MoodCubes: Immersive Spaces for Collecting, Discovering and Envisioning Inspiration Materials

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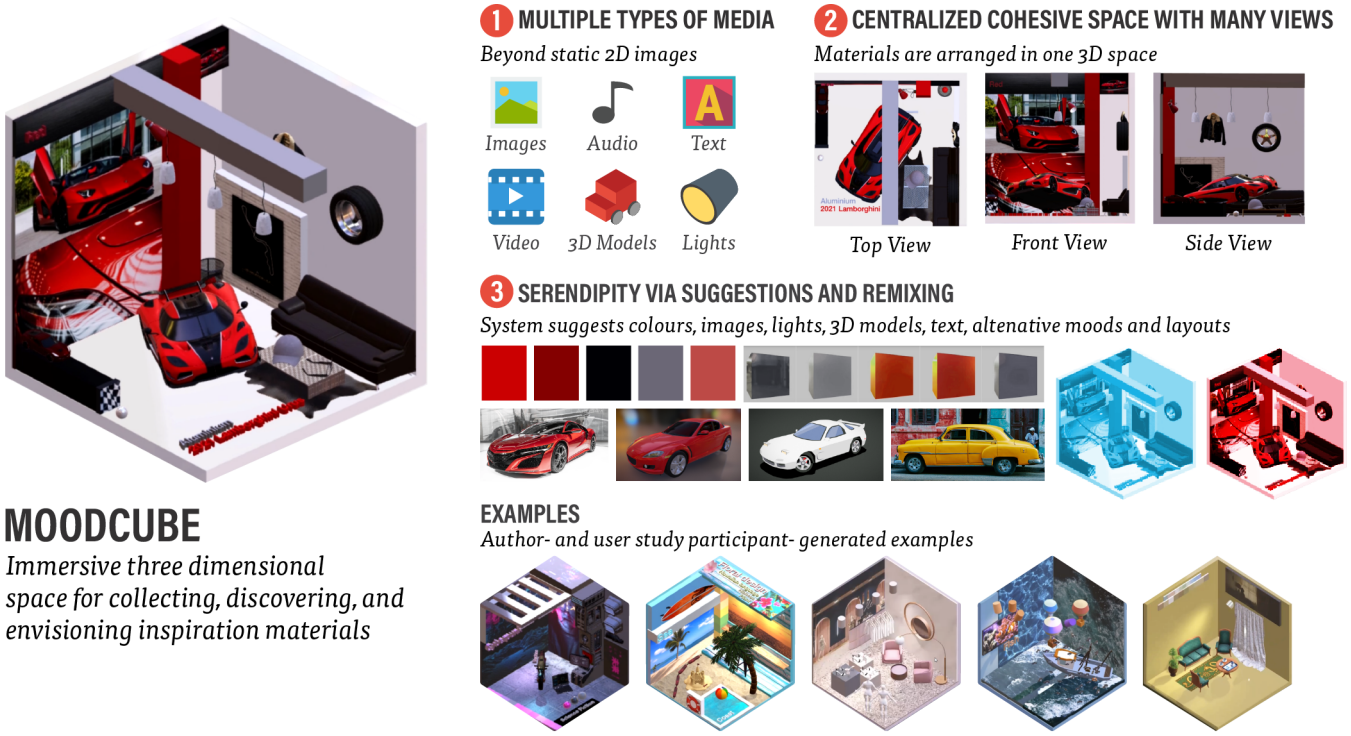

Figure 1: MoodCubes is an immersive 3D space for collection, mood setting and simulation, which supports multiple kinds of media and provides new materials serendipitously via computationally generated suggestions and remixing techniques.

ABSTRACT

In early stages of creative processes, practitioners externalize and combine inspirational materials, using strategies such as mood board creation to achieve a desired vision and aesthetic. Yet, collecting and combining materials can be difficult: (1) mood boards bias towards 2D images, neglecting audio, video, and 3D models; (2) alternative externalizations such as prototypes are best suited for later stages and can be time-consuming and tedious to create; and (3) online searches lead to disjointed sources between different websites and assets in the file system. To address these challenges, we created MoodCubes, a system for rapid creation and manipulation of multimedia content. When adding content, MoodCubes decomposes objects (e.g., extracting colour palettes), suggests new materials without the need to search (e.g., 3D models, images, lighting effects), and provides filters to change the scene's aesthetic. We studied eight creative professionals using MoodCubes, which suggested ways the system might advance existing design practices.

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CCS CONCEPTS

• **Human-centered computing** → **Interactive systems and tools**; • **Computing methodologies** → *Machine learning*; • **Applied computing** → *Arts and humanities.*

KEYWORDS

Creativity Support Tools, Creative Practice, Mood Boards, Digital Collections

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1 INTRODUCTION

In creative practices, a common premise is that if the right framing for a given problem can be devised, it is possible to achieve better-suited and more original solutions to the problem at hand [21]. This stage of the creative process is often referred to as *"problem construction"* [21]. While activities like prototyping are effective at answering questions once a problem has a solidified definition, they are ill-suited early on for acquiring insights on the problem space. This is because in the first stages of design processes, the goal is ultimately to learn more about the problem itself, rather than solutions to it [48]. To achieve a better understanding of a problem space, creative practitioners and people in industries that develop products [9] – including design, architecture, film, and theatre – actively collect materials. These materials are often described as providing "inspiration" [15, 34], and consist in a variety of media types such as photos, videos, text, audio, and more.

The physical act of collecting implies sampling the real world [9, 15, 34], which often can include the serendipitous discovery of relevant materials during moments in every day life. Material discovery also takes place in the digital realm, however collections can be difficult to manage due to a lack of curation tools and the large number of disjointed online sources providing specialized types of media (e.g., Pinterest [44] for images). Without an effective means for compiling and arranging disparate sources of assets, digital inspiration materials end up lost across decentralized content sources. Moreover, current collection tools do not enable direct interaction with the media materials as they are integrated into the space – there is no way to immerse one self into the collected media in the same way one can do in the physical world [34] (e.g., arranging objects in space, grasping objects with ones' hand, etc.).

