COLOR ANTONYMS

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Abstract: The main goal of this paper is to give a formal account of the denotation of chromatic gradable color adjectives. These adjectives are sui-generis among gradable adjectives, for they do not form antonyms. In this paper, I propose and defend an account of their denotation, according to which adjacent colors play a similar role regarding color adjectives than regular antonyms do with regards to other gradable adjectives. I will defend the thesis that the best way to account for the semantic behavior of color adjectives is to assign them as their denotation two independent valuation functions, each one with a different threshold and domain. This means, for example, that there is no single green scale (on the hue dimension) but two: one for the property of being green-rather-than-yellow and another for being green-rather-than-blue.

The main goal of this paper is to give a formal account of the denotation of chromatic gradable color adjectives.[1] In particular, my aim is to develop a model that at satisfies two basic desiderata that any account of the denotation of color adjectives must satisfy: First, it must be consistent with what we already know about the semantics of gradable adjectives, and second, it must also account for the inner structure of color adjectives as a lexical category. In the first part of the paper I will present these desiderata in fuller detail and then offer what I take to be the best model satisfying them. This model will veer closely to the traditional gradable adjective model, as contained in the work of Kennedy and McNally (2005), and Rotstein and Winter (2004), among others, except for a minor but central feature: While the traditional model assigns one value function as the denotation of every gradable adjective, my model will assign two value functions to each color adjective. Without getting in too much technical detail at this stage, the central idea is to divide the denotation of each color adjective into two different, but related properties; so that, for example, the denotation of color

[1]. From now on, I will use the term “color adjectives” to refer to basic chromatic gradable color adjectives (“green”, “blue”, and “yellow” and “red”.), except when explicitly stated. Yet, the proposed model can be easily extended to non-gradable (“orange”, “purple”), non-chromatic (“brown”, “pink”) and neutral (“white”, “black”, ”grey”) color adjectives, as is shown in the appendix.

Chromatic color adjectives, correspond to color hues, i.e., to colors whose differences “depend primarily on variations in the wavelength of light reaching the eye” (Byrne and Hilbert 1997, 447). In contrast, non-chromatic color words mark differences in brightness (ligthness and/or luminance) or saturation. The difference between “pink” and “red”, for example, is a difference in saturation, not hue (i.e., *pink* is *unsaturated red*). A basic color term is a color word “(a) that is monolexemic (unlike "reddish-yellow"); (b) whose extension is not included in that of any other color term (unlike "scarlet", whose extension is included in "red"); (c) whose application is not restricted to a narrow class of objects (unlike "roan"); and (d) that is psychologically salient” (Byrne and Hilbert 1997, 443) so that it “has stability of reference across informants and across occasions of use.” (Crawford 1982, 342) Finally, as explained in the text, an adjective is gradable if it accepts comaparative and superlative forms. It is worth mentioning, that even though the classification of color adjectives I present in this footnote is pretty standard, there is no total agreement as to exactly which color adjectives are gradable, and which are not.

adjective “green” depends both on how *green-rather-than-blue* and how *green-rather-than-yellow* things are.

Besides accounting for the aforementioned data, the model I present here has two surprising, but not entirely unwelcome features. On the one hand, it allows us to find semantic relations between color antonyms analogous to those between gradable antonyms, so that we can extend our everyday notion of antonymy to talk about antonyms among color adjectives.[2] On the other hand, it predicts that it must be easier to say of two objects that one is, say, greener than the other, if both are of different shades of yellowish green, than if one of them is yellowish green, while the other is blueish green. Given that these are both novel empirical predictions, current empirical research on the use of color adjectives is completely silent about them. Even though the intuitions of many native speakers consulted by the author confirm these predictions, further research is needed to empirically test the model.

I. What is so special about Chromatic Gradable Color Adjectives?

Even though there is a vast literature on the semantic behavior of gradable adjectives (and color adjectives have been used as paradigmatic examples of gradable adjectives in the literature), certain peculiarities of the semantic behavior of color adjectives make them sui-generis among gradable adjectives. For example, while most gradable adjectives have well known antonyms, like hot (and cold), wet (and dry), big (and small), etc., color adjectives do not seem to form such pairs. Instead, they form what Barwise and Seligman (1997) have

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2. In some of the literature on color terms, the expression “antonym” is used as a synonym for “opposite” (for example, in Moroney 2009). However, this use of the term does not cohere well with the current linguistic use of the word “antonym”, where it is often recommended to differentiate between pairs of opposites (like *up* and *down*, or *precede* and *follow*) and actual antonyms (Lyons 1968, 1977, Cruse 1986, 2004). It is very important for me that the way I am extending the notion of antonym is as faithful to current linguistic use as possible.

called a classificatory system. A classificatory systems is a set of closely related adjectives we use to classify objects regarding some aspect or feature. The adjectives “pair” and “odd”, for example, form a classificatory system for natural numbers, regarding their divisibility by two, while “formal”, “social” and “natural” form a classificatory system for sciences, regarding their domain. Taxonomical systems, like those used in the biological sciences to classify living beings, and measurement systems associated to magnitudes like weight, length or time are all paradigmatic examples of classificatory systems (Lyons 1995). In a similar fashion,we use adjectives like “red”, “green”, “blue:”, etc. to classify objects regarding their color. Thus, color is a single determinable magnitude that can be described, with more or less precision, with the use of color adjectives (Sanford 2008, Gärdenfors 2004, 70-75, Sivik 1997, Lyons 1995).[3]

However, unlike adjectives belonging to other classificatory systems (for example, those used in biological taxonomy, or to measure magnitudes), many chromatic color adjectives are gradable, i.e. they accept both a comparative and non-comparative mode. All other adjectives used in classification and measurement (“animal”, “vegetal”, “third”, “twenty seven”, etc.) are non-gradable, i.e. they do not accept a comparative mode. Thus, while sentences (1) and (2) ahead are grammatically acceptable, (3) and (4) are ill-formed:

(1) This shirt is greener than that one.

