Palette, Purpose, Prototype: The Three "P"s of Color Design and How Designers Navigate Them

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ABSTRACT

This paper contributes to understanding of a fundamental process in design: choosing colors. While much has been written on color theory and about general design processes, understanding of designers' actual color-design practice and experiences remains patchy. To address this gap, this paper presents qualitative findings from an interview-based study with 12 designers and, on their basis, a conceptual framework of three interlinked color design spaces: purpose, palette, and prototype. Respectively, these represent a meaning the colors should deliver, a proposed set of colors fitting this purpose, and a possible allocation of these colors to a candidate design. Through a detailed report on how designers iteratively navigate these spaces, the findings offer a rich account of color-design practice and point to possible design benefits from computational toolsthat integrate considerations of all three.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**.

KEYWORDS

Color design, color choice, design practice, qualitative methods, interview studies

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1 INTRODUCTION

Most visual design involves colors. Their choice is critical for human–computer interaction and the broader effects of a design. Colors guide visual attention and are critical for supporting such aspects of accessibility as readability and legibility. At the same time, they help a brand or product stand out, convey emotions and meanings, and affect user behavior. Color design clearly holds great importance. Yet little work has examined how designers actually decide on colors in their day-to-day practice. While research has studied some facets of color design for centuries [41], the majority has been focused on what one might call normative accounts of color design. For instance, "color systems" enable describing colors unambiguously on the basis of their properties [50]; e.g., the Munsell system describes colors by their hue, value, and chroma, properties by which one can create compelling contrasts in visuals [27]. Meanwhile, some HCI researchers have proposed interaction techniques developed to promote efficient color choice, such as palette-generation tools [2, 9, 14, 37], color-selection interfaces [5, 18, 52, 53], and mechanisms for ideation and inspiration-seeking [20, 25, 26, 47].

The few empirical studies of color-design practice offer only a fragmented picture of the landscape. Kim and Suk [21] conducted a controlled study with designers, asking them to find one color that matches a given image (for display next to it) and keyword. The participants' color choice was directed toward supporting coherence between the word and image, which requires both understanding the image and identifying a color that reflects the word. Often, the colors chosen came directly from the image, but the process also included comparing alternatives and "tweaking" various colors. Turning their attention to these more abstract levels, specifically how designers create visual metaphors, Kang et al. [20] found a role of color in those metaphors and showed that designers consider color when searching for design examples. We are aware of only one interview study asking designers about how they choose colors [8]. However, even that dealt mostly with quantitative results: how often certain keywords appeared in the 20 design professionals' interview responses. The study – in which designers cited "meaning" most often as the highest-priority factor – serves as an interesting starting point for looking at how designers choose colors in practice. However, research thus far has limited itself to specific use cases or quantifying the related factors, without encompassing qualitative analysis.

Hence, several vital questions remain. How do designers apply normative theories of color, and which aspects of these are useful? What do they find to be the core objectives in color design, and which facets of design are experienced as challenging? What relationships exist between color considerations and broader design processes, and how do these tie in with other design practices? In short, we need to know how colors are "done" in practice.

To begin filling the knowledge gap, we present findings from interviews with 12 designers. We devised an interview process that affords balance between designers' personal viewpoint and sufficient concreteness in the reporting. Thus, we sought to learn how designers approach the problem of color choice. Our questions addressed whether they experience getting "stuck," or fixated on a single design direction, and how they might try to overcome this. The questions probed the process's specifics too: do designers sketch

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and prototype colors, and, if so, is this handled via abstractions such as mood boards, or is "the rest of the design" (content, shapes, layout, etc.) more relevant? We expected that the non-normative facets to color design might well involve extensive tacit knowledge best illuminated via concrete examples. Besides the "nuts and bolts" of color choices, we strove for a vantage point to the sometimes "messy" stages, wherein designers need to make sense of the project and work out what it entails. Finally, we looked at color design as a collaborative and computer-assisted effort. Since designers spend considerable time communicating with others, we hoped to learn about how color choices feature in their communications. To render our work more relevant for HCI-based efforts to support designers, we broached questions about design tools and how promising AI-assisted color design might be.

We summarize our results under a framework (the three "P"s[1]) describing the process and how designers think when tackling colors. This model comprises three interconnected decision spaces: purpose, palette, and prototype. The first of these is populated via the communication requirements of color selection: colors should support a function or message. The other spaces, in contrast, are primarily visual. Purpose involves considering which colors the design should contain, an inquiry process that, in essence, consists of defining the underlying color palette, while the third "P" is the space for implementing these colors in a particular prototype. We assert that the color-design process entails exploring and aligning all three spaces.

The following sections begins with a survey of related work on color design, covering both normative accounts and empirical research, alongside HCI researchers' attention to interaction techniques and tools. We then introduce our interview method. The remainder of the paper is devoted to our findings and their implications, to provide a rich account of designers' views and practice. The consideration of our findings is centered on two questions: 1) What, if anything, makes color design special? For possible answers, we consider the findings against the backdrop of prior, general accounts of design practice. 2) What role does normative theory fill in day-to-day color choices?

2 PRIOR WORK ON COLOR-DESIGN PRACTICE

Our study is positioned at the intersection of three research areas: HCI scholarship, which displays an interest in understanding and facilitating color design; design research, which seeks empirical perspectives on designers' practices; and, finally, multidisciplinary research into color theory. We argue here that there is a need to examine designers' real-world practices, thereby complementing the picture yielded by normative accounts of color and enriching the HCI field's efforts to devise better interaction techniques.

2.1 Color Theory

Color theory addresses the properties of colors and, on their basis, offers guidance on how colors might best be chosen. Among this field's tools are the aforementioned color systems, which describe colors systematically by assigning each of them an unambiguous place in a given structure [50]. The Munsell colorimetry system serves as one example [3]. Another framework is the Pantone Color Matching System [46], which allows re-creating colors across media and also covers colors not displayable on a screen, such as neon and metallic tones. Looking beyond the framings themselves, some scholars examine their application in efforts to guide color choices. Kopacz [27] considered how to enhance designs through recognizing contrasts' effects on perception of color. Here, "contrasts" refers to difference in hue, value, chroma, or temperature [27]. The monograph *Interaction of Color* [4] highlights that colors in mutual proximity influence each other. This classic pre-digital-age work details practical experiments spotlighting this theme, some of which were recently replicated with digital printers [39] and a mobile app.[2] Through these, the book still performs its intended educational function: practitioners learn to sharpen their intuition about colors and trust it over rule-following.

Alongside color systems, color wheels are another tool in widespread use. These circular arrangements, with similar hues next to each other, take various forms, depending on the underlying color system. Under some theories, color schemes can be classified in terms of their hues' relative locations on one of these wheels [16] (see Figure 1). Many color-design tools follow on color-wheel-based conceptions of harmony [2, 9, 14, 37]. Data analysis has revealed that the most popular schemes feature a value gradient and contain warm colors and cyans [40]. Still, the researchers found no evidence of adherence to particular color-wheel patterns, raising the question of how color wheels get used, if at all. Theories of color help us model, classify, and explain colors and their combinations, so they are a mainstay of design education. However, the ways in which designers apply this knowledge are less clear.

2.2 Color Psychology

Designers display awareness of research into how color affects the human perceiver also. For example, people find blues and reds appealing but show an aversion to yellows and yellow-greens both as individual colors [15, 43] and in color combinations [42, 44, 45]. We develop some color preferences by connecting colors with the emotions elicited in relation to items of those colors. This abstraction of colors from the objects perceived explains general preferences in addition to individual-level or group-linked ones [15]. Scholars have validated color palettes' emotional associations via a data-based model aligning colors from magazine covers with evocative words [17]. That said, color preferences are largely context-contingent, hinging, for example, on the type of object involved [38]. Given such a rich web of associations, we may find little surprise in evidence of color's physiological effects, such as heart-rate changes or altered perception of time upon spending time in a room of a certain shade [38]. Colors are bound up with popular trends; some aspects of expectations develop over time and depend also on location and industry [13]. Researchers have also developed models for evaluating patterns in the ultimate associations produced. For instance, Kobayashi [23] examined color–adjective mappings andlater contributed the Color Image Scale [24] for mapping color combinations on a similar basis.

[1] Project page at www.cbl.aalto.fi/3p-framework

[2] See http://yupnet.org/interactionofcolor/.

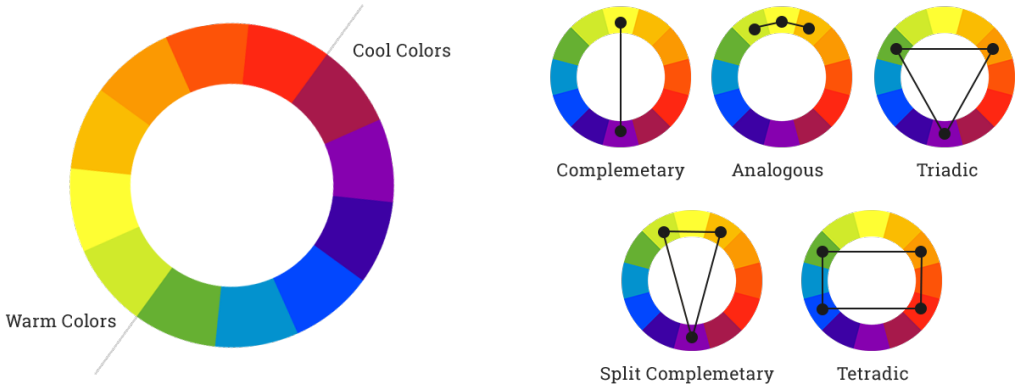

Figure 1: An example of a color-wheel diagram, from seekpng.com (under "Color Theory – Color Wheel"), distinguishing between cool and warm colors and presenting types of color harmony by hue.

Although much of the literature articulates well-grounded ideals for design goals and strategies, there is evidence that not all designers follow that guidance. Tigwell et al.'s 2017 survey of designers [55] revealed that, while around two thirds of the respondents were aware of guidelines for accessible color use in Web design, only a third applied them, and more than half admitted to not considering accessibility at all before arriving at a functional design. Hence, what role these principles play in practices related to ideation, sketching, prototyping, etc. has remained unclear.

