

Piet: Facilitating Color Authoring for Motion Graphics Video

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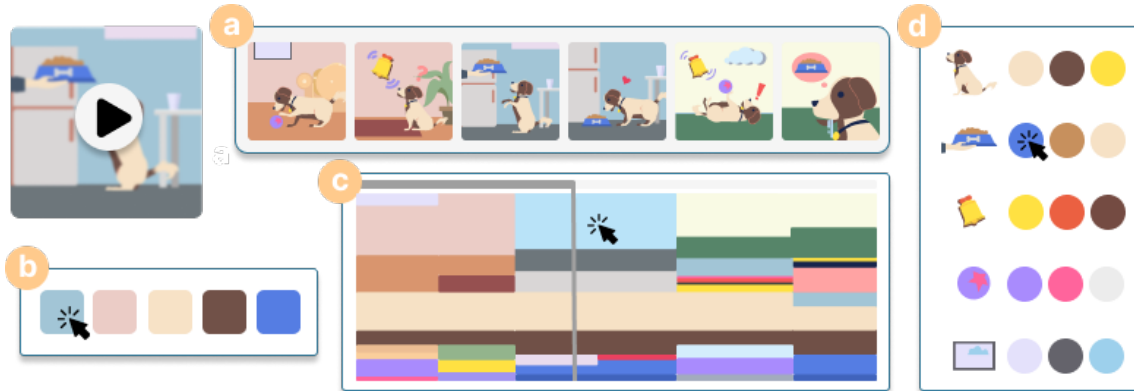


Fig. 1. Piet is a color authoring tool tailored to motion graphics videos (a) by providing different interactive color representation views summarizing colors from broad video theme overviews (b) down to detailed scene (c) and element perspectives (d).

Motion graphics (MG) videos are effective and compelling for presenting complex concepts through animated visuals; and colors are important to convey desired emotions, maintain visual continuity, and signal narrative transitions. However, current video color authoring workflows are fragmented, lacking contextual previews, hindering rapid theme adjustments, and not aligning with designers' progressive authoring flows. To bridge this gap, we introduce Piet, the first tool tailored for MG video color authoring. Piet features an interactive palette to visually represent color distributions, support controllable focus levels, and enable quick theme probing via grouped color shifts. We interviewed 6 domain experts to identify the frustrations in current tools and inform the design of Piet. An in-lab user study with 13 expert designers showed that Piet effectively simplified the MG video color authoring and reduced the friction in creative color theme exploration.

CCS Concepts: • **Computer systems organization** → **Embedded systems**; *Redundancy*; Robotics; • **Networks** → Network reliability.

Additional Key Words and Phrases: motion graphics color authoring, interactive video color palette, color recommendation

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1 INTRODUCTION

Motion graphics (MG) videos are short animated videos crafted to engage audiences in a logically connected narrative and facilitate content comprehension [1, 25]. By delivering the visual, animated, and auditory elements in an organized

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53 and appealing manner, these videos make it effective and memorable to simplify complex concepts or narrate a brand
54 story [7, 16, 17]. The rise of online video platforms motivates both institutions and individual creators to leverage such
55 videos for enhanced outreach. As a result, these videos are widely popular in various fields such as education and
56 marketing [11, 27, 29]. For instance, Figure 1(a) shows frames from an explainer MG video introducing Pavlov’s dog
57 experiment.
58

59 Color is a powerful visual language to shape the effectiveness of MG video. As evidenced in static graphic designs,
60 color evokes emotions, improves visual harmony, and directs viewers’ attention [2, 13, 14]. Particular to MG videos,
61 color is also essential to maintain *visual continuity*. Across a series, consistent theme colors establish the brand identity,
62 while within individual videos, adherence to a color theme ensures both captivating visuals and lasting impressions.
63 Furthermore, colors can signal *narrative transitions*: a sudden change signifies a plot shift, while a subtle gradient
64 indicates seamless scene progression. Such complex roles of color demand careful design to achieve desired visual
65 effects, often causing designers to invest considerable time in iterating and repeatedly modifying colors.
66
67

68 Despite the extensive studies in HCI and media have investigated approaches to animation authoring [16, 19],
69 exploration of visual storytelling [21, 28], and the broader difficulties faced in motion graphics creation [17], the
70 specific process and challenges of color design in MG videos remain largely unexplored. Despite the wealth of research
71 addressing the challenges and opportunities in static graphics colorization [9, 18, 32, 33], the knowledge gap in MG
72 video color design and authoring is evident. Currently, there is a limited understanding of the color authoring process
73 in MG videos and the specific challenges designers face during this process. Aiming to bridge this gap, we conducted a
74 formative study with six domain experts. Our objective is to systematically explore how they perform color design in
75 MG video creation, pinpoint what challenges they encounter, and identify design opportunities to streamline the color
76 authoring experience in this field.
77
78

79 Our formative study identified three primary challenges in MG video color authoring. First, the current workflow
80 separates the element creation and coloring from animation, depriving designers of immediate contextual previews to
81 gauge the impact of color alterations on the overall video. Typically, designers use Adobe Illustrator¹ for coloring and
82 then switch to After Effects² for animation. Making color modifications often means frequently switching between
83 these tools to ensure the edits do not disrupt the visual continuity and narrative flow, thus leading to a disruptive and
84 time-consuming experience. Second, current tools lack the support for collective adjustments for diverse elements in
85 different frames, e.g., linearly shifting the saturation of a group of colors to be more vibrant while preserving their
86 distinct hues. This limitation prevents designers from creatively exploring various color theme alternations and makes
87 post-animation color theme changes difficult. Lastly, existing tools lean more towards an object-driven methodology,
88 forcing designers to always start from the most details for each object, contrasting to the fact that many designers prefer
89 a top-down, progressive approach to color editing. The top-down strategy fosters visual continuity by prioritizing
90 the dominant color adjustments and holding off on minor refinements, and thus designers can maintain a big picture,
91 instead of being distracted from isolated object hues.
92
93
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95 The challenges outlined above make MG colorization a time-consuming and complex task. Even though there are
96 several tools available, including mainstream ones like Adobe Illustrator¹ and After Effects², and lighter alternatives
97 such as the Lottie editor³ and Figma⁴, none has fully addressed pressing difficulties of color authoring. For example,
98 while the Lottie editor offers a feature for quick color palette selection in MG projects, it restricts users to a limited,
99

100 ¹<https://www.adobe.com/products/illustrator.html>

101 ²<https://www.adobe.com/products/aftereffects.html>

102 ³<https://lottiefiles.com/lottie-editor>

103 ⁴<https://www.figma.com>

105 predefined five-color palette, offering no room for detailed adjustments. Platforms like Figma⁴, Animaker⁷, and Vimeo⁸,
106 while easing the animation creation process to some degree, do not have features that specifically tailored to designers’
107 needs for the color authoring phase.

108 To address these challenges, we introduce Piet, an interactive tool for MG video color authoring with a more
109 integrated workflow, multi-level color adjustment, and progressive editing (Figure 1). Piet combines color authoring
110 and video playback, and proposes an interactive video palette that offers a visual abstraction for color distributions
111 across the video. As shown in Figure 1(c), the video palette exhibits a visual style of dynamic Mosaics, illustrating the
112 dynamic fluctuations in color and their proportions throughout the video timeline. Designers can directly manipulate
113 this palette for multi-faceted color adjustments, with the flexibility to zoom in and out to control their desired focus
114 levels. Specifically, Piet supports context-aware, group-wise, and multi-level color modifications spanning video, scene,
115 and object dimensions.

116 We evaluated how Piet impacts designers’ authoring experience with 13 expert designers in a controlled in-lab user
117 study. Participants found Piet provided a more intuitive, fluid, and engaging color authoring experience and facilitated
118 their theme exploration and visual continuity management, a notable improvement over existing tools. Additionally,
119 findings suggest that Piet could seamlessly be integrated with Adobe After Effects, potentially shifting the color planning
120 to post-animation stages and reducing reliance on initial color decisions in Adobe Illustrator. This research thus has
121 threefold contributions:

- 122 • A **formative study** with 6 expert motion graphic designers that identify the typical MG creation workflow, understand
123 common approaches employed for MG color design, and pinpoint challenges in color authoring.
- 124 • A **prototype system, Piet**, co-designed with experts, to support *context-aware*, *group-wise*, and *multi-level* color
125 authoring tailored to MG videos.
- 126 • An **expert evaluation** confirms the effectiveness of Piet, revealing its advantages and limitations. The derived
127 insights shed light on future investigation of video authoring designs.

134 2 RELATED WORK

135 2.1 Color Design and Interactive Color Authoring Tools

136 Color design, which consists of choosing specific colors and allocating them to distinct design elements, is crucial in
137 designers’ workflow, greatly shaping the visual aesthetic appeal [13]. Instead of examining colors in isolation, designers
138 typically “feel” colors within a composition as a whole [20] because the relationships among colors can profoundly
139 change the overall aesthetic and emotional resonance [38]. To craft balanced and captivating color compositions,
140 designers frequently turn to predefined color palettes. Popular platforms like Adobe Color⁵ and ColorBrewer⁶ offer
141 palette suggestions rooted in established harmonic principles [39].

