



HAL
open science

Color Portraits: From Color Picking to Interacting with Color

Ghita Jalal, Nolwenn Maudet, Wendy E. Mackay

► **To cite this version:**

Ghita Jalal, Nolwenn Maudet, Wendy E. Mackay. Color Portraits: From Color Picking to Interacting with Color . Proceedings of the ACM International Conference on Human Factors in Computing Systems, 2015, May 2015, Seoul, South Korea. 10.1145/2702123.2702173 . hal-01226494

HAL Id: hal-01226494

<https://hal.science/hal-01226494>

Submitted on 18 May 2016

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial 4.0 International License

Color Portraits: From Color Picking to Interacting with Color

Ghita Jalal
Jalal@lri.fr

Nolwenn Maudet
Maudet@lri.fr

Wendy E. Mackay
Mackay@lri.fr

Inria, Université Paris-Sud, CNRS, Bâtiment 650, Université Paris-Sud, F-91405 Orsay, France

ABSTRACT

Although ubiquitous, color pickers have remained largely unchanged for 25 years. Based on contextual interviews with artists and designers, we created the *Color Portraits* design space to characterize five key color manipulation activities: *sampling and tweaking* individual colors, *manipulating color relationships*, *combining colors* with other elements, *revisiting previous color choices*, and *revealing a design process through color*. We found similar color manipulation requirements with scientists and engineers. We designed novel color interaction tools inspired by the design space, and used them as probes to identify specific design requirements, including: interactive palettes for sampling colors and exploring relationships; color composites for blending and decomposing colors with other elements; interactive histories to enable reuse of previous color choices; and providing color as a way to reveal underlying processes. We argue that color tools should allow users to *interact* with colors, not just pick or sample them.

Author Keywords

Color picker; Color tools; Creativity; Generative Design

ACM Classification Keywords

H.5.2 [User Interfaces]: Theory and Models

INTRODUCTION

Desktop computing supports the creation of diverse types of digital media, including drawings, spreadsheets, photographs, video and multimedia documents. Applications for creating digital media usually include a *color picker*, with three common features: a visual representation of a specified color model, the organization of displayable colors into a three-dimensional color space, and controls to change parameter values within that space [6]. Users can select individual colors from the color space, either with the mouse or by specifying a three-digit code, such as an RGB value. Some color pickers also allow users to select a color from a pixel in an image or from existing color swatches.

Despite being ubiquitous, color pickers have changed little over the past 25 years. Fig. 1 shows almost identical layouts and controls for three common color pickers; the only new features are their underlying color spaces, which have been updated according to research in color perception [7] and representation [20].

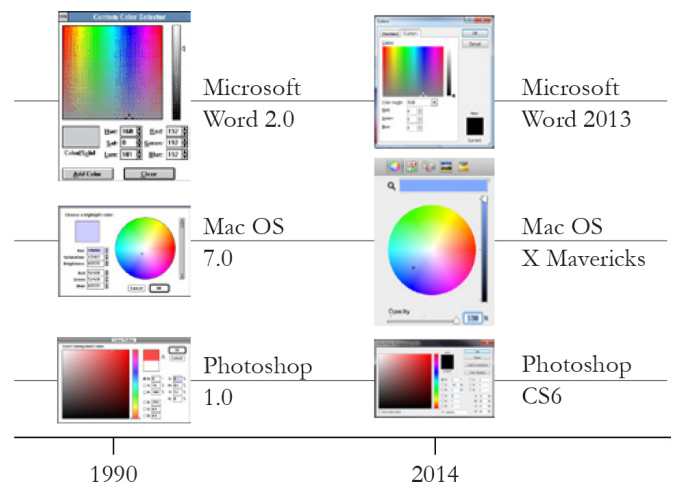


Figure 1: Today's color pickers have changed little since 1990.

Of course, one reason that color picker design is static could be that color picking is a "solved" problem—users can successfully manipulate color in digital documents. However, Bailey et al. [2] show that untrained users still have trouble selecting particular colors, and Albers [1] argues that professional artists do not want to simply follow prescribed color systems and theories.

We are interested in how users, especially artists and designers, manipulate color as part of their creative process. We begin with a review of related research on color perception, techniques for visualizing color spaces, and the design of specialized color manipulation tools. We describe our findings from interviews with artists and designers who focus on color, and frame the results as a design space, called *Color Portraits*. We verify our design space through a second set of interviews with non-expert color users, and an analysis of current color tools. Finally, we present a set of novel color-manipulation tools that test the generative power of the design space. We presented these to users as probes and conclude with implications for the design of more advanced color manipulation tools.

G. Jalal, N. Maudet, W. E. Mackay.

Color Portraits: From Color Picking to Interacting with Color.

In CHI 15: Proceedings of the ACM International Conference on Human Factors in Computing Systems, ACM, May 2015.

Authors Version

RELATED WORK

Color is a deceptively complex domain, studied from a variety of different perspectives. Psychologists seek to understand how humans sense and perceive color whereas human factors experts codify this knowledge into simple, easy-to-apply design rules. Computer scientists and mathematicians build upon our understanding of color perception to create multi-dimensional color spaces that can be represented on the screen. Artists and designers work with the resulting color representations to explore color relationships and generate aesthetically appropriate colors for each individual artifact.

Sensation and Perception of Color

Color perception is more complex than directly sensing wavelengths of light. Instead, the brain interprets signals from individual photoreceptors as distinguishable, subjectively different colors [16]. Psychologists study optical illusions, where color perception differs from the physical signal. For example, the McCollough effect [18] involves staring at a colored test image, looking at a different background, and seeing new, non-existent colors. The simultaneous contrast illusion [8] presents a solid color bar on a gradient background, from dark to light, making the bar appear as a gradient from light to dark. Human factors experts create guidelines based on these physiological and psychological studies of color [17]. However, artists and designers often break these rules, playing with optical illusions to achieve specific effects.