(2) Some butter is more yellow than other.

(3) # Shamu is more whale that Keiko.

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3. As aforementioned, the model I will develop here will not include all color adjectives, but only chromatic ones. Also, as usual when dealing with gradable adjectives, I will assume that colored objects are of one and only one color, even though this is rarely so. In a more realistic model, it might make sense to assign multicolored objects not a single value in the color spectrum, but sets or intervals of values (Schwarzschild and Wilkinson 2002). I will ignore this complication from now on, considering only a domain of monochromatic objects.

(4) # Peter came more second than Johannes.

Furthermore, like other systems of classification associated to measurable magnitudes (like distance or weight), color adjectives seem to be structured by some sort of order order (i.e. some colors are said to be next to others, and it makes sense to say that one color is between two others) and, as we shall see further ahead, their comparative form depends on this ordered structure (for example, since green is between yellow and blue, something can be of a blueish shade of green or a greenish shade of yellow, but not of a yellowish shade of blue or a blueish shade of yellow). Thus, we expect an account of the denotation of color adjectives to make sense of this structure.

From a developmental perspective, color adjectives also seem unique among gradable adjectives, since they are acquired relatively late in children´s development. Even among gradable adjectives whose extension depends on easily perceivable features like “big” and “small”, etc., color terms are specially difficult for children to learn (Nelson and Benedict 1974, Bartlett 1976, Mervis, Bertrand & Pani 1995, Shatz, Behrend, Gelman & Ebeling 1996, Sandhpfer & Smith 1999, Pitchford & Mullen 2001, Pitchford 2006), and it has been speculated that this may be due to the fact that colors do not form simple pairs of antonyms (Carey 1982, Park, Tukagoshi & Landau 1985, Soja 1994, Sandhofer & Smith 1999). This suggests that the semantic structure of color adjectives is more complex than that of other gradable adjectives.

These peculiarities makes color adjectives sui-generis among gradable adjectives, and therefore ripe for semantic analysis. My purpose in this paper is to determine just how similar (and thus, how different) the semantic behavior of color adjectives is in comparison to that of other gradable adjectives. The article is structured as follows: First, I will present what is currently the standard account for the denotation of gradable adjectives. Then, I will show that there is no simple and straightforward way of adapting it to account for the denotation of color adjectives. In particular, there is no simple way of making it do justice to the structure of our systems of color adjectives. Consequently, I will suggest some amendments to the traditional account, resulting in a new model that incorporates all the virtues of the traditional model, while incorporating also the structural peculiarities of our color vocabulary.

I. The Standard Account of Gradable Antonyms

1. Gradable Adjectives

Many accounts of gradable adjectives like colors (see e.g., Bartsch & Vennemann, 1973; Bierwisch, 1989; Cresswell, 1977; Heim, 1985, 2000; Hellan, 1981; Kennedy, 1999, 2007, Kennedy and McNally, 2005; Klein, 1991; Seuren, 1973; von Stechow, 1984, Rotstein and Winter 2004) assign them as their denotation a function, known as its "measure function", from a domain of individuals to (positive) degrees of the adjective in some scale. Measure functions are converted into properties of individuals by degree morphology, which in English includes (at least) the comparative morphemes (*more, less, as*), intensifiers (*very, quite, rather*, etc.), the sufficiency morphemes (*too, enough, so*), the question word *how*, and so forth. Thus, while the denotation of the bare adjective "happy" is a measure function (from people to how happy they are), the denotation of "very happy" is the property determined by the aforementioned measure function (i.e., the property of being very happy).

Degree morphemes serve two semantic functions: they introduce an individual argument for the measure function denoted by the adjective, and they impose some requirement on the degree derived by applying the adjective to its argument, typically by relating it to another degree. However, their positive form does not have any overt degree morphology, yet its denotation is a property of individuals. Many solutions have been developed to overcome this problem. One common solution (and the one I will adopt here) is to assume that the gradable adjective in the positive form is headed by a null morpheme that has the same semantic function as overt degree morphology: it takes a gradable adjective denotation and returns a property of individuals (see e.g., Bartsch & Vennemann, 1972; Cresswell, 1977; Kennedy, 1999; von Stechow, 1984). The null morpheme thus takes a measure function and maps it to a property of individuals whose value in the function exceeds some (many times, contextually determined) threshold called its "standard value". For example, the denotation of "wet" contains a function that assigns to objects in its domain their degree of wetness, i.e., how wet they are.[4] Thus, an object is more wet than another, if its degree of wetness is higher than the other's; and an object is wet, if it is wet to a sufficient degree.

2. Antonyms

The denotation of a gradable adjective is closely related to that of its antonym (if it exists). This is manifest in what I will call the fundamental law of gradable antonyms:[5]

(5) *Fundamental law of gradable antonyms:* Gradable adjectives *A* and *B* are antonyms if and only if for all *X* and *Y* in their common domain *X* is more *A* than *Y* if and only if *Y* is more *B* than *X*.[6]

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4. In general, however (for any gradable adjective *A*), talk of *how A something is* may be severely misleading, since it suggests that for something to be *A* to a certain degree, it must already be *A*. However, this is not always so. One may ask of a short object how tall it is, for example, without falling into contradiction.