To integrate different collected items, a common strategy across creative disciplines is to create mood boards [34]. Mood boards are visual collages that serve to create a cohesive aesthetic that surrounds the problem at hand [12]. Lucero [35] highlights how mood boards serve different roles, from defining the limits of projects, grounding communication across stakeholders, contrasting ideas, integrating abstract and concrete concepts, and setting the general direction forward. Despite the short amount of time spent to create mood boards [12], they often remain in the workspace as a passive reminder of the materials collected throughout the design process. Both physical and digital mood boards have unique limitations and advantages for displaying collections of content. With physical mood boards, it is possible to integrate a variety of materials into the collage beyond clippings from documents and magazines, such as interesting textures, or physical objects (e.g. pins, branches). While many of these visual qualities are lost in digital mood boards, they have a potential to effectively display dynamic multimedia content. Nonetheless, digital mood boards are typically constrained to 2D static images and short segments of text prompts, leaving aside a significant set of collected materials that cannot be integrated into collage software. While it is possible to add links to songs or videos, it is often not an active part of the board itself. Rather these links detract from the immersion into the problem space, requiring different windows to display their contents.

This paper explores how digital collections of inspiration materials can provide creative practitioners with moments of serendipitous discovery and a consistent space for collecting content. This is done through a novel system, MoodCubes (Figure 1), which is a three-dimensional environment that supports importing existing materials, arranging them in space, and finding and creating new elements through suggestions and remixing functions. The contribution of MoodCubes as a system for creativity support lies on three key design principles: (1) enabling different types of media to be combined in a unified environment; (2) providing a virtual space for centralizing collections while setting a cohesive aesthetic; and (3) fostering serendipity through automated suggestions and remixing. Our observation with eight practitioners further promoted reflection on these features and pointed to the value of three dimensional spaces virtual for different roles in the creative process beyond inspiration. Our author-generated MoodCubes, along with eight short participant creations reflect rich expressive ways to immerse one-self into the creative process while enticing curiosity and encouraging playfulness.

2 RELATED WORK

There are two ways to situate MoodCubes within existing literature – MoodCubes as a design method, and MoodCubes as a system.

2.1 MoodCubes as a Method: Inspiration and the Creative Process

There are many models that look to represent the creative process [21], dating as early as the 1920s [51]. However, in 2011, Sawyer [48] integrated disparate models into a single framework, which he further labelled for easier communication. The stages in the framework are: *Ask* (find the problem), *Learn* (acquire knowledge), *Look* (gather related information), *Play* (incubation), *Think* (generate ideas), *Fuse* (combine ideas), *Choose* (select the best ideas), and *Make* (externalize ideas). These models of creativity have been used generally to describe creative processes across different domains. For instance, Sawyer examined the stages across areas such as visual arts, writing, music, theatre, and science [48]. Of particular importance, Nazzal [41] further connected models of the creative process to disciplines such as engineering and design, outlining key parallels to Brown's design thinking model [4]. Thus, Nazzal [41] adds brainstorming as part of idea generation, and prototyping as part of idea selection.

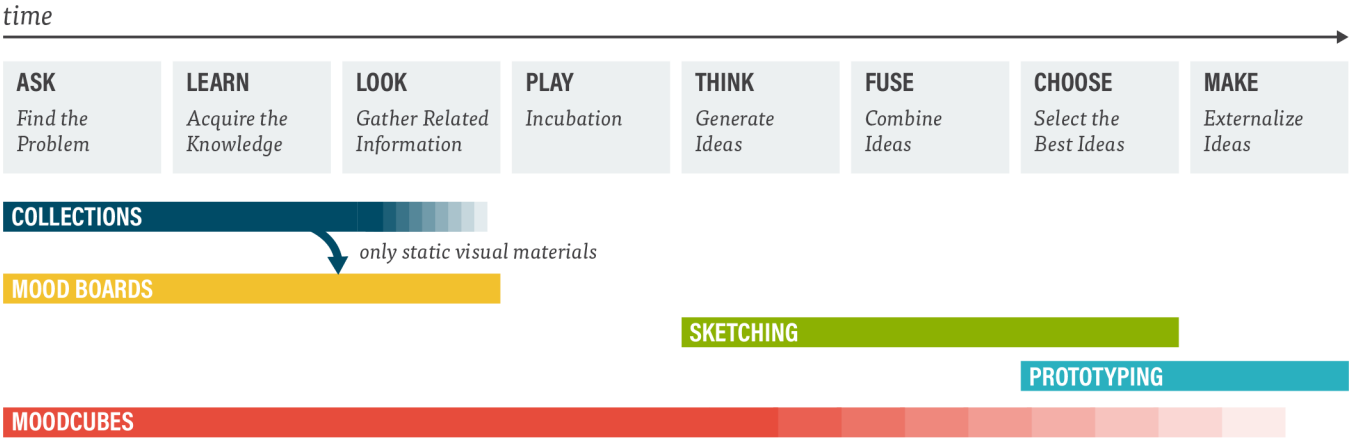

Figure 2: MoodCubes as situated within the creative process according to Sawyer with respect to other activities.

To navigate through the creative process and arrive at "aha" moments [21], creative practitioners rely on different domain-specific activities to help both problems and solutions co-evolve [10]. These activities include collecting materials, creating mood boards, drawing sketches, and making prototypes. While certain activities tend to take place at respective corresponding stages of the creative process, practitioners also repeat activities across later project stages with different levels of sophistication and precision [19].

