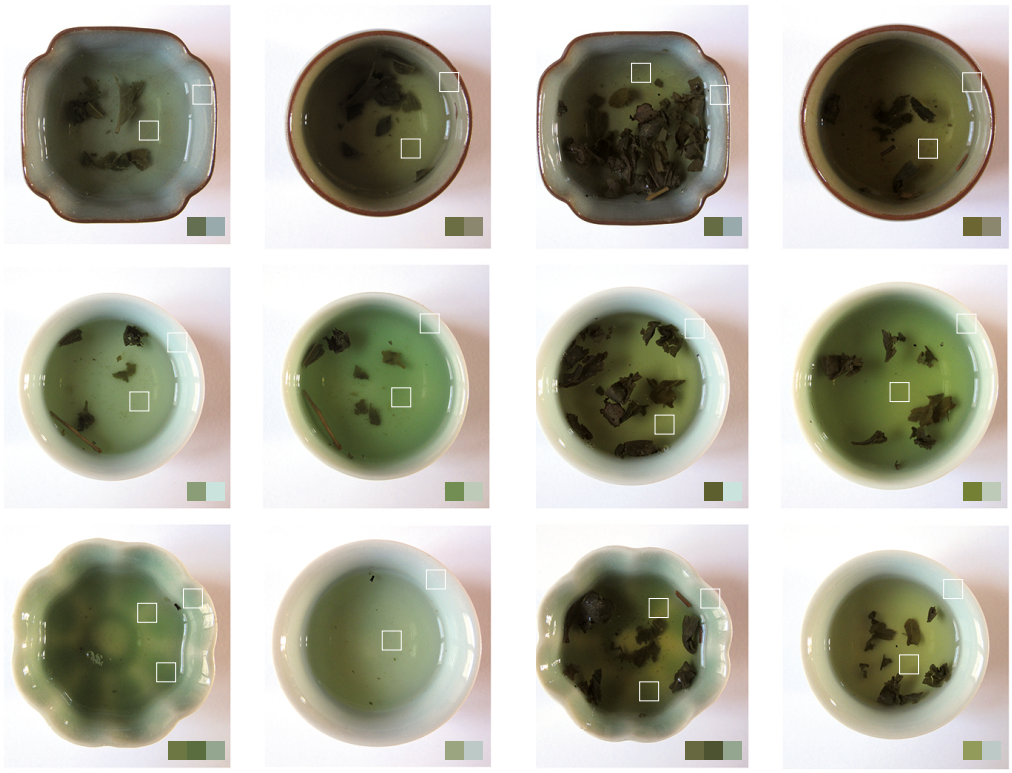


Figure 3 - Experience with Tuocha

Beyond writing and the gesture (drink tea), imagination and poetry are build up by ritualized practice. Michel Culas evokes especially the *"elegant gatherings"*, where scholars *"made float their bowls into the streams."* It's another life for object. It evolves on a wider scale. *Celadon* cups

Figure 4 - Experience with Sencha (left)

Figure 5 - Experience with GunPowder (right)



become as little boats or bottles *"thrown into the sea"* as messages posted to a deeper spiritual order.

To develop innovation, we have to take into account this part of imagination which can be extended in any object. Although the shape of the object, its color and usage scenarios suggest somehow principles of *fictionnalisation*, this is the user who decides to fictionalize more. It is also question of an additional effort of perception,