2.3 Interaction with Tools for Color Design

Research into color tools has investigated several aspects of the process by which users choose colors and how to support it. Examining various common color-picker implementations' effectiveness, Brathovde et al. [7] discovered that effectiveness depends on the type of color-picker. Likewise, Alex et al. [5] found that the picker interface influences the colors present in virtual art. These two studies attest to the impact of color-pickers on color choices. However, they tested the interfaces in general conditions only, not with design experts. The authors of a paper on the Playful Palette system [52], in contrast, did consider expert users. They introduced a novel interface developed to meet the requirements identified from studying how artists use palettes with physical paint: enabling artists to blend colors, quickly explore color combinations, maintain a history, and organize colors. Still, while artists are experts in color use, their color-picking needs might differ from designers'. Jalal et al. [18] interviewed both designers and artists, then observed their interaction with colors and developed a design space responding to the five activities pinpointed. They found that 1) designers often take colors from samples and usually tweak these before application, 2) most study participants used not individual colors but palettes they created, 3) color is closely linked to textures and/or material, 4) earlier colors and intermediate steps get reused, and 5) the colors involved shed light on the process. Such prior work permits us to conclude that greater expressiveness in the interaction with color-manipulation interfaces supports high-quality color choices by designers. Nevertheless, it serves as merely a starting point: interacting with the interface for picking a color is likely to be just one part of arriving at the color scheme.

Large-scale text-to-image generators have recently found a place in design [57], where they already enjoy widespread use for producing image references [22], inspiration, and low-fidelity prototypes [22, 57]. Given that designers often sample colors from preexisting materials, one would expect an immediate impact of generated images on color choice. At the same time, though, designers criticize the models for not obtaining acceptable aesthetics and color harmony except with human intervention [57].

2.4 General Understanding of Design Practice

Notwithstanding the rarity of empirical studies specific to color-design practice, extensive work on design practice in general offers a valuable starting point. Accordingly, we situate our findings within the landscape of empirical understanding of design practice. Four important nuggets from this vast body of knowledge hold special importance from the standpoint of our study. 1) Designers' task is seldom to produce a solution to an assigned problem. Making sense of what the assignment "means" [10] is a critical challenge in their projects: they must translate the design brief, typically a verbal description of the design's target, into an actionable description that can guide the design choices [11]. The translation often coalesces in visual output [56] such as sketches or a mood board (a collage from inspirational material collected to aid in integrating the visual possibilities for the design and embarking on discussion with stakeholders [33]). Initial solution propositions help with further crystallizing the problem, ultimately contributing to iterative co-evolution of problem and solution [35]. 2) Multiple stages follow this in the design. These differ in their representation approach and level of abstraction [11]. For example, the early stages may focus more on ideation and framing (e.g., conceptualization via mood boards). One stage-based model for design processes that has gained popularity in recent years is a "double diamond" that refers to alternation between divergence and convergence in in dedicated phases of discovering, defining, developing, and delivering the project. 3) Along the way, designers often struggle to overcome design fixation, the experience of getting stuck and being unable to produce new ideas [19]. Therefore, idiosyncratic and context-bounded methods of seeking inspiration, generating ideas,

and pursuing a creative leap by taking new perspectives constitute an essential aspect of design practice [10]. At least for some, browsing curated example galleries may lead to better coloring of designs [30], and designers sometimes gather relevant inspirational material more easily if able to filter by graphical style, using color-related and other search terms [47]. 4) Lastly, design practice is tightly bound up with getting stakeholder "buy-in" and feedback. This demands communication and collaboration. Throughout the project, designers typically discuss their visual-design choices with the client, translating them back into verbal form in the process [56].

While color design may constitute a key component of these practices, scholarship has been silent as to how. Research into real-world design has produced a rich knowledge base that can inform understanding of color design, but how well the general findings apply specifically to color design remains to be investigated, as does color design's position in the larger picture of design practice.

3 THE INTERVIEW METHOD

Our study method was guided primarily by the goal of gaining deep knowledge of concrete color-design practices from the designer perspective. We recruited 12 visual designers, 10 of them professionals and the others individuals who regularly performed design tasks in their leisure time. Because the foundations of color design, lying largely in color wheels and contrast types [4, 16, 27], associations [23, 24], and color trends [13], extend beyond the boundaries of design's sub-disciplines but may manifest themselves uniquely in each, we aimed for diversity in our recruitment. We sought a group that represents multiple aspects of fields oriented toward visual design while also striving to cover a wide spread of experience levels.The interviews followed a semi-structured protocol, to guarantee coverage of all relevant topics while still granting the interviewer sufficient flexibility to follow interesting flows of thought that emerged. Moreover, we strove for balance in the data between general considerations and case-specific description: we wanted the interviews to capture designers' overall views yet also be anchored in concrete practice. Therefore, some parts of them probed experience and preferences in broader terms while other portions asked interviewees to present recent projects and discuss their work approach particular to these. Recognizing the importance of visuals in color design, we video-recorded the interviews and took screenshots of key visuals during transcription.

3.1 Participants

We focused our recruitment on people experienced in visual design, those with experience of designing artifacts for computer-users or consumers especially. This scope did exclude the color-design expertise evident in some branches of the arts, but their practices and purposes diverge enough from those central to our study that they could have diluted our findings. The resulting sample, detailed in Table 1, consisted of 12 designers, with varied background (in terms of design education, years of work experience, and design discipline). For inclusion in the study, we required the designer to have been responsible for choosing and applying color in a recently completed design project, in line with our interview design. Two participants were professionals in a non-design field who completed design projects outside work hours (one for personal projects, the other as a volunteer for events). At the time of the study, all participants were based in Europe. Participants were compensated for their time with a payment of 50 euros.

3.2 Setup

Each interview took one to two hours and was conducted as a video call. We asked the participants to be prepared to present the project during the interview, for which they all opted to share their screen. We encouraged participants to show us earlier versions of their designs so that we could see how the project evolved. However, this was optional since we had no wish to exclude designers who had not retained such materials or who lacked permission to share them. Restricting the sample in that way could have biased the types of practice captured.We recorded all audio, video, and chat content.

3.3 Interview Structure

The interviews followed a conversational approach [29] with which the discussion built from general questions at the beginning and then homed in on more specific matters for the main part of the discussion before returning to a wider perspective toward the end [28, 48]. We structured the interview flow via questions about color design in general, leading toward anchoring in the recent project and details of its particular creation process. From these specifics, the discussion moved on to tool use and general sentiments related to the tasks constituent to color choice. The interviews applied a mixture of established question types: "tour" and "stages" questions about the chosen project, questions grounded in that project, and probing for other examples. When an important concept arose, we followed up by asking about the participant's understanding of it and beliefs about the concept. We go into the structure and its rationale below, and the full interview guide with the set of guiding questions is presented in Figure 8 in the appendices.

Introduction and warm-up: Every interview started with the interviewer offering a personal introduction and outlining the discussion's focus, objectives, and structure. Once informed consent had been obtained, video- and audio-recording commenced. Interviewees were given a reciprocal opportunity to introduce themselves, along with their design experience (and its context), specific field of expertise, educational background, and tenure in the field.

General discussion: After this, conversation gradually shifted toward the central topic. Queries delved into the interviewee's experience with color design, the types of projects that had involved color choices, and the interviewee's familiarity with predefined color schemes. Discussion covered participants' perspective on what constitutes "good coloring," with the associated criteria.

The project and in-depth discussion based on it: Shifting from general color-design issues to practical instances, the interviewer solicited an overview of the interviewee's chosen project work, with a request to present the project with its goals and coloring needs. The following questions pertaining to the color-design process thus were angled for specific and realistic answers. For those regarding collaboration, emphasis was given to external influences on color choices, particularly the role of any design team in color-related practices. Further exploration pursued thorough understanding

Table 1: Participants' design experience and the project types considered in the interviews.

ID	Design experience	Design specialty	Project(s) presented	Country
P1	Master's student, with part-time and summer-work projects	UX	Portfolio	Finland
P2	Master's degree and three years of work	UX/UI	Brand style guide	Finland
P3	12 years' hobby experience	Graphic	Printed flyer	Germany
P4	Bachelor's degree and 2.5 years of work	Product and UX/UI	UI/UX for app	UK
P5	Self-training and 16 years' work experience	Brand and digital-product	Two visual brand images and the visual identity for a digital product	Finland
P6	Master's degree, internship, and some freelance work	Multimedia	Online game and slide deck	Finland
P7	Master's degree and several freelance projects	Fashion, visual-communication, and illustration	Web site and animation	Finland
P8	Master's student	Industrial and service	Service-design slide deck	France
P9	Self-training and unpaid design projects for three NGOs	Graphic and UI	Promotional material for an event	Romania
P10	Master's student, with project work as a student design consultant	Industrial	Event brand identity	Italy
P11	Doctoral degree in the arts, >15 years in graphic design, and work as a lecturer	Graphic and art	Typography collage	Finland
P12	Master's degree, >15 years in the field, lecturer, and leader of a design consultancy	Industrial	Two steering-wheel demonstrators for vehicles	Finland

of the design process's overall structure, the role of color design within it, ideation practices, and color refinement. The discussion extended to exploring alternative design solutions, the assessment and selection procedures employed, and the criteria for deeming the exploration complete. To examine potential challenges, the interview zeroed in on moments in which the designer may have experienced a sense of being stuck (or unable to devise a novel color solution), identified corresponding scenarios, and addressed strategies for overcoming such obstacles.

Tools and AI's integration: Turning next to tool use, we asked about the use of software in the project presented. Attention then shifted to envisaging the roles that AI might be able to play. This encompassed how AI capable of color design could be integrated into design tools, the tasks it should undertake, and the knowledge required for the functionality implied.

Cool-down and closing: We followed the expansive reflection on AI with retrospection. This dealt with the interview itself and the design process in more general terms again: which tasks the interviewee perceived as especially challenging, easy, enjoyable, or frustrating. Additionally, the interviewee was encouraged to express further thoughts on any key topics that had arisen. We ended the interview by thanking the participant, offering an opportunity to pose questions, and outlining the next steps after the study.