142 Innovative tools have been developed for color authoring in images, largely enhancing traditional color picker
143 interfaces [26]. For instance, Color Portraits [18] pioneered the *in-context* exploration, enabling users to play with color
144 interrelationships (i.e., size, position) using color swatches. However, the palette exploration and its assignment to
145 the intended design remain separate. Bridging this gap, tools like Color Triads [32] and Histomages [9] introduced a
146 triangular-shaped palette and color histogram, respectively, to allow users to directly recolor images by manipulating
147 the palette. Specifically tailored for fine-grained color blending, Playful Palette [33] employs a free-from unstructured

148 ⁵<https://color.adobe.com/create/color-wheel>

149 ⁶<https://colorbrewer2.org>

palette for artwork colorization. Generally, these solutions can be categorized as palette-based image editing. They are mainly designed for hue and saturation adjustments while neglecting lightness which is typically adjusted via curve-based methods. A most recent work, ColorfulCurves [5], unifies the palette and the curve-based solution to allow for interactive regional lightness adjustment.

While existing tools provide promising solutions for static design color exploration, there remains a gap in tailored solutions for motion graphics video color authoring. The closest approach is found in [12], which employs a spatial-temporal geometric palette for video recoloring. However, this method is designed for pixel-based, real-world captured videos and is anchored to the image color space. In contrast, this paper focuses on motion graphic videos crafted from vector graphics. Inspired by the benefits of interactive palettes in color exploration for static design coloring tools, our aim is to extend such a palette-driven approach in motion graphic video color authoring.

2.2 Intelligent Tools for Motion Graphics Authoring

Motion graphics are pieces of animated graphic design that uses text, graphical elements, and animation to convey information in a concise and immersive way [1]. Over time, studies have investigated to understand this complex domain, producing a set of design principles [35] that govern the effective use of motion and animation in communication. The creation of motion graphics often presents significant challenges. Dominant commercial tools like Adobe AfterEffects offer advanced capabilities but come with a steep learning curve that can be unfriendly for novices and even some intermediate users. Recognizing the need for ease, platforms like Animaker⁷, Vimeo⁸, and Doodly⁹ offer template-based tools, making motion graphic creation accessible for beginners. However, the template-based solution has limited flexibility, and customization is not straightforward.

To seek the balance between simplicity and flexibility, several innovative solutions have emerged. For instance, Katika [16] provided an end-to-end system, enabling amateurs to produce animations through a three-fold approach: generating shots from scripts, sourcing animations from a crowd-contributed library, and modifying animations using modular motion bundles. Similarly, Kitty [19] introduced a sketch-based platform, which empowers artists to craft animated, interactive visuals by delineating entities and their interrelationships. This is further enriched by an underlying graph model that visually conveys dynamic interactions and causalities as viewers engage with the content. Complementing these, Ma et al. [24] proposed a layered authoring tool for 3D animation authoring, employing a timeline sequencer for easy preset stylization effects, while also offering a node-graph-based UI for further customizations.

Despite significant advancements in motion authoring, there remains a notable gap in tools for color authoring. Current trends typically segregate motion authoring from element design, leading to the challenges of making seamless color adjustments. In this paper, we propose seamlessly integrating a video preview with color authoring tools, and further investigate how to provide a more intuitive and efficient authoring experience for post-animation color adjustments.

2.3 AI-assisted Motion Graphics Generation and Augmentation

Creating motion graphics is complex and difficult, which typically involves narration writing, script planning, coordination of visuals, and animation implementation [17]. To streamline the fragmented and tedious nature of this process,

⁷<https://www.animaker.com>

⁸<https://vimeo.com>

⁹<https://www.voomly.com/doodly>

209 researchers have employed AI techniques, primarily making their efforts to automatically generate motion graphics
210 and augment existing videos with animated visuals.

211 **Automatic MG video generation.** Narration-driven methods dominate the field of automatic motion graphics
212 (MG) generation. Key works include AutoClips [31], which automated data video creation through a two-step process
213 of clip library usage and optimal clip arrangement. DataParticles [4] simplified animated unit visualization creation
214 using block-based and language-oriented authoring, obviating the need for expertise in tools like D3.js and AfterEffects.
215 Similarly, Data Player [30] and Wonderflow [37] presented a narration-driven data video generation approach but with
216 an enhanced focus on narrative-animation synchronization. Broadening the scope of data-centric motion graphics,
217 TakeToons [34] presented a script-driven approach for performance animation where authors annotated scripts with
218 animation events. These annotated scripts would then be compiled into a story model, bridging gaps in the fragmented
219 production process. Doc2Video [10], introduced a pipeline applied for general transforming documents to talking
220 head motion graphic video solution, consisting of document parsing, script planning, and video synthesizing, greatly
221 automating the content transformation process.
222

223 **Augmenting existing videos using animated visuals.** Enhancing videos with animated visuals has grown
224 in popularity, predominantly aiming to enhance communication and viewer engagement. Notably, Visual Captions
225 [23] enhanced video conferencing with a visual intent model to predict and display the most apt visuals during
226 conversations. RealityTalk [22] addressed live presentation tools' limitations, offering real-time speech-driven graphics
227 control. Similarly, Chironomia [15] took this further in remote presentations, overlaying interactive visualizations on
228 webcam footage, augmenting the presenter's gestures, which not only allows presenters to control visual elements but
229 also enhances their expressiveness. Different from the presentation-centric efforts, Sporthesia [6] ventured into sports
230 video augmentation by detecting textual insights, converting them into animations, and seamlessly embedding them,
231 enriching the viewing experience.
232

233 These works offer promising solutions for automatically generating motion graphics and animated augmentations. Yet,
234 a significant gap remains: none of them carefully consider the color choice, despite its influence on viewer perception and
235 emotional resonance [36]. In this field, human designers invest significant time in fine-tuning color choices. Recognizing
236 this gap, our paper investigates color authoring in motion graphics. We believe that addressing this aspect will bring
237 such generative solutions closer to real-world applications, ensuring enhanced visual aesthetics.
238

239 3 FORMATIVE STUDY

240 A formative study was conducted to gather insights from expert motion graphic designers, with the aim of understanding:
241 (1) what are the typical workflows of motion graphics video creation; (2) how designers approach early-stage color
242 exploration and late-stage color adjustments; and (3) what are the challenges they encounter during color authoring.
243

244 3.1 Participants and Procedure

245 We conducted semi-structured interviews with six domain experts, all of whom have received professional training
246 in motion graphics design, hold a formal degree in Design, Arts, or Digital Media Arts, and have over four years of
247 experience in crafting explainer MG videos. Further demographic details are provided in Table 1. In the subsequent
248 explanations, we refer to our experts as E#.
249

250 The interviews began with background questions about participants' professional roles and experiences in MG video
251 creation. Participants were then asked to introduce their typical workflow for designing and creating explainer MG
252 videos by showing us intermediate results of one recent work and demonstrating their process in their preferred editing
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Table 1. The table records our interviewees' demographic information, including genders, range of ages, occupations, and experiences of motion graphics video creation in years (denoted as Exp. in the table).

ID	Gender	Age	Occupation	Exp.
E1	F	25-29	Motion Graphics Designer	7
E2	F	25-29	Visual Designer	6
E3	M	20-24	Student in Digital Media Arts	4
E4	F	25-29	Motion Graphics Designer	5
E5	M	25-29	Graphics Designer	6
E6	F	20-24	Motion Graphics Designer	4

tool. Subsequent discussions revolved around the early exploration and late-stage adjustments of color choices in the MG video, and the common challenges they encountered in color authoring. Each interview lasted approximately one hour, during which both audio and screen-sharing were recorded.

3.2 Data Analysis

We conducted the thematic analysis of the interview data and built an affinity diagram to investigate the patterns of designers' workflow and themes of challenges they encountered. Two researchers independently analyzed and open-coded the transcribed interviewees' responses. Then, they discussed and reconciled any discrepancies in the coding process to ensure a consistent and accurate representation of the participants' perspectives. Subsequently, the researchers used affinity diagramming to categorize the initial codes onto cards. Through an iterative discussion and organization of the codes, we identified several recurring patterns and themes from the collected data.

3.3 Key Findings

Our findings regarding the workflows (Section 3.3.1), approaches to handle color exploration and adjustments (Section 3.3.2), and challenges in color authoring (Section 3.3.3) have been summarized as follows.

3.3.1 Workflows for MG Videos Creation. Crafting an explainer motion graphics (MG) video is a complex, time-consuming, and full trial-and-error process. This process involves a multi-step workflow commonly adopted by designers, consisting of six major steps: narrative analysis, storyboard sketching, styleframe design, element creation, scene animation, and video compilation. An example of intermediate results from these steps, provided by E4, is illustrated in Figure 2. Although communications with clients and discussions within the design team primarily take place during the static design stages (S1 to S4), the process is not always linear. As experts emphasized, "*when doing animations (S5), we often need to go back to earlier stages to make adjustments.*" -E2, a loop that includes communications with clients and iterative refinements.

Table 2. Six stages of motion graphics video creation.

Stage	Description
S1. Narrative Analysis	Analyzing client-provided scripts to extract logic and segment into scenes based on story flow.
S2. Storyboard Sketching	Drafting line drawings of key scenes to outline the video progression and crucial transitions.
S3. Styleframe Design	Developing 3-5 keyframes (depending on scenes and budget) to set the style and define theme colors.
S4. Element Creation	Creating visual elements with tools like Adobe Illustrator, finalizing detailed color choices.
S5. Scene Animation	Animating scenes individually using After Effects to maintain organization and reduce complexity.
S6. Video Compilation	Assembling animated segments using Premiere Pro or AE to produce a cohesive MG video.