Representing and Visualizing Color

Color can be displayed according to mathematically or perceptually based coding schemes. RGB is a device-dependent color model comprised of additive primary colors, red, green and blue, which combine to create various colors, including white. HSV describes color as hue, saturation and value (brightness), defined arbitrarily in different tools or standards [15]. Both models emphasize color generation, not color perception. For example, RGB produces a wide variety of greens, but very few reds.

An alternative strategy is to define color spaces in terms of color perception [21]. For example, perceptually uniform color spaces, such as CIELUV and CIELAB, create equal perceptual distances among the colors [27]. Other coding schemes reduce cognitive effort by mapping the represented data set to the capabilities of the human vision system [5, 26]. Color is also affected by how it appears on a computer screen [25]. For example, data visualization researchers use computer-aided color-coding to represent and interact with their data [11] or to map data along color dimensions to create a pictorial representation [3]. The print industry defines standard color references, such as the PMS Pantone Matching System, according to specific ink formulæ or a CMYK mix [22], with corresponding reference guides for various print devices and substrates.

Many color tools are based on computational algorithms that hide the complexity of color manipulation. If users do

not understand the underlying models, they have trouble using them to achieve specific effects. ACE (*A Color Expert*) [20] addresses this by automatically selecting colors based on a model of the functional relationships among components of a design drawing. Wang et al.'s [26] interactive colorization process lets users choose hues from a color wheel. Then, an expert system calculates optimal brightness and saturation. These expert systems support clearly defined tasks but are less helpful for creative tasks in which users define their own rules and constraints.

Interactive Color Tools

Several web-based tools allow users to experiment with different color combinations. Adobe *Kuler*¹ lets users combine colors around a particular theme: they can manipulate multiple color swatches sampled from images or generate palettes based on color rules, e.g., color triads or complementary colors. Other tools pre-select sets of colors to address specific requirements. *Color Brewer* [10] helps users choose effective color schemes for coloring maps, based on specific properties of the data being represented and human color perception. *IWantHue*² helps users generate palettes with optimally distinct colors. Both have the advantage of simplicity, but with a very limited scope.

Several recent tools explore innovative ways of manipulating color. For example, *Histomages* [4] allows users to edit images by modifying a histogram of the colored pixels within the image. Users can select and change subsets of colors, such as turning the sky from shades of blue to shades of orange. Pouli and Reinhard [24] demonstrate how to transfer color by progressively matching a histogram to a target image's color, and Meier et al.'s *Interactive Color Palette Tools* [19] offer additional techniques for interacting with color. Although these tools offer promising new techniques for manipulating color, they remain isolated from mainstream authoring applications.

Designing with Color

Color is often fundamental to an artist's or designer's work. According to Itten [14], artists must control *impression* (perception of color), *expression* (emotional reaction to color), and *construction* (conveying meaning), combining all three to create each desired effect. Albers argues that color is "*the most relative medium in art*" [1] and uses practical exercises to teach novice artists about the nature of color and to explore how it can convey mood and meaning. Artists and designers thus develop nuanced understandings of color perception through intensive practice and experience.

Our goal is to improve how authors of digital media manipulate color to achieve desired effects. This requires a more detailed understanding of current color practices, beyond the use of the ubiquitous, but unchanging color tool: the color picker.

¹ www.kuler.adobe.com

² www.tools.medialab.sciences-po.fr/iwanthue/



Figure 2: Eight artists and designers demonstrated how they manipulate color to achieve effects in both physical and digital media.

HOW DO ARTISTS INTERACT WITH COLOR?

Participants: We observed and interviewed eight artists and designers (4 men, 4 women; age 23-45) who consider color an essential part of their work practice (see Fig. 2). Their professions included painter, illustrator, ceramist, spatial designer, graphic designer, product designer, service designer and interaction designer.

We are interested in the tools and techniques artists use to incorporate color into their work, especially how they produce specific color effects. Although digital color tools are our primary concern, we also want to understand physical color practices that have evolved over centuries and may inspire new ways to manipulate color online.

Procedure: We interviewed participants in their studio or office for about one hour. We asked participants to tell stories about their use of color in recent projects and to show us the resulting artifacts. We probed for situations in which their interaction with color was particularly effective, but also when it was extremely difficult or impossible.

Data Collection: We recorded audio for each interview and took written notes. We also recorded video of participants' interactions with the objects they had created, and photographed each artifact and any related color creation or manipulation tools.

Analysis: We created a storyboard to illustrate each story, with a photograph of the artifact, as well as drawings to describe each step in the color creation and manipulation process (see Fig. 4). We later showed these storyboards to the participants to verify the details. We used a grounded theory [9] approach to define ten different color manipulation categories and mapped each story to one or more categories. We chose the five most representative categories to create the *ColorPortraits* design space.

RESULTS: COLOR PORTRAITS DESIGN SPACE

We collected 35 separate stories from eight participants. We identified several surprising practices: one artist explicitly chose an 'incorrect' color to indicate to the client that the final color had not yet been chosen, and several participants moved back and forth between physical artifacts and digital colors. However, our analysis here focuses on the most common color manipulation practices, chosen because they appeared for half or more of the participants, usually with multiple examples per participant.