5. I say that an object *X* is in the *domain* of an adjective *A* if and only if the sentence "*X* is *m A*" is grammatical for at least some degree morpheme *m* (not necessarily the positive one) and that an object *X* is in the *extension* of *A* if the sentence "*X* is *positive-A*" is true. Thus for example, big objects are in the domain of the adjective "small" (because they are less small than big objects) without being in its extension.

6. I use upper case variables *X*, *Y*, etc. to refer both to terms in natural language and the objects that those term refer, indicating which one only in cases where confusion might arise. I will use upper case letters *A*, *B*, etc. to refer to adjectives.

For example, “big” and “small” are gradable antonyms because if (and only if) something is bigger than something else, then the later is smaller than the former. Presumably, this means that antonym adjectives share a single measure function. Thus, determining the length of an object, for example, tells us both how long and how short it is.[7] In more formal terms, the positive form of a gradable adjective *A* denotes a subinterval of its relevant scale S_A; this subinterval is determined by a *threshold value* δ_A on the scale. Given an adjective *A*, a scale S_A ordered by a relation $\leq_A$, and a threshold value $\delta_A \in S_A$, we define [*A*] to be the denotation of the positive form of *A* as follows:

(6) *Standard Account of Gradable Adjectives*: $[A] =_{\text{def}} \{x \in S_A : \leq_A(\delta_A, x)\}$

Thus, in order to derive the fundamental law of antonyms, we add the following constraint for gradable antonyms:

(7) *Gradable Antonym Constraints*: If *A* and *B* are antonyms, and $[A] = \{x \in S_A : \leq_A(\delta_A, x)\}$, then $[B] = \{x \in S_A : \leq_A^{-1}(\delta_B, x)\}$.

Sometimes, but rarely, the threshold degree necessary to be in the extension of the adjective’s positive form is minimal. For example, only objects with a zero (or very close to zero) degree of incompleteness are complete, and only objects open to a zero (or very close to zero) degree are closed. Gradable adjectives of this later kind are called “minimal absolute standard” (Kennedy & McNally 2007), “partial” (Yoon 1996, Rotstein and Winter 2004) or “existential” (Kamp and Rossdeutscher 1992). I will use this later term. Other examples of existential adjectives include “straight”, “whole”, etc.

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7. This does not mean that both adjectives are assigned the same denotation, for each one of them reverses the other’s order relation.

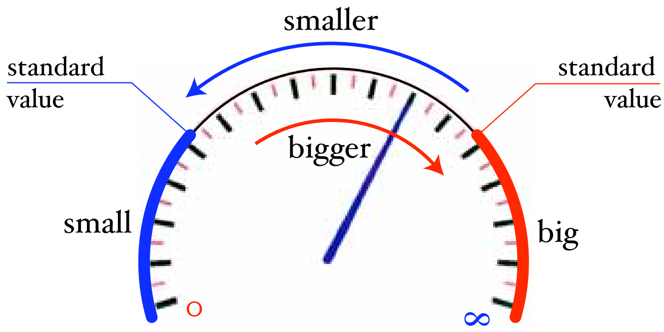

Fig.1. Non-complementary gradable antonyms

Most of the times, there are objects in an adjective's domain that are neither in its extension, nor in its antonym's extension. For example, not everything that is not pretty is ugly, and not everything that is not big is small. In cases like these, we say that the antonyms are not mutually complementary, i.e., that they do not jointly exhaust their domain. The standard model can account for this phenomenon by allowing some space between one adjective's standard value and the other's. Thus, an object can be neither dry nor wet if it is too wet to be dry (i.e., their degree of wetness is too high for them to be dry), but not enough to be wet (i.e., their degree of wetness is too low for them to be wet) (figure 1).

Most gradable antonyms are not complementary. However, some are, like "complete" and "incomplete", "truthful" and "untruthful", etc. (Rotstein and Winter 2004) These rare cases commonly involve an existential adjective and its negation. In those cases, the degree required to be in the extension of one of the adjectives is zero (or very close to zero) and it is enough for the degree to be higher than zero (or not very close to zero) to be in the extension of the other. For example, something is pure, only if it it has no degree of impurity, an it is impure if it has at least some degree of impurity. In this case, the complementary antonym of the existential adjective is called "maximal absolute standard" (Kennedy & McNally 2007), "total" (Yoon 1996) or "universal" (Kamp and Rosdeutscher 1992); from now on, this later term is the one I will use.

The standard account can easily accommodate complementary antonyms by simply making the standard values of both antonyms identical (figure 2):

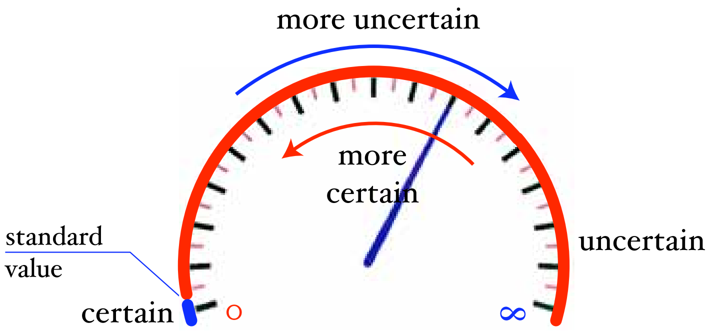

Fig. 2. Complementary gradable antonyms

(43) *Gradable Antonym Complementarity*: If A and B are complementary antonyms, and $[A] = \{x \in S_A : \leq_A(\delta_A, x)\}$, then $[B] = \{x \in S_A : \leq_A^{-1}(\delta_A, x)\}$.