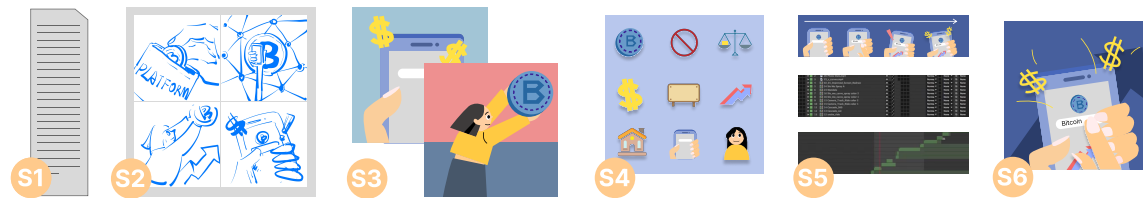


Fig. 2. An example provided by E4 explaining Bitcoin, showing the typical workflow to create an explainer motion graphics video. The original narration is missing, thus we replaced it with a representational figure for S1. We have received consent from E4 to include this in the paper.

3.3.2 Early Exploration and Late-stage Adjustments of Colors. Colors are always a crucial part in MG video creation. Prior research [32] revealed that color design is an iterative process in static graphic designs. Our findings dive into the color design process in MG videos, particularly, how designers explore the color choices in an early stage and how they make necessary adjustments later.

How do designers explore color choices in an early stage? The initial discussions about colors between designers and clients happened during the styleframe design stage (S3). Initially, designers will select a palette of 3-5 colors, guided by the emotional tone of the story, brand impressions, and the target audience. Then, designers apply these color choices to several keyframes, i.e., styleframes. They demonstrate the interplay of these colors within the frames, offering a glimpse of their potential impact in the final video. It helps clients form a concrete picture of the final video's visual aesthetics and styles. During this stage, designers may present alternative color schemes for clients to consider, while also welcoming client suggestions for different color combinations. It facilitates early color exploration, allowing for quick and cost-effective adjustments. Ideally, this stage is supposed to clearly set the client's expectations regarding the video's style and firmly establish the color themes to avoid later changes.

Why do color adjustments often happen in late stages? Despite the conversations in the styleframe design stage defined the styles and color themes, late-stage (i.e., post-animation) color adjustments can not always be avoided. As noted by E1, *“while we aim for a linear and smooth process, there's always that back-and-forth on tones that can drive us crazy.”* This primarily results from the differences between the designers' envisioned outcome and the client's expectations, a gap often noticeable when comparing static styleframes with the final video. All experts interviewed had encountered such late-stage color adjustment requests, which generally fall into two categories: tweaks to a specific color tone (e.g., shifting from one shade of blue to another) and changing the entire color scheme (e.g., revising theme colors from green and yellow to blue and pink). For the former, E6 shared us her experience, *“in one project, the client gave us the wrong blue tone by mistake, a color that used a lot, here and there in the video. They spotted this when all animations were already done. This forces us into a lot of painful changes”*. E4 provided us with her experience on the later types of adjustment requests, *“Once, we produced a 150-video series for history education, each about 30 seconds long. The client wanted a unified feel, so we applied a consistent color theme across the series. Just as we neared completion, the client jumped in, asking, ‘Can we make the visuals more colorful?’ You can imagine how such a request is annoying.”*

How do designers handle late-stage color adjustments? Such late-stage color adjustments are very tedious and challenging, E5 called it *“a disaster and tough to rescue”*. In such cases, designers will *“go back to create new static styleframes, and re-evaluate the potential impact of the color changes on the final video.”* -E2. Once the new color choices are confirmed by clients, designers will *“revisit the original Illustrator element files to modify colors of related elements”* and *“avoid directly make adjustments on AE source files.”* -E5. However, *“if the existing files are cluttered and messy, it sometimes becomes more practical to craft new elements from scratch, replacing the previous ones entirely.”* -E3 This highlights the

365 importance of early-stage project planning including “*file naming, graphic grouping, and layer organization*” -E5; however,
 366 “*the chaos is the normal*” -E4. Experts all noted that disorganized project planning and collaborative work, which are
 367 often the cases in their work, make using original files for post-animation color adjustments extremely challenging.
 368

369 3.3.3 *Challenges in MG Video Color Authoring.* Given that late-stage color adjustments in MG video creation is frequent
 370 but challenging, we further discuss with experts about the specific challenges and frustrations they encountered.
 371

372 **C1: Absence of immediate contextual feedback.** MG video color authoring is notably different from static
 373 graphic design because MG videos incorporate dynamic, moving elements. The color choices in MG videos not only
 374 influence a single frame but also affect the perception of sequences of frames. This distinction makes it important
 375 for designers to ensure that edited color effects cohesively align with the story’s narrative scaffolds, maintaining
 376 consistent visual harmony throughout the video. E3 emphasized that “*color choices should ‘act’ with the story rather*
 377 *than standing as isolated elements.*” Yet, as E2 expressed, the current process often feels like “*assembling a puzzle without*
 378 *knowing what the final image looks like. Each piece feels right, but then it doesn’t fit into the larger scheme of things.*” -This
 379 common frustration arises from two reasons: the fragmented workflow and the lack of real-time previews. E3 expressed
 380 frustration about the frequent need to “*switch between Illustrator and After Effects, particularly for minor tweaks*” which
 381 “*can be very annoying and disrupt the holistic design experience.*” The separation of element coloring from its resulting
 382 effect, based on its interaction with other elements and storyline flow, causes this back-and-forth. Designers thus
 383 expressed their wish for “*live previews of changes, so we don’t work blind.*” -E1.
 384
 385

386 **C2: Inability to group colors for joint manipulation.** For static designs, designers appreciate the efficiency of
 387 jointly adjusting hue and saturation for multiple regions, like using Photoshop’s hue/saturation adjustment layer¹⁰. It is
 388 ideal to afford rapid experimentation with color tones. However, this convenience is missing in MG video authoring, as
 389 suggested by E4, “*it would be super useful to have that where we can tweak colors for elements spread across different*
 390 *scenes in MG videos.*” E2 explained the inherent reason leading to this challenge: “*each element is crafted separately to*
 391 *keep our files neat and organized.*” As a result, each element is isolated, making collective adjustments difficult. This
 392 mandates designers to “*modify the smallest unit each time.*” -E2. Alternatively, E5 mentioned that “*there do exist ways*
 393 *to globally adjust, like adding some universal filters [to the whole video], but let’s be real, there is no magic fix. Proper*
 394 *[color] adjustment is complex, it is shifting some colors here in this way, then fine-tuning some colors in that way, there is no*
 395 *one-size-fits-all deal.*” In summary, existing tools only support the two extreme solutions, either tweaking every detail or
 396 just blindly applying a universal filter to the entire video, with no room in between for grouping target colors flexibly
 397 for strategic adjustments. Such limitation makes it tedious and time-consuming to maintain or change a consistent color
 398 theme across videos, particularly for extensive projects. This highlights the necessity for supporting joint manipulation
 399 for grouped colors.
 400
 401

402 **C3: Difficulty in progressively authoring colors.** An MG video, much like a static image, can contain a lot of
 403 colors. Yet, it is the dominant colors that leave a lasting impression, revealed by visual saliency theory [] and also
 404 confirmed by our interviewees. Designers naturally adopt a top-down strategy: “*starting from the predominant colors that*
 405 *cover large areas or appear frequently, then on secondary hues, and finally refining less obvious details, such as character*
 406 *hair.*” -E4 The benefit of this strategy is noted by E1, “*prioritization makes me more clear to the larger picture I want to*
 407 *paint.*” However, the current tools challenge this approach. Designers must “*repeatedly play the video, find dominant*
 408 *colors, adjust them, and move to the next,*” -E2 such hierarchy should be kept on track mentally. E3 complained that
 409
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 411
 412

413 ¹⁰<https://helpx.adobe.com/photoshop-elements/using/adjusting-color-saturation-hue-vibrance.html>
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417 “as the number of elements grows and the video gets longer, keeping track [such hierarchy] mentally becomes hard.” She
418 attributed this to the manipulation nature adopted by current tools, calling it “object-by-object disconnected logic”.
419

420 3.4 Design Goals

421 Driven by the observed challenges in MG video color authoring and our discussions with motion graphics professionals,
422 we derived the following design goals, each addressing one specific challenge in MG video color authoring, which
423 guided the development of Piet.
424

425 **D1: Integrate color editing with video playback for real-time contextual feedback.** The temporal nature of
426 MG videos requires a continuous and cohesive narrative. By merging color editing with video playback, designers can
427 immediately see how color changes impact the storyline. This not only speeds up the design process but also ensures
428 that the narrative flow remains undisturbed by color modifications.
429

430 **D2: Enable both individual and group-wise color adjustments.** In MG video authoring, designers have dual
431 needs: refining individual elements and harmonizing colors across multiple elements for style consistency. This balance
432 stems from two distinct design perspectives: the *object-driven* focus on isolated components, and the *scene-driven*
433 approach, which emphasizes holistic visual cohesion. To support both, it is crucial to offer different views that highlight
434 individual objects and the overall color palette within scenes. By facilitating both types of adjustments, we simplify the
435 editing process, enabling designers to swiftly transition between detailed tweaks and broad thematic edits.
436

437 **D3: Present an overview of color distribution with adjustable detail levels.** Understanding the color distribution
438 in a video is important for informed color design decisions and prioritizing designers’ edits. Our study indicates that
439 color dominance in an MG video hinges on its visual presence and recurrence across frames. Therefore, it is essential to
440 ensure these aspects are reflected in the color distribution overview. In addition, an adjustable overview is necessary
441 to allow designers to zoom in on specifics or zoom out for a broader perspective, giving them flexibility in how they
442 approach and execute their color adjustments.
443
444
445

446 4 PIET

447 Piet is a color authoring tool tailored to motion graphics videos by providing different interactive color representation
448 views summarizing colors from broad video overviews down to detailed scene and element perspectives.
449

