The Scarcity of Universal Colour Names

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Abstract: There is a trend in Computer Vision to use over twenty colour names for image annotation, retrieval and to train deep learning networks to name unknown colours for human use. This paper will show that there is little consistency of colour naming between languages and even between individuals speaking the same language. Experiments will be cited that show that your mother tongue influences how your brain processes colour. It will also be pointed out that the eleven so called basic colours in English are not universal and cannot be applied to other languages. The conclusion is that only the six Hering primary colours, possibly with simple qualifications, are the only ones you should use if you aim for universal usage of your systems. That is: black, white, red, green, blue, and yellow.

1 INTRODUCTION

Under ideal conditions, humans can perceive over four million different colours. But how many can we consistently *name?*

This question is important when computer vision and pattern recognition interacts with humans and colour is involved. Examples are using deep learning (or other methods) to name unknown colours or, more frequently, to use colour names for image annotation and retrieval. A seminal paper is (van de Weijer et al., 2009) that uses up to 22 English colour names for these purposes. This paper has been much cited and the many colour names in it are often used.

However, the colour names people use are not universal and depend on many circumstances, e.g., the culture and language in which the person grow up and her interests and hobbies. I will show that there is very little consensus on how to name the parts of the human colour gamut. What is azure to one may be simply blue to another and be the same colour as grass to a third. There is even clear evidence that your mother tongue influences how your brain processes colour, even when no naming is involved.

In view of the non-consensus of colour names, the trend of using many colour names in computer vision and pattern recognition becomes problematic.

How meaningful are the deeply learned names for people who were not themselves first trained to "correctly" name the colours the researchers chose? How well will images be retrieved if users are allowed to freely use their own colour names or do not understand the imposed English names? These are the questions this paper aims to answer.

When discussing colour names most linguists use the Munsell colour chips, Fig. 1. Colour hues are divided into 40 steps, denoted 1-40 from red to red, and for each hue there are eight lightnesses denoted B-I. Saturation is always maximal. A greyscale in ten steps, A-J, is also included. There are thus 330 chips.

Each colour name has a *focus*, i.e., the most typical Munsell chip for that colour; and a *range*, i.e. all chips that can be called that colour.

Section 2 will briefly describe human colour vision, historical and current colour linguistics, and give an insight in personal colour names. Section 3 will describe three experiments that show that your colour naming system influences how your brain responds to colour stimuli. Finally, Section 4 will contain conclusions and recommendations.

2 COLOUR NAMING

2.1 Human Colour Vision

Humans have three colour opsins in the retina, S(hort), M(edium), and L(ong), where length refers

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to light wave-length. S, M, and L cones are most sensitive to purple, green, and greenish yellow, respectively. The signals from the three opsins are combined in the retina before they are sent on to the brain in three channels: the M+L channel that measures "lightness;" the M-L channel that measures "redness;" and the S-(M+L) channel that measures "blueness."

Ewald Hering studied human colour vision and came up with six "Urfarben" (primary colours), (Hering, 1878). He based these on his knowledge of human perception and our "ghost" colour after images. After having stared for a time at a red square on a white background, we briefly see a ghostly green square when the red one is suddenly removed. The same is true for blue/yellow and white/black. These three pairs are closely linked to the three colour channels in the optic nerve, even though they had not been discovered at that time.

2.2 Early Colour Linguistics

The study of colour names across time and cultures started in the second half of the 19th century (Biggam, 2012). The first publication was (Gladstone 1858) (written while William Gladstone took a break from British politics). He was intrigued by the scarcity of colour terms, and the strangeness of those used, in Homer's works (e.g., green honey, violet sheep). Lazarus Geiger, how knew very many ancient and modern languages, made the same observation for Indian Vedic Poems in Sanskrit; Old Testament in Hebrew; Quran in Arabic; and Sagas in Icelandic (Geiger, 1869). The general conclusion, made possible by the recent theory of evolution, was that full colour vision had evolved very recently in human history.

At this same time linguists, anthropologists, and missionaries studied the languages of "primitive" tribes and discovered that many of them had few and confusing (to the Europeans) colour concepts, just as the ancients. Therefore it was concluded that they had not developed full colour vision either.

