

Unconstrained web-based color naming experiment

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Abstract

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ABSTRACT

This paper describes an ongoing web-based¹ approach to collecting color names or color categories. Previous studies have tended to require a large number of observations from a small number of observers. These studies have also tended to limit responses to one-word or monolexical replies. Many studies have also focused on response time or levels of intra-observer agreement in order to identify focal colors. This web-based study uses a distributed design to collect a small number of names from a large number of observers. The responses are neither limited to nor restricted from being monolexical. The focal color analysis is then based on statistical analysis of monolexically named colors. This paper presents the methodology and infrastructure, as well as considerations for data analysis. Finally, preliminary results of the experiment are results are considered. The data from over 700 participants results in CIELAB hues and lightnesses for the basic colors that agree with previous investigations as well as those investigations agree with each other.

“Artists can color the sky red because they know it's blue. Those of us who aren't artists must color things the way they really are or people might think we're stupid.” Jules Feiffer

“Where does the violet tint ends and the orange tint begins? Distinctly we see the difference of the colors, but where exactly does the one first blending enter into the other.” Herman Melville

INTRODUCTION

There is a large body¹⁻²⁵ of research in the area of color naming or the communication of a given color perception. The classic study by Berlin and Kay²⁶ proposes that there are 11 basic color categories for any given fully developed language, and that these basic terms tend to be added to a language in a somewhat fixed order. There are deeper philosophical, linguistic, psychological and anthropological considerations. There have also been a number of recent studies that have attempted to validate, modify or contest Berlin and Kay's hypotheses. While the deeper issues are of great interest, this paper does not seek to address them directly. Instead, the author was motivated to explore the advantages of using an online visual experiment to explore the general topic of color naming. During the design of this experiment the author was impressed to learn that General Motors used an internet-based color naming survey to collect over 250,000 color name submissions²⁷ for an automobile that they were developing. Performing a color naming experiment on the internet also has the advantage that there are multiple previous investigations to compare with to validate the results.

This paper complements previous research on color naming in that:

1. it makes use of the internet as a testing mechanism and explores the advantages and disadvantages,
2. it uses a distributed design to collect a small amount of data from a large number of observers,
3. it makes use of monolexicity as a criterion for the analysis of focal colors,
4. it provides a more detailed investigation of the non-basic colors.

Previous research has proposed that black, white, red, green, yellow, blue purple, orange, pink and gray are basic colors or are universal categories. In contrast, some researchers have hypothesized varying degrees of linguistic relativity in which each language segments color space in a completely or partially arbitrary manner. Colors other than the basic colors have been referred to as non-basic colors and are a somewhat neglected topic given the ongoing debate regarding the basic colors. A consensus color is another common term in the area of color naming research and it refers to a stimulus in which all observers agree on the same basic color name. Finally, a focal color is a consensus color that is

¹ http://www.hpl.hp.com/personal/Nathan_Moroney/color-name-hpl.html

named most quickly by observers. Given the large number of participants and the distributed design, the concept of consensus color will not be used in this paper. Similarly, timing information was not collected and therefore the focal colors had to be computed based on the color names. Specifically boundaries were assumed to exhibit more complex naming and that foci could be computed based on the average of monolexical or one-word names. Color name is used to refer to any number of words used to describe a color. A color term is any single word used to create a color name. A substring is a fixed sequence of letters that may be all or a part of a color term. For example, the color name “greenish blue” consists of two terms and includes the substring green.

Applications of color naming²⁸⁻³⁶ include graphical user interface design, color schemes for data visualization, object segmentation in images, as a property in image database queries, and derivation of color palettes for designers. Previous researchers have gone beyond basic colors by proposing various color naming hierarchies, expert naming, or only in limited detail. This paper does not address applications of a rich color vocabulary but instead focuses on deriving an extensive vocabulary of English color names from hundreds of participants using the web.