II. The Semantic Structure of Color Adjectives

The model presented above has been very successful in accounting for the denotation of gradable antonyms. Thus, it would be fruitful if we could extend it to systems of more than two (mutually exclusive and jointly exhaustive) adjectives, like color adjectives. Under such proposal, color adjectives would have as their denotation functions from colored entities to degrees in an appropriate chromatic measure function. (For simplicity, as customary, we will focus on hues and simplify the function to values along a single dimension. The complete tridimensional model is offered in the appendix). For example, the denotation of "green" would be a function that assigns to colored objects their degree of greenness, i.e. how green they are. Thus, an object is greener than another, if its degree of greenness is higher than the other's; and an object is green, if it is green to a sufficient degree (fig. 3).

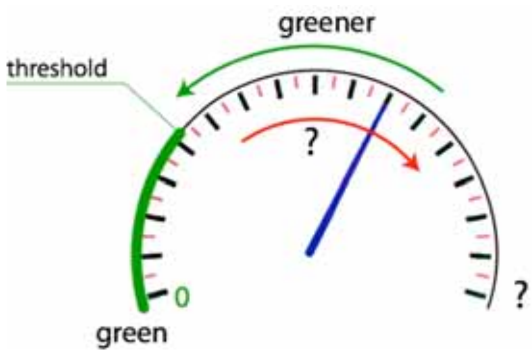

Figure 3. The traditional account of the denotation of color adjective "green"

As previously mentioned, color adjectives are not only gradable, but are also ordered, and this order affects the behavior of their comparative forms. For example, since green is between yellow and blue, no object *X* can be greener than another object *Y*, unless *Y* is either less yellow or less blue than *X*. Furthermore, all different color systems (i.e. the different systems of color adjectives, like Hering's system, Pantone, RGB, CMYK, etc.) respect the same chromatic order, so that for any three colored objects *x*, *y* and *z*, if for some color adjective *A*, *x* is more *A* than *y* and *y* is more *A* than *z*, then there is no other color adjective *B* such that *x* is more *B* than *y* and *z* is more *B* than *x* (Kay, Berlin and Merrifield 1991). This strongly suggest that hue is a single magnitude, partitioned into different color concepts. In other words, this suggests that when modeling the semantics of color adjectives, all color adjectives may share a single measure function *S* (with either one of two mutually inverse ordering relations $\leq$ or $\leq^{-1}$), and differ only in their threshold values:

(15) *Color as a Single Magnitude:* If *A* and *B* are color adjectives, then $S_A = S_B$ and either $\leq_A = \leq_B^{-1}$ or $\leq_A = \leq_B$.[8]

[8]. With a little caveat: The hue spectrum seems to be circular, so we must either adopt a conventional zero point to straighten out the spectrum, or use a circular scale like the one used to measure geometrical angles.

The hypothesis of color as a single magnitude is further bolstered by the fact that color adjectives, just as complementary antonyms like “open” and “closed” or “dirty” and “clean”, are also mutually exclusive and jointly exhaustive of their common domain.[9] Every colored thing is of one color, and everything that is of one color, is not of any other (salvo provisions for vagueness, perhaps, that I will ignore from now on).[10] The main difference between complementary antonyms and systems of adjectives like those used to describe color is that complementary antonyms share a single border. Each antonym borders the other and none other. This is not so for systems with more than two adjectives. Most of them border, not one but two other adjectives.[11] This means that, in order to determine the extension of each adjective in the positive form, the null morpheme must consider two standard values — a minimal standard value β and a maximal standard value δ — to determine the relevant interval of values that would fix the adjective's extension, as follows (figure 4):

(16) $[A] =_{def} \{x \in S_A : \leq_A(\beta_A, x)\ \&\ \leq_A(x, \delta_A)\}$

9. After Wittgenstein's seminal work on color, there has been significant debate on whether or not these facts are semantic and therefore the kind of things that a semantic theory ought to account for. Yet, the fact that they can be easily accommodated in a theory of denotation (as I intend to do here), and that they are structurally very similar to other doubtlessly semantic phenomena (i.e., the relation of antonymy) give us good reasons to believe that they are semantic indeed.

10. Besides, removing this idealization requires only a minor adjustment, i.e., making the minimal standard value of one color adjective different from the maximal standard of its adjacent color adjective (Rotstein & Winter 2004).

11. The lowest and highest value in a scale, if they exist, border only one other value. However, since hue is a circular spectrum, there is no strict lowest and highest value. Remember that we are currently consider only differences in hue, and we will deal with brightness and saturation on the appendix.

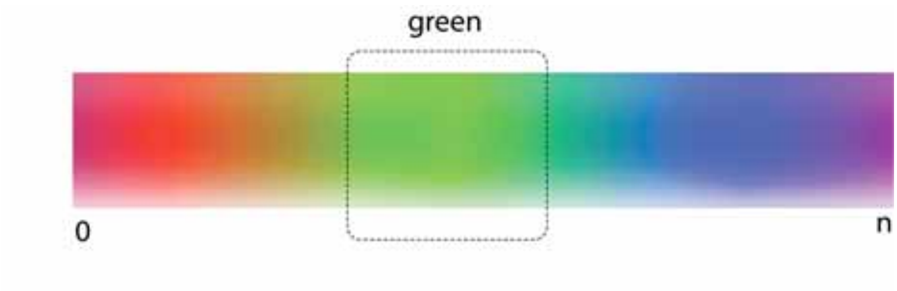

Fig. 4. The extension of positive "green" on the hue spectrum.