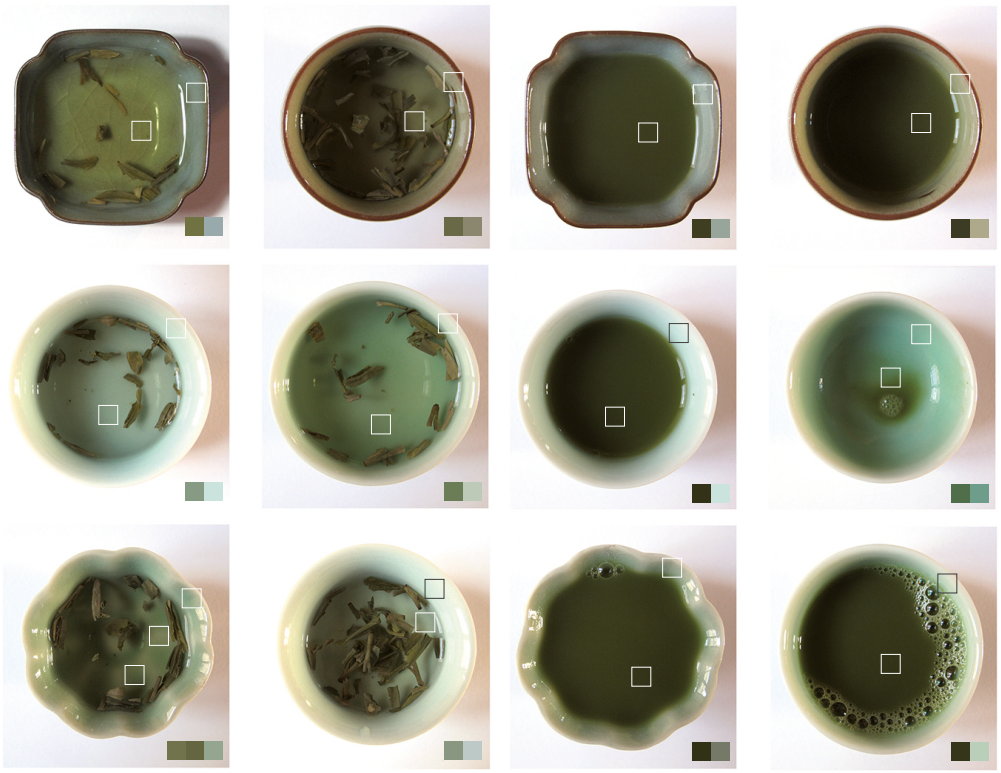
"*See more than there is"* like Josef Albers said. He also suggested that

> *"Seeing here implies Schauen (as in Weltanschauung) and is coupled with fantasy, with imagination."*(p 2)

For example, the Norwegian designer Runa Klock designs poetic objects in order to create new usage scenarios. She imagined a collection

Figure 6 - Experience with Long-Jing (left)

Figure 7 - Experience with Matcha (right)



entitled *"Rocks"* where geometric shapes made of soapstone or marble sculptured come *"chill [a] drink without diluting it."* Simple shapes and natural tints of steatite (ochre to gray-green) develop an imaginary landscape without altering the flavor of the liquid as defined the designer:

> *"Soapstone is non-porous and thus odorless and tasteless and does not affect the taste."*

The hue stone diffuses a colored light adding one more chromatic scale to the beverage.

5. PERSONAL EXPERIENCES

In the continuity of this article, I have make some chromatic experiences to understand the reality of the complex relationship between tea and celadon. The little tea bowls used, come from Longquan a Chinese city known for its traditional production of *celadon* (recognized in 2009 as a UNESCO World Heritage Site).
I didn't need to use a lot of *"raw material"* to observing a chromatic variety. In fact, I have chosen five different types of tea: *Tuocha, Sencha, GunPowder, Long-Jing* and *Matcha* and six emblematic enamels like *fenqing* and *guan*. I have been focusing on the principle of combinatorial and by the third color which appeared when tea meets celadon. The six little cups become each time different, sometimes more vibrant and luminous than ever (*Sencha* and *Long-Jing tea*), sometimes deeper (*Tuocha*).

6. CONCLUSION

As a conclusion, we can observe that the correlation which develops among tea and celadon suggests concepts as *"skin tone"* and *"incarnation".* The tea infusion comes to dwell within celadon. It's like a second *"life"*, the ceramic wears a second skin, a second enamel and the opposite effect happens on tea. The ceramic object is activated by different colors effects. The interaction is always new and always original. The variability is related to various factors: degree of infusion, presence or absence of plant-covered, water temperature which might create additional effects (steam, bubble, effervescence). All these elements participates one more time to emphasize the elusive identity of *celadon*.

Furthermore, the words *"skin-tone"* brings an expressiveness near from the "flesh". That is to say, an organic dimension. The enamel, an unsettled material by nature (color in action, motion-color), is more perturbed by organic and vegetal Elements (water and vegetal (tea)). So, water and tea can be perceived as living organisms. Chromatic vibration or chromatic vibrance is possible thanks to them.
By the changeover from actual to factual - two ideas described by Josef Albers, we can see how color acts and how it is playing with us. In the case of tea and celadon, the link is especially interesting that color characteristics are close. That's why, this relation of tension (or *"tonos"*) is subtle because it plays on clarity or materiality. Tea infusion's going to create some depth effects which can find in Chinese ceramic Art. Some patterns were carved into the bottom of the bowl to simulate depth effect.