EXPERIMENTAL INFRASTRUCTURE

JavaScript was used to create dynamic HTML that consisted of the experimental instructions, a form and other information. Observers then downloaded the form and completed the naming task using his or her display and computer. FormMail was used to convert the responses to email that were then mailed to the experimenter. An initial screening was then conducted to ensure that obvious outliers, such as empty forms, were discarded. The individual responses were saved to a directory and then various forms of analysis were carried out using C++ filters. Links were requested to several web sites, listed in the acknowledgments sections, and data was periodically processed into a summary form. The overall flowchart is shown in Figure 1 and a screen shot of the actual experiment is shown in Figure 2. Note that a white background was used and that it was not possible to eliminate other content from the participant’s screen.

Javascript code fragments are shown below to illustrate how a quantized series of random RGB triplets was generated for each observer. A quantized psuedo-random number is used to create a hex value that is then combined to create the patch color. This color is actually created by using the table command to fill a blank entry. The code also dynamically creates the input text field that will hold the observers response. Not shown are additional preliminary code, which establishes additional hidden fields, such as experiment revision, status, language and so on. There is also additional code for the other test color, test fields and the reset and submit buttons. An optional comment field was also provided, which a number of participants chose to make use of. A screen shot of the actual experimental layout and accompanying text is shown in Figure 1.

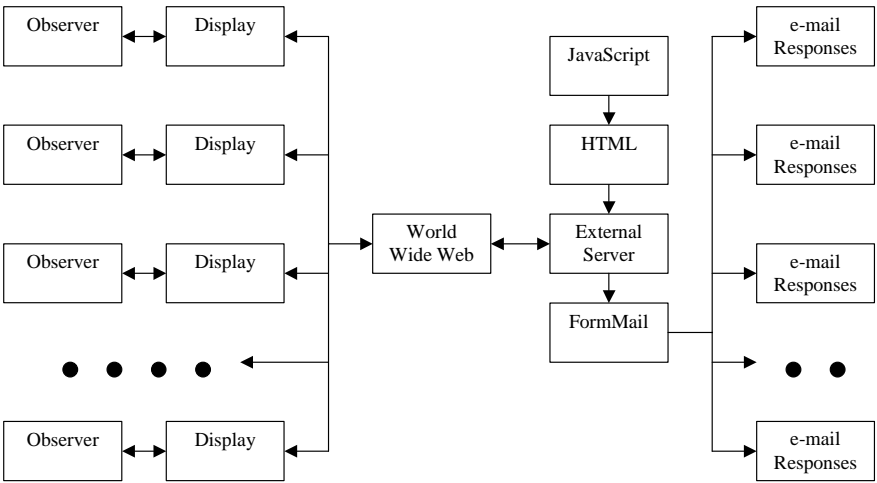









Figure 1. Overall flowchart of web-based visual experiment.

This is a simple color naming experiment. It requires a JavaScript enabled browser. Please use the best possible color name for the following seven color patches. When you are done please hit "Submit Names" to register your results. Preliminary details regarding the objectives and results of this experiment will be made public during the summer of 2003. In the mean time, you might find the following web sites ([1](#), [2](#), [3](#), [4](#), [5](#), [6](#), [7](#)) relating to color naming of interest. Thank you for participation.

	<input type="text"/>
	<input type="text"/>
	<input type="text"/>
	<input type="text"/>
	<input type="text"/>
	<input type="text"/>
	<input type="text"/>

Please note that participation in this color naming survey is strictly voluntary and anonymous. No additional data is collected other than the date, your color names and any comments you might have. Please direct any questions you might have regarding this experiment to Nathan Moroney (contact information at the bottom of this page). By clicking on the "Submit Names" button you agree to participate in this experiment. You may quit the experiment at any time by hitting the "Reset" button. For a complete statement with respect to Hewlett-Packard's privacy policy refer to the link "Privacy Policy" in the lower left corner of this page. Thank you again for your participation.