3.4 Affinity Diagramming and Thematic Analysis

Our data analysis combined the methods of affinity diagramming and thematic analysis [1]. Both authors were involved in the analysis process, in which the first step was to transcribe the interviews and read through the transcripts several times for solid familiarization with the data. Then we carried out the affinity diagramming [34], to identify recurring themes. This involved capturing the interview content on (digital) sticky notes and arranging them on canvases such that related notes formed clusters. We approached note-taking as identifying units of meaning in the transcripts and summarizing each on one note, in a method similar to the "meaning condensation" of Kvale [29]. Each of the resulting 661 notes featured the ID of the participant in question, to retain the connection to the original data and allow quantifying how many participants referred to each theme. As we refined these clusters iteratively, additional notes – of a different color – were added to assign labels to themes and sub-themes. This procedure yielded three affinity diagrams, corresponding to the stages in the interviews: one for the general accounts of color design (including the factors in good color choices), one for color-design practices (including the topics discussed in light of the participant's project), and one covering tools/AI and the interviewees' sentiments with regard to the various tasks that contribute to color design. From the diagrams (included in the paper's appendices) we identified 11 themes, with 79 sub-themes in all.

In the next stage, we reviewed the themes identified. Returning to the original transcripts, screenshots, and video material, we developed a thematic map. Then, proceeding from the themes pinpointed in connection with the affinity diagrams, we extended the articulation to a set of unifying higher-level themes linked to the following research question: What are the decision spaces that tie together the goals and processes in color design? We conceptualized these themes as the three "P"s of our framework. We acknowledge the impact of preexisting frameworks on our thinking, especially the problem–solution co-evolution framework [35] and the concept

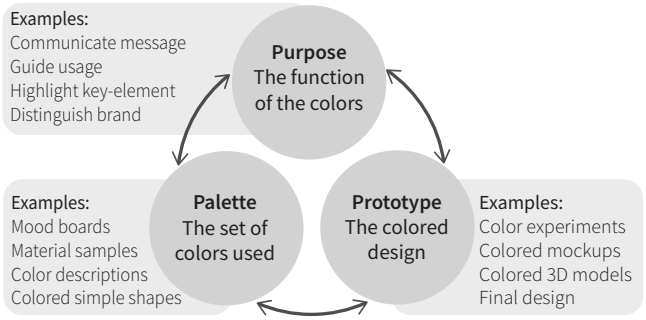

Figure 2: The three-"P"s framework: We conceptualize the process of color design as exploring and aligning three interconnected decision spaces. The purpose space is devoted to communicating a message/mood or guiding users, the palette space is for the choice of colors, and the prototype space covers applying them in assignment to the prototype at hand.

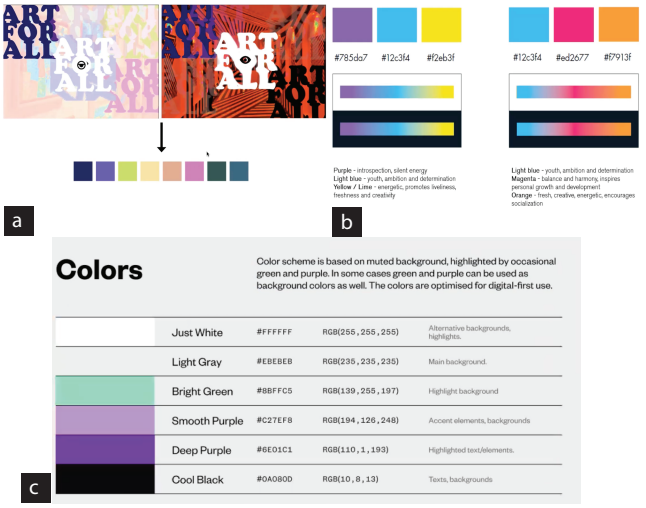

Figure 3: Examples of color-palette visualizations produced in multiple steps in the design process: from its early stages, a) a palette inspired by images that the client provided to P7; from mid-stage work by P10, b) two palettes that facilitated discussing color options with the client (these were complemented with the meaning that the design team associated with each color); and c) a finished deliverable from P5, specifying which colors belong to the scheme and how to use them.

of the design space. The completeness and descriptiveness of the final framework were verified by organizing the screenshots and participants' statements about them into tables, with a column for each "P" (similar to Figure 4).

4 FINDINGS

We begin our presentation of the findings by situating them within our conceptual framework. Figure 2 depicts the three "P"s, the **purpose**, **palette**, and **prototype** decision spaces. We posit that the process of color design involves exploring and aligning these interconnected spaces.

The first "P" follows from the communication requirements of color choice. Nearly all interviewees stressed that the colors should support a **purpose**, which might be anything from underlining attributes of the design to highlighting its functions:

> *It needs to boost the best things about the product. So whether it's a comfortable sofa (the colors and the materials need to highlight the fact that it's a comfortable sofa) or a performance tool or product, the colors need to emphasize the use. So obviously the colors need to create a good marriage with the product, not just be a sort of superficial extension of the product.* (P12)

Participants frequently reported that color should communicate a message, with six citing it as the single most relevant requirement, as this comment from P1 illustrates: *"To me, the color is all about communicating the message, so being able to support that would be the biggest thing for me."* For their audience, these designers captured the purpose verbally, typically via keywords such as *"freshness"* (P10), *"premium"* (P12), or *"serious"* (P2) or by describing the functions, with such terms as *"indicating groups"* (P3), *"highlight and put that as a central element"* (P8), or *"indicate that those are the elements that you click on"* (P4).

We distinguish between the more visual spaces (palette and prototype) because the interviewees discussed two distinct questions in this connection. The first involves which colors to use in the design – in other words, what the underlying color **palette** should be. Even if the designer does not choose to visualize that palette explicitly, the set of colors for the design is limited. That said, separate palette visualizations are common: many participants presented visualizations, which emerged at various stages in their design processes (P2, P4, P5, P7, P9, P10), or at least mentioned using palettes (P3, P12). Palette visualizations typically employ simple geometric shapes to show the colors in use alongside each other (see Figure 3 for examples), though some projects involved exploring the palette space via alternative forms of representation, such as mood boards (P5, P6, P12) or prototypes for the product. When discussing their palette exploration, interviewees spoke in terms of colors' attributes, such as *"bright, contrasting color"* (P9), or color names, as with P5's *"tech blue and gray."*

Participants experimented with the colors in **prototypes** to answer the second question: how to apply the colors from the palette. This aids in determining how to assign colors to the design's various elements, such as text, the background, and graphics. They described testing how well the colors support the purpose in the composition of the design, with the stages at which the tests occur and the fidelity levels of the prototypes hinging on the prototype. Since its proportions and shapes may well differ from those in a simple palette visualization or mood board, the overall impression can change (P7, P12). In some cases, colors that harmonize in theory mesh poorly with the actual design, as P7 noted: *"[S]ometimes I have a defined color palette that should work and I try it out with different combinations but then some of them just don't work and then I am a bit annoyed and then it is a lot of experimentation."* Furthermore, this testing can reveal "holes" in the palette (P2, P9) or colors that need adjustment (P5). Simple mockups with several color schemes can

function as early-stage prototypes (as Figure 5 illustrates), while a (digital) model's coloring might serve design work with physical products (P12). In later stages, designers might apply the colors to the nearly finished design.

The three-"P"s framework articulates a key theme emerging from our data: color design is not just about choosing palettes; it is also a matter of their assignment and communicative function. While designers focus initially on **exploring** the spaces, they must ultimately tend to **aligning** them, so that the three converge in a coherent solution. While evaluation and iteration are crucial for coherence, these are mechanisms in working with the spaces, not the subjects of decisions made by designers, so we do not regard them as spaces in their own right.

Next, we focus on specific observations through the lens of the framework. Throughout, we report on themes raised by participants who represent multiple backgrounds, but we also offer a breakdown by discipline and experience level where appropriate. Table 2 in the appendices characterizes the sample accordingly, with special regard to the participants' projects, the tools used therein, and who was involved in them. While all of the sub-disciplines shared consideration of the three "P"s, priorities varied. For instance, guiding users with colors was more relevant for industrial and UX/UI designers and considered less by graphic and media designers. On the other hand, industrial designers were less likely to cite contrast as an attribute of good palettes, while many others found this important for guaranteeing legibility and accessibility.

4.1 Ideation for Palettes

To translate the purpose into a suitable color palette, designers seek inspiration from meanings, metaphors, and preexisting visuals. Sometimes, they summarize the purpose by using keywords as bridges to colors, expressing widely accepted connotations of the colors:

> *Every color has a meaning that's been defined/established in our world [...]. So knowing the meaning of these colors has helped me a lot when I'm using a color within a context.* (P2)

A metaphor connected to the purpose offers another option, through the colors implied; e.g., a cloud-free sky may convey facilitation of clear communication in a service-design presentation via blue and yellow (P8).

Mood boards commonly featured among the means for examining possible translations of the purpose to colors (P5, P6, P8, P10, P12). In addition, our work uncovered several cases of referring to image collections or individual inspiring images. For instance, P10's team collected visuals related to the keywords and thereby *"saw, for example, [...] that there was always the light blue and [...] for 'freshness' we had the lime,"* which led to the decision to use light blue and yellow for the relevant event's branding. Online search too was commonplace – e.g., *"I look at my peers' work, which often leads to Instagram pages. And when I was working at the design studio, everybody was making things on Pinterest"* (P6).

Many participants used software or online tools dedicated to palette generation for seeking suitable palettes. Strategies for online search ranged from exposing oneself to new palettes somewhat arbitrarily – with P5 referring to,

> *for example, these automated Web tools that you might use to create different kinds of color themes to kind of challenge my own tastes [...] so I usually just play around, click around, and change things until I get this feeling "that's okay – there's something there"*

– to tools supporting a more systematic approach, with which *"you could search for keywords and they would suggest [...] a matching color palette"* (P3).

A few participants mentioned that, although the color combinations are rooted in their intuition in most cases, they like turning to color-psychology literature as inspiration for a new palette, whether *"researching color psychology and using that to influence the colors that I select"* (P4) or delving into interactions among colors (P7, P11).

