Effectiveness of Color-Picking Interfaces among Non-Designers

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Abstract. There are relatively few studies on the effectiveness of color picking interface. This study therefore set out to measure both the efficiency in terms of task completion time and preference of four color-picking interfaces found in many design software applications including RGB, HSL, map and palette. A controlled experiment was conducted involving $n = 16$ participants without formal design training. The results show that the map and RGB interfaces were preferred by the participants while the palette interface resulted in the shortest task completion times. The HSL was the least favorable color picking interface for the given cohort of users. The results indicate that the palette, map and RGB color pickers found in entry level software probably are the most suitable for users without training in the use of colors.

Keywords: Design, engineering, collaboration, color picking, HSL, RGB, palette

1 Introduction

Color selection is a key operation in most design processes such as print and web-design, product design, interior design and design in the build environment [1]. Color selection is provided by most design-oriented software such as word-processors, graphing software, presentation software, image processing application, drawing programs, CAD/CAM, etc. Color is perceived as important to people and is deeply rooted in cultures, traditions, and personal preferences. Groups of designers collaborating in teams may often debate color choices in heated discussions.

Software application designed for general users often include color selections based on palettes, RGB-selectors and various types of two-dimensional maps, while application aimed at professional users such as designers also include the HSL model. There is no consistent name for a map and by map we mean color picking interfaces where several colors are presented in a two-dimensional space with some additional control that changes the attributes of the displayed colors. Clearly, the displayed colors are quickly accessed by a single click. It may however be more challenging to find colors that are not displayed by modifying the secondary control.

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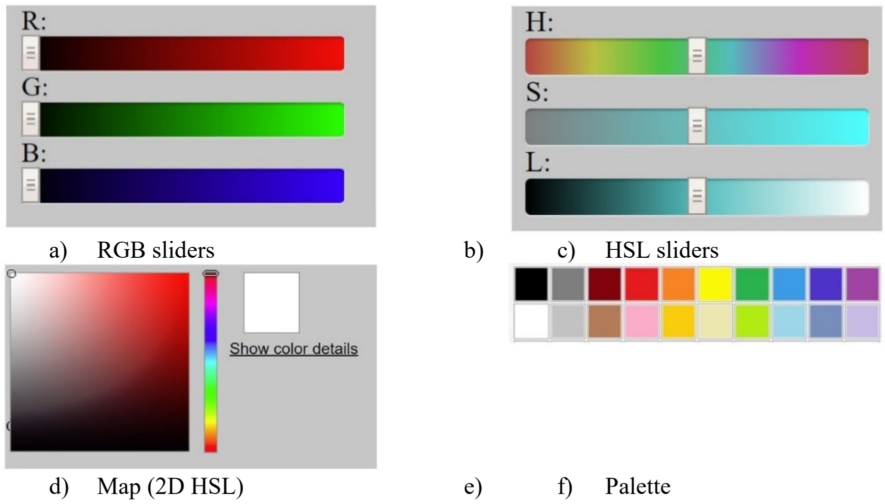

Fig. 1. Color-picking interfaces used in the experiment.

Palette interfaces are similar to the color charts found in hardware stores and comprise a fixed set of predetermined colors. It thus easy to access all the colors and the palette interface is easy to understand. RGB color pickers are also common and easy to understand representing the additive model where the users control the amount of red, green and blue that is mixed into the resulting color through three sliders. The hardware centric RGB model is widely understood among computer scientists as most programming languages and html/CSS coding is done using RGB-vectors even though these technologies also support the HSL model. The HSL model is less intuitive and requires some training where the perceptual qualities of colors are controlled independently, that is hue (red, orange, yellow, green, etc.), saturation (signal red, pastel red, etc.), and lightness (dark, light, etc) controlled using three sliders. However, once learned, the HSL model is superior to the others as it makes it easier to describe colors linguistically, facilitating collaboration and easy communication and reasoning about colors among designers in a team. The HSL representation makes it much easier to find aesthetical color schemes and adjust contrast for readability. There are also around twenty other color models used for different purposes such as CMYK for print and perceptual color spaces [2] such as CIElab which are designed to be better aligned with the human visual system.