Comments (Optional):

Figure 2. Screen shot of the basic layout and content of the visual experiment.

```

<script language="JavaScript">
function rColor(){
  index = Math.floor(Math.random() * 6);
  if (index==0) return("ff");
  if (index==1) return("cc");
  if (index==2) return("99");
  if (index==3) return("66");
  if (index==4) return("33");
  if (index==5) return("00");
}

var q = "\n";
var color1 = ""+rColor()+" "+rColor()+" "+rColor();

document.write("<input type=\"hidden\" name=\"theColor1\" value=\""+color1+"\">");

document.write("<table><tr><td bgcolor=#"+color1)
document.write("><pre>          </pre></FONT></td>");
document.write("<td><pre>          </pre></FONT></td>");
document.write("<td> <input type=\""+q+"text"+q+" name =");
document.write(q+"theName1"+q+" size="+q+"25"+q+"> </td>");
document.write("</td></tr>");
document.write("<tr><td><pre>          </pre></td>");
document.write("<td><pre>          </pre></td>");
document.write("<td><pre>          </pre></td></tr>");

```

Considerations for the raw responses included spell-checking, typographic conventions and detecting multiple responses per entry. One possibility was to conduct spell checking before data analysis. Instead data was processed without spell checking since there was enough data that a rate of spelling errors was minimal relative to overall participation. Future extensions also make use of patterns in misspelling, such as the multiple spellings provided for fuchsia. Hyphenated and comma separated responses were treated as a single multi-word response. Hence, “red-orange” and “tan, brown” were treated as a two-word answer with equal weighting for each term. Items included in parentheses were treated as comments and discarded. The frequency of such responses was very low but for thoroughness it is worth pointing out that there were some assumptions made to deal with responses that included punctuation marks. Multiple entries were assumed by looking at the originating IP address as provided by FormMail. Over 95% of participants only submitted one set of seven colors names. Given that observers were not required to or restricted from participating more than once and that they consisted of a minority, all multiple entries were used.

A total of 36 submissions were rejected for being incomplete. This was done assuming that an incomplete submission was a result of the participant opting out of the experiment. Eight submissions were rejected as being obviously disruptive, including using actual names such as ‘Stacey’, using only consonants, using only white or in one case submitting the actual hexadecimal encoding of the color. Six submissions were rejected for using inappropriate terminology, and fourteen were rejected for gross disagreement with the mean, such as naming a white black. These gross disagreements were flagged by use of an initial sampling derived using a controlled set of participants, specifically a pool of internal Hewlett-Packard employees. Finally, six were rejected for other reasons, primarily for using languages other than English. These rates of disruptive observers are low relative to the overall response rate but cannot be overlooked and clearly will likely always be higher than controlled laboratory experiments.

An important point to note is that none of the observers named all 216 of the test colors. This experiment actually makes use of *distributed psychophysics* in which the time requirement for each observer is reduced to a minimum by having a large number of observers, none of which complete the entire experiment. This reduces the impact of any given participant and provides a means to reduce the effect of multiple submissions and disruptive observers. In addition, the use of a larger number of observers likely resulted in a richer color vocabulary than could otherwise have been achieved.

At the time this paper was completed, 701 trials had been completed to collect 4907 color names from a minimum of 670 unique IP addresses. The page was viewed 2407 times and resulted in a voluntary participation rate of 30% and fluctuated somewhat month-to-month. Data collection is ongoing and the next phase will expand the experiment to languages other than English.

The advantages of using a web-based experiment include: access to a large number of observers², minimal interruption to observers and experimenter, automatic, seamless processing from input to analysis, around the clock and unattended and that they include real-world sources of variability. The disadvantages of using a web-based experiment include: uncontrolled hardware, software and viewing conditions, no real-time feedback or interactive clarifications, difficult to screen observers, possibility of malicious or disruptive observers, and that they include real-world sources of variability. Other references³⁷⁻³⁹ provide additional discussion of these and other considerations for web-based experiments.