After a train accident in 1875 Sweden, that was caused by a colour-blind driver mistaking the red stop signal for green, Fritiof Holmgren (Holmgren, 1877), devised a simple test for colour blindness, using differently coloured yarns. The test became widely used, not only to improve traffic safety, but also to determine that "primitive" people had perfect colour vision.

The conclusion was that colour naming completely is random and *only* depends on culture. Research in colour linguistics stopped for a long time. However, all humans that have all three colour opsins have very similar colour perception. Should that not lead to similarities in how the colour space is divided?

2.3 Basic Colour Terms

In 1969 the area of colour linguistics restarted with (Berlin and Kay, 1969). Their study was based on many, mostly North and South American, languages.

A key concept is the *Basic Colour Terms* (BCT) present in a language. A BCT should fulfil many conditions, the most important being:

- Meaning is not understood from itself (yellow vs. lemon)
- Cannot be contained in a larger category (red vs. scarlet)
- Can be used for everything (yellow vs. blonde)
- Consensus among native speakers
- Adapts to grammar (greener vs. "avocadoier")
- High frequency in speech and writing
- Not a recent loan word
- Short response time for naming

The very few languages with only two BCTs only distinguish dark/cold colours from light/warm colours. The Dani in New Guinea use such a language, where *mili* is used for black, dark and cold colours with focus in dark blue or dark green; and *mola* is used for white, light and warm colours with focus in pink or dark red, (Heider, 1972).

A much earlier study (Almqvist, 1883) of the Chukchis of Siberia discovered that they had three BCTs (although the term was not used then): *nukin*, focus black, *nidlikin*, focus white, and *tschetlju*, focus red.

Based on the conditions above, place names from a road atlas (Motormännen, 2011) and plant names from a flora (Lid, 1974) I consider my own language Swedish to have eight BCTs. In place names the colours black, green, and red are most common, while for plants names they are yellow, white, and blue. Grey and brown are also significantly present in both categories. All other colours are very rare.

The Americans Berlin and Kay took English as the standard for *all* languages and identified eleven BCTs. In addition to the eight Swedish ones they list pink, orange, and purple, see Fig. 1 again for English BCT foci. All languages investigated so far has from two to twelve BCTs – eleven is not universal.

Regularities between languages that cannot be explained if colour naming is completely random were described in (Berlin and Kay, 1969), but some of the conclusions have been superseded by later studies including more languages, see the next Subsection.

2.4 The World Colour Survey

After the restart of colour linguistics researchers went all over the world collecting colour naming systems from as many languages as possible using the Munsell chips in a standardized way. In 2009 the World Color Survey was published (Kay et al., 2009) (the same Paul Kay 40 years later), presenting the results for 110, mostly pre-industrial, languages from all over the world. For each language the focus and range for all BCTs, as roughly agreed by a number of informants, are marked on the chip chart.

Note that in the following I use English colour names, like BLACK, not as BCTs, but as rough indications of the colour ranges of the BCTs of different languages.

Languages are divided into five stages, I-V, depending on the number of BCTs. Stage I have two BCTs and stage V six or more.

There are no Stage I languages in the World Colour Survey, but several Stage II. The amazing discovery is that *all* of them divide the chips in roughly the same way, into BLACK, WHITE, and RED, just like the Chukchi. An example is shown in Fig. 2. If colour naming was completely random, this would not be the case.

Languages with four BCTs divide colour space in different ways, but the divisions are still not random. Except for a very few cases, all languages follow one of five "paths," A-E, see Fig. 3.

The most common Stage III is III^{A} which have WHITE and RED, but divides BLACK into BLACK and "GRUE." Including both green and blue colours in a single BCT is so common that linguists have invented the term grue to denote it.

The other common possibility for Stage III, III^{BC}, is to divide RED into RED and YELLOW and keep all dark, cold colours together. Indications show that Proto-Indo-European, that was spoken on the steppes north of the Black and Caspian Seas about 10,000 years ago and is the ancestor of almost all European and many Middle East and Indian languages of today, was Stage III^{BC} (Biggam, 2012).

There are also a few Stage III^{DE} languages where the four BCTs are WHITE, BLACK, RED, and "everything else," see Fig. 4.