4.2 Experimenting with Prototypes

Participants described experimenting with colors in prototypes both early on and later in the color-design process. Several reported suspending logical thinking about the colors at the early stages and experimenting freely: P5 said, *"So we'll start with this: try to be as open-minded as possible and try to do something crazy so you can find something [new],"* then mused thus:

> *It's probably closer to making art, because you need to think really abstractly, and it's really difficult to approach it purely intelligence-wise. So you really need to just approach it through emotions and feelings and these weird associations and tangents and just try stuff out.*

The early versions serve designers' learning as the process progresses. These are rarely revealed, lest the client fixate on them, as P7 stressed: *"I didn't show them the wild examples"* (in Figure 5's pane b), explaining that *"I didn't want [to] show something and they really like it and I know it doesn't work."* Also, these are "scratch work" that the designer may have discarded. As P5 explained with reference to the sketches in pane a, they *"are sort of like odd candidates that I usually don't want to show to anyone, so I'm making an exception here [...]. But there's still something to learn from them."* In contrast against palette visualizations, the early prototypes mimic a realistic layout, including placeholder text and shapes, icons, and backgrounds.

Some regarded this work with bold options as an enticing challenge:

> *I also really like if that is done well [...]. If you see a design where this is nicely put together with the shapes and amounts, then it is like "cool – now I don't hate it anymore."* (P7)

On the other hand, a few cast it as *"painful"* (P5) or at least time-consuming, as in the project wherein P6 *"played with the colors for several hours, I think, before choosing those."*

The need for experimenting with color-design prototypes grew still more pronounced further along, *"in the development stage – when we start applying the colors and the materials, the color 'breaks' quite often"* (P12). Rearing its head throughout the project as prototype fidelity rises, this issue necessitates iteration over the color palette. Both P5 and P7 vividly illustrated the gradual move from

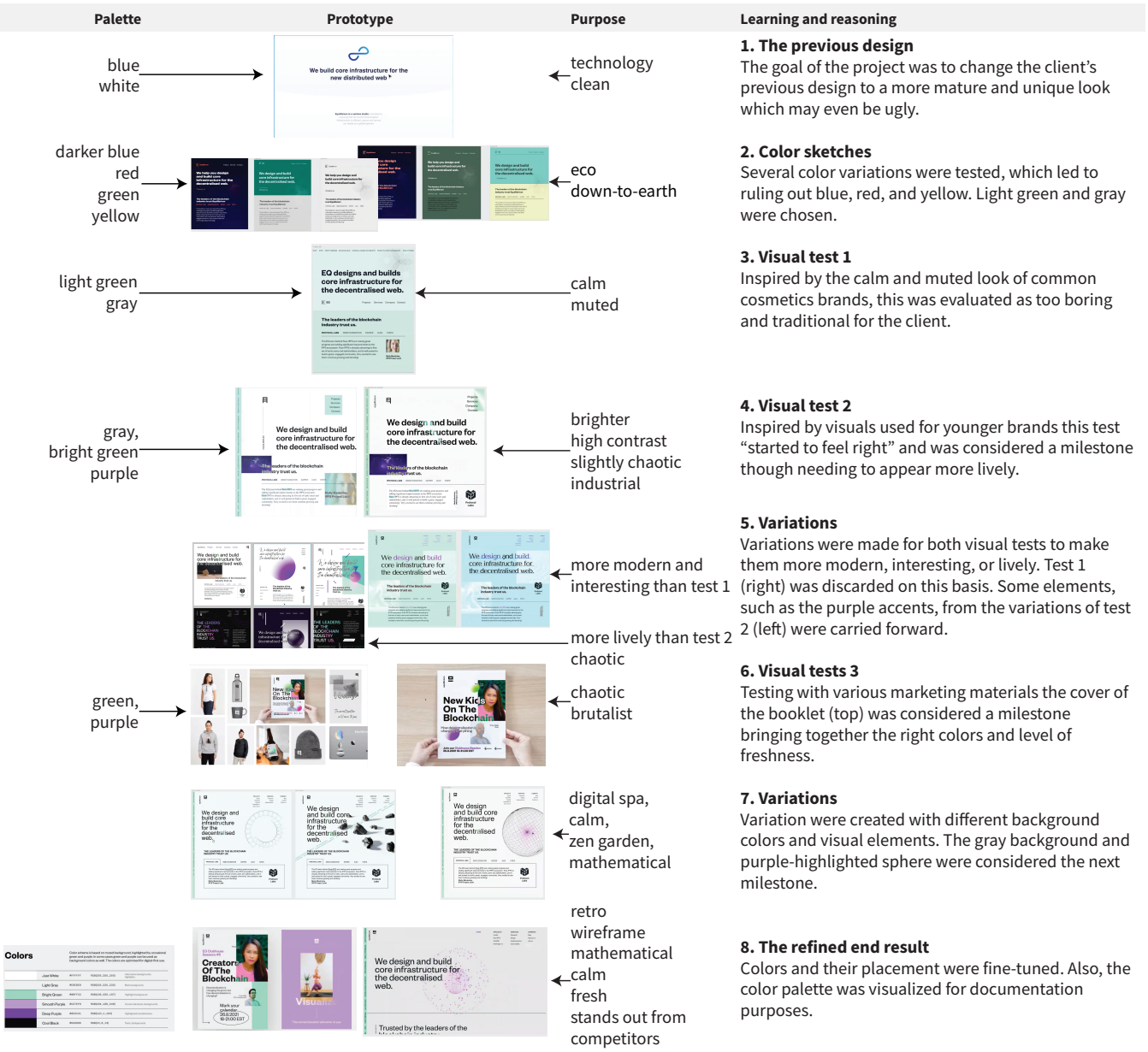

Figure 4: Iterative exploration of the three spaces in a project by P5. In pursuit of the color purpose, palette and prototype developed together in iterations. The keywords in the corresponding two columns come verbatim from how P5 described the palette and purpose. The text on the right summarizes the walk-through and the lessons from each iteration. In this project, the designer chose to represent the palette implicitly in the prototype and refer to color names alone until documenting the final palette, shown at bottom left (Figure 3 gives examples from earlier stages). The colors changed so extensively in iterations 1–4 that even the main colors' names (for blue, red, and white) changed.

experimentation to more strategic color use via their collections of prototypes (see Figure 4 for an example).

Our attunement to all three decision spaces enabled us to observe a tendency toward a more linear approach among the hobby designers. After initial exploration of palettes in the projects presented, they settled on a palette after fewer tests and proceeded to apply them to the designs. Hence, P9 described regretting having set the palette and color proportions *"in stone"* once a need arose for applying them in an unexpected new setting on the event page designed.

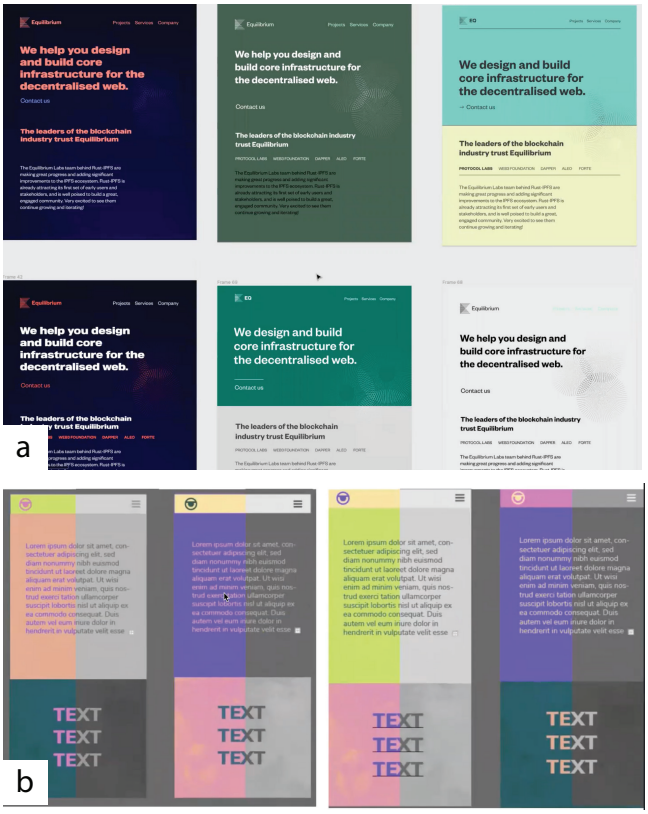

Figure 5: Examples of early-stage prototype color designs. The creator of pane a's prototype described having experimented with several completely different hues to learn which areas of the color space had merit. The designer of prototype b wanted to reduce the number of colors in the palette (see Figure 3, a) and experimented by non-methodically juxtaposing them to reveal which combinations show potential. Neither prototype was shown to the client.

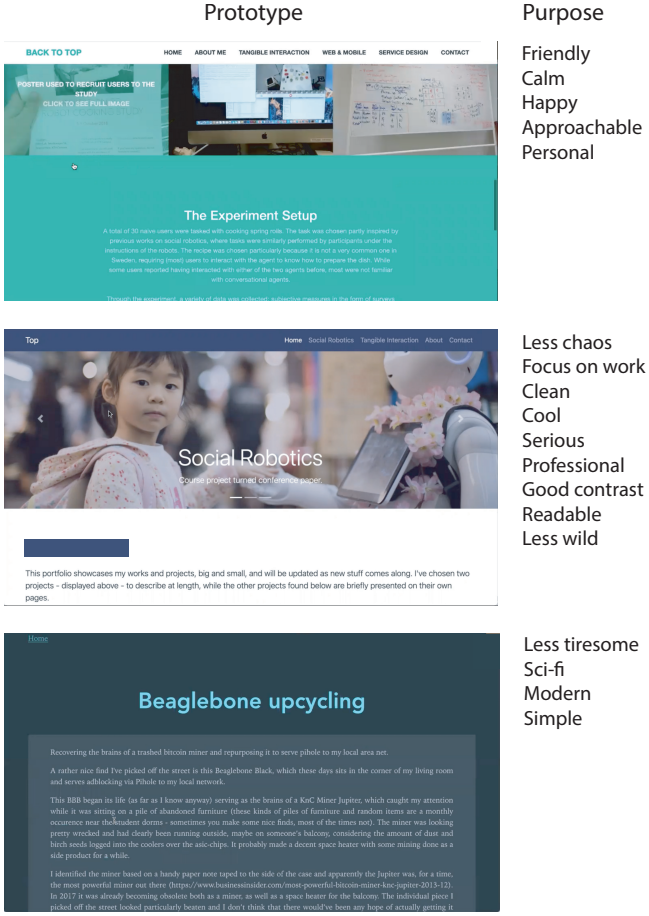

Figure 6: Three prototypes from P1's project and the words with which P1 expressed the message and the goals behind the color change. The colors and their purpose changed significantly between prototypes.

