Rivista di Estetica

quadrimestrale
n.s., 43 (1/2010), anno L

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BASIC COLOR TERMS DO NOT REFER TO BASIC COLORS

Abstract

A widely held view on color cognition is that it is structured by a set of color fundamentals. Three sorts of evidence may be invoked in favor of such a "foundational" approach to color cognition: physiological, phenomenal and lexical. This paper focuses on the lexical evidence, which draws from a predominant view in color categorization, the Basic color terms theory (BCTT). It argues that the BCTT does not consist in a foundational approach to color cognition and does not provide such evidence.

Introduction

In his book, *Color for philosophers*, Hardin refers to a widely held view on our color experience according to which some colors are unique in that they are characterized by the impression of purity that accompanies their sensation. These colors cannot be described on the basis on any other colors, while all other color impressions can be described on the basis of these unique hues (Hering 1964). Hardin briefly argues for this view as follows: «The distinction between unique and binary hues in the Hering theory proves not to rest on some accident of description or parochial feature of European languages, but rather to pick out a fundamental functional feature of the visual system which is reflected quite generally in color-classifying behavior and linguistic practices»[1].

More generally, the view that Hardin briefly sketches in these lines holds that there is a set of color fundamentals on the grounds of which other color experiences can be described. Thus, red being a fundamental, a unique hue in Hering's sense, the red attribute, or "redness" is perceived in other colors such as orange, purple and pink. In this paper, I qualify this approach to color as "foundational".

[1] Hardin 1988.

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This expression is borrowed from the epistemological terminology, and is meant to refer to the tendency to ground theories on unquestionable primitives. These primitives are fundamental, often simple or un-analyzable. On the other hand, the theory's superstructure is made of complex elements inferred from the fundamentals. In this sense, the theory's primary and fundamental elements are necessary to the theory. Thus, in this paper, any approach to color cognition that relies on a set of fundamental colors, thought to be necessary in a semantic, epistemic, perceptual or metaphysical sense, is called "foundational".

Three sorts of evidence are usually provided for this foundational approach to color: physiological, phenomenal and lexical. When Hardin asserts that the distinction between unique and binary hues «proves not to rest on some accident of description», he refers to the study of macaques' lateral geniculate nucleus (LGN) cells by De Valois and colleagues in 1966[2]. Historically, De Valois and colleagues' work on opponent cells consists, in a confirmation of the Hering approach to color.

What can be called the "standard vision theory" that prevailed until the early 1990's holds that vision is trichromatic, or that three photoreceptors (maximally sensitive to long, short and medium wavelengths) in the retina feed the luminous information to our low-level perceptual mechanisms. Following De Valois and colleagues' study, it was believed that in these post-retinal low-level perceptual mechanisms, intervened opponent cells. De Valois and colleagues had observed that when these opponent cells are excited by a Red input, they are inhibited by a Green input, and vice-versa, the same being true of the Yellow/Blue interface – Red/Green and Yellow/Blue being none but Hering's opposed pairs of unique hues. In this consists the «fundamental functional feature of the visual system» in Hardin's sense.

However, several studies at the turn of the 1990's questioned the grounding of Hering's primaries on low-level mechanisms of the visual process[3]. It is today held that not only these unique hues cannot be grounded on the LGN's opponent cells, but that we can hardly talk of color vision at this early stage of the visual processing.

Thus, the physiological evidence to which Hardin alludes in favor of a foundational approach to color cognition, today no longer holds. Two sorts of evidence remain, and may be invoked in favor of such a view: the phenomenal evidence, which contends that red, yellow, green and blue are irreducible features of our color impressions, and the lexical evidence. In this paper, I will not address the phenomenal evidence and will concentrate on the lexical evidence, which draws from a contemporary theory of color categorization, the Basic Color Terms Theory (BCTT), first published in 1969 by Berlin and Kay[4].

[2] De Valois, R., Abramov and Jacobs 1966.

[3] Lennie, Krauskopf and Sclar 1990; De Valois, R. and De Valois, K. 1993; Abramov and Gordon 1994.

[4] Berlin, B., and Kay 1969.

In what follows, I first briefly present the BCTT. Next, I argue that the BCTT is incompatible with a foundational approach to color cognition for three different reasons, and, as a result, does not provide an argument in favor of the foundational approach to color sketched by Hardin.

1. The lexical argument to a foundational approach to color cognition

1.1. Introduction to the Basic color terms theory

Color categorization has received much attention in the past century, as color offers a good field of investigation to address the question of the interaction between culture and cognition in categorization. In the beginnings of the 20th century, it was believed that color categories were arbitrarily determined by language[5]. This view on color categorization was however contradicted in the early 1970's by Berlin and Kay[6], who suggested based on their field study that, contrarily to what is contended by the relativist view, there are universal color categories referred to by universal color terms (the "semantic universality thesis"). Furthermore, these color terms, which jointly partition the perceptual color space, emerge in the lexicon following a partially constrained order, which approximately corresponds to: black, white, red, yellow, green, blue, brown, pink, purple, grey (the "evolutionary sequence thesis").