Opinions about color models vary yet there is little empirical evidence about the effectiveness of these color models from a user perspective. This study therefore set out to gather empirical evidence about the effectiveness (productivity) and subjective preference of four common color picking interfaces in terms of task completion time.

2 Related work

Although several approaches to computer-based color work has been proposed, that is the selecting and organizing colors [3], color picking interfaces has changed little over the years [4]. Studies on color picking interfaces have addressed topics such as its use in the build environment [1], two-handed color exploration [5] and how to specify colors as part of image retrieval queries [6]. Misue and Kitajima [7] designed a color picker based on the CIElab perceptual color space. Douglas and Kirkpatrick [8] did a thorough study of different color picking interfaces and concluded that visual feedback is more important than the color model used.

Based on interviews with designers Jalal, Maudet and Mackay [9] identified five key areas of color manipulation and proposed corresponding tools, namely the probing and tweaking individual colors, manipulating color relationships, combining color with other elements, revisiting previous color choices and revealing design process through color. Researchers have also addressed the assessment of color, for example the study by Heer and Stone [10] who proposed a probabilistic model to assess the accuracy of human naming of colors, or Luncy, Haber and Carpendale's [11] visualizations of how artists use of color have changed over time.

Much of the literature on color picking interfaces has evolved around the end result. Reinecke, Flatla and Brooks [12] addressed the situational perceivability of the chosen colors such as screen glare caused by sunlight or dimly lit screens. Others have especially focused on the higher contrast levels needed by users with low vision [13]. Webster [14] have argued for contrast requirements to be integrated into design tools and several such tools have been proposed based on the RGB-domain [15, 16] and HSL-domain [17]. Others have focused on the balancing of aesthetics and accessibility requirements [18]. Approaches to help adjust colors so that adhere to standardized minimum contrast levels have also been proposed [19] as well as visualization approaches to help designers conceptually understand contrast [20].

Some of the research has been directed towards the selection of color for data visualization purposes [21, 22, 23, 24], for instance how to select colors that still look aesthetical when they are mixed through the stacking of transparent layers [25] or extracting aesthetic palettes from images [26, 27].

3 Method

3.1 Experimental design

A randomized controlled experiment was set up with two independent within-subject variables, namely color setting interface and color task type. The color setting interface factor had four levels, namely RGB, HSL, map and palette. The Color task types had four levels, setting color from name (easy), setting color from name (hard), copying the color of a physical object, and setting the color from association with a physical object memory. Task completion time was measured as the dependent variable. We also measured preference as a dependent variable for the color picking interface as independent variable.

3.2 Participants

A total of 16 participants were recruited from the authors institution of which approximately two thirds were male and one third female. The participants were all students in their 20s and 30s. None of the participants were trained designers. None of the participants exhibited any signs visual impairment including color blindness. Participation was voluntary and anonymous.

3.3 Task

Each participant was asked to set four colors using the four interfaces, two of the colors were derived from linguistic names, one from association with an object from memory and one based on a physical object. The color tasks were designed such that they would not generate any follow up questions during the experiment. The colors included pink (an unsaturated red), signal green (a saturated green), the color of the sleeve of a book with a turquoise color and the yellow color in the IKEA furniture store logo. The IKEA logo was chosen as this is a visual profile that most people in the cohort were expected to be familiar with (the experiment also confirmed this).

The participant set the four colors using the four interfaces (see Fig. 1). These included RGB which comprises three sliders controlling the red, green and the blue components respectively (Fig. 1a), HSL comprising three sliders controlling the hue, saturation and lightness of a color (Fig. 1b), a two-dimensional map (Fig. 1c) and a palette showing 20 predefined colors (Fig. 1d). The map interface used was in fact an HSL interface with the saturation varying along the horizontal direction and lightness along the vertical direction (see Fig. 1c). The hue was controlled using the secondary control. The user thus had instantaneous access to all the brightness and saturation settings for a given hue. The interface presentation order was randomized to prevent any learning effects. The order of the color tasks was fixed

The participants were also asked to rank each of the interfaces using a 10-point Likert scale displayed next to a picture of the respective color picking interface where 1 indicated a strong dislike and 10 indicating a strong preference.