In Stage IV^{A} YELLOW is split from RED. In Stage IV^{B} BLACK splits into BLACK and GRUE, while in Stage IV^{C} BLACK is divided into BLACK and GREEN.

This is how the Vikings talked: all dark and blue colours were called "blå," i.e., blue. Thus they called Africa "Blueland" where the "blue men" lived!

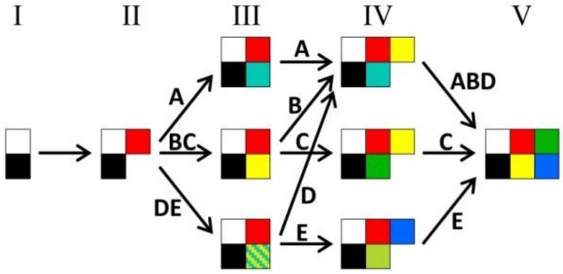

Figure 3: The five paths of colour naming that describes almost all of the very many languages investigated. See the text.

Stage IV^{D} is IV^{A} again, while IV^{E} divides the "everything else" into BLUE and yellow+green.

Finally all Stages join in V, where all the Hering primaries are BCTs. With more BCTs there is so little regularity that all attempts of finding "paths" have been abandoned.

It should perhaps be noted that grey is a special case, which can be present as a BCT in earlier Stages than V.

Thus it does seem that human vision has an influence on colour naming after all, as in all known languages with enough BCTs the Hering primaries are BCTs. Also, the borders between BCT ranges tend to be in about the same places, when they are present at all.

2.5 Blue

As already mentioned, many languages place green and blue colours into one BCT, denoted grue. This is the case for all Celtic languages, e.g., Welsh, Irish, and Breton and many African ones, like Bété and Zulu. Until very recently Japanese was also a grue language, although it seems at present to be moving towards separation. Of course green and blue *can* be distinguished also in grue languages, by, e.g., saying "grue like grass" and "grue like sky."

A few languages with twelve BCTs exist, to the English-speaking linguists' surprise. The most cited example is Russian, which divides English BCT blue into синий (siniy) for dark blue and голубой (goluboy) for light blue. As we will see later, this divide actually influences Russian brain organisation. Linguists seem not completely convinced, but Italian blu (dark blue) and azzurro (light blue) should perhaps also be considered BCTs? Another twelve BCT language is Hungarian that separates English BCT red into dark red and light red.

The paper that inspired this one (van de Weijer et al., 2009) lists blue, cyan, turquoise, and azure as useful BLUE terms among their 22 colour names.

(Strangely not indigo, that is traditionally one of the colours of the rainbow.) Only blue is an English BCT while the other three are included in the blue BCT range. Having one colour term that includes three others, and then considering all four separate is both illogical and confusing.

2.6 Personal Colour Names

In the previous Subsection differences between languages were discussed. In this one the focus is on differences between individuals. The colour names used vary considerably within the same language depending on age, sex, education, being mono- or multi-lingual, urban or rural... So, how many colour names does a person usually use? And how many colours can they remember?

One way of sorting colour names is dividing them into four groups: 1: BCT (green), 2: qualified BCT (dark green), 3: qualified fancy (spruce green), and 4: fancy (avocado), (Biggam, 2012).

It is often said that women are better at colours than men. A 1977 American study (Rich, 1977) using 25 Munsell chips showed that men and nuns mostly use categories 1-2, while other women mostly use categories 3-4. Other studies have showed similar results. Just like the scholars in the 19th century thought the ancients colour-blind, this has resulted in the myth that women have better colour vision than men. This is as false as the earlier myth. That colour blindness is more common in men and a few rare women do have superior colour vision (Jameson et al., 2001) does not affect the waste majority of both sexes that has normal colour vision.

Two more recent studies of young people have showed no sex differences for university students and teenagers in USA (Smith et al., 1995, Machen, 2002), so this difference between the sexes may be disappearing. Earlier sex differences are thought to reflect women's greater interest in colours for hobbies and appearance.