These first results brought about the World Color Survey (WCS) around 1975, which gathered color-naming data from 110 languages of non-industrialized societies. The WCS experimental protocol consists in a naming task and a mapping task. In the naming task, participants are asked to name 330 of the most saturated colors taken from the Munsell color solid, ranging over the whole color continuum. Basic color terms are identified after the naming sequence, which also leads to the identification of the basic color term's extensions in the Munsell model. During the mapping sequence, the 330 Munsell color samples are arranged in an array representing the color continuum and participants are asked to show the basic color terms' best example, or foci. The data gathered on 110 languages following the WCS protocol confirm the universalist hypothesis according to which there is a determined set of universal color terms and categories that appear in the lexicon following a partially constrained evolutionary sequence.

1.2. Accounting for the observed regular categories with color fundamentals

The BCTT is a powerful and complex theory that was elaborated at the crossroad of linguistics, physiology, psychology, anthropology, ethnography, and to some extent phenomenology. It has dominated the literature in the past four

[5] Whorf 1956; Parsons 1924; Ray 1952.

[6] Berlin, B. and Kay 1969.

decades and has continuously evolved[7]. During its most radical days (1978-1997), in line with the "standard color vision theory" briefly described in the introduction to this paper, proponents of the BCTT argued that basic color terms referred to basic color categories grounded on physiological mechanisms occurring at the low (post-retinal) levels of the light treatment process[8]. More specifically, the BCTT contended that color categorization was based on 6 color fundamentals, which corresponded to the Hering primaries[9], resulting from the opponent mechanisms then thought to occur in the opponent cells of the LGN[10].

In the first stage of the evolutionary sequence, where the whole color space is jointly partitioned by two color terms, corresponding to black and white, the term "black" actually refers to the fundamental colors black, green and blue, and is grounded on the corresponding "fundamental neuronal responses"[11]; the term "white" refers to the fundamental colors white, red and yellow. These categories that include several fundamentals in their extensions are called "composite" and usually appear in the first 4 stages of a lexicon's evolution. Next, the composite categories are gradually differentiated, leading to the fundamental categories (black, white, red, yellow, green, blue). After the fundamental colors are singled out during the lexicon's evolution, "derived" categories, consisting in the intersection of perceptually adjacent fundamentals, emerge. Thus, for example, orange and pink, are categories respectively derived from the fundamentals red and yellow, and red and white.

Basic color terms were attributed cognitive and psychological advantages, partly thanks to Rosch's work, and this physiological grounding was mainly thought to account for them. Rosch was indeed the first to explore the cognitive meaningfulness of basic color terms in the 1970's[12]. She had done a series of experiments with the Dani, a population of New Guinea believed to have only two basic color terms (white and black), that have widely contributed to the establishment of the BCTT. Rosch had argued that the universal categories identified by Berlin and Kay were organized around natural prototypes. As a consequence, she had shown that these basic categories and their color foci are universally more codable, thus easier to learn in association with color terms then non-basic categories[13]. They are also more accurately remembered then non-basic colors[14], and are independent of language[15].

[7] Key references would include: Kay 1975; Kay and McDaniel 1978; Kay *et al.* 1991; Kay *et al.* 1997; Regier *et al.* 2007.

[8] Kay and McDaniel 1978; Kay *et al.* 1991.

[9] Hering 1964.

[10] De Valois, Abramov and Jacobs 1966.

[11] Kay *et al.* 1991.

[12] Rosch 1971; Rosch and Olivier 1972; Rosch 1973.

[13] Rosch and Olivier 1972.

[14] Rosch 1973.

[15] Rosch and Olivier 1972.

Thus, when the physiological grounding of Hering's unique hues was challenged, the universality of color categorization, supported by the WCS data and by Rosch's results, was not questioned. Simply, the BCTT's account of this observed universality had to be revised. One possibility was to keep Hering's unique hues as an explanatory basis, while rejecting their low-level physiological grounding[16]. Thus, the BCTT's initial postulate (P), "Basic color terms universally refer to basic color categories", first argued for by the physiological argument (A1), "Basic color categories are grounded on unique hues understood in a physiological sense", was next argued for by the phenomenal argument (A2), "Basic color categories are grounded on colors that have a particular phenomenal status".

This change in the BCTT's argumentation implies that regardless of the grounding of Hering's unique hues on the low-levels of the light information processing, these colors remain the phenomenal interface for the understanding of color cognition. Proponents of the BCTT have simply substituted in their universalist argument physiologically grounded unique hues by phenomenally grounded unique hues. This implies that phenomenally grounded unique hues are thought to account for universal color foci and color categorization, regardless of the perceptual and cognitive mechanisms responsible for the occurrence of these sensations.