Samples: Picking and Tweaking

One of the most common tasks is simply to choose a particular color. Colors are derived from different sources, either from the color space provided by a color picker or from an existing sample. Although users can apply these colors directly, they more often tweak them before applying them to an artifact. Fig. 3 defines two activities related to color selection, including:

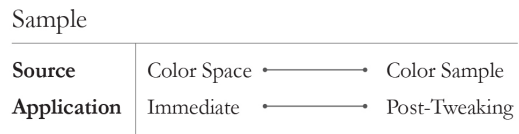


Figure 3: Users pick colors from diverse sources, and often tweak them later.

Surprisingly, only two participants mentioned cases in which they selected a color from the color picker and used it without further modification. P6 (Product Designer) used Adobe Photoshop's color picker to recreate a particular blue she had already used for a website, and P4 (Graphic designer) tried to create 'unusual colors' by using Adobe Illustrator's color picker.

The remaining participants used commercial color pickers, but only as a small part of a much more elaborate color manipulation process. Most (7/8 participants) chose from a variety of samples, including online websites, color palettes and photographs, as well as physical objects, such as ceramics or textiles. Occasionally, participants used the sample color directly, such as when P4 (Graphic designer) chose a blue from a catalog to ensure that the printed version of his poster would appear exactly as he wanted.

More often (7/8 participants), participants started with a sample and then tweaked it before applying it to the artifact. For example, P2 (Exhibit designer) sampled colors from paintings she had found online, and then used the color picker's design space to modify the samples before adding them to her mood board. P7 (Service designer) created a palette using *Kuler*, extracted colors from the screen with *InDesign*, changed one of them, and then used the resulting palette in his final design. P1 (Painter) selected a set of three tubes of oil colors and mixed them to obtain the final colors for his painting (see Fig. 4).

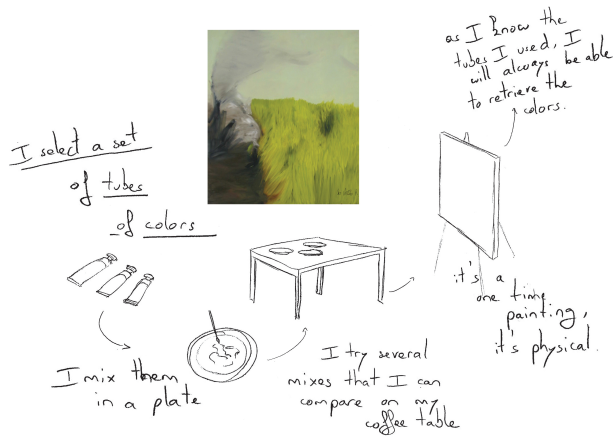


Figure 4: Each storyboard includes a photograph of the artifact and drawings of each step in the color process

Most participants preferred to select a color from a sample, but some found the color picker useful for modifying colors. For example, P8 (Illustrator) used the eyedropper tool in the Macintosh OS color picker to select a colored pixel from an image in a magazine. She decided to purify it by “removing the black”, which she accomplished by placing the color in CMYK color space and sliding the black (K) parameter to zero.

Palette: Manipulating color relationships

Participants rarely worked with individual colors. Instead, they created coherent sets of colors and manipulated them in groups, called palettes. Fig. 5 defines five activities related to color palettes, including: comparing swatches of different sizes, layering or repositioning colors, manipulating groups of colors as a unit, and interacting with color independently, such as within a color picker, or in the context of the remaining colors.

Most participants (7/8) created related sets of colors rather than separate individual colors. Color pickers provide a list of past color choices, but with no context. Participants wanted to create coherent sets of colors, according to the characteristics that they specify. For example, P2 (Exhibit designer) took photographs of related colored objects. For her, “each picture is a different palette.” [P2]. Although the pictures contained the same objects, their positions differed, which resulted in different color compositions.

Palette	
Size	Fixed ↔ Resizable
Layout	Juxtaposed ↔ Layered
Position	Static ↔ Dynamic
Manipulation	Individual ↔ Group
Context	Independent ↔ Dependent

Figure 5: Users adjust size, layout and position of one or more colors, ideally in context.

Participants were very concerned with how different colors appear when used together. For example, P8 (Illustrator) had a restricted palette of one blue and one red for a set of book illustrations. She bought a variety of blue and red pencils and tested how they looked together, before making a final choice.

Participants also wanted to apply a single color change to affect an entire palette. For example, P8 (Illustrator) created one palette and then modified the hue of each color by the same amount, which generated a new palette. Simultaneously adjusting one property for the entire set of colors allowed her to maintain a related, harmonious color palette.

Participants often wanted to manipulate spatial dimensions and contextual characteristics of each palette to control color relationships. Unfortunately, color pickers do not allow users to resize or reshape color swatches, nor do they let users explore color variations in context.

Composites: Assembling disparate elements

Colors are affected both by their surrounding colors and by other adjacent elements. Fig. 6 defines two activities related to color composites, including: composing and decomposing multiple components, and manipulating these components individually or together.

Half of the participants (4/8) wanted to couple color with other elements, such as texture, and manipulate the resulting combination. P2 (Exhibit designer) described the screen as “a flat surface that does not always transpose the richness of the physical world”. To reproduce the yellow texture of a tablecloth on the screen, she scanned it and used the resulting image to provide the effect she wanted. For her, the color did not exist without the underlying texture. P8 (Illustrator) used Photoshop to manipulate a color and a texture that she paired together in several illustrations, which she had to manipulate separately each time. P1 (Painter) created a special preparation that added a particular type of light reflection to each color. He considers this combination of color-plus-reflection as his personal signature.

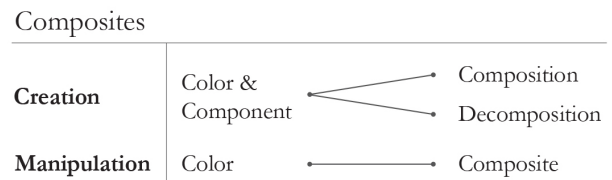


Figure 6: Users combine and decompose colors with disparate components.