The key goal of activities such as collection, mood boarding, sketching and prototyping is to eventually arrive at a solution. These activities all rely on different degrees of externalization that foster reflection [49], which Dix and Gongora describe as serving multiple functions [11]: *informational* (passing ideas to others), *formational* (vague ideas becoming clearer), *transformational* (using materials to think), and *transcendental* (thoughts and ideas becoming objects of thought). Especially early on however, the most important activity is to identify the right problem, which creativity theory refers to as *"problem construction"* [21]. Thus, problem construction acts as a foundation that eventually informs ideation processes. Cross' investigations on designers [10] highlight three key points that contextualize problem construction: (1) problems and solutions co-evolve through constant reframing; (2) ideas do not exist in a vacuum, rather they co-exist; and (3) solutions emerge as each activity outcome (e.g., sketch, prototype) answers more questions. Problem construction is described as often being automatic [46, 47], yet more experienced practitioners will deliberately engage in problem construction [13, 14]. Mastering problem construction leads to higher originality and quality solutions [46, 47].

As a means for answering questions, prototyping is an activity that is often carried out to explore the problem space through making [31]. As described by Lim et al. [31] prototypes serve as opportunities to explore unique combinations of *manifestation dimensions* (with different *materials*, *resolutions*, and *scopes*) and *filtering dimension* attributes (such as *appearance*, *data*, *functionality*, *interactivity*, and *spatial structure*). The prototyping activities, their level of precision, and how much time they take to make depends largely on the field and the media utilized. Because in many cases prototypes tend to take considerable time, they are typically seen as more definite explorations [7]. Often, prototypes serve as a form of simulation, such as foam models (at scale that can be grasped and held) for products made by industrial designers.

MoodCubes is designed to serve the initial parts of the creative process, integrating elements of collecting materials and mood board making, while providing a space to create compositions and play until creating a vision. However, in our user study we also found them being used as simulations of physical spaces, which hint to a role comparable to prototyping. Figure 2 shows how MoodCubes covers different stages of Sawyer's model [48] compared to collections, mood boards, sketches and prototypes.

2.2 MoodCubes as a System: Physical and Digital Collections

To better understand the problem at hand, creative practitioners collect a variety of materials. Designers for example, collect physical objects, magazines, photos, etc. which serve as reference or inspiration [34]. This collection process is not limited to design practice however, as Csikszentmihalyi and Gretzels describe how artists benefit from holding and inspecting physical objects when drawing [14], looking at the tactile qualities, examining how the light reflects, and manipulating the objects to view them at different angles. Collection practices have different terms such as "sampling the real world" [15], or visual research [9]. Indeed, found objects act as everyday resources for creativity [32]. These bodies of work typically focus on encouraging creative practitioners to collect a variety of media, both physical (e.g. objects) as well as digital (images, videos, etc.). The resulting visual collections include a mixture of materials made by the creative practitioner themselves, as well as reference materials made by others. Arranging collections further aids the creative process by encouraging situated creative learning [24], which suggests a key role of curation activities. Among the curation processes, Keller et al. found practitioners engage in activities such as active collection, serendipitous discovery, visual interactions, breaking rhythm, and having information always accessible [22]. In our own study, participants showed different types of physical and media collections beyond static images, which also included 3D models, text, video, and music. While MoodCubes is

not the first system to integrate different types of media, the three-dimensional nature of the system made it so the representation of these media types could work well together and be always on - every media type had a visual counterpart that works and can be transformed within that 3D space (e.g., audio would display the cover art and would play directional audio relative to the orientation of the audio object). The result is an integrative space that encourages manipulation and juxtaposition.

Creating Collections. Watkins et al. [52] describe specific challenges tied to digital collections. While they demonstrate there is benefit in the process and act of collecting (e.g., making Pinterest [44] boards), these collections are often lost in a sea of data. This highlights the importance of bringing together this information, perhaps through tools such as InkSeine [18] as a means to actively integrate collected media. Nowadays, commercial tools such as Mural [40] and MilaNote [39] provide a large canvas to collect visuals and create annotations. Meanwhile, systems such as Thinga.Me [16] found that adding curation to digital collections through visually appealing virtual shelves increases the willingness to create displays that are in turn more frequently revisited. Shelves are one of many skeuomorphic metaphors to place digital information, similar to files and folders as introduced by the Xerox Star [20], piles of objects as done in Bumptop [1], or even a physical room as seen in Microsoft Bob [53]. Thus, while there is benefit to the process of collection, digital materials need a place where they can be collected and curated so they are not lost.

Finding and Arranging Materials in Collections. Another salient aspect of collections is how individual items can be found. Digital media can be collected from a variety of sources such as search engines and though dedicated websites like Pinterest.

Literature in information seeking suggests that search is optimized to minimize irrelevant items rather than maximizing relevance [38]. Yet, LeClerc's ethnographic investigation found that a key component in collections for creative practitioners lies in happening upon unexpected materials serendipitously [29]. Thudt et al. describe different factors that can help serendipitous discoveries and applied them to their own visualization of book collections [50]. They explain that individual factors (e.g., personality, observation skills, open-mindedness) can support serendipity, but software can also provide multiple access points, entice curiosity, and enable playful exploration. For this reason, inspiration and mood board systems typically include some integration of suggestions and results. This is why galleries (e.g., Pinterest) and canvases to arrange visuals (e.g., Mural) fall short and have been extended with specialized mood board software.

Some of the unique features of past mood boarding systems include: large displays and tabletop interfaces [36, 37], streams of suggestions [33], suggestion and recombination capabilities [23], integrated search and composition [2], collaborative curation with alternative visual arrangements [45], tangible reality capture and virtual arrangement [6], extracted semantic search terms [28], and intelligent suggestions [26]. ImageSense [27] integrates and expands on these approaches, as it analyzes images in a virtual mood board while displaying relevant search terms, associated colours, and even pre-arranged annotated image sets.