1.3. What is the lexical evidence for a foundational approach to color cognition?

In the introduction to this paper, I defined "foundationalism" in color cognition as follows: is foundational any approach to color cognition that relies on a set of fundamental colors, necessary in a semantic, epistemic, perceptual or metaphysical sense. More specifically:

1) A is semantically primary if the expression referring to A is semantically necessary to the expression referring to B. For example: to understand the sentence "the door is blue" (B), one needs to understand the term "door" (A). B is not semantically accessible without the semantic access to A.
2) A is epistemically primary, if the knowledge of B presupposes the knowledge of A. For example: in order to know that a building is 30 floors high, one needs to know the number 30.
3) A is perceptually primary, if the perception of B presupposes the perception of A. For example: According to Hering, perceiving orange, necessarily presupposes the perception of yellow and red. Yellow and red are primary to orange.
4) A is metaphysically primary, if the existence of B presupposes the existence of A. For example: The existence of a crowd presupposes the existence of the individuals that compose it. Individuals are metaphysically primary to a crowd.

[16] Kay *et al.* 1997.

In 2005, Cook, Kay and Regier offered the following succinct description of basic color terms: «The smallest set of simple words with which the speaker can name any color»[17]. Underlying this description of basic color terms is thus the idea of a set of color terms that a speaker cannot do without in his reference to his color impressions. Some color terms, the ones that have been called basic, are necessary to an individual's color lexicon.

Let A be a simple lexical category, different from B. According to the BCTT, A is primary to the extent that in order to understand the reference of B, I need A. A is thus necessary to the comprehension of B, and A is included in the intension of B. However, the comprehension of what A refers to does not rely on the comprehension of what B refers to. In this sense, A is primary. For example, take the English basic term "red", and the English non-basic term "carmine". I can describe the color samples to which "carmine" refers with the term "red", but not the color samples to which "red" refers with the term "carmine". To understand what "carmine" refers to, I need to understand what "red" refers to. "Red" is thus necessary to the comprehension of "carmine", and "carmine" includes "red" in its intension. However "carmine" is not necessary to the comprehension of "red". "Red" being a "simple term by which other colors can be described", "red" is not semantically accessible by any other lexical category. In this case, the semantic necessity of "red" also amounts to an epistemic necessity. My knowledge of what carmine is depends on my knowledge of what red is, to the extent that in the perspective of the BCTT, carmine is a kind of red.

Can the necessary character of "red", also be perceptual in the context of the BCTT? Are the colors referred to by basic color terms primary while the colors referred to by non-basic color terms not primary? To the extent that basic color terms are grounded on basic colors, then it may be argued that the basic color term "red", which refers to my sensation of red, is also primary in a perceptual sense. It is because my sensation of red is thought to be primary that it can be said that carmine is a kind of red – and not red a kind of carmine. This line of argument suggests that when I perceive a carmine colored object, I perceive a kind of red. In other words, carmine is characterized by its redness.

To the extent that the BCTT argues for the universality of categorization based on a semantic and epistemic foundational approach to color cognition, and accounts for this universality by a perceptual foundational approach to color cognition, the BCTT, and the data the WCS gathered on over a hundred lexicons in the world, can be thought to provide an argument for a foundational approach to color cognition.

In this paper however, I argue that the BCTT may *seem* to adopt a perceptual, semantic and epistemic foundational approach to color cognition, thus providing an argument for it, but that in fact, a foundational approach to color cognition is not compatible with the BCTT's universalism.

[17] Cook, Kay and Regier 2005.

Indeed, the observation of basic color terms is independent of the semantic, epistemic and perceptual necessity attributed to some colors and color terms. If the BCCT seems foundational, it is not because universal color terms are observed, but because of the way this observation has tentatively been accounted for.

In what follows, I will argue that the BCTT cannot be said to adopt a foundational approach to color cognition by presenting three arguments. The first argument, developed in section 2, lies in the fact that the BCTT makes simultaneous use of two conceptually incompatible approaches to color, Hering's and Munsell's, which implies that none is considered fundamental by the theory's proponents. The second argument (section 3) consists in the idea that (A2) is challenged because it maintains a foundational line of thought. The last argument (section 4) results from the evolutionary aspect of the BCTT, which, I argue, is incompatible with a foundational approach to color.

2. The Conceptual incompatibility of Munsell's and Hering's approaches

The history of color theories is marked by the notion of "primaries", "unique hues", "basic colors" or "fundamental colors", appearing in contexts varying from physics to phenomenology, psychophysics, metaphysics, or art and painting. In what follows, I suggest an analysis of the Munsell and Hering approaches, which have determined the development of the BCTT, from the perspective of their respective primaries. In doing so I intend to uncover the deep contradiction that lies between Munsell's and Hering's approaches to color, and to show how far in history the notion of "basic colors", from which the BCTT has inherited, goes.