Unfortunately, color tools are designed to manipulate properties based on pure colors. They do not support creation of complex color-texture composites, nor can users manipulate individual elements as separate subcomponents that can be assembled and disassembled as needed.

History: Interacting with past actions

Participants often performed similar tasks again and again, or revisited old artifacts when creating new ones. They needed to remember both how they initially created colors and also how the colors were applied in the final artifact. Participants were also interested in intermediate steps, which would let them explore alternative paths without starting over. Fig. 7 defines two activities related to history, including: preserving source materials and final artifacts, and capturing intermediate steps in the selection process.

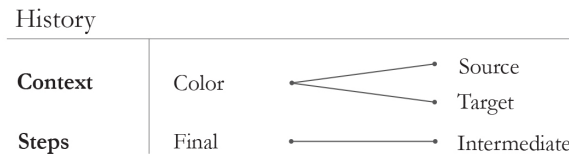


Figure 7: Users record color sources and targets, as well as intermediate steps.

Half the participants (4/8) sought ways to save meaningful intermediate steps in the process of creating a final color. For example, P5 (Cerapist) kept samples of every color she created over the past decade, as well as notebooks containing personal names, codes and the numbers of trials needed to obtain each color.

A few participants (2/8) also kept track of source colors. For example, P7 (Service designer) saved images he downloaded from the internet: “I use these images to extract colors for my palettes and I keep them for later reuse.”[P7]. Other participants saved their final palettes with the resulting artifact. For example, P4 (Graphic designer) placed different-sized rectangles with each final color into the unused space beyond the margins, and saved them as part of the final document.

Some participants (2/8) wanted to return to a previous use context, with both the initial color source and the final artifact. For example, P5 (Cerapist) used several previously created red tiles to develop a nuanced set of three slightly different red tiles for another client.

Unfortunately, color pickers support only the most limited form of history. Although many provide slots for recording previous color choices, these colors are devoid of context about their sources, the sequence of steps necessary to recreate them, and the final result.

Process: Revealing activity over time

Sometimes participants who create physical objects observed color changes that revealed useful information about interim states. Unlike previous dimensions, color here is not the focus, but rather a means to an end. We are interested in how this physical use of color can affect electronic media. Fig. 8 defines two activities related to the color change process, including: manipulating color that results from other activities and revealing on-going processes.

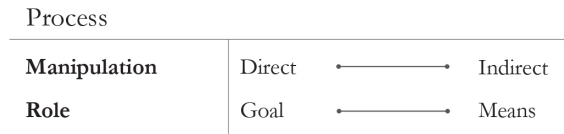


Figure 8: Users react to naturally occurring changes in color to indicate progress.

Half the participants used color to indicate how they created an artifact or the amount of time spent on its creation. P6 (Product Designer) observed colors to determine important details about her design process: “Just by looking at the pot, you can see how many layers I used”. In another project, she heated metal chairs, which caused the metal to change colors. She stopped the process when she liked the color and applied a coating to stabilize the color. Here, she manipulated color indirectly through changes in temperature. This suggests an interesting opportunity for electronic color manipulation tools, in which color change reveals the underlying changes in an online activity.

Color Portraits Design Space: We observed multiple examples of each design category, which form the five key dimensions of the Color Portraits design space:

- Sample* start from an initial color; tweak properties to obtain a final color.
- Palette* manipulate relationships among groups of colors.
- Composite* combine colors with other elements such as texture; decompose to disparate elements.
- History* capture and reuse source and target color contexts; preserve meaningful interim steps.
- Process* reveal progress through color changes.

EVALUATING COLOR PORTRAITS

Color Portraits reflects core color manipulation needs for a specific user group: artists and designers. We are also interested in whether other users who create digital content use similar techniques, and how well current color tools meet the needs we have identified. We would also like to explore how this design space can offer new insights into the design of more powerful color manipulation tools.

Testing with non-color specialists

To test the broader applicability of the *Color Portraits* design space, we interviewed eight scientists and engineers (6 men, 2 women, aged 23-45), from the following disciplines: biology, biochemistry, computer science, data visualization, game developing, virtual reality engineering, automatics and information theory. Each interview lasted approximately one hour, in the participant's office. As before, we asked participants to show us recent artifacts they had created and to describe the steps they followed to incorporate color. At the end of the interview, we asked for additional stories related to each design space category. We recorded audio for all interviews and recorded video of participants' interactions with the resulting artifacts.

Results and Discussion

We collected a total of 34 stories, three to five per participant. Fig. 9 shows that scientists and engineers have similar color manipulation requirements as artists and designers. We saw similar proportions of activities for both groups and were surprised at how important these participants consider color manipulation. For example, P10 (Biochemist) organized a full afternoon with his colleagues to choose colors to represent different molecules. P15 (Information theorist) found choosing a color for a figure very time-consuming: *“I might spend half an hour to find the right amount of blue in my color”*.

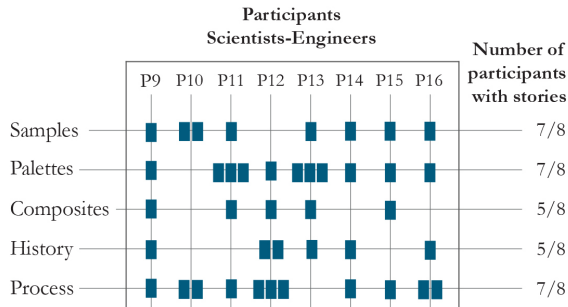


Figure 9 Mapping stories from scientists and engineers, to the Color Portraits design space. One story can map to more than one category.