MoodCubes integrates many lessons from past work, including: creating a visual space that encourages revisitation while integrating collection and search; fostering serendipity and playfulness; and providing intelligent suggestions. By expanding into the 3D space and incorporating multiple kinds of media, MoodCubes enables a variety of machine-generated suggestions. Through the decomposition of objects and retrieval of related assets, the system provides creators with a mix of new possible visuals such as 3D models and lighting effects. This environment can thus foster a spatially immersive experience that reflects an overall "feel" and facilitates creating a cohesive aesthetic that can shape the creative direction of a project.

3 MOODCUBES

MoodCubes is a system featuring a 3D environment for collecting and discovering inspiration media (Figure 3).

3.1 Design Rationale

The design of MoodCubes is rooted in three core considerations. These ideas were devised while ideating the system and was informed by prior literature as well as previous explorations and studies with different creative practitioners. The three key considerations are described below.

R1. Supporting Different Types of Media. Given the variety of creative practices, there is a breadth of materials people work

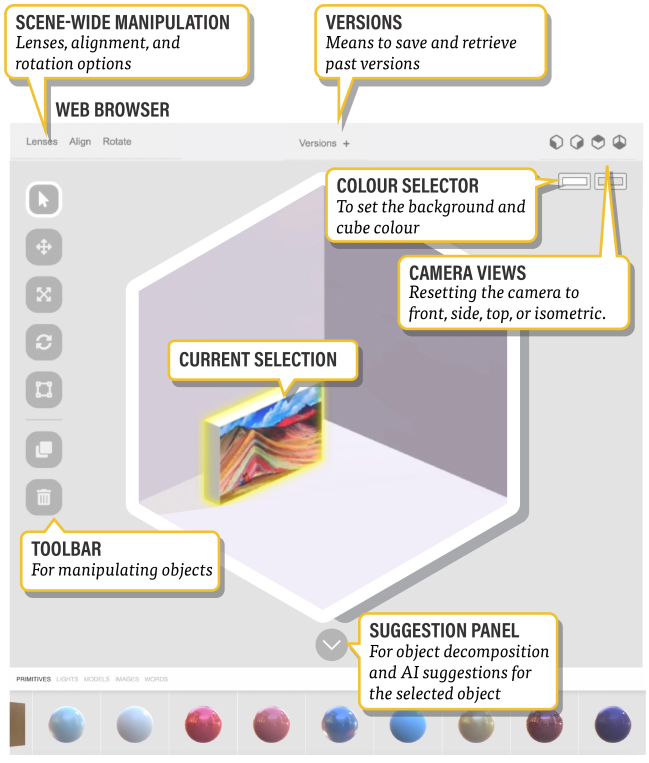

Figure 3: Annotated screenshot of the MoodCubes interface with a selected imported image, highlighting the locations for: scene-wide manipulations, versions, colour selection, camera views, toolbar, and the suggestions panel.

with beyond images. Past literature [12, 15, 34], as well as unpublished interviews we conducted speak to the importance of collecting materials as part of a creative practice, and the wide variety of physical and digital materials that might be available. In particular we noticed that while past work discusses audio and video, mood board systems to date adapt the physical practice into the digital world. We thought that 3D models were a natural extension as well. With this in mind, we set out to integrate a broader set of compatible media into a unified inspiration collection space and adapt their representations to suit a three-dimensional environment.

R2. Providing a Virtual Space to Centralize Collections. One notable concern in creative practices that also extends to knowledge work is the challenge of centralizing information [3, 17, 52]. For collected media to remain useful, it needs to be in a single location, and integrate into the virtual space. Moreover, part of the role of mood boards is to have the important information always at a glance [35]. For this reason, it was important for us to ensure that we could combine all media into a single 3D space that was both a place to store content, as well as to discover new one.

R3. Serendipity. We wanted to provide ways for practitioners to discover new media related to imported assets, particularly extracting individual pieces, and suggesting new ones. Past work (e.g., ImageSense [27]) inspired using image analysis to extract elements such as colours or provide search suggestions. This prompted us to extend past approaches and generate a broader spectrum of materials, such as primitives based on properties present in the asset such as colours and textures, as well as images, colour swatches, keywords, 3d models, and lights. To increase serendipity, we intended for MoodCubes to suggest images and models that were similar to the imported asset, but we also thought about extracting keywords that we could use to also pull new material.

3.2 Example Scenario

The MoodCubes interface (Figure 3) consists of a three dimensional hollowed-out cube. One can drag and drop assets from the file system or the suggestions panel to arrange materials, where tools on the left toolbar enable basic 3D manipulations for individual selections. The top of the interface features controls for scene-wide manipulations (lenses, rotation, alignment), versioning tools, and resetting the camera to specific angles. The bottom panel includes suggestions generated by the system based on the scene contents.

We present a scenario for a video game designer (Gary). For an upcoming project, Gary wishes to create a MoodCube to inspire the level design of a forest setting. Walking through this scenario provides a user-perspective view on how the interface elements come together to create an expressive MoodCube (Figure 4). Note that this scenario spans up to 5 hours including collecting assets, arranging objects in the scene, and ensuring to cover all major features of the tool. Given the multitude of steps and fine-tuning taking place, the scenario is summarized in different stages.

3.2.1 Setup Stage: Importing Images and Initial Arrangements. Gary opens the MoodCube app on a web browser and accesses the assets folder in the file system, arranging the folder next to the browser to drag and drop assets to be imported. He begins by dragging a few images from the folder into the scene and they are automatically converted into 3D objects. Once Gary imports enough images, he decides to use the scene rotation tool to make all images face away from the target wall, then enters the alignment tool to move them against one of the walls of the cube. This makes it so now the set of images appear to be a backdrop for one of cubes sides in a traditional mood board fashion.