There are, not surprisingly a large number of potential sources of color variation. The include, but are not limited to:

1. Display technology, age, stability, cleanliness, video card, calibration, bit-depth
2. Software, color management set-up, OS, browser
3. Viewing conditions/angle, flare, ambient illumination level, room color
4. Observer age, gender, experience, bias, motivations, deficiencies & anomalies
5. Observer English proficiency
6. Screen contents, window size, workspace

However, the advent of sRGB⁴⁰ has provided some degree of convergence in color encoding and display for the world wide web. Furthermore, colorimetric display models and color appearance models allow some estimation of likely areas of maximum variability. It is also unclear when and if all of these issues can, or even should be, addressed such that the real world is in better agreement with laboratory conditions. There is of course perhaps something to be said for a study that must compete with real world sources of variability. There is perhaps a criterion for ranking or assessing the significance of results based on whether or not they are larger or smaller than real world variability. In that respect, the world wide web provides a much better cross section of this variability than the laboratory. Reips quotes a rule-of-thumb proposed by Martin that “the more highly controlled the experiment, the less generally applicable the results. ... if you want to generalize the results of your experiment, do not control all of the variables.”³⁷

EXPERIMENTAL PROCEDURE

The core task for the observer was: “Please use the best possible color names for the following seven color patches.” This was purposefully left as vague as possible so as not to bias the observer. There is much experimental work based on monolexical or single-word naming but in this case the observer was neither required to nor restricted from using monolexical naming. The results provide an indication of how often naïve unconstrained observers use monolexical naming versus naming with two or more words. This resulted in directions that were fairly vague and open to some degree of interpretation. Ideally the experiment was designed to be short enough and easy enough that participants would not spend too much time thinking about how to color name and would simply use a more natural naming criterion.

RESULTS AND DISCUSSION

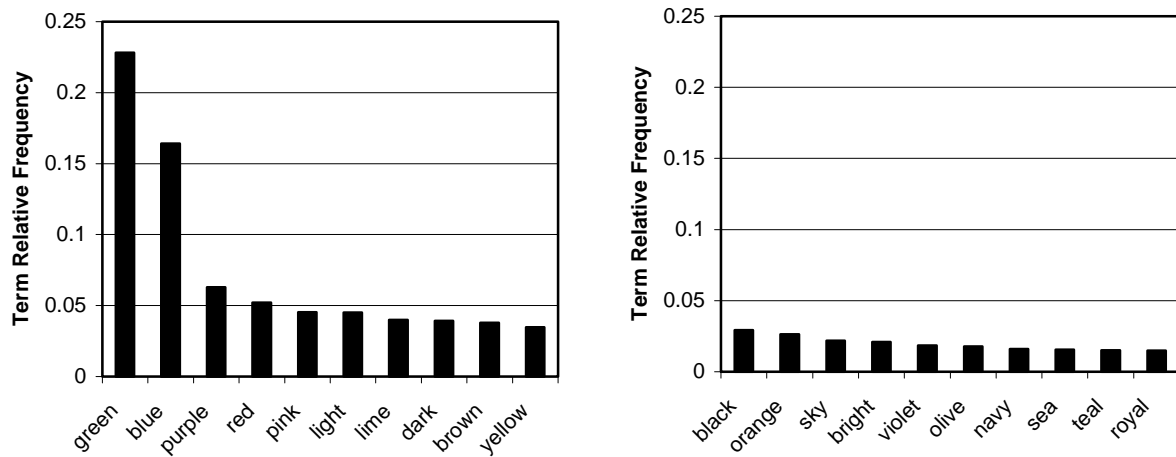
Given all of the potential sources of variability listed in a previous section, the results are broken into general and specific assertions. The general assertions are simply based on analysis of the responses and assume only that a large number of observers named a large number of colored stimuli. The specific assertions are based on linking the responses to the displayed RGB triplets and an assumed nominal display. These assertions assume that the colored stimuli and overall variability were roughly uniformly sampled and that relative measures of dispersion can be used informative for various comparisons.

1. General Assertions

Even though observers were not instructed to use one-word or monolexical naming, roughly 54% did so. Two-word names were used 42% of the time and three or more words were used 4% of the time. Monolexical basic color naming was used 27% of the time and non-basic monolexical naming was used 27%. That is basic and non-basic monolexical color naming were roughly equally likely. Blue, green and purple were the most common monolexical basic names and

² More, in fact, than all the previous psychophysics experiments conducted by the author combined.

white, yellow and orange were the least frequent monolexical basic names. White was the least commonly occurring basic color term with a relative rank of 46th and a relative frequency of 0.005.