3.4 Equipment

A specialized application was programmed in PhP and JavaScript for the purpose allowing the balancing of the presentation order to be automated and completion times to be measured accurately. The tests were run on a Dell XPS 9550 laptop with a 15-inch display.

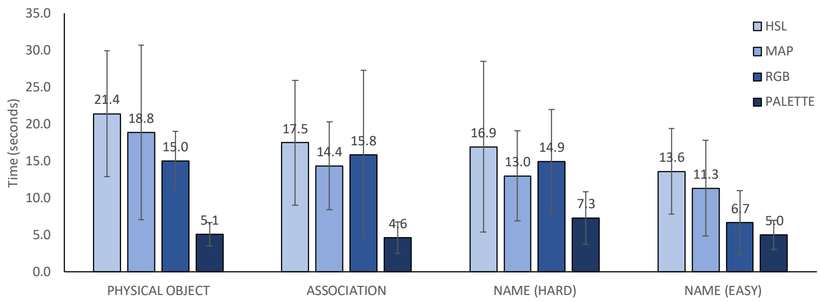

Fig. 2. Task completion time for different colors using the four interfaces. Error bars shows standard deviation.

3.5 Procedure

Each participant was first briefed about the experiment. The preference survey was presented after the participants had completed all the tests. Steps were taken to keep the conditions as constant as possible for each participant. The experiment was conducted in a quiet meeting room in the authors home institutions under the same lighting conditions. The order of the color picking interfaces was balanced while the order of the color tasks was fixed. All the tests were performed using the same laptop computer and a mouse. Each session lasted approximately 10 minutes. The data were analyzed using JASP 0.9.1.0 [28].

4 Results

The results of the timed experiments (in seconds) are shown in Fig. 2. The results shows both a significant effect of color picking interface ($F(3, 45) = 45.710$, $p < .001$, $\eta^2 = .757$) and a significant effect of color setting task ($F(3, 45) = 7.938$, $p < .001$, $\eta^2 = .346$). Mauchly's test of sphericity indicated that the assumption of sphericity was violated for the interaction ($p < .001$). A Greenhouse-Geisser correction was therefore applied since the Greenhouse-Geisser epsilon was .340, that is, less than .75. No interaction was detected ($F(3.064, 45.964) = 2.057$, $p = .118$).

The results shown in Fig. 2 reveal that the palette was associated with the shortest task completion time for all the color tasks ranging from ($M = 4.6$, $SD = 2.1$) to ($M = 7.3$, $SD = 3.6$). Bonferroni post-hoc tests also revealed that the palette interface was statistically different to the other interfaces ($p < .001$). Moreover, the HSL interface was consistently the slowest interface with completion times ranging from ($M = 13.6$, $SD = 5.8$) to ($M = 21.4$, $SD = 8.5$). Post hoc tests confirms that the HSL interface was significantly different to the three other interfaces, namely RGB ($p = .013$), map ($p = .023$) and palette ($p < .001$). There is no significant difference between the map and the RGB interface in terms of completion time ($p = 1.0$).

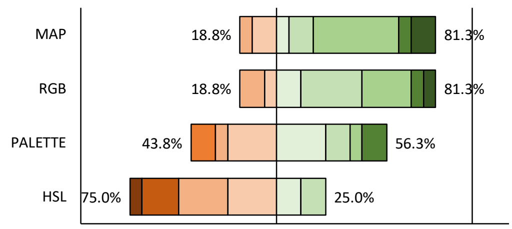

Fig. 3. Participants' subjective preferences. Orange indicate negative responses and green indicate positive responses.

Fig. 3 shows the participants preferences for the four color-picking interfaces suing a diverging stacked bar chart [29]. The chart reveals that most of the responses are positive for the map, RGB and palette interface while most responses are negative for the HSL interface. The map and the RGB interfaces both are the most preferred interfaces although the map interface has a higher frequency of high Likert responses. As the Likert data are of interval type a non-parametric repeated measures test was used for significance testing. The Friedman test shows that the preferences for the four color-picking interfaces are significantly different ($\chi^2(3) = 18.73$, $p < .001$). Connover's Post Hoc comparisons shows that the difference between two most preferred interfaces, namely the map and the RGB interfaces are not significantly different ($p = 1.0$). The least preferred interface, HSL, is significantly different to both the map interface ($p < .001$) and the RGB interface ($p < .001$). However, HSL is not significantly different to the palette interface ($p = .173$). The palette interface is significantly different from the map interface ($p = .006$) but not the RGB interface ($p = .147$).