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A Look into Cross-modal Associations between Taste, Color and Music

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ABSTRACT

This paper explores how color and sound can alter taste perception and in particular whether there are any cross-modal associations between these three stimuli. It questions how information from stimuli outside the realms of gastronomy is combined in the brain to influence a person's taste perception. This study tested how colored ambient lighting and piano music can influence people's sweet taste; this is the first experiment to study the associations between all three stimuli. The experiment provided some interesting results; most significantly it was found that the color red and high pitch piano music both have a significant impact upon a person's enjoyment of sweet taste.

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1. INTRODUCTION

The study sits firmly inside the realms of perceptual psychology and explores the theories of cross-modal associations (multisensory interactions) and aims to further understand how color and sound can influence non-synaesthetic people's taste when consuming something sweet. It is known that color and sound can alter a person's mood and feelings, therefore this investigation reviewed similar experiments conducted in controlled laboratory conditions as well as real world applications. The research attempts to show whether the combination of certain sounds/music and colored ambient lighting can have an impact on a person's taste, even though the senses involved in perceiving these stimuli are not linked in any way. Since this study investigated whether and to what extent taste is affected by color and pitch perception, we reviewed (in different sections) the literature on interactions between taste and color as well as between taste and auditory cues. As yet there has not been a study involving these three stimuli combined in non-synaesthetic people.

1.1 COLOR AND TASTE

Color can warn of danger and convey mood hence it is incredibly important in relation to food and cooking. Color is important whilst cooking and is often the first point of sensory contact used to decide on taste opinions [1, 2]. Colors and their meanings are built into a person's culture and are therefore situational and dependent on learnt associations, which can be subject to change [3]. Zampini et al. [4] created an experiment that taste tested different colored flavored and unflavored liquids and found that the participants' flavor identification response was influenced by the color of the liquid. This shows that the visual information presented to them superseded any awareness or learnt associations they had about the particular color and flavor combination.

In 2009, Oberfeld et al. [5] conducted a tasting experiment where participants judged wine in different ambient lighting conditions. Blue was found to be the most pleasant overall, which is in agreement with the average color preferences in western adults [6]. Interestingly, in a red illuminated room, the 260 participants perceived the wine to be 50% sweeter than under the blue, green or white lights. These colors are often used in visual perception experiments and that is why they were chosen for the study presented in this paper. An explanation of these results could be that the differences in color affected the participants' moods (subconsciously), which could have altered their taste as red is commonly associated with the sweet taste [7]. The participants' mood and current state is a very important aspect in perception studies [8].

A taste testing experiment which involved administering randomly ordered, sucrose solutions of various sweetness (in a blind experiment situation), demonstrated that participants could successfully identify changes in sweetness in clear liquids, yet they could not identify a change when the liquid was red [9]. When only the color had been changed and not the sweetness, they wrongly noticed changes in sweetness when there were none. This is an adaptation of the *"Stroop effect"* [10] and clearly shows that color can directly alter flavor perception.

1.2 SOUND AND TASTE

Music and taste have been intrinsically linked for centuries; Zarlino, an important musical theorist of the 16th century, described the minor consonances as "sweet" and "soft" [11]. Music and taste descriptive words are often used together subconsciously and can affect a person's decision making. The Fat Duck restaurant in Bray, England serves a dish of seafood with an iPod hidden in a seashell; the iPod plays sounds of the sea through headphones. This sound apparently makes the flavors in the dish stronger and more appealing [12].

Crisinel and Spence [13] created an experiment where 12 different flavors, representing the five basic tastes, were presented to participants while a melody from a number of different instruments was simultaneously played; the audio samples increased in pitch from C2 to C6 (Western scale). They found that the piano was the most pleasant and brass instruments the most unpleasant across all the flavors. The piano instrument was generally preferred in experiments involving the sweet taste and sound. Another experiment involved taste testing different chocolates (milk, marzipan & dark) while listening to music played by varying instruments (piano, strings, woodwinds and brass) in various pitches (C2-C6 western scale) [14]. The piano instrument was most closely linked to high scores of pleasantness but a significant association between chocolate and pitch could not be established, yet a significant relationship between sweetness, pleasantness and the piano instrument was established.