Figures 3 and 4. Relative term frequency of usage of the 20 most commonly used color terms.

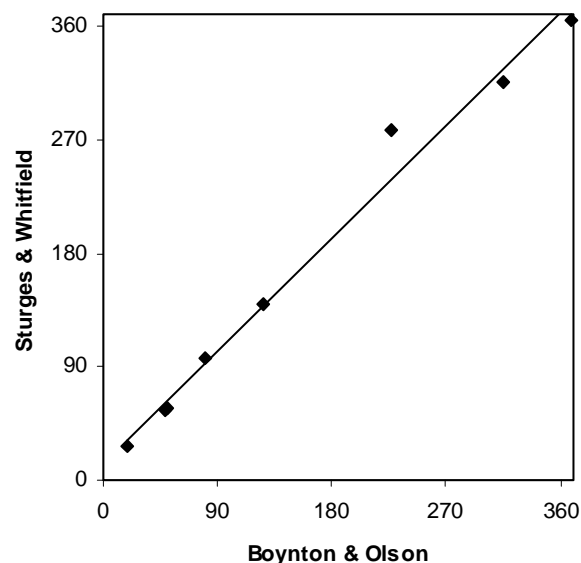
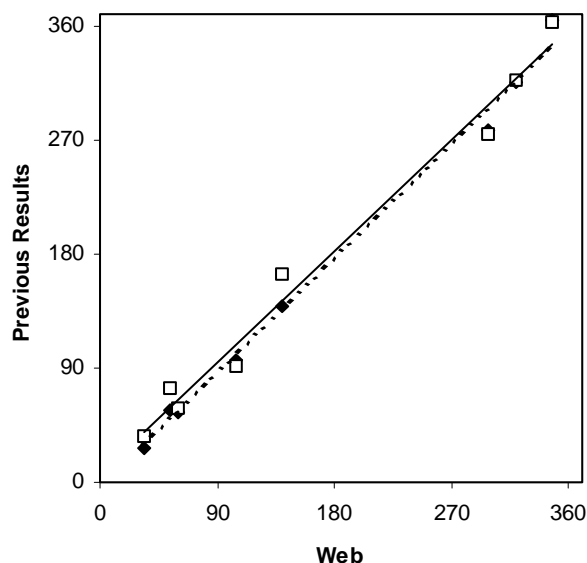
The relative term frequency for the 20 most common color terms are shown in figures 3 and 4. Green and blue are clearly used at a disproportionate frequency. There are also a number of terms that are in the top ten that are not basic colors, such as light, dark, and lime. A clear trend is for the term green or blue to be used as a modifier for a more complex color name. Likewise, modifiers for green and blue such as navy or royal are also quite common. For relative monolexical color naming the order of names is blue, green, purple, red, black, pink, brown, orange, yellow, gray and white with a more gradual fall-off in frequency. Blue green and purple occur more frequently than chance or 11% of the time, while the other colors occur less frequently than 11% of the time. The terms light and dark are also used disproportionately with the color names green, blue and purple. This is not surprising given that some basic colors have associated lightness boundaries, for instance there is likely more ambiguity between light brown and dark orange than there is between green and light green or blue and light blue.

The *-ish* suffix was used with all of the basic colors except white and black. More data will be required to verify this observation but it appears that at a minimum the *-ish* suffix is less commonly used with white and black than it is for the other basic colors. This raises some questions about distributional potential but may suggest that the *-ish* suffix is bound more closely to gradations of hue while white and black are closer to anchors or absolute colors. Similar trends can be seen in the use of typographic symbols, such as dashes and comas for multiple word color names.

2. Specific Assertions

Assuming sRGB³ as a nominal display, the corresponding RGB triplets for each color name can be converted to CIELAB coordinates. For example, it would be possible to compute monolexical centroids and then calculate the resulting CIELAB lightness, chroma and hue values. This would allow the results of this experiment to be compared to previous results. This section compares the results of the web-based experiment with the laboratory results previously published by Boynton and Olson⁴¹ and those of Sturges and Whitfield⁴². The Boynton and Olson results were derived using the OSA Uniform Color Scales and as a result are based on the 10 degree observer. Therefore, the nearest Munsell equivalents as derived by Sturges and Whitfield are used. This section also presents some means testing for various pairs of color names. Finally some trends for color naming for the non-basic color are considered.