3.2.2 Composition Stage: Retrieving Suggested Assets and Laying them Out. Gary begins retrieving new assets he discovers by clicking on the imported images and exploring related media in the bottom suggestions panel. He drags assets from the bottom menu to insert a couple of 3D models, including a leaf, a white tiger, and an animated waterfall. He then looks at some suggestions for primitives, and adds a few glossy white spheres that he believes could inspire the design direction of gems discovered in the game. "Leaf" and "Rock" keywords are also added to evoke additional thoughts while viewing the scene from different angles. Given his excitement seeing the waterfall being animated, Gary recalls a running water video from a previous project that might compliment the scene, which he adds along the back of the MoodCube to convey a river-like aesthetic. As Gary continues arranging objects, he comes across a 3D model of a flashlight in the suggestions panel. The asset inspires him to navigate to a light primitive suggestion and attach it to the flashlight model. The effect makes the flashlight appear to be a source of light and is carefully positioned to highlight models across the adjacent wall of the cube. Gary creates shelf-like levels using the suggested primitives and images to vertically place different objects and imports a few more videos for the background. At this point, Gary has arranged the imported assets such that one wall of the cube features a more friendly rocky aesthetic while the other includes more ominous plants and references to a cabin, where he envisions an enemy tiger will exist in the game. To enforce these themes, he searches the web for an audio file of a relaxing forest soundscape – with birds chirping and running water – then places the asset along the rocky wall by the waterfall. He then imports a second audio file with a darker dissonant timbre and places it along the other wall. As Gary he rotates the cube in the scene, a spatial audio effect mixes the volume of the two playing background tracks at different levels. Rotating the cube to face the rocky wall exclusively plays the relaxing soundscape while rotating to face the other wall plays the ominous track. When interactively turning the cube between these two views, the audio mixing dynamically crossfades the two separate tracks. After adding the audio, Gary tries out a few foreground and background colours for the MoodCube scene using the built-in colour picker, ultimately selecting different forest-like shades of green for both .

3.2.3 Versioning Stage: Exploring Past Versions of the MoodCube and Restoring Deleted Assets. Throughout the MoodCube design process, Gary clicked the '+' button at the top to save versions at different points in time. As the MoodCube approaches its final form, he decides to take a step back and look at previous versions he saved. Looking at the past versions, he notices that at one point he removed a 3D model of a pine tree which did not make sense at the time, but now fits within his concept. He selects the pine tree from the old version and clicks the "restore asset" button. The pine tree is now duplicated into the active MoodCube in the same location he had it before.

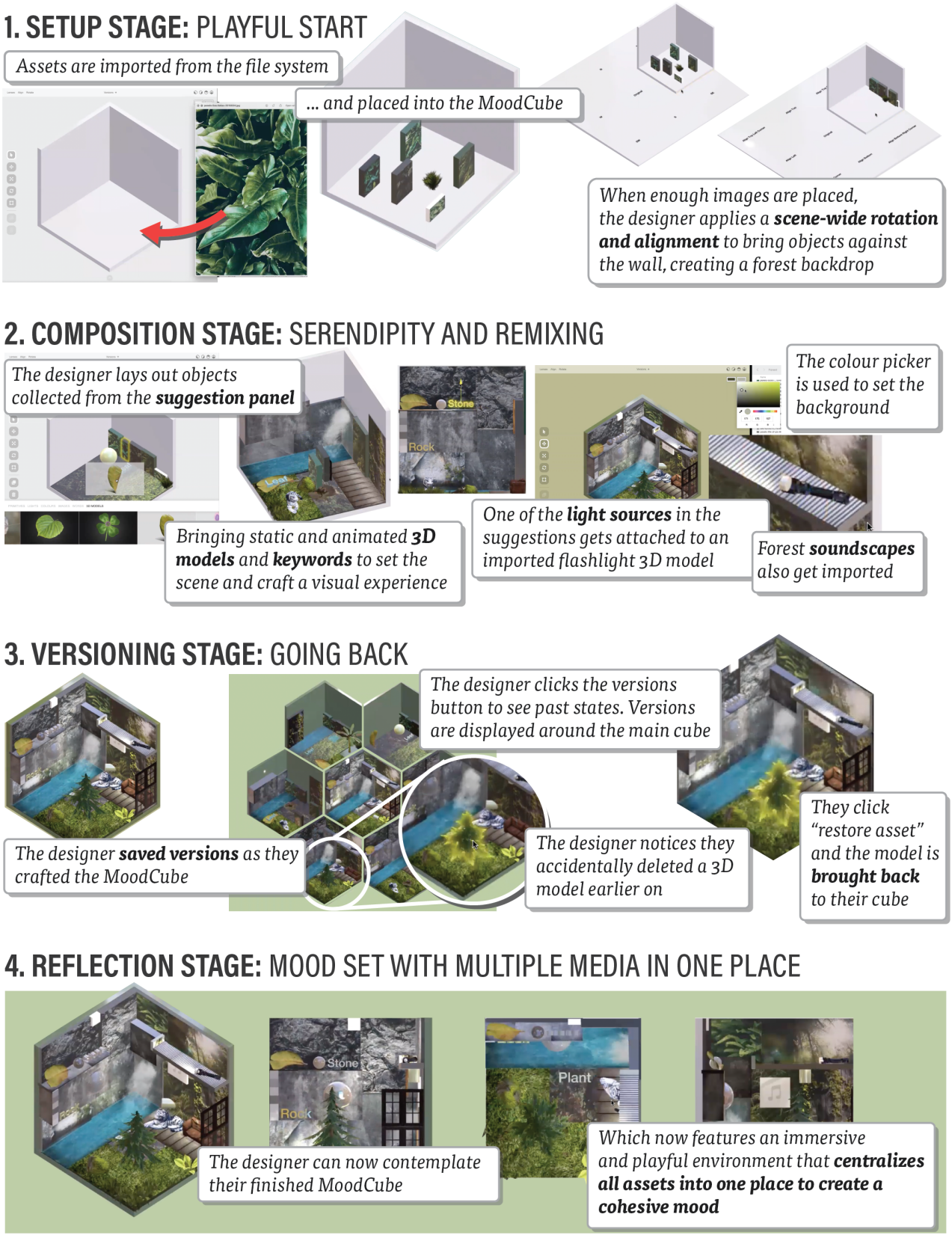

Figure 4: Usage scenario featuring the four stages for a game designer creating a forest MoodCube: (1) Setup, (2) Composition, (3) Versioning and (4) Reflection. The figure consists of a comic with cutouts from screenshots and added annotations.