4.3 Exploring the Purpose Space

Importantly, the purpose is not a set context for the color-design process. Its space sits alongside the other two in that designers explore it actively. Some participants directed extensive effort to developing a description of the color's purpose early on, for guiding the rest of the project (P4, P10). A few invited the client to join in refining the purpose through discussion (P9, P10).

Designers frequently circulate through the three spaces as the color-design process continues, gathering insight as to whether the colors work in context from the prototypes. Surprisingly, that insight serves not only palette adjustments but also exploring alternative approaches in the purpose space – e.g., in terms of the message conveyed: P1 presented three iterations for the portfolio website, having significantly altered the colors' message after each in light of the previous one's shortcomings (see Figure 6). Others discovered which concepts and moods fit the client's brand (P2, P5). Showing us three projects involving brand design with short iterations, P5 evocatively described the learning from these prototypes in terms of which concepts and moods represented the client well. As the designs evolved, P5 repeatedly altered colors and layout to examine alternative color combinations. In the course of sharing the visuals, P5 talked about how the set of keywords to capture the intended message developed – e.g., from *"mature and unique"* via *"down-to-earth"* and *"muted"* to *"mathematical and retro"* (see Figure 4).

We observed prototyping-prompted shifts in the purpose space from a more function-oriented perspective too (P1, P5, P8, P9). After P1's prototypes revealed issues with readability and ease on the eyes, these were added to the requirements for the colors. Also, P7's initial color choice, intended to reference a colleague's fashion show, evoked unpleasant associations in the context of P7's animation, so P7 changed the colors' purpose. Instead, they would support the visibility of the animation's shapes and action. These, in turn, referenced the fashion show.

4.4 Working with Constraints and Objectives

The diversity of projects in terms of objectives and scope situates the designer as an interpreter who must understand the key aspect of the design and convey this via colors. Purposes run the gamut from communicating a message/mood or directing the viewer to *"focus on the content"* / *"use the colors in order to have a hierarchy"* (as in P8's informative designs) to helping target groups connect with the product via colors that feel familiar:

> *If you're building a serious IT tool for chief technology officers, then you probably want to take colors that those people feel confident with, the tools that they're already using, and maybe build on that [...] so when they see it for the first time they get this feeling that "okay, this looks pretty trustworthy."* (P5)

Choices accounting for industry-specific color trends play a crucial role in this connection (P6, P7, P12). While trendy colors can help certain target groups connect with products, they also cause the look of designs to *"age"* (P5), appear commercially oriented (P7), or look ordinary (P6) – which are sometimes good reasons to avoid them.

Frequently, the palette space and prototype space are highly constrained. Eight of the 12 participants had worked with either predetermined primary colors or a fully defined palette complete with rules for applying the colors to new layouts. Wherever the task lies on the spectrum, it demands sense-making from the designers and understanding of the guidelines and conventions relevant for the project, and – crucially – their flexibility. One participant summarized brand guidelines' effect on the work thus:

> *Good brand guidelines usually have a bit of leeway. You have this chance to have these supportive colors, so you can have some accents and stuff like that (but some brands are really strict about color use, so then you have to work within those constraints). And, depending on the brief you get, it might be really easy, because you don't have to think about it at all.* (P5)

If the restrictions conflict with the intended purpose, this can prove frustrating.P11 mentioned at their client's company *"they were talking about sustainability and they had chosen this yellow color, and gray, and black and it's so industrial so cold with no character"*. In these cases, the designers must decide whether to seek room for deviations: *"usually you can negotiate your way out of it and make your case.*(P5) vs. acquiesce in light of situational factors: *"I thought they wouldn't have funding to support me reinventing their color scheme, so, [while] I didn't actually think it was the best one, I thought it was the best solution to just leave it like that"* (P11). For projects with a somewhat restricted palette space, predefined colors may come from the logo (P12) or design elements such as graphics (P8) or photos (P1, P3, P9). A need to support these was mentioned by P12 (*"The rest of the colors need to 'collaborate with' this one color that you can't change"*), P8, and P9. This too can pose problems:

> *I would say the most challenging is when you need to work with a [set] color because of the clients [...] and then you can't really change the color. And then you need to find a way around it and find colors that match with that.* (P8)

While sensitivity to trends and required colors existed across all disciplines represented, designers differed in the sorts of limitations encountered in relation to the color range permitted and, thereby, the palette space they had to know and obey. These limits stem from the media and materials involved. For instance, P5 noted printer and ink limitations that affect the color choice for brands if printed materials are needed. For P9, variations in screens' color-display range proved relevant in UI design. Finally, P7 mentioned that limitations in dyes for fabrics affect colors in fashion design and P12's industrial design had to consider the cost and availability of materials.

4.5 Strategic Separation of Spaces

Palette visualizations and mood boards explicitly separate the palette space from the prototype space. Participants articulated several reasons behind this strategy. One factor here, influenced by project type, is timing. This became evident in some projects wherein the first colorized prototypes appeared relatively late.

> *If you're doing a brand, it probably comes pretty early on. If you're doing a digital product – for example, a mobile app – you probably start with just wireframes and you think about the brand at the end of the process.* (P5)

P12 discussed undertaking the color implementation only *"once the concept has been locked."* To preclude color-based dismissal of promising ideas, concepts' first renderings might be in grayscale, since then

> *[p]eople look at the design and product and not just the colors. Because colors can be polarizing [...]. It's very easy to kill a concept by choosing a color that the CEO of the company doesn't like.*

P4, P9, and P11 stated that they too begin with black and white, adding color only after the concept and shapes demonstrably work. Nonetheless, with palette visualizations, designers develop color ideas in parallel (P9, P12).

In contrast, P4 postponed graphically articulating the first palette until creation of the high-fidelity prototypes for the app, despite having reflected on the color concept from the start: *"I had the teal in mind from the beginning of the process"* because it meshed with the project's topic. In one technique, exaggerated bright colors served as placeholders in cases demanding a bright final color, helping P7 be certain of the shapes' and motions' visibility during the animation process.

Whether occurring in parallel with other procedures or part of a linear process, the separate palette exploration enables coping with color design's complexity through a "divide and conquer" strategy. Some participants presented projects wherein colors were among the last things chosen (P4, P7), while P10's team arrived at palettes before starting to work on the shapes. For P1, whose portfolio required highlighting colored material of various sorts, each of these two options has its advantages: For content-first,

> *[i]f you already have creative content, pictures and so on, potentially you could pick a color that then complements these or a color that somehow binds these together.*

Nevertheless, P1 saw value in starting with the colors when time permits –

> *I feel like you can focus a little bit more on communicating the mood or the emotion. And if you can get that from the beginning, then I think that it will maybe aid in the rest of the creative process.*

4.6 Overcoming Uncertainty in the Purpose–Palette–Prototype Match

Knowing that color perception, interpretation of meaning, and aesthetic appeal are idiosyncratic, designers must assess their ideas and solutions alongside others. Color experience's ambiguity ushers in doubts (P1, P2, P5), which P2 cast into sharp relief – *"I was nervous: 'are these colors actually going to work, and are they going to communicate the same thing that we want to communicate?'"* – and creates a need for validating one's choices. Two strategies for this, both mentioned by P5, are testing (*"because, going forward, you need to use the earliest decisions [...] [and] if they can stand the test of time and the test of trial[s], then you know that you have made the right decisions"*) and feedback (*"If two trained professionals can have the gut feeling, then you can lean into it more"*). Three further interviewees (P8, P10, and P12) mentioned discussing the selection within the design team, which involves rationally justifying how the colors serve their purpose, often by relying on color theory, psychology, or guidelines. Characterizing this, P12 said, *"Basically, you talk through them. And what we try to do is always have something [to explain] why you've selected or why you're recommending something."* Some solicit input from specialists in fields other than design:

> *So it's a lot about discussion with the client also and their point of view, telling them, "That is what we want to communicate to you. Do you feel it or not?" And you know from that whether it's working or not.* (P10)

P4 found end users' preferences to be the ideal source of feedback: selecting *"would be just a case of user testing, getting feedback from users, just seeing what they prefer."*

Color theory was identified as a particularly valuable source by P3 as a novice seeking color combinations' outside validation but also by P4 and P5, who echoed this sentiment with regard to the role of theory earlier in their career:

> *[M]aybe like at the beginning, when I was still in school seven years ago, then I would rely on textbooks and use those as points of reference. But over time it's [become] just sort of like muscle memory.* (P4)

As a means of filtering, learned rules can make color selection more efficient: there are

> *certain rules that you have to follow in terms of color palettes [...]. So when you've got a set of rules that you understand in the back of your mind, it becomes easier to dismiss colors when it comes time to choose.* (P4)

4.7 Explaining the Colors

Designers use color theory and guidelines to explain color choices to fellow designers and clients or for internally rationalizing their ideation. Besides evaluation and selection among concepts, this is pivotal for client interaction.

After the early *"browsing in the what-if world"* (P12) comes a refinement phase characterized by shifting from unrestricted ideas toward a refined version, creating explanations, and developing a narrative. For P5, this coheres as a phase of working in a

> *creative mode where you can use these crazy ideas to combine stuff [in such a way] that you can actually, intelligently explain to people why you're doing it. [...] [Y]ou go into this explaining mode [in which] you can also explain it to yourself .*

Some participants mentioned verbalizing the colors and discussing them with the non-designers so that those members of the larger team with less extensive color knowledge could be part of the color choice and develop a sense of ownership. For instance, P8 recounted that a non-designer on the project team

> *felt like he wouldn't be the most effective [with the colors] and we [the designers on the team] can do it. So he agreed with what we were saying and then wanted to be part of the discussion because it was group work: he should like our final thing, and it's good if he gives his opinion.*

Some designers devoted considerable time to these discussions. For instance, P2 reported, " *"When we were creating the brand bible, we discussed a lot about the color theory. Literally, I think it took us three hours to choose the right shade for [the] yellow."*

In addition to ownership factors, interviewees discussed explaining their color choices to clients to gain trust (P7, P11), support them in selecting from alternatives (P9, P10), or *"try to direct them"* (P8).