An interesting study is (Derefeldt and Swartling, 1995) that addresses colour naming and colour remembering. The purpose was to investigate how many colours a person can remember correctly, if they are allowed to name the colours themselves. In the learning session the subjects were shown a set of 35 colour chips on a normalized colour display and asked to name and remember each colour. In the identification session only one colour was shown on the screen and the subjects asked to name it. The subjects could then correctly identify 30-35 colours, with a median of 32.5.

This was a study where subjects were allowed about half an hour for training. Other studies have showed that with intense training it is possible to remember many more colours (Derefeldt, 2007), but it could be argued that this study shows the approximate number of remembered colours for the average person. If everybody agreed on the *same* thirty colours the over twenty in (van de Weijer et al., 2009) would be reasonable, but this is not the case.

Also interesting are the names used by the subjects in the study. It was done in Swedish, so they are translated here and in the report. The only unqualified BCT (group 1) used was brown. Qualified BCTs (2) were also rare, but a few like "dark yellow" and "medium grey" were used. The most common category was qualified fancy (3), e.g., "flag blue," "pigeon blue," "thunder blue," and "midnight blue." The oddest was "Elvis green" (from the cover of an Elvis record). There where also some fancy names (4), such as "cerise," "plum," and "jade." Some names were obviously invented during the test, showing that the subjects did not have enough colour names in their vocabularies for the 35 chips.

Another observation is that the authors Derefeldt and Swartling use the English BCTs without comment even though they are *not* suitable for Swedish. The most obvious problem is the authors' attempts to squeeze the many different colour terms for "blue-red" used by the subjects (showing there is no suitable Swedish BCT here) into the English BCT purple. There were also problems with English BCT pink, which one subject called "white-red." Even though this is a single case, further investigations would probably show that many other modern languages do not fit in the English Procrustes bed.

3 EXPERMENTS

3.1 Russian Blues

In this experiment (Winawer et al., 2007) English and Russian subjects were shown a big blue square with two smaller blue squares beneath it, see Fig.5 left. The task was to, as quickly as possible, determine if the left or right small square was equal to the big one. For English subjects, for whom all colours were covered by the BCT blue, the decision time was linearly dependent on the distance between the colours: the more different the colours the faster. For Russians, for whom the lighter blues are in BCT goluboy, while the darker ones are in BCT siniy, the results were different. They were faster when the colours were in different BCTs even if the colour distance was the same as within a BCT.

The test was repeated, but this time the subjects had to repeat out laud a string of random numbers, thus occupying the brain's linguistic centre. This time, also the Russians' decision times were dependent only on colour distance. The linguistic classification of colours does determine how the colours are perceived, even when no names are involved.

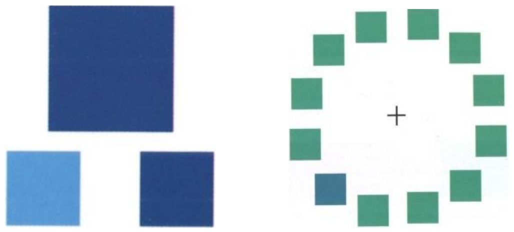

Figure 5: The set-up for the "Russian blues" (left) and the "Brain divided" (right) experiments. From (Winawer et al., 2007) and (Gilbert et al., 2006).

3.2 A Brain Divided

Most language processing is done in the left hemisphere of the brain. Therefore, (Gilbert et al., 2006) devised a test to see if there is a difference between the hemispheres regarding colour perception.

As they had English subjects, they used the green-blue BCT border instead of the siniy-goluboy one, but otherwise the test was similar to the previous one. A ring of small green or blue squares, see Fig. 5 right, were shown to one hemisphere of the brain (this is not very difficult to arrange, as the left half of the retinas of both eyes communicate with the right hemisphere and vice versa). In this way, they could investigate if language has an influence on colour handling even when using only one language. One square was different and the task was again to determine if it was on the left or the right side of the ring.

The results were clear. When the left hemisphere saw the colour patches, the response time was shorter when the two colours were on different sides of the blue-green border, while no such difference was noticeable for the right hemisphere. Again, proof that your mother tongue influences how your brain processes colour.

3.3 In Focus or Out

In the previous tests response time was used as a measure of brain activity. In the experiment by (Tan et al., 2008) brain activity was measured directly using Magnetic Resonance Imaging of the subjects' brains. The language used was Mandarin Chinese.