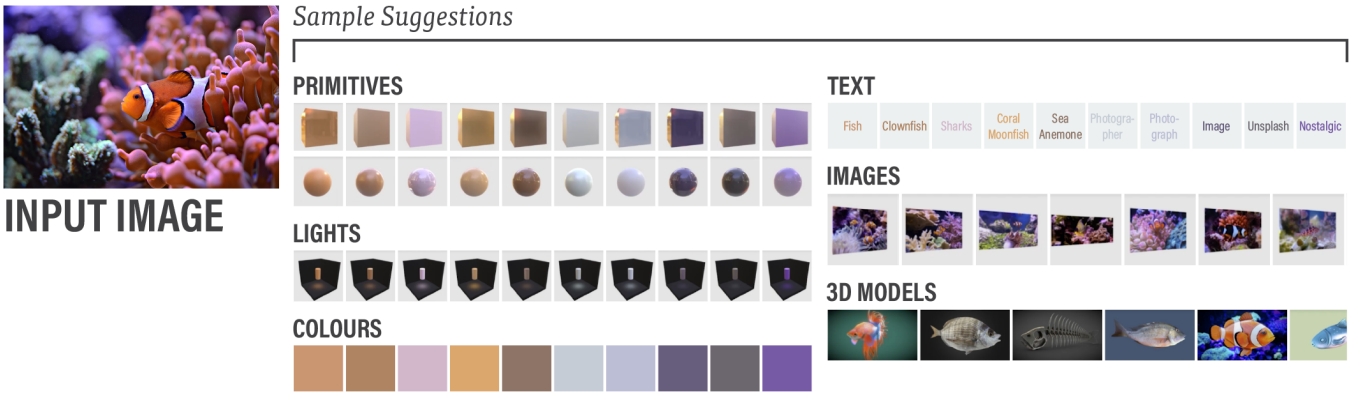

Figure 5: Diagram showing suggestions derived for a single image imported into MoodCubes. MoodCubes suggests primitives, lights, colour swatches, text, images and 3D models.

3.2.4 Reflection Stage: Navigating the Final Cube. Gary is finished working with the MoodCube. He decides to take a final look and maybe make some minor adjustments. As he navigates the scene he checks specific angles from the navigation panel to get the front, side, and top views. He notices that each side of the cube evokes different envisioned target aesthetics, and finally brings it back to the reset isometric view he can see how these come together.

This scenario looks to depict how MoodCubes affords an immersive space that encompasses many media types. The system provides an environment that might entice curiosity and playfulness while leveraging computational intelligence to empower creators to reframe open ended problems and shift to problem-solving.

4 IMPLEMENTATION

MoodCubes runs on a client-server architecture combining JavaScript and Python. While the client enables all key interactions with MoodCubes, the server maintains a database of all imported items and analyzes them to generate suggestions. Both the client and server use BabylonJS for 3D processing, where the client is responsible to render visuals and enable 3D interactions. The environment uses an orthographic projection, as our explorations showed that the front, top, and side views can appear flattened and potentially offer new perspectives to the current design.

4.1 Multimedia Support

The client supports a variety of media formats that can be dragged directly from the file system, including static and animated 3D models, images, videos and audio files. After files are uploaded to the server for processing, imported 3D models are rendered using the .gltf file format data. Meanwhile, images retrieved from imported images, videos, and audio album artworks are applied as textures to extruded 3D planes. Audio files also support spatial directional playback. When the 3D viewport faces the front of an audio asset sounds play at the maximum volume, while reorienting away from the audio asset will decrease the sound's prominence.

4.2 Intelligent Suggestions

MoodCubes offers automated suggestions in two ways (Figure 5):

Object Decomposition. When a viewer selects an asset in the scene, the bottom panel displays a generated collection of assets that are comprised of related lower-level visual elements. These decompositions include colour palettes, 3D cube and sphere shape primitives that take on the colours and materials present in an asset, and lighting effects inspired by an asset's colours.

Retrieved Suggestions. The bottom panel displays semantically relevant content suggestions derived from a computer vision analysis. This approach yields 3D models, keywords, and images.

When images, videos, or 3D models are added to the scene, they are uploaded to the server. The server then imports these files into an invisible BabylonJS scene powered by the Puppeteer node package which serves two purposes: (1) to capture a screenshot of the asset in a 3D scene by itself which can be used within the suggestions panel; and (2) to analyze the file to extract deconstructed components and generate suggestions. The screenshot is then processed asynchronously using the Google Vision API to extract keywords, dominant colours, and related images. With this information, the system then generates a set of 3D assets with 3D text keywords, primitive forms, colour palettes, lights, and related images. These assets are imported into the invisible scene, one at a time, to generate a preview screenshot for each item to display in the client application.

Additional processing is performed on videos, 3D models, and audio files. Videos are further analyzed via the Google Video Intelligence API to capture additional keywords. A custom computer vision script also generates a barcode visualization of the colors present throughout imported videos and creates a filmstrip asset including 5 interconnected video frames. 3D model suggestions are retrieved using the SketchFab API by performing searches with different extracted keywords retrieved from the Google Vision API. Unlike other suggestions, the 3D model suggestions are loaded on the client directly and then synchronized to the server. Only after a 3D model is added to the scene, its information is uploaded to the server as well. Lastly, audio files use the Python Mutagen package to extract mp3 id3 metadata tags, including the album art which is returned as an image suggestion, and keywords that can be used for further searches of related assets.