4.8 Navigating the Fragmented Tool Space

Most participants' color-design process combined several tools (the appendices' Table 2 lists all of the tool types, broken down by participant). Every project presented in the interviews was set within a design-type-specific software environment, for domains such as graphic-design editing, video/photo editing, programming, user-interface prototyping, or CAD.

Seven participants used tools dedicated to generating palettes. These cover a substantial range. As P7 noted, there are *"a lot of these tools to find a color palette, [and] some of them are quite nice."* They variously simplify picking colors with specific harmony from color wheels, generate and present palettes at a single button press, extract colors from images, and facilitate browsing designer-made palettes (Figure 7 shows examples). In addition, five interviewees pointed to Web sites for browsing reference images or designs. Finally, three participants used online contrast- and accessibility-checkers. It is noteworthy that these tools, being separate from the design-type-specific software used primarily, impose an overhead for switching back and forth between tools.

While the professionals' use of palette-generators focused on ideation, design hobbyists tended to rely on them for judging whether colors match – P3 described *"knowing that there is some theory which tells you what is good or not [..], maybe not trusting my own eyes, to decide if it fits or not"* and, accordingly, using colors

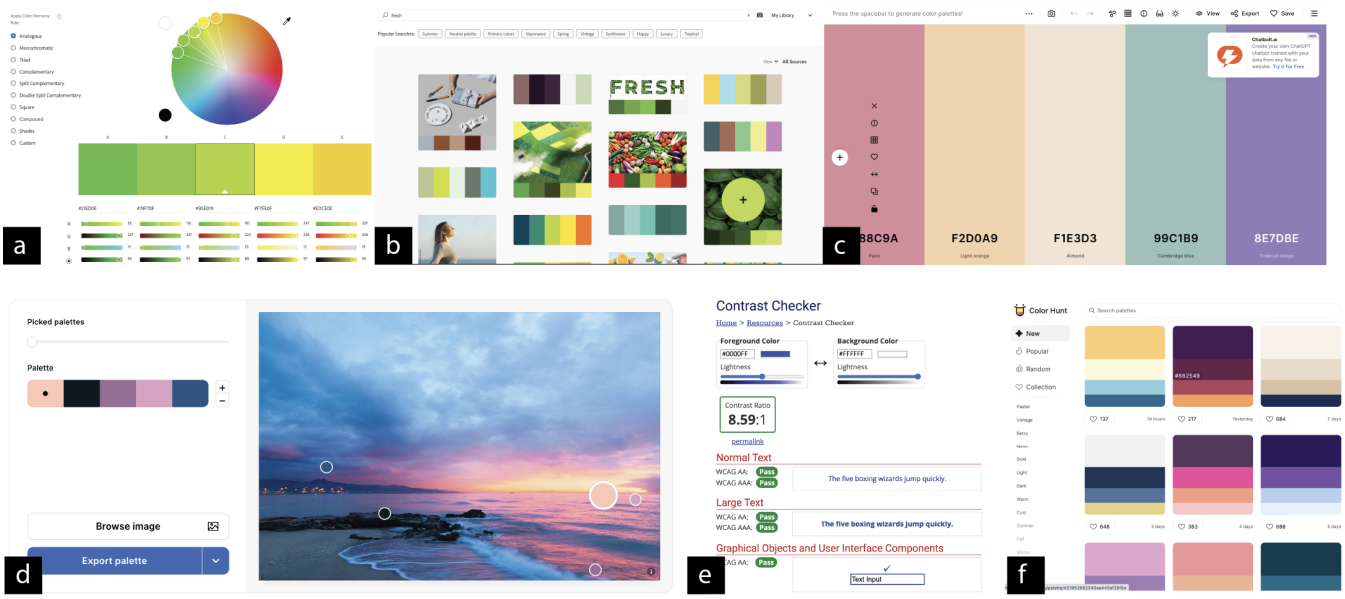

Figure 7: Examples of online color tools that participants mentioned using: a) the color wheel of Adobe Color generates palettes in line with specific color-harmony types (P10); b) Adobe Color's color-search engine lets one browse palettes in line with keywords (P3); c) a palette-generator from Coolor generates palettes with five colors each, from which users can specify and lock in the colors they want to keep (P5); d) Coolor provides a tool for extracting colors from images (P10); e) contrast-checkers evaluate whether the input text and background colors meet accessibility standards (P5); and f) one can browse collections of designer-made palettes, such as the one shown here, which displays the colors in different proportions, a feature hinting at ways to apply them (P7).

more bravely when the palettes came from tools, whereas any independently created combinations would consist of several similar colors. In a similar vein, P9 hypothesized that not using generators would lead to fixating on familiar types of palettes.

4.9 Perspective-Taking To Overcome Fixation

Most participants were intimately familiar with feeling stuck and unable to devise a novel color design, and they generally deemed it a challenge. All interviewees we probed about this phenomenon reported experiencing it. Several described getting caught in cycles of fixing and fixing again (P7, P8, P9); in P9's words, *"you might end up trying to fix it more and more and getting into a rut; whatever you try, it doesn't look good."*

Limitations such as having to apply a specific palette had left several participants feeling stuck (P7, P8, P9, P11), with P8 saying, *"Sometimes I think something is not matching, but sometimes you can't really see why"* and P7 too reporting this sense specifically in connection with not knowing why certain colors failed to work. Paradoxically, **lack** of limits was cited as one blockage to forming color schemes: *"If you don't have any limitations and you can do anything, it's very hard to get started with something"* (P12).

The most common strategies for overcoming the impasse were to get a second opinion (P5, P8, P9), seek other external inspiration (P5, P6, P9, P12), and alter the palette (P7, P8, P11). When asked about strategies, P8 said, *"If I'm really stuck [...], I'd say then I will ask other people, 'What do you think? Do you think I should choose this, or what colors match better?'"* and opined that, thanks to multiple opinions, teamwork is less prone to "stuckness." In this regard, we identified a disadvantage facing the hobby designers, who are not integrated into design teams or a network of professional designers. Alternative external inspiration might be found in other designers' work, tie in with the target audience or context (P12 described preparing *"a mood board that fits the user or the use situation and then collect[ing] products that fit this, then [...] looking at the tones and the colors that they use"*), or be related to ways of positioning the design (P12 also mentioned *"looking at what colors and combinations the competition is using and then thinking 'how can you be different?' because most of the time [...] you want to stand out"*). Less frequently listed were the strategies of reducing the color palette's complexity (P9), taking a break to calm down (P7), and tracking what one has already tried (P7).

4.10 AI-Supported Exploration of the Three "P"s

Our data suggest that designers would welcome AI that aids in creatively exploring colors so long as they stay in control of the decisions. When asked about their preferences (what an AI-incorporating tool should do), nine of the 12 pinpointed wishing it to generate palettes and prototypes, with P12 specifically recommending a function whereby one could *"drop in the objectives"* in the form of *"adjectives like 'premium product,' 'sporty,' 'European use,' 'durable'"* whereupon the tool *"would automatically give you a selection of choices."* Participants envisioned such features as affording more

efficient creation of prototypes for evaluation – e.g., *"I set the colors and then it would give me around 20 examples so then I wouldn't have to change them manually"* (P7). Another vision was P5's:

> *What I dreamed of was that I could have this sort of AI that would work like a generator tool so I could make this sort of exploration phase really quick.*

The participants also envisioned systems generating variations (P5, P8) or recombinations (P5, P6) of previous color designs (P5, P6) on the basis of inspiring material. Ideally, the tool should take the project and its context into consideration for the material created and, furthermore, apply it to prototypes (P2, P3, P9, P11). This synthesis represents a strong contrast against the typical use of many tools in combination and the color tools' consequent lack of access to the project as a whole.

The participants saw potential in AI helping them evaluate their designs' alignment of purpose, palette, and prototype. This found expression in P4's comment *"I want something to tell me that what I choose is right for the purpose"* and P6's that *"I think it would be interesting to get a second opinion from an algorithmic standpoint to inject novelty into a design and try something else."* Scenarios ranged from scoring that affords selecting from among several design options (P4) to an AI design partner capable of collaborating, with its own ideas, as a colleague might (P11). Also of interest was AI able to transfer knowledge between designers or understand other people's color associations (P5, P10). Some participants expressed a desire for color-evaluation tools that can spark improvements by means of more in-depth feedback (P3, P6, P7, P10) – for instance, via explanations of accessibility issues (P7) or color harmony (P3, P10).

Intriguingly, many stressed that AI should remain agnostic to their style. This stands in contrast to the findings of many AI researchers who study preference-learning [32]. The participants strongly favored AI that, instead, adjusts to the project. They saw potential in AI adapting to client requirements or to such specifics as the intended message or relevant keywords (P1, P5, P8, P12), predefined colors (P3, P9, P12), the document type required (P2, P3, P8), the target audience (P8, P10, P12), and the work mode or stage in the process (P1, P3, P11). Most showed little interest in color-design tools adapting to them. One concern, expressed by P4, is that the tool might end up reflecting the designer's biases and preferences in conditions where *"I'd want this thing to make a decision agnostic [to] my preferences."* This scenario was deemed problematic also by P12, in that the *"designers are not designing for themselves."* A few saw value in such adaptation but only for personal projects (P3), to inform shortcuts (P7), or to account for one's expertise level (P10).

5 FRAMEWORK VALIDATION

Validation steps assessed whether we had interpreted the interviewees' color-design process correctly. We sent all interviewees a draft document depicting the framework and explaining its elements. The accompanying invitation encouraged criticism, to improve the framework and instructed to:

> Please, open the attached PDF and read it carefully. Take a moment to reflect on it on your own. How does it relate to your design practice? After gathering your thoughts, follow the link to the form and answer the questions.

We sought fuller understanding of each "P"'s relevance through soliciting feedback in three steps. 1) We requested participants to rate whether each process listed is important for their color-choice practice, using a five-point Likert scale. 2) We asked whether we had overlooked other decisions, which might not lie within any of the spaces presented. 3) Finally, we asked for comments and additional feedback. The questions are included in Appendix D.