450 4.1 System Overview

451 Piet has three main panels: the Video Playback (Figure 3a), the Color Representation (Figure 3b), and the Color Picker
452 (Figure 3c). Within the Color Representation panel, there are three views: 1) the Video Theme, summarizing the
453 dominant colors and their proportions throughout the video; 2) the Scene Palette, illustrating detailed color distribution
454 on the timeline; and 3) the Element List, detailing colors for every element. These views are both interactive and
455 synchronized: modifications in one view automatically update the others. They are presented at all times, side-by-side
456 as the layout shown in Figure 3.
457
458
459

460 We require MG video imported to Piet must be in *Lottie* format³ a JSON-based animation file format that can be
461 exported from current most widely used motion graphics creation tools and platforms such as Adobe AfterEffects,
462 Figma, and Canva. While Lottie handles both vector (SVG) and raster (image) elements, we only consider MG videos
463 constructed from SVG elements due to the notable difference in colorization between images and SVGs. In Lottie, each
464 SVG shape is represented as a layer, characterized by static Bezier paths and animated property transformations such as
465 how its color, opacity, scale, position, and rotation change across keyframes. From Lottie, we extract each SVG element’s
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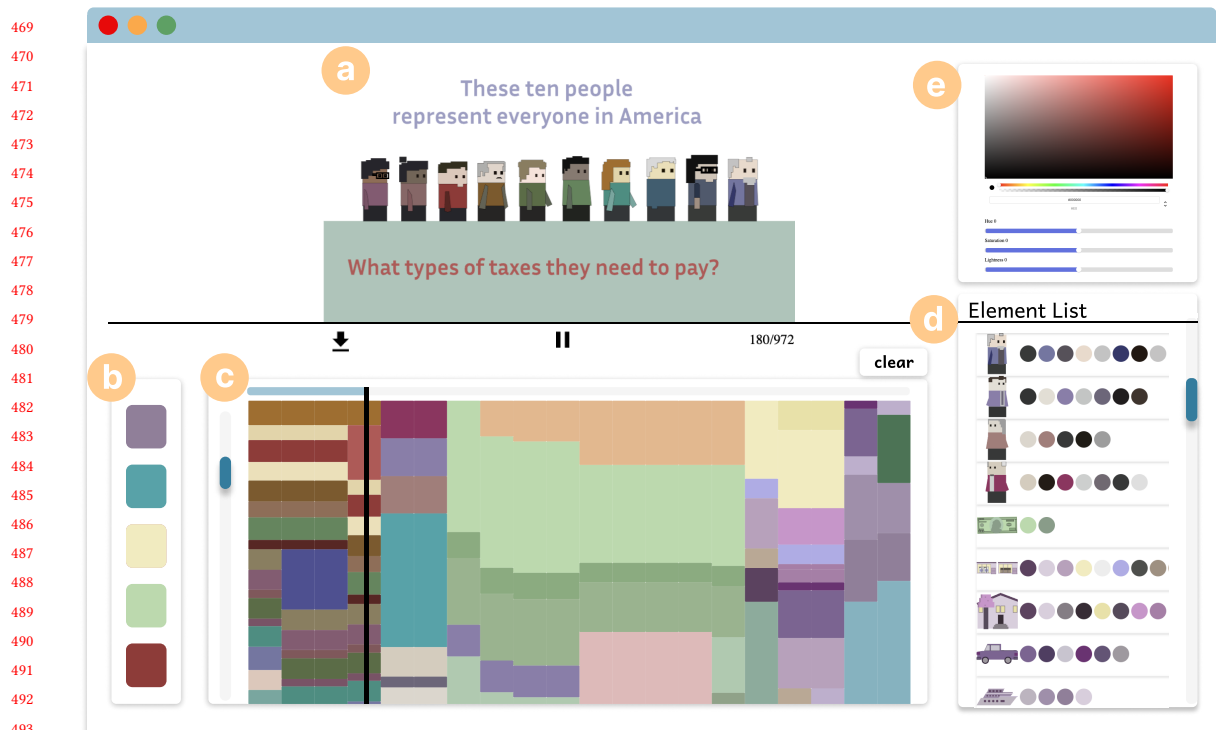


Fig. 3. User Interface of Piet, consisting of (a) Video Playback, (b) Video Theme summarizing the dominant colors and their proportions throughout the video, (c) Scene Palette illustrating detailed color distribution on the timeline, (d) Element List detailing colors for every element, and (e) Color Picker. These views are both interactive and synchronized.

color information including **RGB value**, **opacity**, **approximated size**, and **timing**. The RGB and opacity are directly accessible, whereas a color's size is derived from its shape's Bezier path bounding box area. These properties align with keyframes, marking the start and end time of each color's appearance.

4.2 Constructing Color Representation Views

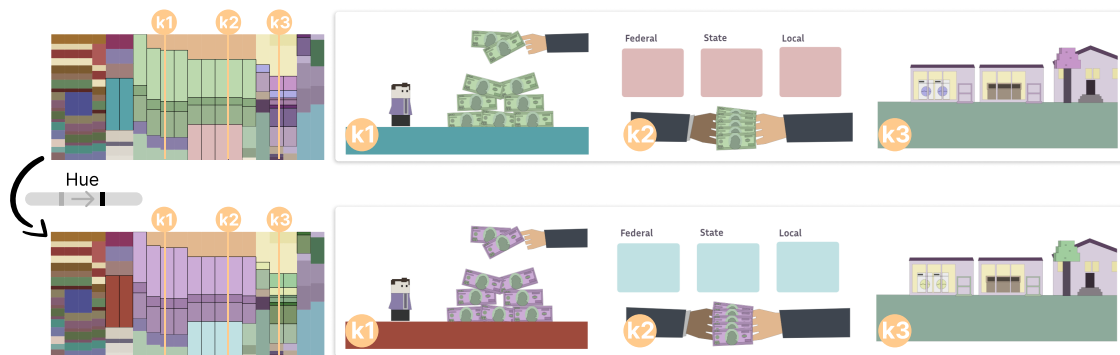
4.2.1 Video Theme View. The process of extracting theme colors is based on the frequency and proportion of the color appearing throughout the video. Initially, all colors present in the video are converted into LAB representation. Subsequently, the K-Means algorithm is applied to derive k clusters of colors, simply based on the DeltaE distance. Within each cluster, the color with the highest proportion, is selected as the theme color for that cluster. In our system, we have chosen k to be 5.

4.2.2 Scene Palette View. The scene palette aims to represent the color distribution throughout the timeline of a video, essentially illustrating how the colors and their size change over time (D3). In other words, the scene palette serves as a visual representation of the color scheme in a video over time. There are two primary considerations for displaying this visualization in a way that effectively communicates the color distribution to users. Firstly, there is the challenge of encoding the colors from the video into color rectangle units within the palette. Secondly, there is the matter of how these different color rectangles are arranged or stacked within the palette.

521 **Visual encoding.** The height of each colored unit in the palette is determined by its corresponding shape in the
 522 video. However, this involves converting visual perception from 2D to 1D (i.e., encoded from a 2D area to a single height
 523 dimension). To address this, we have adjusted the height of a colored rectangle in the palette to be proportional to the
 524 square root of the bounding box size of the respective shape in the video. Specifically, the height is calculated using the
 525 formula: $Height_c = \alpha \times \sqrt{Shape_c}$, where α is a modifiable parameter used to control the zoom level of the color palette.
 526

527 **Color merge and sort.** Grouping identical colors together offers a more streamlined and comprehensive view of
 528 the color distribution for viewers. For instance, in the given video example, there are numerous instances of cash.
 529 It can be beneficial to merge these instances to view and edit the color collectively. Firstly, we merged all identical
 530 colors, even though they might appear on different elements. The reasoning behind this is that the scene palette aims to
 531 provide an overview of how colors are distributed throughout the timeline. Moreover, according to the Gestalt law,
 532 humans perceive identical colors as a group. Secondly, we arranged similar colors in close proximity based on their
 533 DeltaE distances using the LAB color representation. This is because designers often use colors with slight variations to
 534 maintain visual continuity while avoiding the monotony of overusing a single color. By grouping similar colors together,
 535 the scene palette can accurately mirror such human perception habits and provide a more intuitive understanding of
 536 the color distribution.
 537
 538
 539

540 **4.2.3 Element List View.** In the element view, each component can comprise various sub-shapes, like a person having
 541 eyes and a hat. This approach complements the scene palette view. In the Scene Palette, colors form the palette,
 542 disregarding their association with specific elements, and focusing on the overall image. Yet, it's essential for designers
 543 to maintain precise control over each detail, facilitating fine-tuning at later stages. The element-centric perspective of
 544 this view enables swift navigation to targeted elements for refinements, making the design process more efficient and
 545 precise.
 546
 547



561 Fig. 4. Piet features group-wise color adjustments. Users can select multiple colors on the Scene Palette and then modify the color
 562 properties using sliders for hue, saturation, or lightness in the HSL space.
 563
 564

565 4.3 Interacting with Scene Palette

566 **4.3.1 Linking Color to Elements in the Video.** Piet optimizes the authoring experience by allowing the designers to
 567 modify colors while staying within their authentic video frame context. Hovering over a color block in the scene
 568 palette automatically shifts the time marker to the corresponding frame, presenting it in the video playback area.
 569 Simultaneously, the associated SVG element pulses with a black animated border, offering designers a clear visual cue
 570
 571
 572

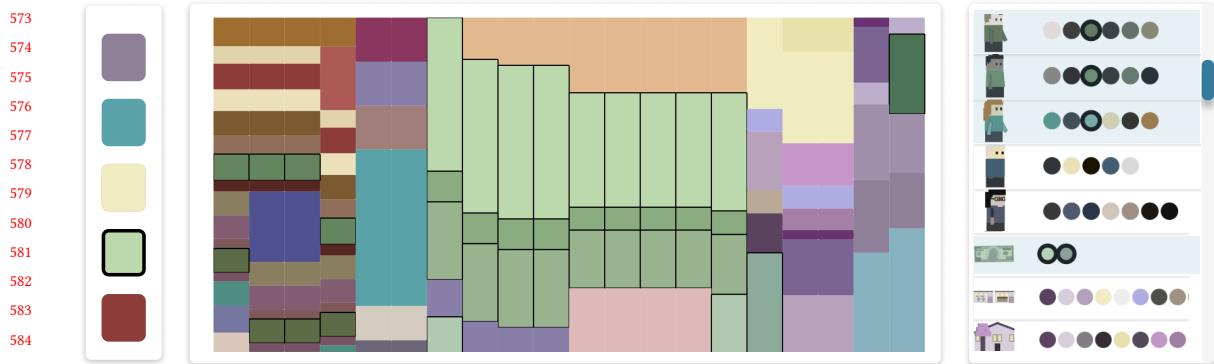


Fig. 5. The three color representation views, i.e., Video Theme, Scene Palette, and Element List are synchronized to help designers inspect how theme colors are distributed throughout the timeline and interconnected scenes.