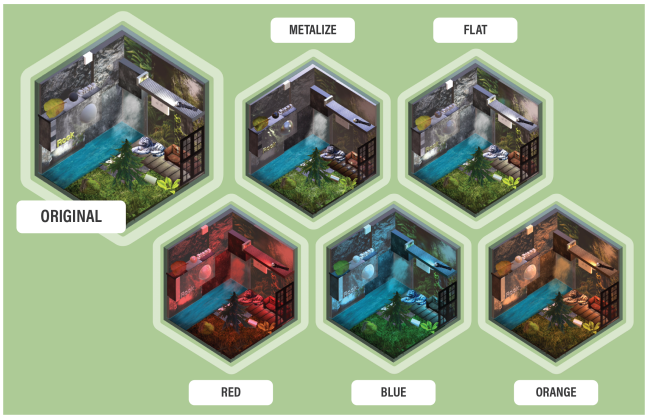

Figure 6: Sample lenses in MoodCubes, highlighting an original cube that is transformed into different textures such as metalize and flatten, as well as going through red, blue, and orange colour filters.

4.3 Modifications to the Scene through Scene-Wide Modifications

Objects in the cube can be further transformed via scene-wide modifications, which include lenses and rearrangement tools. Both of these mechanisms are universal operations meant to drastically change the aesthetic of the cube. While the current implementation applies the scene-wide modifications to all objects in the cube, it can be extended to treat individual selections of one or more objects.

Lenses. A set of filters can be applied to the contents of the cube which include changes to assets' material properties (e.g., metallic and smoothness), colour changes (e.g., make all elements red, or blue, among others), and lighting changes (e.g., new lights are added with different intensities and arrangements). Examples of lenses are shown in 6, where contents of Figure 6-a are metalized (Figure 6-b) or turned to red (Figure 6-c).

Spatial Rearrangements. Objects in the cube can be modified into different orientations so that all objects face a specific direction, or into different spatial alignments that move all objects to one edge of the cube. The spatial arrangement tool showcases a large plane below the cube in which one can move the entire cube in the different spaces of a grid and preview how the objects are to be affected if such transformation is applied. Operations such as the filters and scene-wide manipulations are achieved through the BabylonJS framework by modifying all of a MoodCube's contained assets (e.g., their position, their texture, their colour, their lighting). These transitions are also animated as to show how the operations will affect the current MoodCube before committing to the changes. While the current implementation uses general filters that we devised (such as changing texture and colour), our demonstration shows how more complex operations (e.g., making something feel more "dark" or "modern") could be included in the future.

4.4 Versioning

MoodCubes includes a versioning system for saving and reviewing up to six past states. In the honeycomb-like pattern, viewers can revisit previous cube designs and rotate the collages in 3D space. With an item from a past version cube, it is possible to restore that asset and its past state into the current working cube (Figure 4-3). Seeing the different versions in the honeycomb pattern could invite contemplation over some of the past decisions and show the contrasts that evolved in different parts of the creation process.

5 MOODCUBES IN PRACTICE

To evaluate MoodCubes, we solicited impressions of the overarching MoodCubes concept and elicited feedback on its current system implementation. To do so, we provided eight professional creative practitioners with the current prototype to: (1) validate the low threshold of use, (2) explore the benefits and drawbacks of incorporating the system into existing practices, and (3) generate a set of external examples that showcase the expressiveness of the tool within a short time frame.

5.1 Participants

We recruited 8 creative professionals (6 Female, 2 Male) aged 25 to 39 from disciplines including design, architecture, film, and theatre. Participants worked in organizations of various sizes and were located across Canada, Lithuania, Netherlands, and Panama. Participants were remunerated with a $50 USD or equivalent gift card. More specific information, such as participant's area of creative practice, education, inspiration collection practices, and types of media collections are summarized in the Appendix, Figure 10.

5.2 Procedure

Participants were provided a link to a deployed version of the MoodCubes software and were asked to fill out a pre-study questionnaire collecting data about their background. After joining a remote video call via Zoom to work with MoodCubes at the start of the study, participants were invited to share their screen with the experimenter. In each session, audio and screen sharing videos were recorded and later transcribed for analysis. We also captured the final MoodCubes created by participants. Our study consisted of the following stages: (1) first-use think-aloud, which examined the low threshold of use and basic training; (2) MoodCube creation, which provided participants with time to create a MoodCube on their own; and (3) an interview and critique in which the participants shared their creations, reflected on their experiences, and speculated on the potential role of MoodCubes in their practice with the experimenter.

5.2.1 First Use Think-Aloud (10-15 minutes). We provided participants with a video tutorial of how to use the MoodCubes system, and shared links to different online collections of images, videos, and 3D models. Once a feature was demonstrated in the video, we asked participants to replicate the step. When re-creating the steps, participants were asked to follow a think-aloud approach.

5.2.2 MoodCube Creation (30 minutes). Participants were given 30 minutes to create a MoodCube with the following prompt: *"Think of a past project in which you might have or would have liked to use a mood board. In the next 30 minutes, create a MoodCube that you would use for that project today."*. Participants remained on the call with the experimenter in case questions arose but were left to work on their own with the experimenter's camera turned off.

5.2.3 Interview and Critique (15 minutes). At the end of the MoodCube Creation session, participants performed a walkthrough of

their creation with the experimenter, highlighting design details incorporated in their cube. In sessions where there was insufficient time to complete the concept, participants were also prompted to discuss the challenges they encountered that hindered completion and describe what they would change with additional time. The initial stage of the interview focused on reflecting on the artifact, where the artifact acts as a boundary object to ground the conversation [30]. Next, participants were asked to critique the MoodCubes concept more generally. This included discussions surrounding what aspects of the concept participants were excited or skeptical about, how they might use the system, places they could envision MoodCubes being used, what would be required to integrate MoodCubes into part of their practice, and predictions on how other creative professions might use MoodCubes.