We received replies from nine interviewees (P1–P3, P5–P7, P9, P10, P12), all of whom received the framework positively. Most agreed that all three decision spaces are important: The importance item's median rating was 4 ("Agree") for purpose and palette decisions and 5 ("Strongly agree") for prototype ones. Six agreed that deciding on the purpose is a key process, with a further three agreeing strongly. As for the importance of deciding on the palette, three each agreed strongly, chose "Agree," and were neutral in their opinion about the process. Finally, six agreed strongly and three agreed at 4 level that deciding how to apply the colors in prototypes is a key part of their practice of color design.

By a slight majority, the designers confirmed that no decisions in their color choice fall outside the three "P"s: five did not identify any whatsoever, while four were not sure whether the further factors they proceeded to identify were part of one of the three "P"s. One category of these elements that color choice must account for is limitations such as printability (P3) and adherence to accessibility guidelines (P1, P3) (see Subsection 4.4), and the other was strategic choices – e.g., to stand out against the color schemes of competitors (P5) or align with cultural color symbolism (P9). These can be approached under the purpose for colors.

Some participants supplied insightful free-form comments. For instance, P7 hypothesized thus about the framework:

> *I think it would also make sense to show something like this to the clients, so [that] they can also better understand the color decisions. It could be a good tool to bring the layperson clients and the designers closer to each other and simplify the consultation process.*

Finally, P5 drew attention to the issue of balance by stating that purpose-linked requirements may stand in mutual contradiction: *"Sometimes, strategically correct choices are aesthetically poor or the combinations are not usable (poor readability, does not work in the selected medium)."* Hence, the designer is responsible for alignment – *"strategy, usability, and aesthetics affect the outcome of all three 'P's for me."*

6 DISCUSSION

To our knowledge, this qualitative study is the first to focus on color choice as part of design projects. Our results shed new light on the topic, implying that, while color design is consistent with general understanding of creative problem-solving in design, several characteristics render it unique in its own right. In particular, we learned that designers explore three spaces when working with colors:

- Purpose – the message or function to be served/enriched by the colors
- Palette – the set of colors used in the design

- Prototype – the combination of the colors with the other components of the design

Situated in this framework, our results yield rich qualitative understanding of the exploration. Several key findings emerged.

- Designers ideate, explore, and evaluate design choices in each space to arrive at a color-design solution that represents a good match among the colors, their deployment, and what they communicate.
- Designers show sensitivity to project-specific constraints and objectives (the desired emphasis on mood vs. function, any required colors, etc.) within each space. For this, they must engage in sense-making, work collaboratively, and empathize with clients and target audiences.
- Among the strategies for grappling with the complexity of the color-design process are separating the spaces, referring to inspirational materials, seeking validation and perspectives from stakeholders, and explaining colors through normative accounts.
- Designers make extensive use of computational tools in their color design. However, the tool space is fragmented.

These results point to untapped potential for HCI research to develop interaction techniques and design tools that support color design comprehensively. Below, we reflect more deeply on the findings related to requirements, the design process, and tool use, in comparison with prior work.

6.1 Integrated Tools for Seamless Design Alignment

Often, picking colors is intertwined with other choices, especially in the purpose and prototype spaces. We found that, except when choosing a palette, designers might parallelize among picking colors, exploring the purpose, and adjusting forms/shapes. Upon applying the colors to a prototype, they evaluate the choice of colors. Previous conceptualizations may have been prone to regard aspects such as the design's purpose and form to be merely context/background for the color choice. Our findings, however, suggest that they co-evolve. These conditions suggest that room may exist for alternative interaction techniques.

As they explore, designers frequently travel between the three "P" spaces. While the developers of a recently released color tool cited a similar observation as motivation for their work [52], nearly all of today's color-exploration tools fail to connect these spaces so may not support smooth, rapid flows between them. Analysis of current color-palette design tools has shown that most respond only partially to color-choice needs [53] and only a few allow visualizing the colors in a given design [51, 53]. Tools that do let users explore the color message [20, 25, 26] or translate from keywords to palettes [58] remain isolated from the rest of the workflow. While we know of one tool that supports rapid iteration through all three spaces [12], it lacks support for exploring the purpose space.

Our study spotlighted the guiding role that supporting a purpose plays in working with all other aspects of coloring. Though other objectives exist, participants cited this "interpretative" function most often. Prior work on design practice has likewise stressed designers' role of interpreter as pivotal: they must apprehend the design brief [10], research the problem well, and frame that problem at a level of abstraction from which the project can progress [11]. However, even after making sense of the project, translating the purpose of the design into colors remains a challenge, according to our data. Although there is ample literature on meanings of colors [24], knowing how the target audience will interpret the design can be tricky, since colors' received meaning may differ markedly between groups or individuals [15]. The designer must be aware of meanings for the intended audience and, for making informed decisions and effectively conveying the desired message, consider cultural, historical, and personal context. Although some tools simplify translating keywords into colors [2, 58], they do not handle interpretation in the other direction – from the colors present in prototypes. Regarding this as a challenge, designers yearned for corresponding computational tools.

Designers often must match additional colors to ones that cannot be changed, from brands, logos, graphics, and photos. We uncovered challenges related to the common need to address multiple requirements in this regard. Perhaps most obviously, the new colors must manifest harmony with the others. Tools that generate full palettes when given a few "seed" colors [2, 14, 37] speak to this, but there are other effects to consider. New colors' influence on the preexisting ones must dovetail with the purpose. Among the participants highlighting this issue was P12, who pointed out that one must choose the additional colors such that the given ones blend in or stand out in the manner desired. Although our finding here echoes prior ones [27], state-of-the-art tools still have made few forays in this direction, so designers must rely on their knowledge and intuition for that task [4]. Many interviewees reported possessing corresponding intuition; nevertheless, several participants cited this task as particularly difficult. Often, participants' work required additional colors for a specific use, which emerged mid-project as colors were applied to a design. Since tools that expand partial color palettes do not consider these specific uses, evaluating whether a color fits this use is left entirely to the designer's judgment.

We found that designers often work with colors in standalone representations. This confirms earlier findings that designers maintain palette visualizations [18] or compile source material as mood boards [33]. We observed from the case projects that this separation serves as a practical way to develop a color scheme without impinging on the concept development. Several tools support palette visualizations [53], a frequently used technique. Mood-board design offers the advantage of a more complex form for the colors and, accordingly, more realism. While tools exist for mood-boarding too [25, 26], and for the associated operation of extracting colors from given source material [2], we see room for improvement in this area: since mood boards cannot incorporate such facets of the design as its proportions or full content, the color choices made may "break" when the colors and design concept are brought together. This shortcoming further emphasizes the requirement for integrated color tools that can address the design at hand computationally.

Our next finding, that diverse source materials function as starting points for color exploration (in line with prior work [18, 20, 21]), again draws attention to shortcomings in current applications. Color-pickers could better support capturing and tweaking colors from these materials. One possible technique involves automated color extraction. While some tools offer this function and designers do utilize it, these tools could perform better if they 1) considered

people's preferences for salient and distinct colors [31], 2) applied designers' strategies for tweaking colors after extracting them [21], 3) considered the source material's semantics and their potential connection to the purpose [21], and 4) considered such functionality criteria as the contrasts needed and the number of colors for the prototype. These features might afford extracting colors better suiting the message of the colors in the source material.

6.2 Learning and Inspiration in Color Design

Within the prototype space, designers experiment even with colors they consider infeasible, to learn about the design space and how the colors work for their case. While experimentation is expected in the design domain generally and is encouraged [52, 54], we were surprised by the prevalence of learning from "bad" color designs and "breaking the rules" of color theory, especially in light of color theory's normative status. In these conditions, experimenting with colors is time-consuming: designers create numerous prototypes and tweak each one until they can either rule out or verify the color idea. There are two central implications for tools that support color design. 1) Designers would benefit from automation that applies interesting color schemata to sketches. This would free time for more iteration. 2) Tools that propose not only harmonious but also diverging and possibly extreme coloring ideas could facilitate learning about the design space, even if the proposals are not feasible in their initial form.

We identified a need for taking care to support the development of intuition through reflection and practice [49] in any development of tools putting AI to use for color design. A few participants saw potential in using AI to hone intuition: P5 opined that automating the creation of colored designs would expose them to more design options and therefore encourage frequent reflection. From a design lecturer's perspective, P12 recommended examining well-regarded designers' work and reflecting on it, so as to develop a sense of good design, and P9 mentioned using tools to this end: *"By myself, I sometimes try to get inspiration from existing, appealing artwork. There are actually tools for that."* For solid and responsible intuition support, it is vital that AI-based color design not adapt to the designer's style; again, the designer must remain in control.

Another key finding is that design fixation, a phenomenon that color design shares with other design domains [19], often hampers color designers. While we had hypothesized that fixation might constitute an issue for them, we considered the possibility that the multitude of tools and theories available might enable these designers to overcome it more easily. However, this was not the case. They put considerable effort into overcoming the sense of being stuck, through deliberately adopting different angles to their color design, often by turning to colleagues or external materials for inspiration.

Finally, designers' deliberate rule-breaking notwithstanding, normative accounts of color design have a role in inspiring and justifying the choices. Designers refer to accounts of such aspects as established meaning [23, 24], color interaction [4, 27], and types of color contrasts [16, 27]. These theories serve also to back up and aid in discussing color choices. Some designers create palettes by means of digital color wheels with templates for harmony types, while others reported preferring to find online examples of relevant color combinations or rely on intuition (which might implicitly encode color theory [49]). Also, several interviewees mentioned considering trends in color design. Still, our findings attest that normative approaches on their own do not suffice. They cannot "solve" color-design problems. This helps explain why designers sometimes consciously deviate from them. Knowledge of color theory does not protect against getting fixated, and even choices supported by rules are often subject to doubt until receiving validation by additional means.

7 LIMITATIONS AND FUTURE WORK

We acknowledge a need for validating the framework beyond the work with our geographically limited sample. All participants were based in Europe, as were the authors, yet design history and practice exhibit divergence between cultures [6]. Likewise, color experience depends not only on biological and individual reactions but also on multiple levels of cultural factors [36]. Future work could investigate color-design practices in other cultural contexts, since the process of color selection might be different outside European settings. Also, while we aimed for a sample representing diverse design disciplines and experience levels, the small number of participants in each category made in-depth comparisons across these lines infeasible. The multidisciplinary background of many participants complicated such inter-group distinctions further. Future research to investigate differences in color-design practice could compare between larger samples from each group. Finally, while our work focused on designers, research could fruitfully examine interactions with various stakeholder groups and study the applicability of the three-"P"s framework in designers' communications with colleagues and clients.