In contrast to other studies, Simner et al. [15] matched the sweet taste to low pitch. However, the high pitch stimulus was described as 'unpleasant' by the participants, whilst the low pitch sound was a pleasant vowel noise. *'Hedonic matching'* is where two separate dimensions of a scale correspond, because both ends of the scale are either pleasant or unpleasant [15].

Therefore the experiment generated correlated results because the sweet taste and low pitch were both perceived as being pleasant, which shows that sweetness is not necessarily linked to high pitch. It has been inferred that the sweet taste has a direct link to the feeling of happiness and pleasantness [14].

2. HYPOTHESIS

It was expected that color will have an impact on taste perception, as it is a strong modifier of taste as shown in previous studies. It was also hypothesised that red would be associated more with the sweet taste.
Hypothesis 1: higher pitches and warmer colors have a positive impact on likings of the sweet taste stimulus.
Hypothesis 2: music and color have a correlation to each other in affecting a person's sweet taste perception.

3. EXPERIMENT DESIGN

The aim of the research was to gain a better understanding of how sound and color together can affect taste and in particular which colors and sounds, and in what combination can affect taste. This involved a deceptive administration experiment [16] as each person was told they will be handed *'different samples'* of a sweetened clear liquid yet in reality all the samples were the same. The participants received 24 solutions made of sucrose solidified in water. The participants drunk the stimulus 24 times during the experiment under different colored ambient lighting (red, blue, green and white), while listening to three chords, at 2 different pitches. The experiment followed a repeated measures design and so every participant experienced all conditions. All the stimuli were delivered to the participant in a random and controlled manner.
Similar to Zampini's et al. [4] experiment, each participant faced a computer screen and wore noise cancelling headphones in a darkened room and remained facing forward throughout the study. Once the oral instruction had been given, further instructions were provided on the screen; the experimenter left the room and the samples were passed through a hatch. This method was applied in order to reduce any external distractions, increase the engagement of the participants as well as remove the human element as much as possible in order to lessen the *'Observer effect'* [17]. Each participant was asked the question *"How sweet was that taste?"* after consuming a sample drink (this was measured on a rating scale from 0 = Not Sweet to 10 = Incredibly Sweet).

3.1 TASTE STIMULUS

The taste stimulus was delivered in clear plastic shot glasses so the light from the computer screen could illuminate through the liquid and give a greater amount of color influence. Zampini et al. [4] used colored liquid, whereas in this experiment the color of the lighting and not the liquid color itself was tested. After the pilot trials it was decided that 80g of sugar solidified in 1l of water at room temperature (20 ± 2 ºC) gave varied results along the 10-point scale and was always deemed '*pleasant'*, even towards the end of the experiment. The volume of the liquid was set to 15ml as this seemed an adequate amount to properly taste the stimulus. The participants were asked to rinse their mouth with water before starting the test.

3.2 COLOR STIMULUS

This study used similar colors to Oberfeld's et al. [5] experiment as they have been proven to show cross-modal associations. Red, blue and green represent a good proportion of the primary color wheel whereas white was used to simulate neutral lighting. The white light condition served as the control condition and is not expected to create a positive or negative correlation. The exact color attributes are shown in Table 1.

Table 1 - CIELAB color parameters

	A	B	L
Blue	28.9	-95.4	71.8
Green	-65.9	68.6	72.3
Red	78.5	54.9	71.2
White	-1.6	-0.1	96

These parameters were chosen in order to give the most uniform lightness level across all colors. These were created as images which covered the whole computer screen that illuminated the room. The participants in Hasenbeck's et al. [18] experiment were shown pictures of bell peppers at varying luminance levels, and were asked to rate how appealing they were. Yellow and Blue Peppers were enjoyed most at higher luminance levels and were enjoyed significantly less at lower levels. For this reason the luminance levels of all colors in this experiment remained consistent. The luminance level was measured at a distance of 0.5m for each color, which all fell between 150 and 200 LUX, and the initial color temperature of the room was within the desired restaurant color temperature of 4,000K [19].