Once defined the adjective's denotation, the pressing question is how to determine the denotation of the comparative form of each color adjective in this proposal. The most straightforward way would be to make one object more *A* than another, for every color adjective *A*, if and only if the degree of *A* in one is larger than the degree of *A* in the other, as is usually done with pairs of antonyms:

(17) [*more A*] $=_{def}$ $\{(x, y) : \leq_A(x, y)\} = \leq_A$

However, adopting (16) and (17), together with the hypothesis that color is a single magnitude (15), has at least two undesirable results: first, objects that are not of color *X* would come out as more *X* than those that do. Notice, for example, that no matter how we order the spectrum, the relevant measure function will assign yellow objects higher or lower values than blue objects. Yet, we do not want to say that blue objects are greener than yellow ones, or vice versa. Furthermore, this undesirable result cannot be simply avoided by narrowing the domain of the measure function corresponding to each color adjective to only those objects that fall under its positive form (so that only green objects can have some degree of greenness, for example), since presumably we want objects that are not green, to be less green than those that are. However, we do not want some objects whose color has no green in them to be greener than others. For example, we do not want to say that yellow objects are greener than red ones, even if yellow is closer to green than red in the chromatic spectrum. This means that the denotation of "greener than" must also contain its own limiting standard value. The role of this standard value would be to limit the interval within which it still makes sense to compare greenness. The idea is that outside the determined interval, everything has zero degrees of greenness (without being all of the same hue):

(18) [*more A*] $=_{def}$ $\{(x, y) : (\underline{<}_A(\alpha_A, y) \underline{<}_A(y, \varepsilon_A)) \ \& \ \underline{<}_A(x, y)\}$

Ideally, the absolute values necessary to determine the extension of the positive form could also help in determining the extension of the comparative form:

(19) [*A*] $=_{def}$ $\{x \in S_A : \underline{<}_A(\beta_A, x) \ \& \ \underline{<}_A(x, \delta_A)\}$

[*more A*] $=_{def}$ $\{(x, y) : (\underline{<}_A(\beta_A, y) \ \& \ \underline{<}_A(y, \delta_A)) \ \& \ \underline{<}_A(x, y)\}$

This would mean that only objects in the extension of the positive form of an adjective *A* can be compared with respect of how *A* they are, i.e., color adjectives would be existential in Kamp and Rosdeutcher (1992) terminology, as characterized above. Anything that is not green would be uniformly less green than anything that is green, even if some green things are greener than others, for example. On this proposal, sentences of the form (21) and (21) would follow from sentences of the form (20), for any color adjective *A*:

(20) *x* is more *A* than *y*.

(21) *x* is *A*.

(22) *y* is *A*.

Unfortunately, there are two major problems with this proposal. First of all, if every color adjective were existential, no color adjective could border another one. This is so because the complement of an existential adjective cannot be another existential adjective, it has to be universal. An existential adjective applies to any object that has any amount larger than zero of the corresponding quality. Consequently, for an object to be outside its extension, it must have no amount of the quality. In other words, it would have to be universal. This means that an existential adjective cannot border another existential, it can only border an universal. Thus, if two color adjectives share a border, and one of them is existential, the other must be universal. Therefore, either color adjectives are not jointly exhaustive and mutually disjoint, or not all color adjectives are existential (*mutatis mutandi*, neither can they all be universal). However, the linguistic evidence does not show that next to every existential color adjective, there lays an universal color adjective (Kay et. al. 2010). Therefore, we must abandon (19).[12]

A second, related problem with the hypothesis that color adjectives are existential is that, at least for some color adjectives *A*, there are things that are not *A* yet they are more *A* than others. Remember that for every existential adjective *A*, if some object *X* is more *A* that another object *Y*, then *X* is *A*. That is why a sentence like (24) follows from (23):

(23) The water on the lake is less pure than the one on the tank.

(24) The water on the lake is not pure.

This is so because for an object *X* to be less *A* than another *Y*, *Y* has to be *A* to a degree larger than zero; and, since *A* is an existential adjective, all objects with a degree of *A* larger than zero are *A*. Therefore, *Y* must be *A*. For example, no closed door can be more open than

12. Someone may want to argue that "teal" is an universal adjective, sitting right between existential adjectives "green" and "blue". After all, it makes sense to talk about things being "bluer" or "greener" than others, but there is no comparative form of "teal". However, there are three problems with this reply. First of all, "teal" does not seem to be gradable, i.e., it does not accept degree morphology well. We commonly do not talk of things being "too teal" or "less teal", etc. Second, there is evidence that one may still say of some objects that are bluer than teal that they are at least a little green. This is incompatible with "teal" marking the edge of comparative greenness. A way to account for this is to appeal to differences in precision among scales (Stanford 2008), so that "green" and "teal" belong to different color scales, one coarser than the other. Just like height can be coarsely measured using comparative adjectives like "short" and "tall" or using a more precise scale, like that of centimeters; so can hue be measured using the coarse scale of gradable color adjectives, or any of the more precise scales devised for this purpose. "Tall" and "1.25m" are height adjectives of different scales. As such, none of them can border the other. In a similar fashion, "green" and "teal" are color adjectives belonging to different scales. Thus, they cannot share a border. The final problem with this reply is that it is not generalizable to other adjacent pairs of comparative color adjectives. There does not seem to be any analogous universal adjective between "red" and "orange", or between "green" and "yellow." This gives us good reason to believe that no gradable color adjective is existential (or universal, for that matter).

another (even if this later is not open as well), and clearly neither (25) nor (26) are grammatical:

(25) # This door is not open, but it is still more open than that one.

(26) # This closed door is more open than that one.

Yet, this is not what happens with color adjectives. Suppose we are faced with two color swaths. One is the greenest of the greens, while the other is still green, but not the greenest. It is noticeable yellower than the greenest green, but not yellow enough not to be green. In this context, utterances of sentences (27) and (28) are certainly felicitous:

(27) The second color swath is not yellow, but it is still yellower than the first one.