³ Interestingly, this assumption is not critical to the analysis. Assuming a subset of other nominal displays does not significantly change the results reported in this section.



Figures 5 and 6. Comparison of web-based experiment with previous results for basic color CIELAB hue angles. Figure 5 on the left shows Boynton and Olson results with filled diamonds and linear fit with dotted line, $R^2 = 0.99$. Figure 5 also shows Sturges and Whitfield as open squares and linear fit with solid line, $R^2 = 0.98$. Figure 6, on right shows previous results with linear fit, $R^2 = 0.98$.

The web-based basic color name CIELAB hues values agree as well as the previous studies agree with each other. This is shown in Figures 5 and 6 where CIELAB hue values are shown plotted for the different experiments. Note that in the case where the colors span the 0 degree angle, 360 degrees was added to the smaller hue angle. The web-based results for lightness agree with Boynton and Olson with an R^2 of 0.90 and agree with Sturges and Whitfield with an R^2 of 0.65. In comparison, the lightness results for Boynton and Olson agree with Sturges and Whitfield with an R^2 of 0.68. In this case, the lightness results agree more closely with Boynton and Olson than Sturges and Whitfield agree with Boynton and Olson. The agreement for chroma is considerably worse. In all cases, the web-based experiment results in a uniformly higher chroma relative to the previous results. The R^2 for the web-based experiment versus Boynton and Olson was 0.25 and 0.36 for Sturges and Whitfield. The chroma results for Boynton and Olson agree with Sturges and Whitfield's with an R^2 of 0.75. Given this close agreement for the lightness and chroma results the chroma results suggest either some ambiguity for chroma and color naming or may be an artifact of the technique and processing. For example, the larger the gamut or greater the range of chromas for the test stimuli the higher the resulting chromas of the basic color names. An alternative hypothesis is that the simple arithmetic mean used to compute the centroid skews the results to higher chromas.

Means testing of CIELAB hue angles can also be performed for specific pairs of color names. For example, within a 0.99 confidence limit the mean hue angles of "purple" and "violet" are equal. In contrast, with the same confidence limit "peach" and "salmon" mean hue angles are not equal. Given some speculation about a possible missing basic color of peach or salmon, these results suggest that these two colors are in fact distinct for observers who use these terms. Finally, the following pairs of color names have equal mean CIELAB hue angles within a 0.99 confidence level: aqua-turquoise, magenta-fuchsia, burgundy-maroon, and olive-khaki. Note that this does not necessarily apply to the lightness and chroma values of these colors. One interesting possibility is that there is some degree of equivalence between certain aspects of the non-basic colors.