2.1. The BCTT endorses both Hering and Munsell's approaches as representative of our phenomenology

The Munsell system plays the role of a psychophysical reference to color terms in the BCTT to the extent that it is used in the color naming task and in the mapping task of the WCS protocol, the results of which are used to argue for the universality of color categorization. Though the color categories identified with the help of the Munsell system are thought to be psychologically real, the Munsell system, as any model, is contingent. Any other color model could have been used in the context of the WCS and the use of the Munsell system does not imply that this system is in any way necessary (other models have been used in the context of different experiments, like for example the OSA system, Boynton and Olson 1987, Boynton 1997). However, to the extent that the color categories that are identified with the help of a specific model have a psychological reality, then, this specific model needs to be considered by the proponents of the BCTT as representative of our perceptual space. On the other hand, Hering's approach also plays a considerable role in the BCTT. Hering's unique hues, corresponding to "fundamental neuronal responses" starting 1978, have been considered as

the most natural and simple way to account for the observed regularity in color categorization. To this extent, Hering's approach is also endorsed by the BCTT as representative of the structure of human phenomenology.

2.2. Hering's and Munsell's foundational approaches

Both Hering and Munsell's approaches rely on a set of "primary" colors responsible of their respective structures, and considered as necessary in the description of human color perception. Munsell organizes his color system around five primary colors: blue, green, yellow, red and purple. Hering grounds color phenomenology on four colors: blue, green, yellow and red. For Munsell, the five basic colors structure the color space in five perceptually equal parts. The location of all the colors on the Munsell color circle results from the location of the five primaries that divide the circle into five equal parts, each part being itself divided into ten equal parts. Furthermore, any three colors separated by an angle of 120 degrees are complementary, in that they produce a neutral grey when they are mixed. Thus, the location of any color, and the relation of any color to any other, including that of complementarity, is determined by the primaries. Munsell's foundationalism is therefore epistemic. Our epistemic access to B, intermediate color, depends on our epistemic access to A, primary color, to the extent that the location of all the colors in the Munsell space, hence our understanding of their nature, depends on the primaries[18].

For Hering as well, blue, red, green and yellow are necessary to the epistemic access of all the other colors. The location of the unique hues in the color space is also meaningful in this approach to the extent that it determines the way colors relate to each other and interact with each other. Any three colors separated by an angle of 120 degrees may be complementary in Munsell's system, but in Hering's, the unique hues, opposite each other in the color circle, are perceptually opponent. Their opponency implies that they can never be perceived at the same time. There is no reddish green, no bluish yellow, and conversely. When simultaneously perceived, two opposed chromatic lights cancel each other. Furthermore, if no third chromatic light is shown at the same time, a human observer perceives no color at all, or perceives white[19].

Thus, for both Hering and Munsell a small set of colors plays a fundamental role in an epistemic sense, to the extent that these primary colors structure the perceptual space and the relations between colors. However, for Hering, primary colors also play a fundamental role in a perceptual sense. For Hering, when I perceive B, an intermediary color between the primaries A and C, I necessarily perceive A and C. Thus, for Hering, some colors, the unique hues, are simple, irreducible and necessary to our perceptual space to the extent that

[18] Munsell 1941.

[19] Jameson and Hurvich 1955.

they also consist in attributes that can be found in other colors, like redness is found in purple.

2.3. The nature of the incompatibility between Munsell and Hering

The BCTT relied on these two approaches in the development of its universalist argument. However, the difference between Munsell and Hering in the selection of primary colors leads to different structures of the color space. In Munsell's system, where the color circle is divided into 40 units, there are 12 units between what could approximately correspond to Hering's unique blue and his unique red. On the other hand, there are 8 units between what could correspond to Hering's unique red and his unique yellow, between his unique yellow and his unique green. Whereas according to Hering, the color circle is divided into four equal quarters. This difference in the spacing of the primary colors partly results from Munsell's impression, evidently not shared by Hering, that the perceptual distance between red and blue is too wide and requires another primary color to be introduced in between, i.e. purple. This difference in the way our color space is described causes Munsell's and Hering's approaches to be incompatible[20]. Colors in the two models are not comparable to the extent that they do not relate to each other in the same way. The relation between red and blue in a system based on Hering's colors is not comparable to the relation between red and blue in Munsell's.

The difference of structure between Munsell and Hering's approaches is not only due to the different perceptual distances occurring between colors in the two color spaces. The nature of the relation between the primary colors is also conceptually different. In Munsell's system complementary colors produce a neutral grey when they are mixed. This complementarity-based approach to colors brings Munsell close to Newton. Indeed, according to Newton primary colors are complementary to the extent that they produce white when they are mixed[21]. The fact that Munsell's primary colors produce a neutral grey is accessory and is simply due to the fact that Munsell reasons on the basis of surface colors, while Newton reasons on the basis of aperture colors. Regardless of the exact tone of the produced color, what is central to these systems is that primary colors mix and produce an achromatic color, either white or a neutral grey.

On the other hand, Hering's approach to color is tributary to Newton's historical detractor, Goethe[22]. Goethe aimed at reviving Aristotle's approach, after Newton had overturned it. In Aristotle's perspective, black and white are the primary colors on the basis of which all colors are produced. Colors result from the modification of white light by a dark surface. Goethe's aim was to revive this

[20] Valberg 2001.

[21] Westfall 1962.