3.3 SOUND STIMULUS

The variables chosen for this test were note and pitch as they have been used as variables in previous perception experiments. Pitch, in particular, has been proven to have a significant impact on cross-modal associations [20]. It was

decided to use a chord, rather than a melody, song or tone. Using a melody could introduce personal preferences whereas using a single tone may not have been interesting enough or contain enough harmonic content to influence a person's taste perception. A chord was chosen because they are not as complex as harmonies or melodies and are also easier to define and analyse in a quantitative manner.

All of the notes used were in the major scale (chords C, D & E in Major). These chords were chosen as they were in the middle of the chosen octaves, which started at C2 and went up to C4. The low pitch (C2) and high pitch (C4) variants were chosen respectively because they had featured in other studies [13, 14]. Each audio sample was created using a piano emulation synthesizer; the samples had no effects or equalisation added. They had all exactly the same volume (60-70dB), length (8s), velocity and envelope characteristics.

4. RESULTS

The 19 participants who took part in this test were chosen at random and their ages varied between 18-35. None of the subjects reported being color blind or having hearing problems.

The dependent variable in this experiment was the sweet taste perception of the 24 sucrose solutions which was measured on a rating scale from 0-10. The independent variables were the color (4 levels – red, green, blue and white), the pitch (2 levels – high and low) and the note (3 levels – C, D and E). The chosen method of analysis was a repeated measures within-subject factor ANOVA. A three-way ANOVA was performed for all three factors (color, pitch and note) including all possible interactions. The significance value used in the analysis was $P < 0.05$. It was found that none of the factors violated Mauchley's test of sphericity, except for the note against color factor, which had a p value of 0.006; in this exception the Greenhouse-Geisser correction was used, which did not exceed 0.05.

Figure 1 shows the total sweetness rating of the sucrose drink for each color, note and pitch for all participants. This graph exhibits that the sweetness rating of the stimulus increased when the higher pitched audio was used. The low pitch mean total was 5.15 and the high pitch mean total was 6.8. A 27% (+1.675) increase in sweetness level demonstrates that pitch has an effect on taste. Pitch had a significant effect on taste perception ($p<0.0005$, $F = (1, 18) = 34.086$). A partial Eta squared effect size calculation returned $\eta^2=0.545$, which is seen as a large effect size. It was therefore demonstrated that the participants experienced an increase in perceived sweetness whilst listening to the higher pitched piano sample, as opposed to the low pitched piano sample. The ANOVA found that the notes used in this experiment (C, D and E) did not have a significant effect on taste perception ($F = (2, 36) = 0.249$, $p= 0.781$).

Color was found to have a significant effect on taste perception with a significance value of $p = 0.0005$ ($F= (3, 54) = 7.292$), which also returned a partial Eta squared effect size of $\eta^2= 0.757$. Figure 2 shows the total mean sweetness level scores for each color (full scale range 0-10). Green and red resulted in the same mean score and so they occupy the high scoring group, whereas white (control condition) was lowest, with blue also occupying the low scoring group. A significant difference can be seen between the high group and the low group, in particular between red/green and blue. On average red and green provided the highest positive cross-modal association with the sweet taste stimulus (the sweet taste perception increased when these colors were used).

However, none of the interactions between the three variables were significant (all $p > 0.05$). This means that no new cross-modal links between multisensory stimuli and taste perception could be established in this experiment.

5. DISCUSSION

The results showed that high pitch piano music generated a clear increase in sweetness ratings which is in agreement with our hypothesis and results from previous studies [13, 21]. The use of taste words as metaphors has been happening for centuries (e.g. sweet melody), it is however unclear as to whether people match sweet tastes to what they perceive as sweet music, based on the correlation between the two ends of the positive or negative aspect of the medium (Hedonic matching) or whether the two are matched together because of the *"high-low"* terminology used between the two modalities (semantic matching). This could be an area of further research, to try and prove which process humans use when creating subconscious cross-modal associations. The different musical chords used in the experiment did not show to have a significant effect on taste perception. This was not a surprising outcome, as different chords were mainly used to maintain the subjects' engagement. Furthermore, the small change in chord might have been masked by the large changes in pitch and/or the sample size was not big enough to exhibit a trend in the data.