The experiment used six colours: red, green, and blue, that are BCTs in Mandarin, close to their foci and thus easy to name; and "brown," "grey," and "beige" that are not Mandarin BCTs and difficult to name, see Fig. 6.

First, two squares were shown for a split second and the task was to determine if they were equal or not by pressing a button. No language task was thus involved. For the easy to name BCTs two small areas in the cerebral cortex of the left hemisphere were activated, while for the non-BCTs those areas were inactive.

In the second test, the subject was shown one colour and asked to say the name out loud. This time, the two previously identified small areas in the cortex lit up brightly, thus being very active, for all colours. They are apparently the areas in the brain most involved in colour naming. The test shows they are involved in colour processing of BCTs, but not other colours, even though no colour naming task is going on!

The conclusion of the three experiments is that speakers of different languages probably do perceive colours slightly differently, after all. Gladstone and his contemporaries did have a point, not because of different colour vision, but because different cultures and languages wires our brains differently.

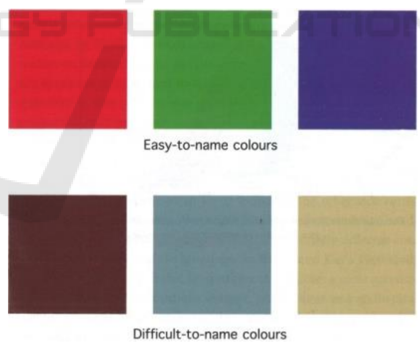

Figure 6: The colours used in the Chinese MRI brain activation test. From (Tan et al., 2008).

4 CONCLUSIONS

I have showed that colour foci and ranges vary considerably between cultures and languages, even though the divisions between BCT ranges are similar when they occur al all. I have also shown the colour names we use vary a lot between individuals even in same culture. The (Derefeldt and Swartling, 1995) study shows as a meta-result the dangers of using the eleven English BCTs as universals.

The experiments cited shows that the colour naming system we grew up with even has consequences for brain organisation, thus influencing our colour processing and perception.

When using colour names in computer vision and pattern recognition applications involving persons not specifically trained to recognize and name the colours used, it is thus best to stay with very few colours. The Hering primaries seem safe enough.

It should also be remembered that although a trained person can remember and identify up to 500 colours, a stressed human can identify only *three or four* colours (Derefeldt, 2007). The latter discovery has, e.g., influenced the designs of displays in fighter aircraft.

It is, by the way, probably no coincidence that the basic heraldic colours used over the centuries in Europe and elsewhere – *or* (gold/yellow), *argent* (silver/white), *azure* (blue), *gules* (red), *sable* (black) and *vert* (green) – are exactly the Hering primaries. Experience had shown that these colours were easy to distinguish, especially since only metal on colour or vice versa was allowed.

Qualifying the six primaries using lightness and saturation is probably also safe, e.g., “light green” and “dark green,” or “vivid red” and “dull red.”

Repeating the questions from the Introduction: How meaningful is it to use many colour names in applications intended for general, untrained, users? It will not be clear for everybody which Munsell chips can be called “azure,” especially if you mother tongue is not English – and is English azure the same as Italian azzurro? Which images will be retrieved using “flag blue?” Woad blue as the Swedish or Ukrainian flag or indigo blue as the British or French?

I suggest results can be disappointing and frustrating if the reality of the non-standardization of colour names is not taken into account.