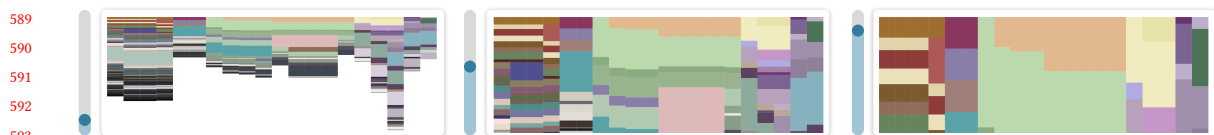


Fig. 6. Piet provides users with the flexibility to adjust the level of details in the scene palette to handle minor color blocks and encourage the progressive workflow.

about the element in focus and its relationship with surrounding elements. Any color changes will be reflected instantly, with the video dynamically re-rendering in real-time, ensuring designers have an immediate, contextual feedback loop.

4.3.2 Modifying An Individual Color. Within the scene palette view, users can modify a specific color by clicking its corresponding color block. The targeted block will be highlighted with a black animated outline, signifying its selection. While users click on one specific frame to select a color, by default, this selection is applied to this color across all frames, given that elements typically maintain consistent color throughout a video. However, for instances where designers choose to vary an element's color across frames, a double-click will isolate the color change to that frame alone. Once the color is selected, users have access to an RGB color picker and HSL sliders for precise adjustments.

4.3.3 Modifying Grouped Colors. Piet features the group-wise color modifications, shown as Figure 4. Users can select multiple color blocks from the scene palette by clicking on them sequentially. Once colors are chosen, they're grouped, highlighted with a black outline, and made editable. The RGB color picker is deactivated during this phase. Users can modify the color properties using sliders for hue, saturation, or lightness in the HSL space, adjusting one property at a time.

Our design choice encourages HSL adjustments for grouped colors to ensure harmonious shifts by making their hues (or saturations or lightness) change uniformly. Editing in the RGB color space to make all selected colors identical is not allowed. This decision stems from the feedback from the pilot studies with our early Piet prototype that users rarely desired this RGB interaction for multiple colors representing diverse elements. Adjusting distinct colors to a single RGB value could unintentionally homogenize visual elements. While designers sometimes aim for a sense of cohesion among different elements, they often opt for varied gradients rather than identical colors.

625 4.3.4 *Adjusting Focus and Interest Levels.* To adapt to designers' progressive authoring workflows and accommodate
626 varying design needs and detail intricacies, the scene palette incorporates both zooming and scrolling capabilities.
627 *Zoom Functionality:* As shown in Figure 6, the zoom slider, ranging from 0% to 100%, is tailored for a progressive color
628 authoring workflow and ensures the smooth manipulation of tiny color blocks. Initially, the scene palette is scaled to
629 mid-size so that dominant colors are clearly visible. As mentioned earlier, colors within the palette are strategically
630 sorted by LAB color representation, the relatively large granularity color adjustment helps in maintaining a coherent
631 and harmonious color scheme throughout the video. As users progressively delve deeper into the palette, smaller color
632 blocks can prove challenging to interact with. Here, the zoom slider becomes useful. By sliding it upward, the scene
633 palette enlarges, expanding all color blocks proportionately. This allows designers to magnify and engage with even the
634 minutest color segments comfortably.
635

636
637 *Scrolling Mechanism:* After zooming, if a designer's color of interest isn't centrally placed, a simple vertical scroll can
638 reposition it for easier manipulation. Moreover, recognizing scenarios with an extensive number of scenes or elongated
639 timelines, a horizontal scroll option ensures users can traverse the scenes on their timeline.
640

641 By offering users the flexibility to magnify, minimize, and navigate their color spectrum, Piet ensures designers have
642 optimal control and visibility at every stage of their progressive color authoring process.
643

644 4.4 Inspecting Visual Continuity

645
646 Visual continuity is important for achieving cohesive storytelling in videos. In line with this, we've designed the three
647 color representation views (i.e., Video Theme, Scene Palette, and Element List) to be synchronized. We introduce an
648 intuitive interaction mechanism to help designers inspect how theme colors are distributed throughout the timeline
649 and interconnected scenes.
650

651 As shown in Figure 5, when designers hover over a specific theme color in the Video Theme view, it triggers a visual
652 cascade. The chosen color, along with its visually similar counterparts, will be spotlighted in the Scene Palette view
653 using an animated grey dashed outline. This visual similarity is determined by measuring the color distance in the Lab
654 space, with a predefined threshold. Parallel to the Scene Palette highlight, elements bearing these colors within the
655 Element List are simultaneously highlighted. It ensures designers see the thematic interplay across all views in real
656 time. By providing this immediate visualization of theme colors and their varied similar colors throughout the timeline,
657 designers can intuitively gauge the video's visual continuity.
658
659

660 4.5 Implementation Details

661
662 All showcased motion graphics (MG) videos in this paper were created using the Figma platform and later exported
663 to the Lottie format, with the version of *LottieFiles Figma v41*. It should be noted that this version captures color data
664 slightly different from the official documentation on the Lottie website. Despite this, all essential color details can be
665 extracted from both the Figma version and the official version, with minor implementation adjustments. The MG video
666 rendering is implemented based on Lottie.js. The front-end was developed using the React framework. Moreover, the
667 D3.js library was utilized in constructing the scene palette.
668
669

670 4.6 System Walkthrough

671
672 We explain how designers use Piet by walking through a typical usage scenario workflow. Imagine Stella is a seasoned
673 motion graphics designer, now working on creating an explainer MG video about American taxation. After crafting
674 each segment to explain each type of tax people need to pay, she presented the initial draft to her client, an educational
675

677 institution. The initial color palette was a blend of blue, black, and gray tones. However, the client envisioned the
678 project evolving into a vibrant educational series catering more to a younger audience. Stella realized she needed to
679 make adjustments to colors to make them more vibrant and engaging for children.
680

681 With the renewed vision, Stella initiated the recoloring process. First, she exported the MG video into the lottie
682 format. Stella then launched Piet and imported the lottie JSON file. The video is quickly displayed in the Video Playback
683 panel. Piet identified the existing theme colors and displayed them with their proportions in the Video Theme view.
684 The detailed color distribution was shown on the Scene Palette, with all SVG elements with their colors represented as
685 colored bubbles listed in the Element List.
686

687 Stella considered the feedback carefully, some cheerful colors that would resonate with young learners came to her
688 mind: purple, green, and orange tones. She hovered over the current dominant colors on the Video Theme. As her cursor
689 glided over the blue, the Scene Palette responded dynamically, highlighting areas near the blue where adjustments
690 would take place. She clicked on the Scene Palette, activating the editing mode. Her artistic intuition guided her to
691 move on to the hue slider, morphing the blue into a rich purple. She repeated the process, changing the somber gray to
692 a vibrant green and the reserved yellow to a lively orange. By changing the theme colors, the overall video looks more
693 resonant with children now, but Stella knew that the transformation was not complete.
694
695

696 She sought to enhance secondary, yet frequently appearing colors to harmonize with the new theme. Her focus
697 turned to the notable appearances of red within the video. She selected the red blocks in the Scene Palette, switching
698 them to a softer pink that melded perfectly with the new palette. As she went deeper into the intricacies of the color
699 palette, Stella realized that some elements required a more detailed touch. The clothing of the characters, though minor
700 in proportion, played a vital role in the aesthetics. Aware of the minute adjustments needed, she utilized the zoom
701 function on the Scene Palette, making the smaller blocks more accessible for fine-tuning.
702

703 To improve the project, Stella navigated to the Element List panel for an even closer inspection. Here, she swiftly
704 examined each element, ensuring even the smallest details harmonized with the vibrant new theme and aligned with
705 the semantic meaning of the element.
706

707 Stella pressed the Play button to watch the video from start to finish. Witnessing the video becomes colorful and
708 aligns with youthful vibrancy, she feels satisfied. Confident that her client would appreciate the polished colors, she
709 exported the newly adorned Lottie file, eager to show it to her client.
710

711 5 EXPERT EVALUATION

712 We conducted a user study to evaluate the authoring experience of Piet. In particular, we aim to answer the following
713 research questions: 1) How participants use Piet and if there are any authoring strategies they employ in Piet? 2) How
714 well Piet can facilitate color authoring in MG video? 3) How might Piet impact designers' workflow in color authoring
715 for MG videos?
716
717

718 5.1 Participants

719 We recruited 13 experts in the domain of motion graphics creation (i.e., 12 females, 1 male) through email lists and
720 personal connections. All participants hold a formal design degree and have more than 3 years of experience in MG
721 video creation. The detailed demographic information is listed in Table 3. The studies were conducted remotely via
722 Zoom. Participants accessed Piet through a web browser. They received a \$25 CAD Amazon gift card for the 60-minute
723 session.
724
725
726
727

Table 3. The table records our user study participants' demographic information, including genders, range of ages, occupations, and experiences of motion graphics video creation in years (denoted as Exp. in the table).