Color showed a statistically significant effect on sweet taste perception, with red and green being linked to higher sweetness scores than blue or white. A probable reason why red and green influenced the level of perceived sweetness is that these colors were generally linked to higher

sweetness than blue or white, as they are more commonly associated with sweets and sugar. The low scoring result of blue and the high scoring result of red and green demonstrate the notion of cross-modal interaction in this experiment. They show that the results were not based on general color preferences but were influenced by the experiment conditions. The process of *'Hedonic matching'* could also relate to the color variable as the words used to describe both high sweetness and high pitch, can also be used to describe colors that are higher in tonal range (lighter) and higher in color temperature (warmer), like red is as opposed to blue. This could be another theory that strengthens the synaesthetic bonds between senses since often similar describing words are used or borrowed to describe perceptions outside of that particular sense.

Nevertheless, this experiment has not found new significant associations between colors, piano chords and sweet taste perception.

A possible reason for not reaching any correlations between all three stimuli could be that there is simply no correlation to be made. Perhaps the sample size was not large enough to exhibit a trend in the data however previous experiments have managed to find associations between the senses in smaller sample sizes. Parise and Spence [22] found synesthetic associations in a sample size as small as 12; this was however between traditional synaesthetic congruencies like pitch and visual size or brightness. These associations are built into our sensory systems from birth and so are formed more quickly and are present in more people [23].

In this study red had the strongest link to the sweet taste, however it was not proven that it has a connection to the sound variable (high pitch) that was also linked to the sweet taste. Therefore even if two variables have shown associations separately with a certain taste group, there is no guarantee that they are compatible together.

6. FUTURE WORK

In the future the test could be repeated by using tones instead of chords as they contain less complex timbres and so a more general understanding of the sound could have been formed, for non-musically trained participants. Another idea of further research could be to involve a lighter shade color condition to go with the higher pitch level condition. This would provide two levels of each stimulus and a semantic correlation possibility. This could help to unify the perception and achieve a unified

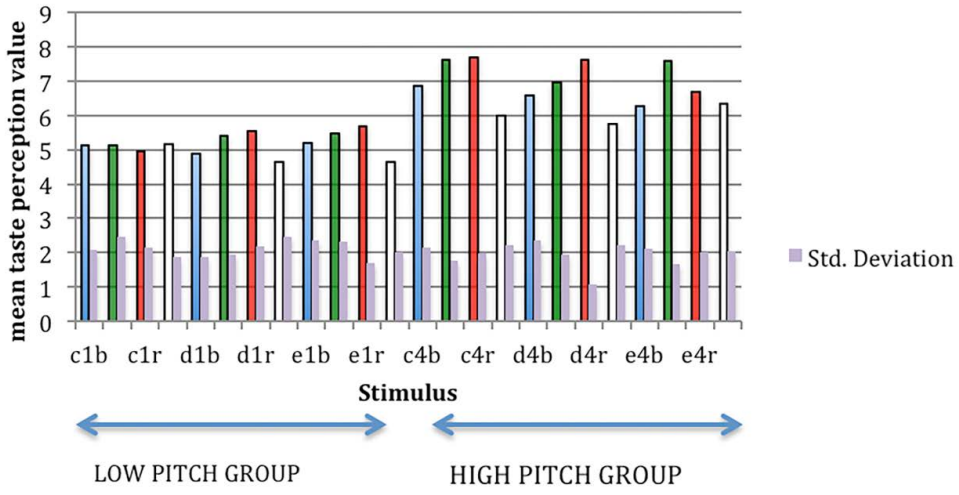

Figure 1 - The graph shows the mean totals for every condition for all participants. The Y=axis is the taste perception ratings scale (full scale 0-10). The X-axis contains every single stimulus condition used in the experiment (e.g. 'c1b' is note C, pitch 1-low and color blue).