Samples

Scientists and engineers, like artists and designers, actively sample and then tweak colors (7/8). For example, P10 (Virtual reality engineer) looked for images on the Internet to find inspiration. He sampled several colors as initial references and then adjusted them to create his own set. P13 (Data visualization researcher) wanted to visualize data about cycling teams, so he began by sampling an image of the team t-shirt. He then modified the colors to make them easier to distinguish from each other.

Palettes

Although none of these participants referred to a palette explicitly, almost all (7/8) interacted with sets of colors. For example, P9 (Programmer) created a palette for a user interface design by selecting a few primary colors. He then programmed a script to add a small amount of black to all of his colors to increase legibility. P12 (Geologist) scanned an image from a microscope image of a rock, using polarizing paper to change all colors simultaneously: *“This lets me preserve the relationships among the colors”*.

Composites

Many participants (5/8) were interested in achieving a particular effect that they then explored by interacting with color and a second element. P10 (Virtual reality engineer) combined a grass texture with green to create the grass for his 3D space: *“I played with the combinations to get this effect with my 3D rendering software.”*

History

Over half the participants (5/8) kept track of interim steps in the context of previous color manipulations. For example, P14 (Game developer) created folders of colors where she recorded her color choices and later reflected on them, in the context in which they had been created: *“I look at the colors, dates of creation and names I gave the colors to see how my perception of these names changed over time.”*

Process

Interestingly, almost all scientists and engineers (7/8) used color to indicate the progress of an on-going activity. P9 (Programmer) used highly distinctive colors for his Java classes in order to quickly check the complexity of a piece of code: *“If the class has many colors, it means that it has a large number of dependencies and it will be hard to test”*. Similarly, P16 (Information theorist) used a colored pen to mark variables in her equations, which helped her communicate and follow the evolution of her calculations.

In summary, seven participants described color-manipulation stories related to at least four of the five dimensions. This suggests that the color manipulation activities we identified for artists and designers, for whom color is a major focus of their work, also obtain for scientists and engineers, for whom color is more of a means to an end.

ANALYSIS OF CURRENT COLOR TOOLS

All 16 participants in the previous studies managed to manipulate color in creative ways, as expressed in the *Color Portraits* design space. We analyzed six existing color tools to see how many support the five key activities: Two for the general public (color pickers for *Macintosh OS X* and *Microsoft Word*); two for scientists and engineers (*Color Brewer* [10] and *IWantHue*); and two for artists and designers (*Adobe's Kuler* and *Photoshop* color tools).

Fig. 10 maps the characteristics of each tool according to the *Color Portraits* design dimensions, based on type of interaction: *System*: Does the tool offer specific, ready-to-use features that support the activity? *User*: Can users personalize their activity? *User-System Interaction*: Can users capture and reuse previous interactions with the tool?

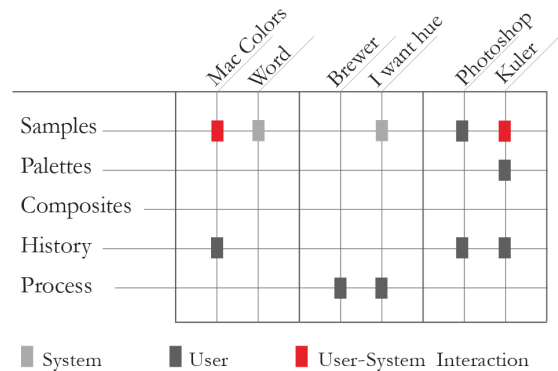


Figure 10: Existing color tools are most likely to support interacting with color samples, but many gaps remain.

Color pickers for the general public

Microsoft Word and *Macintosh OS X* both provide sets of color pickers designed to support color selection from either a limited set of pre-defined colors or else from an extremely wide range of colors within mathematically defined color models. Both tools provide swatches of pre-determined colors, with shades of gray and sets of primary and secondary colors. Users can use the mouse or adjust sliders to select individual colors and create subtle variations, but even with domain knowledge, they have difficulty selecting a precise color, and in many cases, the desired color does not even exist.

The *Macintosh OS X* color picker includes an eyedropper for selecting the color of any pixel on the screen. Users can also save colors as a list of swatches that are accessible from different applications. This offers limited, but somewhat cumbersome, support for history. Thus *Microsoft Word* offers only system-level support for sampling colors, whereas the *Macintosh OS X* color picker also features interaction-level support for sampling and user-level support for history. Neither tool supports interacting with palettes, composites or process. Thus, the most common color tools for the general public support only a small proportion of the color manipulation requirements identified by in the *Color Portraits* design space.

Color Tools for Scientists and Engineers

Color Brewer provides suitable color palettes for online maps and *IWantHue* offers optimally diverse color palettes for data scientists. Unlike other color tools, both explicitly support use of color to represent process: *Color Brewer* helps scientists and engineers to color maps and *IWantHue* supports exploratory data visualization.

On the other hand, neither tool allows users to interact with palettes, make composites or preserve a history of their previous interactions. They offer only a cursory use of samples, which are restricted to a limited set of system-generated colors. Both make a trade-off between simplicity and power, supporting a restricted set of color manipulation activities, but offering little flexibility if the specific tasks require more advanced color experimentation.

Color Tools for Artists and Designers

The *Adobe Photoshop* color tool is embedded within a professional application designed to help artists and designers edit photographs. *Adobe Kuler* is an online tool with a large library of themed palettes contributed by users as well as an interactive tool that incorporates color theory to generate new color palettes. Both support sampling at the system and user level: users can not only select from pre-defined sets of colors, but also create their own.