ID	Gender	Age	Occupation	Exp.
P1	F	20-24	Graphic Design Student	5
P2	F	25-29	Graphic Designer	4
P3	F	25-29	Graphic Design Student	3
P4	F	20-24	Graphic Designer	4
P5	F	25-29	Motion Graphic Designer	5
P6	F	25-29	Motion Graphic Designer	4
P7	F	25-29	Motion Artist	5
P8	F	25-29	Motion Artist	4
P9	M	25-29	Interaction Designer	7
P10	F	20-24	Motion Graphic Designer	3
P11	F	20-24	Motion Graphic Designer	3
P12	F	25-29	Graphic Design Student	5
P13	F	20-24	Motion Graphic Designer	3

5.2 Task and Design

We designed two tasks to evaluate how Piet assists designers on MG video color authoring regarding multiple aspects of creativity and system usability. Both tasks require users to tweak colors in MG videos from a provided MG video to simulate the post-animation color modification scenarios. We made the MG video adapted from Vox¹¹ explaining the tax mechanism in America. Given that our tasks only focus on colors, and users do not need to create elements and implement animations by themselves; thus, we set the time limit to be relatively short: 10 minutes for each task. Tasks are designed to be from a more flexible open-ended scenario to a more constrained closed-form scenario. Details are as follows.

Task 1 focuses on encouraging participants to freely explore and play with Piet. Participants were asked to refine the colors to ensure an effective narrative transition and visual harmony throughout the video. The usage of colors fully depends on the designers' personal taste without any constraints.

Task 2 aims to simulate the cases of changing the color theme from one to another. Responding to client feedback, they want to integrate the video into an existing educational series, thus designers need to align the theme colors to the series. This entails modifying the current color scheme to match the specified theme colors (blue, HEX: #415BB1), ensuring a cohesive look and feel across the series. The specified theme colors are navy blue (#023E73), bright blue (#085CA6), dusty rose red (#8C4265), and pale gold (#D9B97E).

5.3 Procedure

After signing the consent form, participants were given an introduction to the study procedure, duration, data collection, and other important information. Participants were then provided with a brief training session on Piet, during which an example was used to demonstrate how to modify colors using the tool. Participants were allowed to play with the tools using a pre-determined video example independent of the user task video. Once they became comfortable using the tools, participants were introduced to the above tasks sequentially. During both task sessions, participants were asked to "think aloud." After completing the two tasks, participants were asked to rate their experiences with Piet using

¹¹<https://www.vox.com/videos/2019/12/20/21028676/tax-poor-rich-data-video>

Table 4. Question statements of System Usability Scale (SUS).

ID	Question
Q1	I think that I would like to use this system frequently.
Q2	I thought the system was easy to use.
Q3	I found the various functions in this system were well integrated.
Q4	I would imagine that most people would learn to use this system very quickly.
Q5	I felt very confident using the system.
Q6	I found the system unnecessarily complex.
Q7	I think that I would need the support of a technical person to be able to use this system.
Q8	I thought there was too much inconsistency in this system.
Q9	I found the system very cumbersome to use.
Q10	I needed to learn a lot of things before I could get going with this system.

a post-study questionnaire, which included the Creativity Support Index (CSI) [8] and System Usability Scale (SUS) [3] rating on Likert scales. To gain a deeper understanding, semi-structured interviews were conducted to collect their feedback on Piet. All study sessions were audio and video recorded.

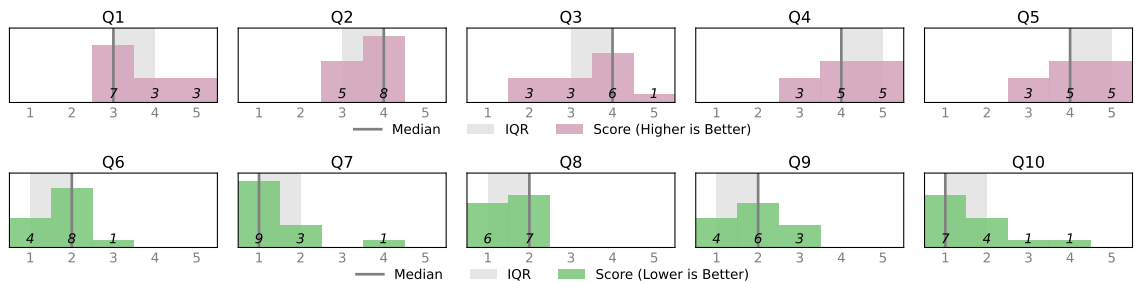


Fig. 7. Results of participants rated System Usability Scale (SUS). For Q1 to Q5, the higher the better; for Q6 to Q10, the lower the better.

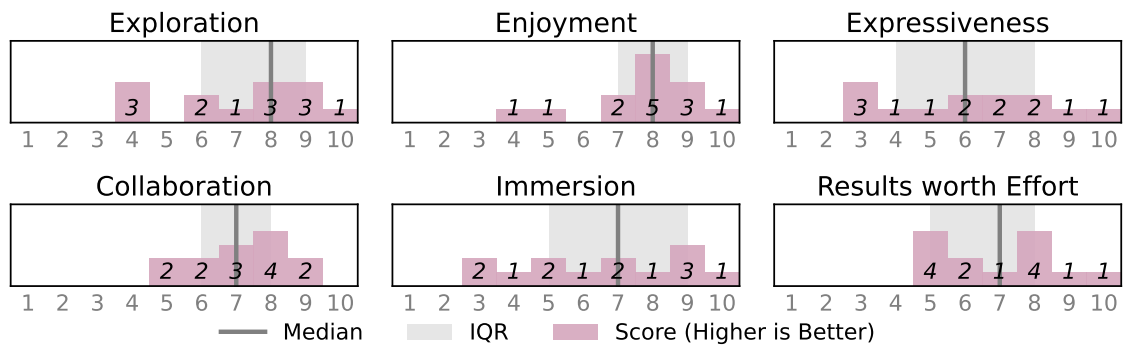


Fig. 8. Results of Creativity Support Index (CSI) regarding six factors: exploration, enjoyment, expressiveness, collaboration, immersion, and results worth effort.

5.4 Quantitative Results

5.4.1 *System Usability Scale (SUS)*. Participants rates their perceived system usability on a 5-point Likert scale (1-strongly disagree, 5-strongly agree). The results, shown in Figure 7 illustrated a generally positive response to the Piet tool, indicating that users found the tool to be user-friendly and efficient in facilitating color authoring for MG videos. They rated that they were able to learn how to use the system quickly and modify the colors easily, felt confident to use the system, and would like to use the system frequently.

5.4.2 *Creativity Support Index (CSI)*. Participants rated six creativity support factors with scores from 0 (worst) to 10 (best). Figure 8 shows the individual CSI score for each factor, i.e., enjoyment, exploration, expressiveness, immersion, collaboration, and results-worth-effort. Overall, participants felt Piet provided great creativity support. Specifically, participants found it easy to explore different color possibilities in Piet, fun to use the system, felt engaged during the usage, and satisfied with the produced results using the Piet.

5.5 Usage Pattern Analysis

We systematically analyzed the interaction patterns of designers with Piet by manually coding the screen recordings. This process helped to understand how the participants navigated through the three provided color representation views: Video Theme, Scene Palette, and Element List over the allotted task duration. All participants used the full 10 minutes on each task. The interaction pattern is depicted in Figure 9, where the x-axis is the entire duration of each task. We identified the following strategies adopted by participants.

Blending usage of the three color representation views. Overall, participants predominantly utilized Scene Palette as a base, while also transitioning to the Video Theme and Element List views to gather detailed insights and make specific adjustments. This pronounced preference for the Scene Palette hints at its alignment with the intrinsic authoring requirements of designers, satisfying the need for an overview of color distribution across the timeline (D3). Moreover, the utilization of all three views, despite being used in varying degrees, facilitates a flexible and dynamic approach to color manipulation, where designers alternate between object-driven and color distribution-driven strategies. Hence, the multi-level functionalities of the Scene Palette, Video Theme, and Element List prove to be instrumental in accommodating the diverse authoring demands at different stages of the design process.

Non-linear yet Progressive Engagement with Different Views. Participants exhibited a non-linear yet progressive engagement with the different views offered by the tool, predominantly anchoring their tasks on the Scene Palette and fluidly navigating between the other panels as needed. Generally, users tended to explore the Video Theme, not for direct color modifications but as a navigational aid, exploiting its linkage with the Scene Palette to group and adjust colors harmoniously with the chosen theme. As they progressed, a gradual shift towards the Element List was observed, particularly for detailed, nuanced adjustments. Nevertheless, this pattern was not universal, with instances like P8 starting with the Element List while using the Video Theme panel later.