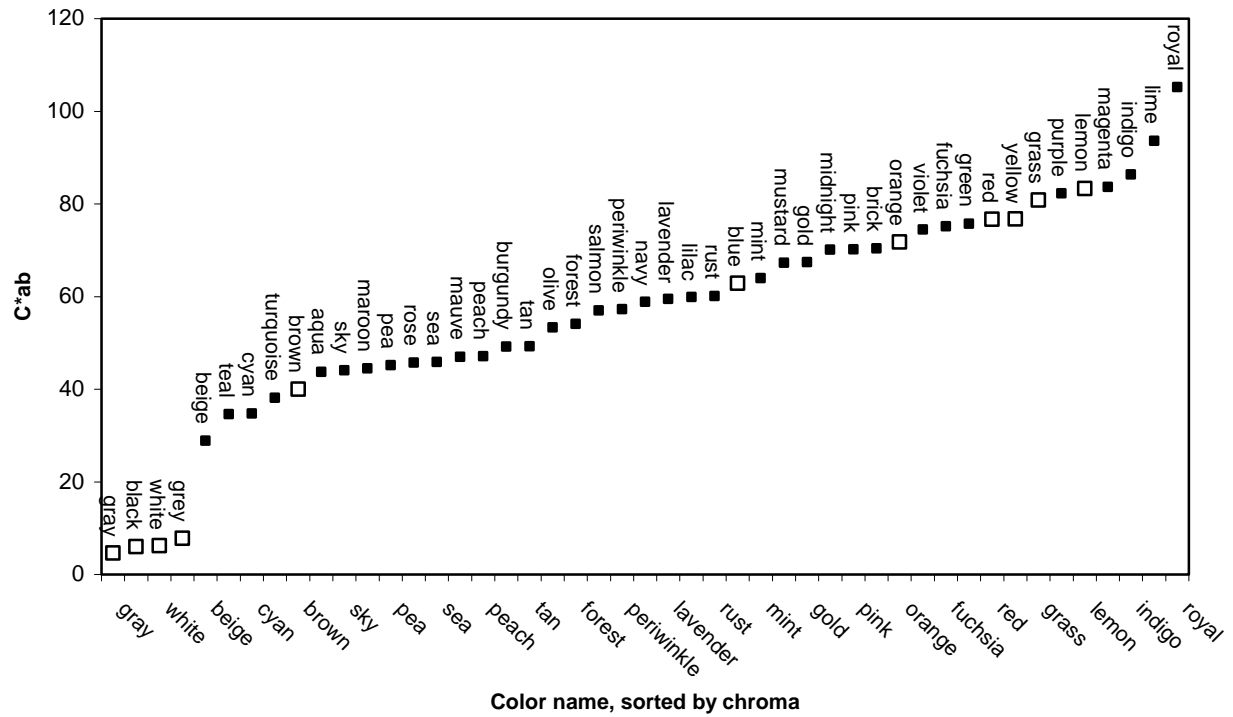


Figure. 7. Trends in color terms as a function of the CIELAB chroma for color names used by at least 15 participants.