[22] Gage 1993.

fundamental opposition between lightness and darkness. His approach to color and the structure of his color circle essentially rests on this notion of opposition, as expressed by the central role afterimages play in his theory[23]. Borrowing Goethe's Aristotelian polar structure of color perception, Schopenhauer, his follower, speaks of the retina's "polarity". In his attempt to make of Goethe's theory a more rigorous subjective system, he even suggests that the retina is stimulated by opposed poles: Red/Green, Yellow/Violet and Blue/Orange[24]. Hering would have been influenced by Schopenhauer's interpretation of Goethe[25].

Thus, when, according to Hering, opponent colors simultaneously shown lead to the perception of white, it is not that white is *produced*, the way it is produced in Newton's sense, or the way grey is produced in Munsell's sense. In Hering's approach, white can be perceived when two opponent chromatic lights are shown together, because according to Hering, opponent colors *cancel* each other. In Munsell's approach, complementary colors mix; in Hering's, opponent colors do not mix by definition.

2.4. The implications of the BCTT's simultaneous use of two conceptually incompatible approaches

Still, the BCTT establishes a strong correspondence between focal colors identified in the Munsell system, and Hering's unique hues. If the BCTT is foundational, how can the fact that it makes simultaneous use of conceptually incompatible approaches be understood? Either the BCTT does not consider them to be incompatible, or the BCTT does not consist in a foundational approach to color cognition. These two possibilities, however, amount to the same thing, because the only way not to consider these approaches as incompatible is by not considering that they are fundamental, or by considering that none of the primary colors put forward by each system is primary in the foundational sense. Only in the case where none of the systems is thought to be fundamental, can they both be considered *differently* representative of our phenomenology.

A little historical precision might at this point bring some further support to this last argument. It is indeed important to emphasize the fact that Hering's unique hues were only adopted at a second stage of the BCTT's evolution. This late introduction of the Hering primaries in the BCTT's approach to color cognition implies that the observed inter-linguistic regularity in categorization is not necessarily linked to a foundational approach to color perception and color phenomenology. When Kay and McDaniel first used Hering's unique hues as a possible explanation for color universals in 1978[26], the BCTT had already been

[23] Goethe 1970.

[24] Schopenhauer 1986.

[25] Gage 1993.

[26] Kay and McDaniel 1978.

developing its universalist argument for the past 9 years. The observation of the regularity in categorization, although attributed to cognitive and neuronal processes of the human species, was not linked to a specific vision theory. The BCTT's main concepts were developed by Rosch between 1971 and 1973, while in 1975 Berlin and Berlin's work on Aguaruna color lexicon [27]and Kay's work on synchronic and diachronic changes[28] deepened the BCTT's approach to color lexicon evolution and color categorization. Hering's approach is not part of any of these developments.

In other words, although adopted and fully endorsed starting 1978, Hering's unique hues were only subsequently added to the BCTT's conceptual apparatus. Hering's primary colors were thus pragmatically adopted. To the extent that, grounded on low-level physiological mechanisms, they provided the BCTT with a good explanation of universal categorization – regardless of the fact that this grounding of lexical categories on physiological mechanisms is disputable. They are in the same way pragmatically abandoned starting 1997 when they no longer provided this explanation[29]. Therefore, the use of Hering's colors, like the use of the Munsell system does not reflect the BCTT's compliance with these approaches' theoretical grounds. The Munsell and the Hering approaches in the context of the BCTT simply consist in conceptual and experimental tools. Thus, although it relies on Hering's primaries, the BCTT's use of these fundamentals does not make of it a foundational approach to color cognition.

3. The limits of (A2)

We have seen in section 1, that following the questioning of the neuronal grounding in the LGN of Hering's unique hues, the BCTT had adapted its argumentation by replacing (A1) "Basic color categories are grounded on unique hues understood in a physiological sense", by (A2) "Basic color categories are grounded on colors that have a particular phenomenal status". In this section, I will argue that (A2) is as challenged as (A1) was. I will show that the reason of (A2)'s weakness lies in the fact that although the physiological grounding of Hering's unique hues was abandoned by the BCTT, (A1)'s foundational approach was not. Thus, showing the limits of (A2) consists in this paper's second argument against the idea that the BCTT provides a lexical evidence for a foundational approach to color.

3.1. Color categories are not independent of language

We have seen in section 1 of this paper, that Rosch's work with the Dani had greatly contributed to the establishment of the psychological reality of color

[27] Berlin, B. and Berlin, E.A. 1975.

[28] Kay 1975.

[29] Kay *et al.* 1997.

universals. However, no study ever tried to replicate Rosch's experiments until the early 2000's. Roberson and colleagues replicated Rosch's experiments, but did not obtain the same results. Indeed, in a series of experiments done with the Berinmo, another population of New Guinea, believed to have five basic color terms[30], none of the cognitive advantages of basic color terms and categories suggested by Rosch were observed. Of particular interest to us, the argument according to which color categories are independent of language and are therefore innate is today widely debated.