Task-Oriented Panel Usage. A notable difference in panel engagement regarding the Video Theme and Element List was observed between Task 1 and Task 2. In Task 1, characterized by its open-ended structure, participants tend to lean more towards the Element List, utilizing it extensively to fine-tune individual elements. This contrasts with the behavior noted during Task 2, where the focus shifted predominantly to the Video Theme to enact broader, thematic modifications. Interestingly, a subset of participants (P9, P10, P13) completely bypassed the Element List in Task 2, signifying a distinct strategy that aligns with the task's demand for cohesive changes. This analysis underscores the

adaptable usage patterns of the tool, where users selectively leverage different panels in accordance with the specific demands and nature of the task at hand, optimizing for both detail-oriented and macro thematic alterations.

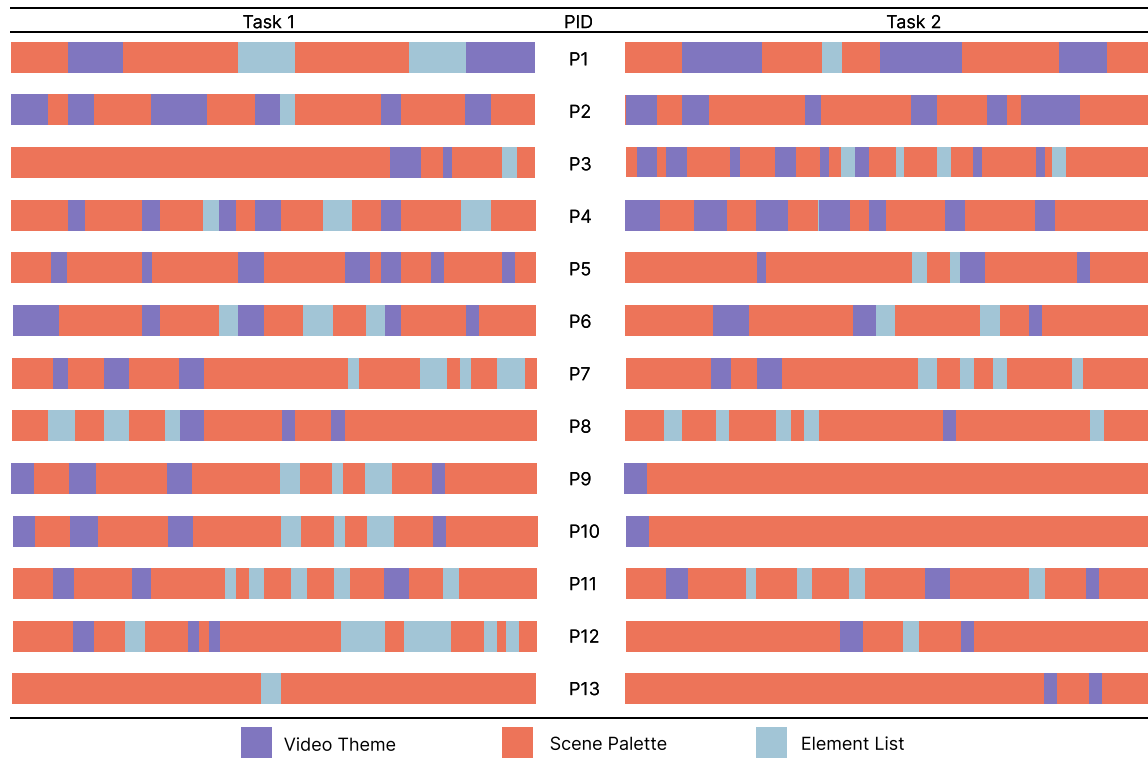


Fig. 9. Visualizing the usage pattern of how users interact with the three color representation views in Piet by manually coding the screen recordings.

5.6 Qualitative Results

By adopting the data analysis approach as described in Section 3.2, we derived the following key findings.

5.6.1 Perceived Benefits of Scene Palette in Enhancing Color Understanding and Authoring. The Interactive Scene Palette is a key feature in Piet, serving two main functions: it helps designers visually track color distribution across the timeline and makes it easier to change colors directly in the video, without adjusting each element separately. Users pointed out several benefits of the Scene Palette, noting that it improves their experience with video color understanding and authoring.

Intuitiveness. Participants found the Scene Palette to be both intuitive and effective. Almost every participant's first comment for Piet is "*the [scene] palette is very intuitive.*" It offers a comprehensive view of the color scheme, allowing them to quickly grasp the proportions and dominance of different colors in different scenes. One participant noted, "*This nicely displayed color overview provides me with a clear sense of which colors stand out and how they harmonize with each other.*"

937 **Focus.** The Scene Palette has been highly praised for maintaining focus throughout the color authoring process.
938 Many Participants (9/12) mentioned that this feature considerably reduces the distraction often caused by the need to
939 jump between individual elements. As pointed out by P7, *“for me, if I go back to Illustrator to adjust a color, in most cases,*
940 *I’d adjust the element’s shapes and lines as well because the switching is costing so I will do all potential changes at once.*
941 *But this is also interrupting my thoughts around colors. But with this tool (Piet) is different. It’s like having a clear path*
942 *without any interruptions and distractions pulling me away, keeping me very focused on feeling and playing with colors.”*

943 **Playfulness.** A notable highlight from the feedback was the enjoyment and engagement the Scene Palette intro-
944 duced. P5 provided an interesting analogy of the authoring experience: *“it is like I am customizing a LEGO character.”*
945 Other participants mentioned terms like *“interesting”* and *“cool”* to describe their interaction with the tool. One user
946 enthusiastically commented, *“You can really play with it, experimenting with colors becomes a joyful task rather than a*
947 *chore.”* -P9.
948
949
950

951 **5.6.2 Group-wise Color Manipulation Enabled Rapid Theme Exploration and Visual Continuity Management.** During the
952 study, we observed participants heavily rely on the Scene Palette to modify colors in groups. Such group-wise color
953 manipulation involved diverse elements from various frames, which is not feasible in existing platforms like AI and AE,
954 is the unique benefit brought by Piet. Participants described it as *“the most impressive and useful feature”*, which largely
955 improved the efficiency of color modifications, especially theme exploration and visual continuity management. P11
956 shared that *“this (group-wise modification) makes changing themes feel so free, so simple. Otherwise, switching from one*
957 *theme to another would be a massive headache, no one want to try out different theme possibilities.”* Another participant
958 emphasized its importance in maintaining the overall mood and theme consistency, stating, *“It’s more about setting the*
959 *direction, the theme, and the overall feeling, which becomes much more manageable with this feature.”* -P4.
960
961
962

963 Overall, the group-wise color manipulation in Piet was seen as a significant leap forward, offering a way to visually
964 plan and adjust color distributions across timelines, which was previously unachievable. This innovative approach not
965 only saves time but also unlocks the potential for greater creativity and freedom in theme exploration.
966

967 **5.6.3 Multi-level Color Representation Views Facilitated Progressive Color Authoring Process.** The multi-level views
968 design of Piet was appreciated by participants for its structured approach to the color authoring process. P12 commented,
969 *“The three panels align well with my work style, guiding me naturally from large color blocks to theme colors, and finally to*
970 *detailed refinements using the Element List.”* Participants found this structured design particularly helpful in tasks with
971 defined color theme changes, such as Task 2, where it provided a clear modification path, helping them focus and avoid
972 distractions. *“In tasks with specific changes, the system clearly guides where and how to make adjustments”* -P6. Even in
973 tasks without clear guidelines like Task 1, the multi-level representation served as a valuable starting point, inspiring
974 an organized approach to color alterations. P11 mentioned, *“The hierarchical design gave me a clue on where to start,*
975 *encouraging a structured approach.”* Overall, Piet promotes a top-down, structured approach to color authoring, making
976 the process more organized, especially for tasks with defined color modifications.
977
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980 **5.6.4 Potentials for Shifting Color Planning to Late Stages.** Piet focuses on the color authoring for MG videos, especially
981 during the stages after animation where colors need to be adjusted. We wanted to know how designers might use Piet
982 in their current workflows for MG video creation and how it might change things for them. All participants thought
983 Piet would work great as a plugin in Adobe After Effects. They expressed that *“I really liked how the tool showed colors*
984 *on the timeline, which fits nicely with how things are done in After Effects.”* -P7.
985
986
987
988

989 With Piet working as a plugin in After Effects, a large portion of participants felt they prefer to shift most of the
990 color work to when they finished the animation. P3 shared, “if had it (Piet) in AE, I’d use AI (Adobe Illustrator) less. I will
991 just make elements in it (Illustrator) without worrying about colors at first, maybe just using some grays. After finishing the
992 animation, I’d play with colors using this tool.” One participant even being more ambitious, “I feel for some simple ones
993 (MG videos), we even do not really necessarily need Illustrator anymore, given AE itself has some basic graphical element
994 creation functionalities and your tool handles colors so well.” -P5. This opinion was quite popular among participants
995 (10/12), with many planning to spend less time on color choices in Illustrator, opting for fast color choices or just
996 grays at first. P8 explained us the reason for such color planning shifting, “When you spend a lot of time choosing colors
997 in Illustrator, sometimes they don’t feel the same in the final video. The way colors change from one scene to the next is
998 very important in videos, and it’s hard to plan this when you’re only looking at one element in Illustrator.” However, two
999 participants wanted to keep planning colors early on and saw Piet more as a supplementary tool to enhance current
1000 workflow, “I think planning colors early is still important. I want to keep doing this, but I can see how Piet could help make
1001 changes later on.” -P6. Thus, we believe that Piet provided a promising way to make working with colors in videos more
1002 flexible and easier. While it is not conclusive that it will change how most people work with colors at first, it offers new
1003 and exciting possibilities for working with colors later in the process.
1004
1005
1006
1007

1008 **5.6.5 Suggestions and Limitations of Piet.** During our study, participants pointed out a few areas where Piet could
1009 potentially improve to make the color adjustment process more adaptable and user-friendly. Here are some of the
1010 feedback and suggestions.
1011