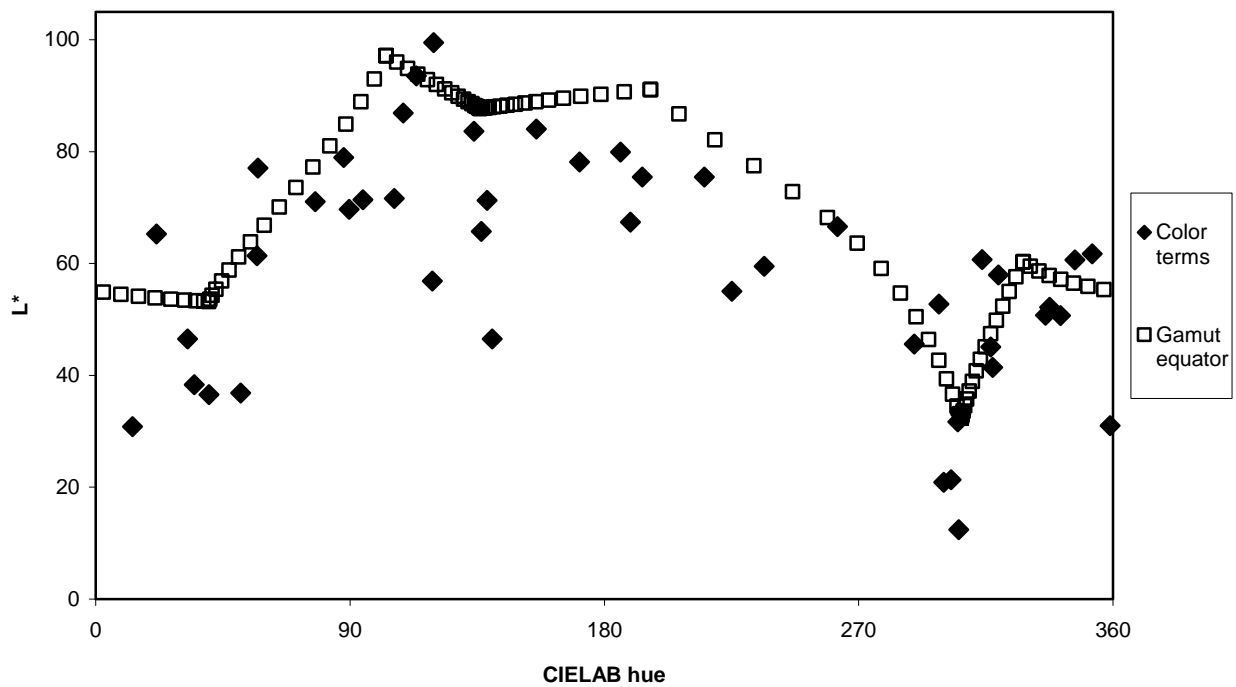


Figure. 8. Trends in color terms as a function of CIELAB hue and lightness with the gamut equator superimposed.

Figure 7 shows the top color names or terms sorted by their CIELAB chroma. Top color names were determined by taking all color terms that were used by more than 15 participants and were not used as a general modifier. General modifiers were those terms used for multiple hues such as light, dark, medium and true. The basic colors are shown plotted with open squares while the non-basic colors are shown with filled squares. The chroma values for the basic colors were computed from the monolexical averages whereas the non-basic colors were pooled for monolexical and non-monolexical averages. For instance, results for “lime” include the color names “lime” and “lime green”. Note that aside from the achromatic basic color names there is a distinct lack of lower chroma color names. In addition, excluding brown the chromatic basic color names tend to have very high chromas.

Figure 8 shows trends in color naming by plotting the CIELAB hue versus lightness for the colors shown in Figure 7. The assumed nominal gamut equator is also plotted as a series of open squares. A gamut is the three dimensional volume of possible colors for a given device and the gamut equator is the largest chroma which can be achieved at a given hue angle. This figure shows the lightness and hue distributions for the basic and non-basic color names. There is a fairly good distribution of hues with a possible gap near cyan or roughly CIELAB hue of 260 degrees. However the corresponding lightness values show a clear tendency to higher chromas. However, the large gaps at the top and bottom are distorted and overly large. Figure 8 is essentially a Mercator projection of the color data and the areas near the top and bottom are distorted, similar to the distortion, which occurs to Greenland on many world maps.

The results in Figure 7 and 8 imply a bias towards higher chroma color names. Additional testing is required to further explore this observation. Intuitively it makes some sense that lower chroma colors would be less robust and more sensitive to contrast effects, changes in ambient illumination and observer variability.

Given the lack of color control, the high degree of agreement for basic color hue and lightness could be used as a validation of the statistical power of large observer pools possible using web-based experiments. Likewise this high degree of agreement could be used to support the importance of robustness for color categories. The results for chroma for both basic and non-basic color names are more ambiguous and require additional investigation.

CONCLUSIONS

Use of the internet to conduct a color naming experiment has proven to be a very powerful and efficient means of further exploring color naming. The results for the CIELAB lightness and hue agree with previous results agree with each other as well as these previous studies agree with each other. The results for chroma show considerably more bias towards higher chromas relative to previous results. Use of a distributed design and a phased roll-out starting with a controlled pool of observers were useful experimental techniques for minimizing the impact of any single observer, collecting a richer color vocabulary and automatic detection of outliers. Basic color names were used extensively both monolexically and as modifiers. Centroids for non-basic colors were also computed and initial results show a “hole” for color naming for low-chroma colors. These color naming centroids also tended to follow the gamut equator of the assumed nominal display device, further suggesting that there is an implicit bias towards the naming of higher chroma colors.

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The author made use of several valuable on-line resources.

- <http://psych.hanover.edu/APS/exponnet.html>
- <http://genpsylab-wexlist.unizh.ch/>
- <http://www.language-experiments.org/>
- <http://www.efg2.com/Lab/Library/Color/index.html>
- <http://www.cis.rit.edu/mcsl/online/links.shtml>

These web sites provided both valuable information regarding web experiments and color naming, but also provided valuable links to the experiment. The author also appreciated informative discussions on this topic from John Krantz, Johan Lammens, Steve Jacobs, and Ingeborg Tastl.

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