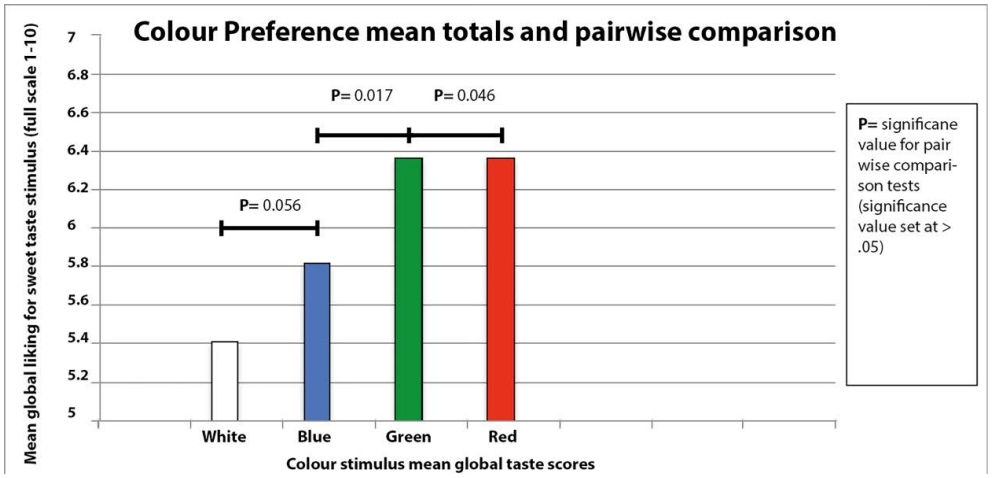

Figure 2 - The Y-axis depicts a scaled version of the taste perception ratings range (full scale 0-10). The X-axis depicts the different colors used in the experiment. The horizontal lines show the pairwise comparison significance values between the low and high scoring colors.

association of color and sound in relation to taste perception. Also the experiment could be modified to include descriptive words of a taste instead of using an actual taste stimulus. This would keep the experiment in the realm of semantics and could provide new cross-modal associations between the words used.

7. CONCLUSIONS

The conclusions that can be drawn from the study are that warmer, brighter colors can increase the sweet taste perception of a sweet taste stimulus. It was also found that the sweet taste was enhanced more under the higher pitched (C4) piano music as opposed to the lower pitched music. It can therefore be concluded that the pitch of an audio sample can affect a person's flavor perception. This shows that information from outside the traditional gastronomical senses can have an impact on a person's taste response. However, the main conclusion is that a relationship between color, sound (pitch and note) and taste was not established in this experiment which could mean that there are no associations between the three stimuli used in this study but it could also entail that the particular stimuli choices may not have been compatible.

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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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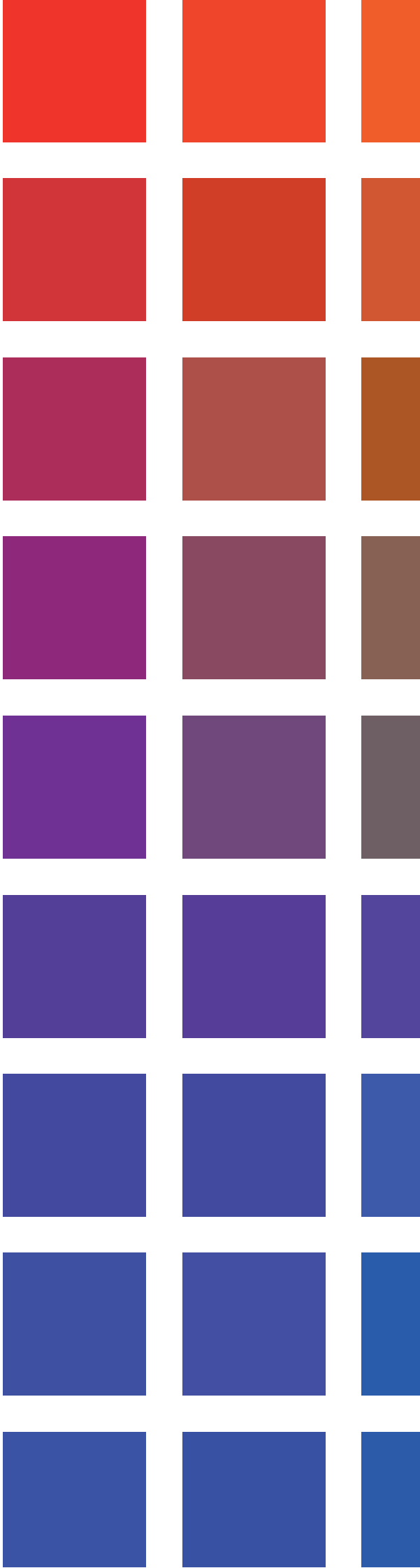

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