The independence of color categories from language can be observed through categorical perception effects. Categorical perception is a phenomenon particular of perceptual domains, referring to the fact that a perceptual continuum is perceived as discontinuous[31]. In the recently observed case of the Berinmo, the border "nol/wor", which does not exist in English, causes categorical perception effects on Berinmo speakers, but not on English speakers. Furthermore, the English lexical border "yellow/green" causes categorical perception effects on English speakers, but not on Berinmo speakers, which is even more meaningful from a foundational perspective, given that "yellow" and "green" are considered as fundamentals[32].

The recent data on categorical perception effects, and more generally the fact that basic color categories do not seem to have the cognitive advantages they were first thought to have, consists in a serious blow to the notion of "basic color terms", and to the psychological role it was thought to play. Basic categories do not seem to rest on innate categories, as they were first thought to be. It is worth noting however, that these data do not question the existence of a set of color terms regularly observed across languages. To this extent, "basic color terms" can still be said cognitively meaningful, but perhaps in a different sense[33].

3.2. What are color fundamentals?

The second challenge faced by (A2) stems from the great inter-subjective variability in the identification of unique hues. In the BCTT's approach to color categorization, each category is organized around a focal color, which is grounded on phenomenally unique hues, independently of language. However, studies of unique hues have shown that their identification varies greatly from one subject to another. Unique blues, greens and yellows have respectively been identified at the following wavelengths: B: 458-495 nm; G: 490-555 nm; Y: 44-

[30] Davidoff, Davies, Roberson 1999; Roberson, Davies, Davidoff 2000.

[31] Harnad 1987.

[32] Roberson, Davies, Davidoff 2000; also see Kay and Kempton 1984; Winaver *et al.* 2007, regarding categorical perception effects and language.

[33] Regier and Kay Forthcoming.

594 nm[34]. In other words, one participant's unique green may coincide with another participant's unique blue.

This overlap was shown to occur with chromatic lights and with Munsell color chips as well[35]. If focal colors are grounded on unique hues (in a phenomenal sense), then one would expect unique hues to converge in the Munsell array like focal colors converge[36].

More generally, the notion of color fundamentals, such as unique hues, lacks a specific and clear psychological operationalization. We owe one tentative operationalization to D'Zmura, according to whom basic colors are perceptual primitives that should operate like filters in the visual processing of images, as other perceptual primitives do[37]. According to this computational approach to visual cognition, there are two sorts of visual processes: parallel processes, which rely on primitives, and are thus automatic, quick, and effortless; serial processes, which do not rely on primitives, and are not automatic, are slow, and effortful[38]. Parallel processes are recognizable by the "pop out" effect. If red is a visual primitive and orange is not, following Hering's approach, then red should pop out in visual search tasks, while orange should not. However, D'Zmura's results do not speak in favor of a hypothesis according to which red, blue, yellow and green operate as filters in color cognition. What would be called "non-basic" colors in a foundational approach to color cognition, are as salient as "basic" colors in visual search tasks. This saliency of non-basic colors undermines the idea of the perceptual superiority of Hering's primaries, even when they are understood in a functional sense and regardless of the processing level at which they are thought to be grounded. Thus, the third challenge faced by (A2) consists in the observation that in this psychological operationalization of the notion of "basic" or "primary" colors, there does not seem to be a difference between primary and secondary colors.

3.3. (A2) operates in a foundational framework

(A2) was suggested by the proponents of the BCTT when the physiological grounding of Hering's unique hues was questioned. In section 3, I have shown that (A2), although not relying on Hering's hues in a physiological sense, still falls short of answering at least three challenges. The reason why (A2) is subject to these criticisms is because (A2) remains foundational in its ambition, to the extent that it still implies that focal colors are grounded on some sort of fundamentals[39]. It is precisely in this foundationalism that resides the weak-

[34] Kuehni 2004.

[35] Kuehni 2001.

[36] Kay, Regier and Cook 2005.

[37] D'Zmura 1991.

[38] Rensink and Enns 1995.

[39] Kay *et al.* 1997; Regier *et al.* 2007.

ness of (A2). If (A2) had not been foundational, or if basic categories were not grounded on a set of fundamentals, the questioning of the existence of innate categories, the inter-subjective variability in the identification of unique hues, and the questioning of the perceptual primacy of basic colors would not have been an issue. That is not to say that the BCTT focal color account is doomed, or that basic categories are not organized around focal colors. What it does suggest is that focal colors should be accounted for in a non-foundational way. One possibility would be to further explore the asymmetries of the color space[40], and to see to what extent this implies that perceptual saliency is relative, and is not determined by fundamentals in the traditional sense.

The fact that (A2) remains challenged suggests that to be able to account for universal categorization, the BCTT needs to abandon the foundational approach altogether, and not just the physiological grounding of color fundamentals. In this observation lies the second argument against the view according to which the BCTT provides lexical evidence to a foundational approach to color.