The *Photoshop* color tool lets users import their own palettes and *Kuler* lets users upload images and extract color samples. *Kuler* also offers advanced interaction capabilities for manipulating samples and can also generate new palettes. However, *Kuler* does not meet the most

advanced level of interaction with palettes: Users can change one color to affect the rest of the palette, but cannot control the spatial arrangement. Although they can take advantage of pre-defined color rules to create certain types of palettes, such as complementary colors, they cannot define their own rules to determine their own personally defined color relationships.

Although *Photoshop's* color tool and *Kuler* both allow users to save colors as they progress through a task, which they can reuse later, neither preserves context. We thus categorize these tools as providing user-level support for history. Neither tool supports creating or disassembling composites of multiple colors and textures, nor do they support the use of color to reveal activity. Not surprisingly, these two professional tools cover a larger portion of the *Color Portraits* design space when compared to tools intended for the general public or for scientists and engineers. However, they still lack support for many color manipulation activities that were identified by the participants.

Although they do not comprise an exhaustive set, these six color tools are widely available and represent the most common strategies for helping users manipulate color. However, when we examine their specific capabilities, we see that many gaps remain in the *Color Portraits* design space (Fig. 10), suggesting opportunities for the design of innovative color tools.

TOOLS FOR INTERACTING WITH COLOR

In order to test the generative power of the *Color Portraits* design space, we created a set of four probes [13], each designed to explore an activity that is not well supported by current tools. The probes were inspired directly from the color manipulation stories, and represent different requirements specified by the *Color Portraits* design space. Note that our goal was not to fully support all possible color manipulation activities, but rather to illustrate how color tools might inspire new directions for designing color manipulation tools. The probes support the following activities: designing and interacting with palettes, assembling and disassembling composites, creating interactive histories, and applying color to reveal the process as users progress through a particular activity.

Palette Explorer – Interacting with Palettes

Almost all participants (14/16) actively created sets of colors and manipulated the relationships among them, but usually in an ad hoc way, combining features from multiple tools or creating their own techniques. *Palette Explorer* lets users create groups multi-colored swatches of different sizes and shapes. In Fig. 11a, the user creates a large green foreground swatch, with a pale blue background and red and blue intermediate elements. The user can move, resize and adjust layers to explore the effects of different spatial relationships. In Fig. 11b, the user changes the background to red and the remaining elements are smaller and repositioned in layers next to each other.

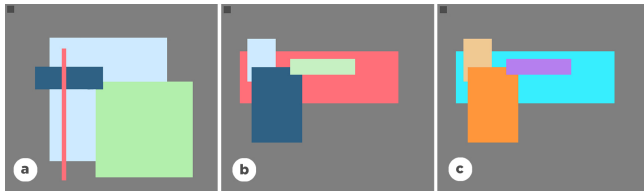


Figure 11: *Palette Explorer*: Users can create interactive color palettes with dynamic swatches, enabling them to explore spatial relationships and manipulate sets of swatches.

Users can modify a color in the context of the remaining colors by moving the cursor along three axes: X for hue, Y for saturation and mouse wheel for brightness. Users can also select sets of swatches or the whole palette and modify them at the same time, retaining the harmony and other characteristics of the original palette. In Fig. 11c, the user has shifted the main foreground blue to orange, and the remaining colors have changed accordingly.

Color Compositor – Interacting with composites

Although some color pickers allow users to include a limited set of patterns or textures [23], they do not allow users to incorporate their own material. *Color Compositor* lets users combine colors and textures to create their own novel composites.

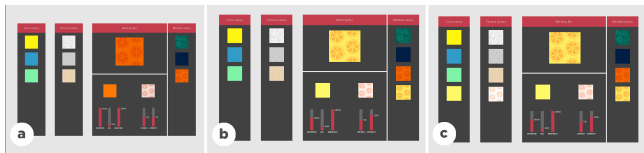


Figure 12: *Color Compositor*: Users combine colors and textures to create and manipulate composites.

In Fig. 12a, the user combines orange with an image containing slices of a citrus fruit. The user can also modify the colors and textures independently. In Fig. 12b, the user turns the orange into a lemon. Users can also decompose the resulting textured image into its component parts. In Fig. 12c, the user extracts color and texture for later reuse.

Color Partner – Interacting with History

Participants often reuse previous material from earlier projects and develop their own ad hoc techniques for capturing a history of their actions. *ColorPartner* lets users capture these interim steps in their color exploration process. Users identify a starting point by specifying two colors, after which *ColorPartner* generates novel, related colors. In Fig. 13a, the user creates a white and a black dot. In Fig. 13b, the system generates a set of related dark colors.

Users can guide which colors are generated through proximity to previously generated colors: moving the cursor closer to a dot produces more similar colors whereas moving the cursor away results in more diverse colors. In Fig. 13b, the user generates paler colors in the red range by moving from the red dot on the right, towards the white dot.

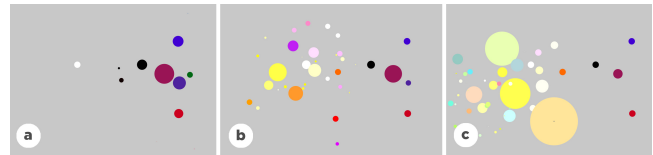


Figure 13: *Color Partner*: Users specify initial colors and move the cursor to control generation of new colors. They can save interesting intermediate colors by clicking on the dot.

Over time, colors become smaller and disappear. However, the user can save colors by clicking on them; multiple clicks enlarge the size of the dot. In Fig. 13c, the user indicates a strong preference for three yellow and pale orange colors. *ColorPartner* allows users to return to intermediate color choices and use them to create new colors. *ColorPartner* offers an interesting partnership between users and the system, since they both collaborate on the creation and reuse of collections of colors.