(28) The second green color swath is yellower than the first one.

For (27) and (28) to make sense, it must be possible for a color swath to be yellow to a degree higher than zero and yet not reach the minimal degree of yellowness required to be yellow, i.e. its semantically encoded minimum standard. In other words, "yellow" cannot be an existential adjective.[13] Consequently, it seems like color adjectives are neither existential nor universal, and therefore closer in semantic behavior to gradable adjectives like "big" or "warm" that do not form complementary antonyms, than to adjectives like "open" and "closed" that do. Notice that, unlike (25) and (26), and like (27) and (28), (29) and (30) are grammatical:

(29) My house is not big, but it is still bigger than yours.

(30) It is warmer in here, but still cold.

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13. Here is an actual quote from a scientific article, where "yellower" is used in a clearly not existential way: "Levulose gives a distinctly red hue, mannose produces a red somewhat yellower than that given by levulose, the color from glucose is blue-red, while galactose gives a color bluer than that of levulose and mannose but yellower than that of glucose." (Foulger 1932, 11). Also, commercial color company Leeward (http://www.leewardpro.com/pricing/standard-colors-macintosh.html) explicitly describes violet as "bluer than purple". Since violet is not blue, being bluer than something is not enough for being blue. Therefore, "blue" is not an existential adjective either.

This means that, in order to determine the extension of gradable color comparatives, we must reject (19) and keep (16) for the positive form and (18) for the comparative. This means that, for every color adjective A, besides the values fixing where in the spectrum the adjective stands (β and δ), we also need extra standard values for where in the spectrum it makes sense to compare how *A* something is (α and ε).

Besides the need for those two extra standard values (α and ε), assigning a denotation to comparatives still requires one further standard value, given the fact that chromatic color adjectives border not one, but two different color adjectives.[14] Consider color adjective "green". It borders both with yellow and blue. This means that no matter in what direction we move across the color spectrum, we may be getting greener for a while and then, after reaching the greenest value, start decreasing in greenness as we keep moving ahead. Thus, a fifth standard value (ϒ) is required to mark the spot where the order of greenness must be inverted, corresponding to the greenest hue in the spectrum (figure 4).

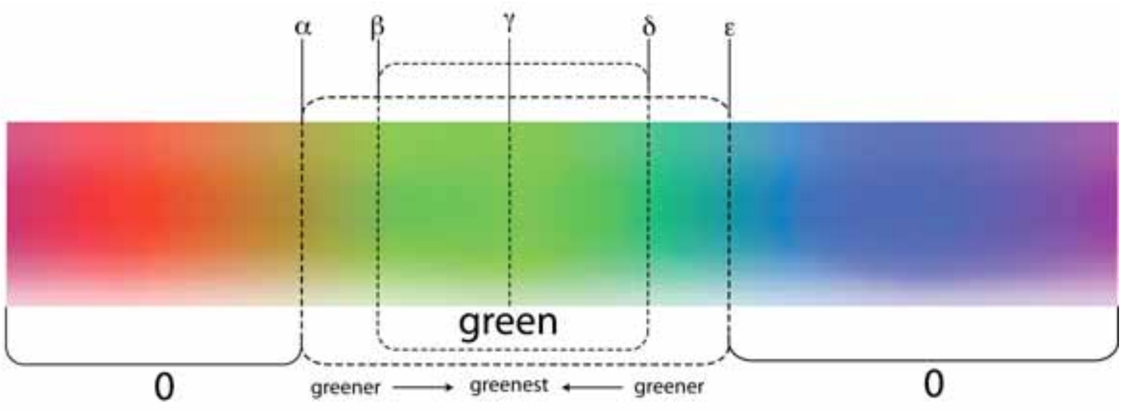

Fig. 4. The five standard values required for the comparative (α, γ, and ε) and positive (β and δ) modes of "green".

Once the five standard values are in place, it is easy to determine the extension of both the positive and comparative forms. For an object to be green, for example, its value must lay between β and δ. For an object *X* to be greener than *Y*, the value of *X* must (i) lay between α

14. Unlike non-chromatic adjectives like "white" and "black" that do not correspond to any hue. See the appendix on how to accommodate them within the present proposal.

and ε and, (ii) if the value of *Y* is lower than γ, *X*'s value must also be lower or equal than γ, but higher than *Y*'s, and (iii) if the value of *Y* is higher than γ, *X*'s value must also be higher or equal than γ, but lower than *Y*'s, as follows:

(31) $[A] =_{def} \{x \in S_A : \leq_A(\beta_A, x) \ \&\ \leq_A(x, \delta_A)\}$

(32) $[more\ A] =_{def} \{(x, y) : [(\leq_A(x, \gamma_A) \ \&\ \leq_A(\alpha_A, y) \ \&\ \leq_A(y, \gamma_A)) \supset \leq_A(x, y)] \ \&\ [(\leq_A(\gamma_A, x) \ \&\ \leq_A(y, \beta_A) \ \&\ \leq_A((\gamma_A, y)) \supset \leq_A(y, x)]\}$[15]

Notice now that if we focus on the first conjuncts of (31) and (32) (corresponding to the left half of figure 4), we get a pair denotation functions (33) and (34) very similar to those of a non-complementary gradable adjective (6) and (13):

(33) $[A] =_{def} \{x \in S_A : \leq_A(\beta_A, x)\}$

(34) $[more\ A] =_{def} \{(x, y) : (\leq_A(x, \gamma_A) \ \&\ \leq_A(\alpha_A, y) \ \&\ \leq_A(y, \gamma_A)) \supset \leq_A(x, y)\}$