4. Basic color terms cannot be taken to refer to basic colors

The simultaneous use of two incompatible color approaches in the context of the BCTT and the weakness of (A2) both directly argue against the perceptual foundationalism of the BCTT. The following considerations on the BCTT's evolutionary dimension mainly constitute an argument against the BCTT's semantic and epistemic alleged foundational approach to color cognition.

4.1. The evolutionary thesis is essential to the BCTT's universalist argument

The evolutionary thesis of the BCTT, according to which basic color terms emerge following a constrained order, is essential to its universalist argument. Without it, the BCTT cannot account for the differences in the partitioning of the color space by languages that have different numbers of basic color terms. It is only because one language's lexical system with *n* terms is thought to evolve into a lexical system with *n+1* terms observed in another language, that it can be said that they both belong to the same universal pattern of color categorization. To the extent that basic color terms jointly partition the color space, the terms "black" and "white" that are found in all languages referring to the same universal color foci, do not have the same extensions in languages at different stages of their evolution. Some might object, for example, that "black" in a stage 2 language and "black" in a stage 7 language are different color terms since they do not refer to the same colors.

[40] Jameson and D'Andrade 1997; Regier *et al.* 2007; or of light, see Philipona and O'Regan 2006.

The BCTT however stands clear of this objection for two reasons: it structures color categories around focal colors that do not vary like extensions do; it hypothesizes that languages evolve from one stage into another. There is thus no interruption between a stage 2 and a stage 7 language, or between the different stages of the same language. They are part of the same universal categorization pattern, because lexicons are thought to evolve following the same evolutionary sequence, determined by the same perceptual and cognitive constraints expressed by the existence of universal foci. In this sense, the BCTT's evolutionary sequence thesis is vital to its universalist argument. However, it is incompatible with a foundational approach to color cognition.

4.2. The psychological salience of color terms in naming tasks

Indeed, if color categorization was determined by color fundamentals consisting in a fixed set of primary colors (namely white, black, red, yellow, green and blue), then it is hard to imagine a reason why these terms shouldn't appear all at once in any lexicon. Instead of going through stages 2, 3, and 4, color lexicons should have the BCTT stage 5, where all six fundamentals are categorized, as a first stage. While in fact, 65% of the languages surveyed in WCS (all of which are from non industrialized societies) do not have all of the 6 terms referring to the 6 color fundamentals at once, but only a sub-set of them[41].

Evolution also poses a problem to a foundational approach to color, when, in its last stages, non-fundamental colors are categorized and become "basic" categories referred to by basic terms. If the BCTT consists in a foundational approach to color, the sense in which terms emerging after stage 5, such as "pink", are "basic" is not clear.

We have seen that non-fundamental colors are as psychologically salient as fundamental colors in visual search tasks. They are as psychologically salient in naming tasks as well. If fundamental colors are innate, one should expect them to be psychologically more salient in naming tasks then colors that are not fundamental. For example, "orange" being derived from the fundamentals red and yellow, it should not be as psychologically salient as the lexical categories "red" and "yellow". However, the simple fact that "orange" is used by the majority of a given linguistic community in reference to the same color samples that we would call "orange" in English, expresses the level of confidence speakers of that language have while using this color term. It implies that "orange" best describes a certain color impression. To the extent that it is referentially consensual, "orange" is as salient as "red" or "yellow" for this linguistic community[42], or, in other words, it is as basic.

[41] Jameson, K.A. 2010.

[42] Kay and McDaniel 1978.

Apart from referential consensus in naming tasks, psychological saliency – which basicness seems to mainly amount to on the ground[43] – may also be measured in terms of consistency in color naming, and in mean response times. In his study of basic color terms, Boynton asks participants to name the 424 colors taken from the OSA set twice. The ratio from consistent to inconsistent naming, leads to the following ranking: "green", "blue", "orange", "purple", "yellow", "brown", "pink", "red", followed by the non basic terms "olive", "peach", "lime", "tan", "violet", "maroon" and "rose". Response times also indicate that so-called secondary terms are at least as salient as primary terms. Terms with faster to slower response times were ranked as follows: "green", "yellow", "blue", "orange", "pink", "purple", "brown", "red", followed by the non basic terms "lavender", "peach", "olive", "lime", "tan", "violet" [44]. Thus, although these results imply that the notion of "basic" terms does refer to some psychological phenomenon to the extent that basic color terms are more consistently and quickly named than non basic color terms, they do not imply that within the set of basic terms and categories, some categories are more fundamental then others. Orange and purple, for example, are named more consistently and more quickly then red, regardless of the fact that purple and orange are not traditionally considered as primary colors.