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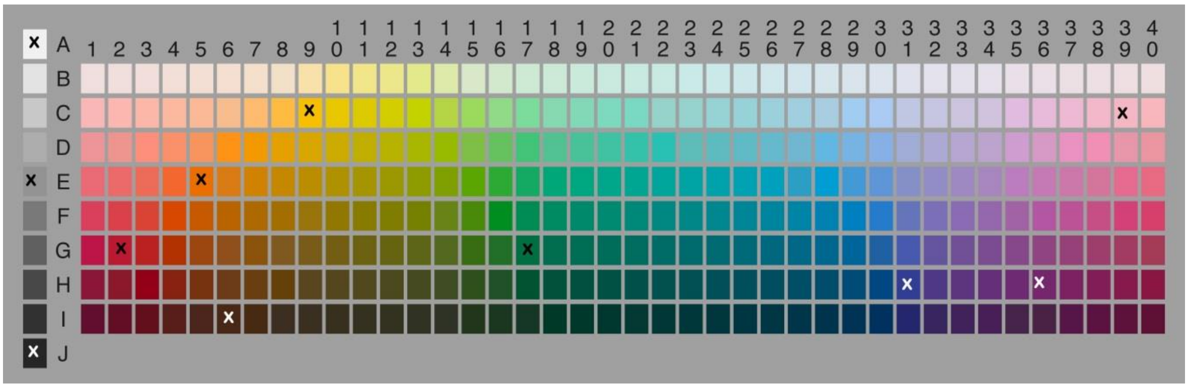

Figure 1: The Munsell colour chips with the approximate foci of the English Basic Colour Terms (x).

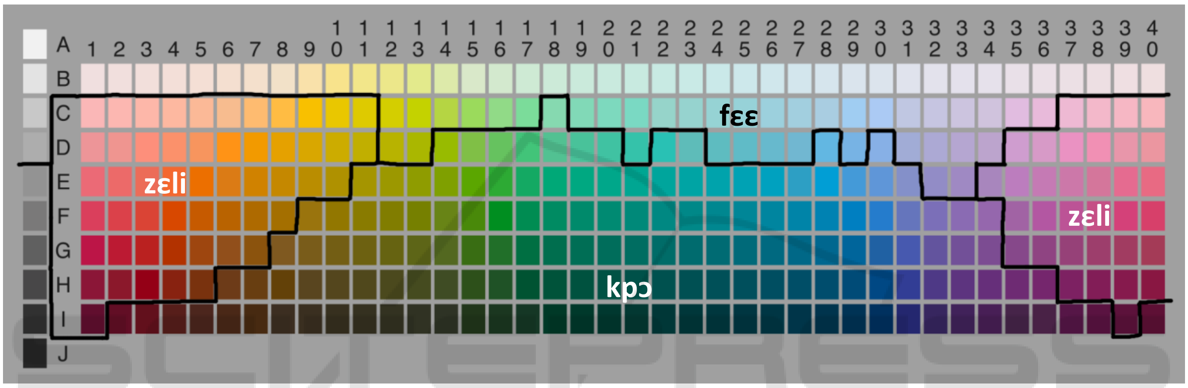

Figure 2: Stage II language Bété with three BCTs. It is spoken by half a million people in the Ivory Coast.

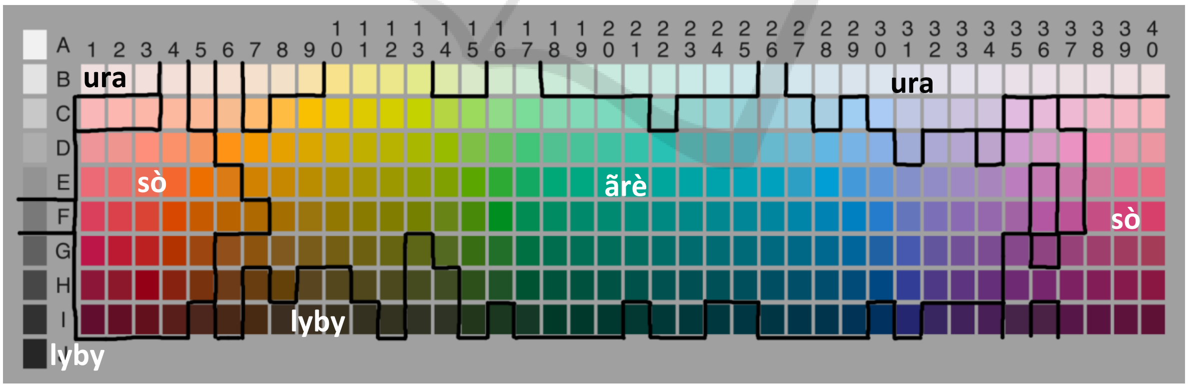

Figure 4: Stage III^{DE} language Karanjá with four BCTs, spoken by about 3000 people in central Brazil.