1012 **Adjusting the Scene Palette’s sorting mechanism.** At present, the sorting in the Scene Palette is based on color
1013 distances in LAB space. However, participants naturally felt that colors should be sorted according to their spatial
1014 relationship on each frame. Many participants (5/12) mentioned they were expecting that colors from neighboring
1015 elements would be placed close to each other in the palette. One of the users noted, “I kept thinking that colors from
1016 elements close to each other would also be near each other in the palette. It feels more intuitive that way.” -P12.
1017

1018 **Enhancing flexibility in color filtering.** The current system highlights neighboring colors in the Scene Palette
1019 based on their LAB color space distance when hovering over the theme color on the Video Theme panel. But participants
1020 suggested having more control over this feature could be beneficial. They mentioned the desire to group and select
1021 colors based on different criteria sometimes, depending on the specific adjustment task at hand. For instance, at times,
1022 they might want to group colors with the same hue but different tones, and on other occasions, they may prefer grouping
1023 colors with similar tones but different hues. As one participant suggested, “It would be so much more helpful if we could
1024 define the rules for grouping colors, sometimes I want to focus on hue, and other times on tone. It would allow for more
1025 precise adjustments.” -P7.
1026
1027
1028

1029 6 DISCUSSION

1030 We reflect on the design of Piet and discuss the lessons we learned and the implications for future research.
1031
1032

1033 6.1 Learned Lessons for Design

1034 **6.1.1 Supporting the comprehensive and hierarchical understanding of color distribution across the timeline.** Our findings
1035 revealed that designers appreciate the multi-view (i.e., Video Theme, Scene Palette, Element List) design of Piet. These
1036 views offer varied levels of abstraction, allowing for a detailed depiction of color information at different granularities.
1037 Such visualization aids designers in forging a hierarchical comprehension of color distribution, guiding them from a
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1040

1041 general overview of dominant colors to in-depth insights into intricate color patterns, thereby facilitating a progressive
1042 color modification process. The Scene Palette, in particular, stands as a middle-level view to display the colors across
1043 the video timeline. Designers noted its efficacy in offering a richer understanding of color evolution throughout the
1044 video, a distinct advantage over traditional methods sticking on static frames or individual elements.
1045

1046 We believe that similar techniques could be employed to edit other properties in MG videos, such as animations.
1047 The present authoring tools for MG videos tend to focus on individual frames, lacking a broader perspective that
1048 encompasses the entire video narrative. It is worth investigating to exploit such a holistic visualization strategy, possibly
1049 with varied abstraction levels to highlight different facets, to enable designers to intuitively understand how an edit (for
1050 color, motion, or other aspects of MG videos) impacts the whole video. This innovation promises a more contextual and
1051 comprehensive approach to MG video editing, expanding beyond the constraints of single-frame editing.
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1054 *6.1.2 Avoiding ambiguous color assignment during manipulation through direct color-element linkage.* Our findings
1055 highlighted a crucial, yet often overlooked, aspect in the design of interactive palettes: the necessity to establish a clear,
1056 explicit color-element association between the interactive palette and the video to ensure precise color assignment
1057 during the color manipulation phase. Designers particularly appreciate the feature of synchronized element highlighting
1058 when adjusting color blocks within the Scene Palette. This preference stems from a deeper need for precise control
1059 during the color manipulation phase. Initially, during the color understanding phase, designers can comfortably work
1060 with abstractions, i.e., Scene Palette in Piet, to intuitively perceive harmony and interplay without diving into detailed
1061 color-element connections. This aligns with previous studies [18], highlighting the benefits of color abstraction for a
1062 better understanding of color interdependence. However, when transitioning to the color manipulation phase, designers
1063 need to know which element is being altered with a chosen color. As pointed out by designers, without the direct
1064 correlation, there will be a lot of “guesswork” that comes with guessing which colors correspond to which elements, a
1065 challenge exacerbated in complex videos hosting a lot of elements with similar colors. This will result in the reluctance
1066 to use the interactive palette, leading designers to resort to the more precise but tedious object-driven way, tweaking
1067 colors for each object individually.
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1070 While existing research, such as Color Triads [32], validated the effectiveness of interactive palettes to facilitate rapid
1071 color manipulations, they overlook such demands of precise control, thus restricting their use to the exploratory stage
1072 and failing to aid designers in producing a polished design. We believe that incorporating the direct linkage mechanism
1073 could largely enhance the efficacy of interactive palettes, making it more effective in supporting color manipulations for
1074 both MG video and static designs by eliminating the need for guesswork and mitigating ambiguous color assignments.
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1078 *6.1.3 Reducing navigation burden for locating colors in complex interactive palette.* During our study, we noticed that
1079 participants frequently used the Video Theme panel as a color filter, selecting the highlighted neighboring colors in
1080 the Scene Palette to finalize their choices before undertaking group-wise color modifications. This behavior emerged
1081 from a common tendency to modify a theme color alongside its varying neighboring colors, which might be dispersed
1082 unevenly across the Scene Palette, presenting a difference in visibility and size. This pattern reveals that in the case of
1083 MG videos, characterized by a rich color palette and complex scenes, navigating the corresponding interactive palette
1084 and selecting multiple target colors as a group can become cumbersome. The integration between the Video Theme and
1085 the Scene Palette naturally alleviated this issue, facilitating smoother navigation to key colors. However, there is still
1086 room for improvement to further minimize navigation efforts. Currently, the neighboring color highlight operates based
1087 on a fixed, predetermined threshold distance, a parameter that could be developed to offer user-controlled adjustments,
1088 providing greater flexibility in selecting color ranges. Moreover, introducing additional navigation aids, such as a color
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1093 search functionality through user input queries, could potentially make the color navigation more smoother. For future
1094 developments, we recommend an increased focus on facilitating smoother navigation and exploring search mechanisms
1095 to make the interactive palettes more efficient.
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1097 6.2 Future Work 1098

1099 *6.2.1 Exploring the design space of the color visualization for MG videos.* In this project, our primary aim was to develop
1100 a holistic system for context-aware, group-wise, and multi-level MG video color authoring, with the interactive palette
1101 as a crucial component. We did not extensively explore the design space for the Scene Palette nor did we evaluate
1102 alternative possible designs. What we learned at this stage suggests empirical evidence for the utility of using such
1103 interactive palettes in exploratory video color authoring. The existing design decisions around the Scene Palette were
1104 influenced both by prior studies emphasizing the significance of color proportions [38, 39], and expert designers' input.
1105 Nonetheless, while current encoding mechanisms are reasonable, there may yet be room to expand upon the complexity
1106 of color distribution visualization within MG videos. For example, future work could explore the importance of spatial
1107 color information within each frame, and how this might be encoded into the Scene Palette to impact the judgment of
1108 color harmonies and viewer perception.
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1110 *6.2.2 Providing flexible parametric configuration of palette visualization.* In recognizing that each designer and project
1111 exhibits unique needs, we envision the potential for future adjustments to Scene Palette designs. We understand that
1112 there isn't a "one-size-fits-all" palette design and it would be helpful to align the palette design with specific usage
1113 scenarios and video characteristics. One approach to providing a flexible solution could be enabling users to adjust the
1114 Scene Palette's parametric configuration, such as the time step and color sorting. We believe that by tailoring palette
1115 visualization to individual requirements, we can better serve the diverse needs and intentions of video creators, driving
1116 the progression of color authoring for MG videos.
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1118 *6.2.3 Supporting diverse asset types.* Our current solution depends on obtaining color information directly from the
1119 structural data of SVG elements. However, not all MG videos solely utilize SVG format elements; some may also include
1120 raster images or GIF videos to augment expressiveness. Extracting color data and corresponding properties, such as
1121 proportion from these rasterized elements, is not straightforward and generally requires specific algorithms. Therefore,
1122 dealing with mixed element formats and subsequently integrating the color data into a palette for comprehensive video
1123 color distribution presents a challenge. Addressing this issue and finding ways to handle all element formats uniformly
1124 is crucial, and is an open question we aim to explore in our future work.
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1126 6.3 Limitations 1127

1128 Our study comes with certain limitations that warrant mentioning. Firstly, we only involved expert users in the formative
1129 study and evaluation study, which does not reflect the experiences of novices. Therefore, our results may not reveal the
1130 challenges that beginners might face when using the color authoring tool for MG videos and the experiences of novices
1131 when using our system. Secondly, the MG video used in our study was relatively simple, featuring just four central
1132 scenes. Actual MG videos can be far more complex than this. Hence, our findings and implications may not represent
1133 all potential scenarios and needs for a more diverse and complex set of MG videos. Various aspects, such as video genre,
1134 scene complexity, color dynamics, or the target audience, can all influence user perceptions and requirements for color
1135 authoring tools. Therefore, future work should expand to include a broader range of video types, complexities, and
1136 diverse demographics to ensure the effectiveness and applicability of our tool to a wider pool of users and needs.
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7 CONCLUSION

In conclusion, this research systematically explored the current process of color design for MG videos, identified the challenges in MG video color authoring, and pointed out the design opportunities to improve the authoring experience. Addressing this, we introduced Piet, an interactive color authoring tool that simplifies color changes in MG videos, helping designers make easy and quick adjustments without losing sight of the bigger picture, and motivating the creative color theme exploration. The expert evaluation highlights its effectiveness in supporting intuitive, progressive, and collective color adjustments. Participants also suggest the possibility of Piet to work well with existing tools like Adobe After Effects, offering a smoother and more integrated workflow for designers. Moving forward, we believe that Piet can steer further research and developments in this field, making the process of creating MG videos more streamlined and effective.

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