Color Revealer – Interacting with Process

Unlike the other activities in the *Color Portraits* design space, process does not treat color as an end in itself, but rather as a means to an end. Color changes reveal intermediate steps or the overall state of an activity as it occurs over time. Like *EditWear* [12], which uses color to support annotation, *ColorRevealer* captures traces of the user's writing process, modifying hue and intensity. Characters each appear in a subtle, colored layer in the background.

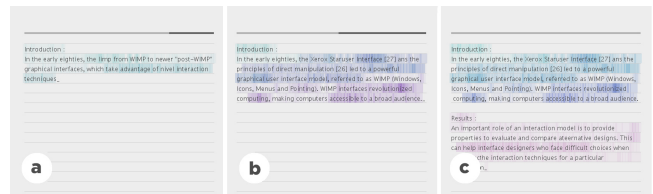


Figure 14: *Color Revealer*: Users' hesitations and corrections are revealed through changes in hue and intensity.

In Fig. 14a, the user writes with very little hesitation, so the layers behind the text appear as a pale green. Additional layers appear as the user deletes or rewrites words. In Fig. 14b, the user has repeatedly deleted and corrected a number of words in his introduction, which introduces blue and purple text. *Color Revealer* allows users to control the mapping of colors to their writing activities and provides an adjustable timeline that lets them scroll back through earlier stages in the writing process. In Fig. 14c, the user needs additional time and has adjusted the time scale accordingly.

These four color tools embody different aspects of the *Color Portraits* design space. We treat them as probes to help us evaluate how color manipulation activities are represented in the design space and, to understand color manipulation more generally.

INTERACTING WITH PROBES

We selected participants from the two earlier studies to try the probes. We wanted to get an idea of how they interpreted each tool in general, and also in the context of their current work.

Participants: We re-interviewed eight participants, half from each of the two previous studies (5 men, 3 women, aged 23-40). Professions included: product designer, illustrator, painter, service designer, researcher in data visualization, information theorist, virtual reality engineer and programmer.

Procedure: Each session lasted approximately one hour in the participant's studio or office. We presented each tool, in turn, and gave the participant five minutes to experiment and perform short tasks with each tool, as follows: *Palette Explorer:* Create a book's cover page. *Color Compositor:* Design a textured color for the background of the book cover. *Color Partner:* Create your favorite red and favorite blue. *Color Revealer:* Write a summary of a recent project. After each task, we asked participants to think of recent color projects in which they manipulated color and show us how the tool might, or might not, be useful for those tasks. We counter-balanced the order of tools across participants.

Data collection: We collected audio recordings of each session and screen captures of their interactions with each color tool. We also took notes based on participants' answers to a common set of interview questions.

RESULTS

Participants suggested different ways of using the color probes both conceptually, by explaining what the tool does, and practically, to solve problems for their current projects. Interestingly, all participants wanted to interact with the color tools immediately, to manipulate swatches, dots or textures to obtain a desired effect.

Palette Explorer – Interacting with Palettes

Most participants (7/8) viewed *Palette Explorer* as a space for sketching color relationships relevant to those in their daily work. P5 (Product designer) described *Palette Explorer* as “a tool for projection and sketching that allows rapid visualization of scale relationships among colors.” She wanted to create a color chart to establish a digital identity for a client and was particularly interested in using it to see how the colors look together in different contexts. For example, she wanted to establish a set of colors and then experiment how they would look with different versions of her client's logo.

Color Compositor – Interacting with composites

Half the participants in each of the earlier studies reported developing ad hoc strategies to combine colors and textures, but felt that *Color Compositor* greatly simplified the task. P3 (Service designer) was happy to avoid using *Photoshop* layers when creating and experimenting with a textured color. P5 (Product designer) wanted to use *Color Compositor's* texture library to group similar components for future use.

Although *Color Compositor* focused on texture, participants had a number of suggestions for combining color with other elements, especially images. They also offered innovative ideas for how to extend it. For example,

three participants suggested reproducing these patterns on very large surfaces, to establish color and texture relationships when creating wallpaper.

Color Partner – Interacting with History

Participants viewed *Color Partner* as a space for exploring color. P1 (Painter) appreciated how suggesting colors helped him make color-related decisions. However, he “would not share the result of generation. The colors I get are more personal”. *Color Partner* also allowed participants to create interesting clusters of colors and to preserve those they would later use to create a new color exploration chain. P16 (Information theorist) felt that the tool would help her get “little by little to the color I want”.

Color Revealer – Interacting with Process

Color Revealer encouraged participants to reflect on how they type and write. P16 (Information theorist) compared *Color Revealer* to an eraser: “When I erase an area several times, I end up seeing the trace on paper”. She also noticed that she always deleted the whole word when she makes a typo, which she had not realized before. P5 (Product Designer) explained that *Color Revealer* “projects your thinking as you write. It helps you feel the intensity of your writing and gives it meaning through making this process visible.”

All but one participant described how they would use *Color Revealer* in their current projects. P1 (painter) wanted to use it when collaborating on a course he is teaching. Since his colleague is a fast typist, he wanted her to use the tool to take notes during class. He would like to then read the notes and use the change of color to help him understand when she hesitated, just as in a face-to-face conversation.

IMPLICATIONS FOR DESIGN

Our observations of how users interacted with the color probes suggest the following directions for designing interactive color tools:

Experimentation: explore color relationships; compare alternatives; and support user-defined constraints.

Ownership: personalize colors; capture interim creative steps; embed meaning; retain context; and support reuse of color creation chains.

Partnership: select within meaningful subsets of colors suggested by the system; and guide the system in new directions.

Integration: combine diverse elements; manipulate composites; and decompose into component parts.