Furthermore, once we consider that standard value α corresponds to the zero degree of *A* and γ to its maximum value, we may reduce (34) to (35), which is just (13) above:

(35) $[more\ A] =_{def} \{(x, y) : \leq_A(x, y)\} = \leq_A$

This means that each of the conjuncts of denotation functions (31) and (32) (corresponding to the left and right sides of figure 4) matches the denotation functions of a regular gradable adjective. Consequently, when we put both conjuncts together, what we get is no longer a single measure function, but two. Thus for example, the denotation of color adjective "green" is not a single measure function for greenness, ordered from the least green to the greenest, but two measure functions, each one with its own order and standard values: one from green towards yellow, and another from green towards blue (figure 5). Under this interpretation, for an object to be in the extension of the positive form of "green", it would have to surpass one of the standard values in one of the measure functions (β or δ), and for a pair of objects *x* and

15. Notice that since it is possible that the distance from standard value Υ to δ be different from its distance to ε (similarly for its distance to β and α), one cannot reduce both conditions to a single condition that only takes in consideration absolute distance from Υ.

y to be in the extension of the comparative form of the same adjective, *x* would also have to be higher than *y* in at least one of the associated measure functions (from α to γ or from ε to γ). In other words, to be green, an object must be either green-rather-than-yellow or green-rather-than-blue, and for it to be greener, it must be either greener-rather-than-yellow or greener-rather-than-blue.

Consequently, the data suggests that the best way to model the semantics of color adjectives is by taking adjacent color adjectives pairwise and give each pair the usual treatment of other gradable antonyms. This way, a single measure function (with inverted orders, as usual) can be given to, for example, yellow and green, and another one for yellow and blue. Since each color adjective will belong to two of these adjacent pairs, the denotation of each color adjective would be not one, but two functions from objects in their different domains (disjoint except for their common highest value)[16] to values in two different measure functions (each one with its own ordering relation).[17]

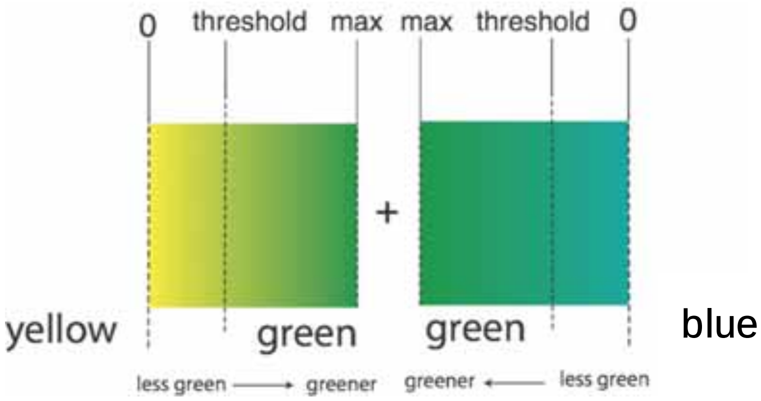

Fig. 5. Green = green-rather-that-yellow + green-rather-than-blue

16. Most likely corresponding to *pure* colors (Miyahara 2003, Hurvich & Jameson, 1957; Hering, 1964)

17. Notice that the model I am proposing allows for cases where, for example, green objects with a little yellow in them might be considered greener that blueish green objects. As long as standard value γ remains contextually determined, we can accommodate this kind of cases moving γ around so that the objects under comparison both fall on one of its sides. That way, we can make sense of why, when comparing objects close to the extreme of each measure function (for example, an object of a green hue with almost no yellow in it in comparison to a blue object with just a little green in it), it seems natural to say that one is greener than the other.

Finally, since both measure functions are independent of each other, it is sensible to conclude that they actually correspond to two different properties. Since there is no single measure function that determines how green an object is, it is better to take each measure function as determining two different values of two different properties: one for how green-rather-than-yellow an object is and another for how green-rather-than-blue it is. Thus, we might still talk of hue as a single magnitude (15), divided into different regions corresponding to each adjacent pair of chromatic color adjectives: orange-yellow, yellow-green. green-blue, blue-purple, etc. In each region, the relevant pair of adjectives will behave as a pair of antonyms. Thus, for example, for any pair of objects *x* and *y* within the yellow-green region, *x* is more yellow than *y* if and only if *y* is less green than *x*, and vice versa. In general, we can obtain a laws for color antonyms that is analogous to (5) above, but does justice to the fact that color antonyms, unlike regular gradable antonyms, border not one but two other color adjectives:

(36) *Color Antonyms:* For every color adjective *A*, there are two other color adjectives *B* and *C* such that *x* is more *A* than *y* only if *y* is more *B* than *x* or *y* is more *C* than *x*.

This way, we have a simple and elegant model that is both similar and adequately different from the standard models for gradable adjectives. It accommodates the special features that distinguish color adjectives from other gradable adjectives, while keeping as much of the traditional account as possible.

3. Conclusions

Color adjectives are sui-generis among gradable adjectives, for they lack natural antonyms. In this paper, I have proposed and defended an also very sui-generis account of their denotation, according to which adjacent colors play a similar role regarding color adjectives than regular antonyms do with regards to other gradable adjectives. Since each color adjective has two different adjacent colors, one at each side of the color spectrum, its denotation will be not one, but two measure functions, each one with its own order and standard values. In this proposal, for example, the denotation of "green" would be two measure functions. The first one would assign zero to all things yellow (orange, red, etc.) and its maximum value to focal green things. The second function would assign zero to all things blue (purple, red, etc.) and its maximum value to focal green things. Based on this denotation, we could fix the semantics of the comparative and non-comparative modes in such a way that for an object to be green, it would have to surpass at least one of the standard values for any one of the measure functions, i.e. it must be either sufficiently green-rather-than-yellow or green-rather-than-blue. Similarly, for an object *X* to be greener than another object *Y*, *X* would have to be assigned a higher value than *Y* by at least one of the associated measure functions. This semantics is, on the one hand, a natural extension of the traditional denotational semantics of other gradable adjectives, and fitting to the special features of color adjectives.