4.3. Evolution and foundationalism do not go together

We have seen that the BCTT's succinct definition of basic color terms is that they are part of the smallest possible set of simple words necessary to describe any color impression. To the extent that "orange" is a basic term in English, then "orange" is part of such a set according to the BCTT. This in turn means that in languages where "orange" is basic, like in the English language tested by Boynton, it is natural that "orange" is consistently and quickly named, as it is natural for it to reach high levels of referential consensus. However, "orange" is not a basic term in all languages. In fact, "orange" is not a basic term in any of the 110 languages surveyed by the WCS. If Boynton had tested the speakers of a language surveyed by the WCS, it is likely that "orange" would not have been consistently or quickly named. From an evolutionary perspective, then, it is only natural that "orange" should at least be as salient as "red" in languages where "orange" and "red" are basic terms. And it is natural that "orange" should not be as salient as "red" in languages where "red" is a basic term, and "orange" is not.

To the extent that "orange" is part of the basic color terms set in English, then "orange" is considered a simple term, as necessary as "red" or "yellow" for any speaker of the English language, in a semantic and epistemic sense. More specifically, "orange" is necessary to the semantic and epistemic access to color

[43] Berlin, B. and Berlin, E.A. 1975; Maffi 1990; MacLaury 1991; Stanlaw 1997.

[44] Boynton and Olson 1987.

terms and color categories, that are not basic in the English language. Exactly as "red" is necessary to the semantic and epistemic access to the non basic color term "orange", in a language where "orange" in not basic. Thus, according to the BCTT, "orange" in English, is necessary to the semantic access of "coral", and "purple" to the semantic access of "mauve" or "lavender".

Therefore, when proponents of the BCTT contended that basic color terms are part of the smallest set of simple terms, they implied *in a given lexicon, at a given time.* To the extent that the BCTT has an evolutionary approach to color categorization, what is considered as a "small" set and a "simple" term necessarily evolves. The notions of "small set" and "simple terms" are relative to the time and place at which they are considered. As a result, the semantic and epistemic foundationalism of the BCTT is relative to both the color lexicon under examination and to the time at which it is examined.

However, a "relative foundationalism" is not equivalent to the type of foundationalism sketched by Hardin. The whole point of a foundational approach to color cognition is that a determined set of colors is fundamental, indispensable and absolutely necessary to our color cognition, in all circumstances and at all times. Since the BCTT cannot abandon its evolutionary thesis, at the cost of seriously undermining its universalist argument, then it can only opt for a "relative foundationalism", which amounts to an abandonment of the foundational approach to color cognition in the traditional sense. As a conclusion, it can reasonably be argued that the mere nature of the BCTT's universalist argument, which necessarily relies on evolution, prevents it from consisting in a foundational approach to color, in the sense sketched by Hardin. Thus, for this third reason, the BCTT cannot be seen as providing an argument for such a view.

Conclusion

A widely held view regarding color cognition is that it relies on a set of fundamentals. These basic colors are believed to be primary in a semantic, epistemic, perceptual or metaphysical sense. I have qualified this approach to color cognition as "foundational" in a loose reference to the epistemological literature where a theory that relies on a set of simple, irreducible, non-inferred and necessary primitives, is called "foundational".

Three sorts of evidence are usually invoked in favor of such an approach to color cognition: physiological, phenomenal and lexical. The physiological evidence (also disputable on a different basis) no longer holds following the questioning of the unique hues' physiological grounding on the low-levels of visual information processing. In this paper, I did not directly address the phenomenal evidence, and concentrated on the lexical evidence, allegedly provided by the Basic color terms theory (BCTT).

After having presented the theory and shown in what sense it could be believed that the BCTT was foundational in a semantic, epistemic and perceptual sense, I argued that the BCTT could in fact not consist in a foundational approach to color cognition, nor provide an evidence for such an approach, for three main reasons.

The first reason is meta-theoretic. In the establishment of the basic color terms theory, two approaches to color are heavily relied upon, Munsell's and Hering's. I argued that these systems are incompatible, and thus, cannot both be endorsed as fundamentally representative of our color phenomenology in the context of a universalist theory of color categorization. As a consequence, none of the primaries put forward by either of these systems can be considered as fundamentals by the BCTT. The second reason I invoked draws from the fact that (A2) according to which basic color categories are grounded on colors that have a particular phenomenal status, and on which the BCTT today relies to account for the observed universal categorization, is not tenable in a foundational framework. To the extent that (A2) treats the set of phenomenally particular colors implicitly like a set of fundamentals, (A2) still consists in a foundational approach to color cognition, and as such, falls under the following criticisms: 1) Basic categories do not have the cognitive advantages they were thought to have, mainly, they are not independent of language and do not seem to be innate categories. 2) There is a great inter-subjective variability in the identification of the unique hues. If unique hues consist in a phenomenal grounding for focal colors, then unique hues should not vary across subjects. 3) Basic colors do not operate like perceptual primitives to the extent that non-basic colors are as salient as basic colors in visual search tasks. The third and last argument against the idea according to which the BCTT provided lexical evidence for a foundational approach to color cognition resides in the argument that such an approach is in contradiction with the evolutionary dimension of the BCTT.

As a result, the BCTT does not consist in a foundational approach to color cognition. Basic color terms cannot be seen as referring to "basic" colors, understood in a traditional sense. Hence, the BCTT cannot be considered as providig lexical evidence and a further argument for the existence of basic colors.

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