SUMMARY AND FUTURE WORK

We created the *Color Portraits* design space to help identify color manipulation requirements that are poorly addressed by today's color manipulation tools. We conducted contextual interviews with 16 participants, who provided detailed examples of how they used color to create 69 different artistic or technical artifacts.

We also created a set of four color probes: *Palette Explorer* manipulates color relationships within a shared context; *Color Compositor* composes and decomposes diverse colors and textures; *Color Partner* generates and captures chains of color, guided by the user; and *Color Revealer* reveals underlying processes by subtly changing hue and color intensity.

The *Color Portraits* design space demonstrates the scope of as-yet unmet color manipulation needs, and the color tools demonstrate the generative power of this design space. In the future, we hope to build upon this work to design innovative new color manipulation tools for creative professionals, moving beyond simply picking colors to truly interacting with color.

ACKNOWLEDGMENTS

This research was supported by ERC grant n° 321135 *CREATIV: Creating Co-Adaptive Human-Computer Partnerships*. Our thanks to the participants for sharing their creative uses of color, and to Inria's Insitu research lab for fruitful discussions throughout the project.

REFERENCES

- Albers, J. *Interaction of Color: 50th Anniversary Edition*. Yale University Press, New Haven, CT, 2013.
- Bailey, P., Manktelow, K., & Olomolaiye, P. Examination of the color selection process within digital design for the built environment. In *Proc. IEEE, Theory and Practice of Computer Graphics* (2003), 193–200.
- Bergman, L.D., Rogowitz, B.E., & Treinish, L.A. A rule-based tool for assisting colormap selection. In *Proc. Visualization* (1995), 118.
- Chevalier, F., Dragicevic, P., & Hurter, C. Histomages: fully synchronized views for image editing. In *Proc. ACM UIST* (2012), 281–286.
- Della Ventura, A. & Schettini, R. (1992) Computer-aided color coding for data display. In *Proc. IAPR* (1992), 3: 29–32.
- Douglas, S.A. & Kirkpatrick, A.E. Model and representation: the effect of visual feedback on human performance in a color picker interface. *ACM Transactions on Graphics* (1999), 18(2): 96–127.
- Faul, F. & Ekroll, V. Psychophysical model of chromatic perceptual transparency based on subtractive color mixture. *JOSA A* 19,6 (2002), 1084–1095.
- Frisby, J.P. & Clatworthy, J.L. Illusory contours: curious cases of simultaneous brightness contrast? *Perception* 4, 3 (1975), 349 – 357.
- Glaser, B. & Strauss, A. *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Aldine Transaction, Chicago, 1999.
- Harrower, M. & Brewer, C.A. ColorBrewer.org: An Online Tool for Selecting Colour Schemes for Maps. *The Cartographic Journal* 40, 1 (2003), 27–37.
- Healey, C.G. Choosing effective colours for data visualization. In *Proc. Visualization* (1996), 263–270.
- Hill, W.C., Hollan, J.D., Wroblewski, D., & McCandless, T. Edit Wear and Read Wear. In *Proc. ACM SIGCHI* (1992), 3–9.
- Hutchinson, H., Mackay, W., Westerlund, B., Bederson, B., Druin, A., Plaisant, A., Beaudouin-Lafon, M., Conversy, M., Evans, H., Hansen, H., Roussel, N., & Eiderbäck, B. Technology probes: inspiring design for and with families. In *Proc. ACM CHI* (2003), 17–24.
- Itten, J. *Art de la couleur, édition abrégée*. Bordas Editions, Paris, 1996.
- Jirousek, C. *Color, Value and Hue. Art, Design and Visual Thinking*, 1995.
- King, T.D. Human color perception, cognition, and culture: why red is always red. *Electronic Imaging, Inter. Soc. Optics & Photo.* (2005), 234–242.
- Kubat, R., Mirman, D., & Roy, D. Semantic context effects on color categorization. In *Proc. CogSci* (2009).
- McCollough, C. Color Adaptation of Edge-Detectors in the Human Visual System. *Science* (New York, N.Y.) 149, 3688 (1965), 1115–1116.
- Meier, B.J., Spalter, A.M., & Karelitz, D.B. Interactive color palette tools In *Proc. IEEE Graphics and Applications*, 24, 3 (2004), 64–72.
- Meier, B.J. ACE: a color expert system for user interface design. In *Proc. ACM SIGGRAPH symposium on User Interface Software* (1988), 117–128.
- Meyer, G.W. & Greenberg, D.P. Perceptual color spaces for computer graphics. In *Proc. ACM SIGGRAPH Computer Graphics* (1980), 254–261.
- O'Neill, J., Martin, D., Colombino, T., Roulland, F. & Willamowski, J. Colour management is a sociotechnical problem. In *Proc. ACM CSCW* (2008), 599–608.
- Pang, W. M. An intuitive texture picker. In *Proc. ACM IUI* (2010), 365–368.
- Pouli, T. & Reinhard, E. Progressive histogram reshaping for creative color transfer and tone reproduction. In *Proc. ACM Symposium on Non-Photorealistic Animation and Rendering* (2010), 81–90.
- Robertson, P.K. Visualizing color gamuts: A user interface for the effective use of perceptual color spaces in data displays. *IEEE CG&A*, 8, 5 (1988), 50–64.
- Wang, L., Giesen, J., McDonnell, K.T., Zolliker, P., & Mueller, K. Color design for illustrative visualization. *IEEE Vis. Comp. Graph.* 14 6 (2008), 1739–1754.
- Wijffelaars, M., Vliegen, R., Van Wijk, J.J., & Van Der Linden, E.-J. Generating color palettes using intuitive parameters. *Comp Graph. For.* (2008), 743–750.