5 Discussion

The completion times viewed in terms of task type are as excepted, namely that setting the color based on names yields the shortest completion time. Clearly the easy signal green is easier to set than the pink which require more effort in order to adjust the saturation level. The results show that the map gives a shorter completion time when setting the saturated color, perhaps because colors are simultaneously displayed at all saturation levels for a given hue while the RGB interface require multiple slider operations to achieve saturation. Similarly, the signal green is easier to set directly with a simple motion in the RGB interface while the search for green requires adjusting the secondary hue control in the map interface.

Next, setting the color via association (from memory) was the third slowest. Setting the color from the object (book cover) was the slowest. This was probably because a real object poses an absolute comparison which may require more time-consuming trial and error, while setting colors from memory does not involve such an absolute quality criterion, just simply a subjective assessment of the results.

Although Fig. 2 reveals practical differences, Bonferroni post hoc tests reveals only the easy naming task and the association tasks are significantly different ($p = .005$), as well as the easy naming task and the object naming task ($p < .001$). The lack of statistical significance was probably caused by the large variation in completion times for the different interfaces and the low number of participants.

The objective measurements are relatively consistent with the subjective measurements as the slowest interface (HSL) was also the least preferred by the participants. The RGB and the palette interfaces which were the most preferred interfaces were only ranking second and third in terms of completion times. The palette which resulted in the fastest completion times ranked as the third preferred interface with close to 50/50 distribution of positive and negative responses.

One may speculate that the high preference for the relatively inefficient RGB interfaces may be related to users' familiarity as it is found in many software applications. Note that we did not ask the participants to what degree they were familiar with the four interfaces. Users preference for the map interface may be explained by its direct manipulation. Even if users are unfamiliar with the underlying HSL model they can still find the desired color quickly. Although the palette interface was the fastest to use there were only 20 color choices which is too limited for most practical applications. The lack of choices may explain the users low ranking of the palette.

The low preference and performance results obtained with the HSL model is as expected from non-trained users. The HSL model require some basic training in color theory. For instance, it is our experience that it takes some time of computer science students to understand the purpose and benefit of the HSL model as they are often strongly attached to the RGB model. Trained designers, however, usually describe colors linguistically according to hue with saturation and brightness/lightness modifiers and are usually trained in working with colors and color harmonies. It is thus possible that the results would have been completely different with trained designers, that is, that they would both prefer and perform the tasks faster with the HSL model. Although the results suggest that the participants were unaware of the workings of the HSL model in hindsight we should have explicitly probed the participants about their practical knowledge about the RGB and HSL color models.

Another weakness of the current study is that the accuracy of the color models was not measured. In addition to perceived preference and speed of task completion it is also essential to scrutinize the results produced with the various color picking interfaces. Future work should therefore include measurements of accuracy. One may speculate that the HSL may provide the highest accuracy as it allows the designer to directly control the independent perceivable dimensions of color. With the RGB interface these dimensions are intertwined, where altering one component affects all three perceivable dimensions.

Finally, only 16 participants were recruited from a narrow student cohort. This may be a too limited source of data to make general conclusions. Clearly, a larger sample including multiple relevant cohorts would add to the power of the experiment and generalizability of the results. The current results should therefore be interpreted with some caution.

6 Conclusions

A controlled quantitative experiment was conducted to measure the effectiveness of four common color picking interfaces on a cohort of non-designers. The results show that the HSL interface was the least effective and least preferred. The users preferred the RGB and the map interfaces, but their observed performance revealed shorter task completion times with the palette color picker. Future work includes expanding the cohort to include trained designers with color theory knowledge as a between groups factor. Future work should also study the accuracy of the color picking interface as the end result often is more important than the completion time and user preferences.

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