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A INTERVIEW STRUCTURE

Figures 8 presents the interview protocol in the form used, with key questions and additional items both.

B AFFINITY DIAGRAMS

Figure 9 presents the affinity diagrams created in the data-analysis stage.

Outline for the semi-structured interview

Introduce the interviewer, purpose, and structure (previous experience, project, tools) of the interview.
Send a link to the informed consent form.
Are there questions at this point?
Ask to start recording – start recording after getting permission.

Experience
Could you describe your background in design? How many **years** of experience have you gathered?
Please describe in which kinds of projects you needed to do color design.
Have you worked with:
Color Palettes / Schemes, if yes how did you acquire them?
Pre-defined colors (e.g., defined by a brand)
What are, in your opinion, the chances and challenges that arise when working with [palettes/schemes/pre-defined colors]?

Requirements
What are the requirements a good coloring needs to fulfill in your opinion?

Project presentation
Let's have a look at the recent project you brought. Could you quickly introduce this project to me?
What was the task?
What needed to be colored?
What were the requirements?

Collaboration
Was there a team or anyone else who had an influence on the color design? How?

Processes
What was the work process i.e., what did you do first, second, etc.? Could you describe providing as much detail as possible about the procedure and your reasoning?
Were color choice and application separated? Should it be that way? (Advantages and disadvantages)

Design alternatives
Were there several candidate designs and how did you choose between them?
Which factors played a role in evaluating the color choices?
How did you pick which colors to try next?
What made you stop at the final design? (And continue at the previous ones)
How satisfied were you with the results of your recent projects with respect to the colors?

Fixation / Feeling Stuck
Did you feel stuck at any time or unable to think of something novel?
Could you describe what happened?

Tools and AI
Which tools did you use for the project?
What could they do / what not?
Did you have to switch tools?
Color Picker type.
If there was an artificial intelligence integrated into a design tool with the ability to combine and apply colors. Could this be helpful for you? In which situations could it help you or with which tasks?
How?
What would it need to know about you and about the design project?

Retrospective
What have been the challenges for you when coloring your design? Easy parts? Fun parts?
What have you learned about coloring during your color design project? How did you acquire that knowledge? (Mostly for hobby and junior)

Wrap-up
Anything that came to your mind during the interview that you would like to share with me?
Do you have any questions or comments?
Interviewer: explain the next steps

Figure 8: Interview protocol guiding the semi-structured interviews.

C PROJECT INFORMATION

Table 2 provides information about each participant's project(s) discussed during the interviews.

D THE QUESTIONNAIRE ON THE FRAMEWORK

The questionnaire sent to the interviewees for feedback on the framework featured the following items.

- *Please indicate your participant number (sent to you by email):* [Dropdown with participant IDs P1–P12]
- *Please list the design field(s) of your practice in which you have to make color choices:* [Short text-entry field]
- *Please rate your agreement with the following statements considering the definitions of purpose, palette, and prototype from the text.* [Five-point Likert scale for each]
  - *Deciding the purpose of the colors is a key process in my practice of color choice.*
  - *Deciding the color palette is a key process in my practice of color choice.*
  - *Deciding on how to apply the colors (color prototypes) is a key process in my practice of color choice.*
- *Are there other decisions in color choice that, in your view, do not belong to any of the three categories above?* [Yes/No choice]
- *If you answered yes, please describe.* [Text box]
- *Please leave your explanations and comments on your ratings here:* [Text box]
- *Do you have other feedback that could help improve the framework?* [Text box]

Table 2: The projects presented during the interviews, the tools that participants mentioned using in these, and the type of team and other stakeholders influencing the colors' choice.

ID	**Presented example projects**	**Tools used in the project**	**Collaborative context of the project**
P1	Three iterations of a personal-portfolio Web site, with the final one being a work in progress	An online example gallery for Web sites, a coding environment, and a color-picker	Solo project
P2	Brand design, including a "brand bible," a slide deck with style guidelines and examples, and slide templates	Prototyping tools, a presentation-slide tool, and an online palette-generator	Discussions with a multidisciplinary team
P3	A printed flyer, intended as a prop for a video, that resembles a museum flyer	An online example gallery for color palettes and a graphic-design tool	Solo project
P4	A high-fidelity prototype for an app, with multiple screens, documentation material, and presentation slides	A graphic-design tool, a prototyping tool, and an online contrast-checker	Solo project involving consultation with domain experts and a supervisor
P5	Visual branding for two companies and one software product, including logos, style guides, mockups, Web-site designs, and further marketing materials	An online palette-generator, an online contrast-checker, color-blindness simulators, a prototyping tool, and online example galleries for design ideas	Discussions with a multidisciplinary team
P6	A video game (3D-rendered, with colors for the textures and lighting), including the project Web site and presentation slides	A photo-editing tool, a graphic-design tool, a layout-design tool, a tool for 3D modeling, a physical mood board, and a coding environment	Work with a design team including a game-developer and a 3D artist
P7	2D animation referencing the theme of a fashion show A Web site for an art festival	Animation: A graphic-design tool, sketches on paper, and a motion-graphics tool Web site: A graphic-design tool	Animation: Collaboration with a fashion designer Web site: Solo project with interaction with the client at some milestone points
P8	Service design, including a slide deck explaining and illustrating the design	A color-palette generator, a page-layout tool, and a graphic-design tool	Client project with a multidisciplinary design team
P9	Branding for an event, covering logos, a Web site, and promotional materials for social media	A prototyping tool and a color-palette generator	Solo project, with consulting of event managers who made the key decisions
P10	Branding for an event, including a logo and both print- and digital-marketing materials	A graphic-design tool, page-layout tool, and text-editing tool	Team of designers interacting with the client at some milestone points
P11	A typography collage of media debate in document form	A page-layout tool	Solo project
P12	A steering-wheel demonstrator A remote-control center for tugboats	A tool for 3D modeling and a photo-editing tool	Design-team work with P12 in the role of the design director and also engaging in consultation with the client

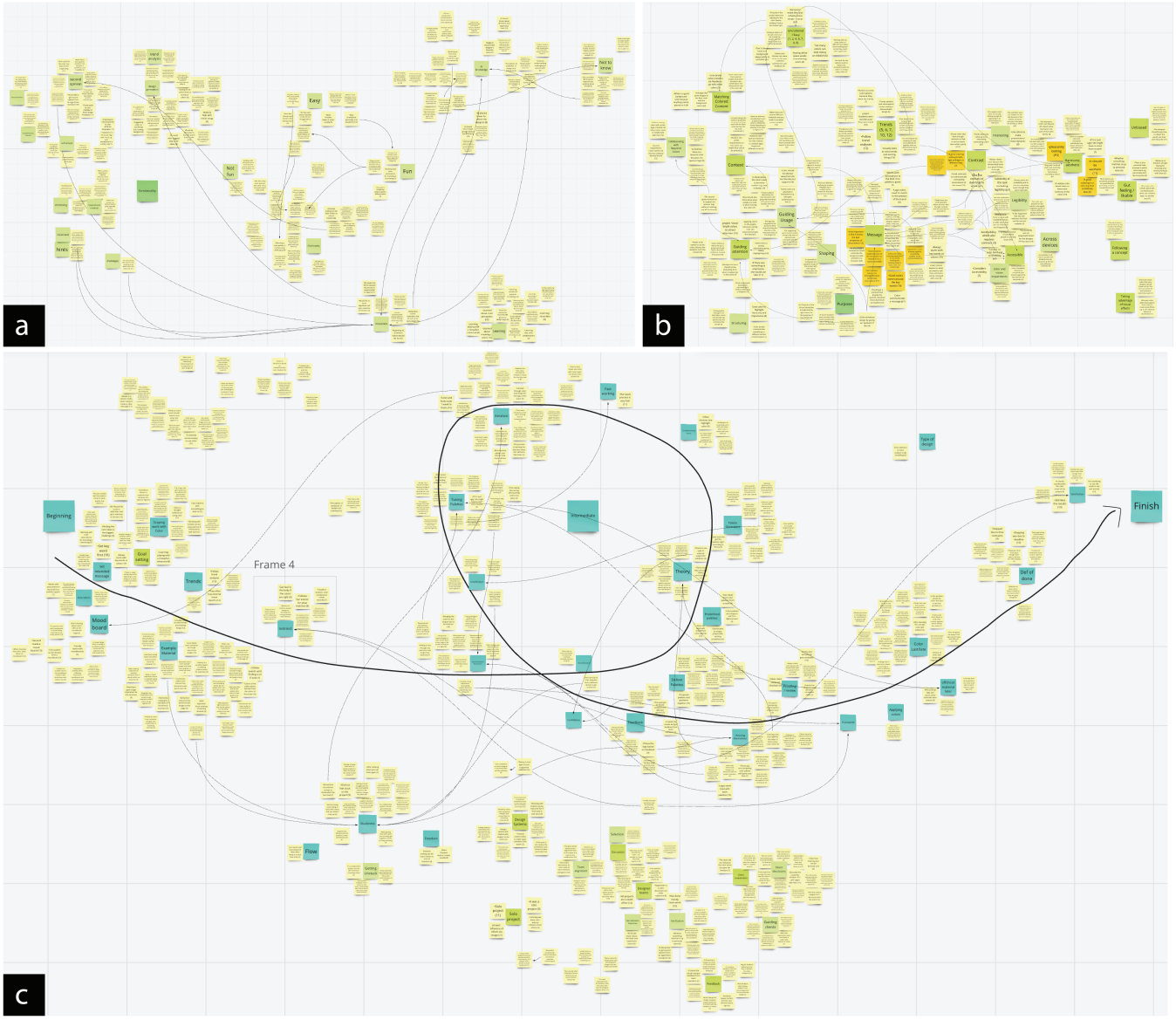

Figure 9: The data analysis encompassed producing three affinity diagrams, which displayed a general connection to, respectively, the initial interview content addressing what makes for good coloring in general (b), solid color-design practices (c), and the use of AI and other tools (a).