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Appendix: Beyond hue

The denotation of color adjectives does not only depend on differences in hue. Sometimes, what distinguishes color adjective *A* from color adjective *B* is not their hue, but also their brightness and saturation. Think of the difference between basic chromatic color "red' and composite colors like "pink" or "brown". Even though it is still a matter of controversy how many parameters determine the denotation of color adjectives (Hunt 2007), I will offer here a tri-dimensional model of color space, adding the aforementioned two dimensions (brightness and saturation) to the hue model above, as an example of how the model might be extended to accommodate whatever dimensions are necessary to account for the semantic behavior of our color adjectives. Unlike hue, *brightness* and *saturation* do not form circular spectrums, so they can be modeled by a simple scale from zero to some arbitrary natural number *n*. Thus, every point on the chromatic scale must be modeled by three values: one for hue, another for brightness and a third one for saturation.

In order to incorporate these new dimension and account for their relevance for determining the denotation of our color adjectives, the theory needs to be made a little more complex. For the positive form, the adjustment is minimal; all that is required is to add a new pair of standard values for each new dimension:

$$(37)\ [A] =_{\text{def}} \{<x_1, x_2, x_3> \in S_A : [\underline{\leq}_A(\beta_A, x_1) \ \&\ \underline{\leq}_A(x_1, \delta_A)]$$
$$\&\ [\underline{\leq}_A(\zeta_A, x_2) \ \&\ \underline{\leq}_A(x_2, \varsigma_A)]$$
$$\&\ [\underline{\leq}_A(\eta_A, x_3) \ \&\ \underline{\leq}_A(x_3, \vartheta_A)|\}$$

The tricky part, of course, is to adjust for comparatives. The model I will offer now is based on the hypothesis that a full account of the comparative form of color adjectives must take in consideration, not only differences in hue, but also differences in saturation or brightness. As mentioned above, we must respect the dictum that we cannot compose differences on different dimensions and compare across magnitudes. In particular, we cannot say of two objects whether or not one is more-*A* than another (for some color adjective *A*) if one is higher on the *A* scale for one dimension, but lower in a different one. Consequently, we can only say of one object that it is more-*A* than another if it is higher on the *A* scale for some dimension and for every other dimension, it is also higher than the other or at least very close in value:

(38) $[more\ A] =_{def} \{(<x_1, x_2, x_3>, <y_1, y_2, y_3>) :$

$[[(\leq_A(x_1, \gamma_A) \ \&\ \leq_A(\alpha_A, y_1) \ \&\ \leq_A(y_1, \gamma_A)) \supset \leq_A(x_1, y_1)]$

$\&\ [(\leq_A(\gamma_A, x_1) \ \&\ \leq_A(y_1, \beta_A) \ \&\ \leq_A((\gamma_A, y_1)) \supset \leq_A(y, x_1)]$

$\&\ [((x_2 <_A y_2) \vee (/x_2 - y_2/ \leq_A \theta)) \ \&\ ((x_3 <_A y_3) \vee (/x_3 - y_3/ \leq_A \xi))]]$

$\vee\ [(/x_1 - y_1/ \leq_A \mu) \ \&\ ((x_2 <_A y_2) \ \&\ ((x_3 <_A y_3) \vee (/x_3 - y_3/ \leq_A \xi))]$

$\vee\ [(/x_1 - y_1/ \leq_A \mu) \ \&\ (/x_2 - y_2/ \leq_A \theta) \ \&\ (x_3 <_A y_3)]\}$

Where μ, θ and ξ are (most likely, contextually determined) standard values close enough to zero representing how similar in hue, brightness and saturation should two colors be for their difference to be negligible.

Differences in brightness and saturation can also be marked by the use of modifiers like “bright”, ‘light”, “dark”, “saturated”, etc. For example. the denotation of *dark A* would be something like the following*:*

(37) $[\text{dark } A] =_{def} \{<x_1, x_2, x_3> \in S_A : [\leq_A(\beta_A, x_1) \ \&\ \leq_A(x_1, \delta_A)]$

$\&\ [\leq_A(\zeta_A, x_2) \ \&\ \leq_A(x_2, \varsigma'_A)]$

$\&\ [\leq_A(\eta_A, x_3) \ \&\ \leq_A(x_3, \vartheta_A)|\}$

Where $\varsigma'_A < \varsigma_A$, so that the brightness of *dark A* is lower than that of *A*.

Finally, we can use the brightness and saturation dimensions to incorporate non-chromatic (non-gradable and universal) color adjectives like “white”, “black” and “grey”: “grey” being the color of the least saturation, “black” the color of least brightness and “white” the color of highest brightness.

(39) [*grey*] $=_{\text{def}} \{<x_1, x_2, x_3> \in S_A : \leq_A(x_3, 0)\}$

(40) [*black*] $=_{\text{def}} \{<x_1, x_2, x_3> \in S_A : \leq_A(x_2, 0)\}$

(41) [*white*] $=_{\text{def}} \{<x_1, x_2, x_3> \in S_A : \leq_A(x_2, max)\}$