5.3 Data Analysis

The data collected includes the pre-study questionnaires, as well as transcribed audio and video screen recordings from the call.

We analyzed the results of the study by extracting and grouping the participant quotes using thematic clustering [8]. Two researchers discussed the results after each participant interview, followed by another discussion once the experiment was over. This enabled the generation of an initial set of themes with an agreed upon rationale. Afterwards, the second author examined all quotes using focused coding based on the identified themes which are described in detail in the next section.

6 RESULTS

All participants completed the think-aloud tutorial within 20 minutes, and successfully created their own MoodCubes within 30 minutes (Figure 7). P01 created a collage of images, highlighting the important elements via the use of different spotlights (Figure 7-A). P02 recreated a scene for an upcoming film project based on early sketches of the room. The participant considered the scene's lighting source and orientation, and added additional mood-evoking elements – including colour swatches and a reference image – to the top parts of the cube (Figure 7-B). P03 created a MoodCube for a virtual museum, related to a course they are instructing, where the different cube planes focus on specific media elements: the left wall highlights colour palettes, the right wall highlights reference images, and the floor of the cube incorporates 3D models (Figure 7-C). P04 created a gallery for a (fake) product with a surrounding set of inspiration source images placed along the walls of the cube (Figure 7-D). P05 created a MoodCube for a clothing product line, compiling a collection of fabric materials, 3D forms, inspirational imagery and relevant textual prompts (Figure 7-E). P06 created a collage of inspiration for a book, and attempted to separate recipe text from images into different versions (Figure 7-F). P07 created a concept for a store (Figure 7-G). Lastly, P08 created a mood board for a gift for a child in the family (Figure 7-H).

6.1 How MoodCubes was Used

The usage of MoodCubes presented different roles, some which went beyond our design rationale.

The Role of Serendipity (P02, P04, P05, P06, P07). The serendipitous suggestions proved to be an effective way to provide creators with new elements to add to the scene. For example, P05 expressed *"the first idea I was going to do was different to what I did... I went up at the beginning to do something abstract and just to get different shapes... But it actually suggested physical items, clothing and curtains. So I created more in the space"* (P05). P06 expressed enjoying the suggested images, as well as the extraction and decomposition: *"the color [suggestions] I thought was the coolest one. You can just pull out a palette of colours from an image and then stick that next to it"* (P06). All participants made use of the suggestions to a high degree, while in some cases still resorting to search outside of MoodCubes (P02, P04, P07). In particular, P07 expressed wanting to search keywords directly from the suggestion tab. In some cases, MoodCubes' suggestions were literal and thus inaccurate. For example, P04 added an image with a lightning to express "power", but all related searches yielded lighting, storm, clouds, etc.

MoodCubes as a Centralized Collection Space (P01, P02, P03, P04, P06). Participants showed how MoodCubes can go beyond a typical translation of a mood board from 2D to 3D. Participants especially highlighted how it can be a common storage space: *"It could be a good place... [to] bring the elements before having a physical setup... we could all collaborate: light designer, set designer, costume designer... in the preliminary phase to see how the elements are showing, discuss it with the director, and then decide and move on to the final design… it provides a space to spatially see the elements that you would only see after the show's done"* (P01).

MoodCubes as a Simulation Space (P01, P02, P03, P04, P06, P07). Five participants reported envisioning MoodCubes as a simulation space, where one can see early on what a potential setting might look like, highlighting the role for set design (P01), preproduction for cinematography (P02), and an immersive gallery (P03, P04, P06). P07 expressed how MoodCubes lends itself naturally to interior design and architecture in terms of having clear spatial references. When comparing mood boards and MoodCubes, P01 expressed: *"when working on a mood board, you're thinking about spatial dynamics… but in this, I felt more immersed, it made me think of the room of a house… it took me to a more metaphorical place"* (P01). P02 highlighted the role of these visual simulations as key for preparation: *"there's never enough prep. So that means that the most amount of field work you can do beforehand... it's going to help you. And there's no 'oh, how long do you need for prepping?' More like, 'how long do you have?'"* (P02).

Storytelling (P02, P04, P05, P07). MoodCubes lent itself to three-dimensional explorations for storytelling. Participants P02, P04, P05 and P07 described the enjoyment of being able to move around the space, with P04 expressing the desire to create a guided tour. P02 spent time on the familiarization stage of the study playing around with dramatic imagery and taking screenshots (Figure 8-A), while P07 often reoriented the camera to see what it looked like to enter the storefront (Figure 8-B).

6.2 Spatial Use of MoodCubes

Across participant sessions, we identified different approaches to working with MoodCubes in terms of how the media was integrated into the cube as well as how its contents were presented.

Attaching Visual Materials to Walls (P01, P02, P03, P04, P06, P08). While all participants had at least one wall with a large image, six of them used the walls to place numerous reference

Figure 7: Resulting MoodCubes created within 30 minutes by participants.

materials. The walls of the cube often functioned as places to "pin" some of the images used. Although this behaviour may have been primed by our video demonstration and by the concept itself, it fits with the creation of traditional mood boards.

Assigning Walls or Rooms to Certain Categories of Materials (P02, P03, P04, P06). Four participants grouped different asset types into separate spaces in the scene clustered by meaning. For instance, P03 dedicated the left wall for colour inspiration with swatches and images, the right for technical references, and the ground to place 3D models. Meanwhile, P03, P04, and P06 expressed they enjoyed viewing multiple cubes in the versioning system, but would have preferred to utilize these cubes as additional, artboard-like, spaces for collecting different groupings of source materials. P03, P04, and P06 described the MoodCube as a gallery space: *"I like how I can just get it all into an environment, like almost like a gallery… I could almost imagine like I'm building an art gallery for my product. This is the museum of my project..."* (P04). They described a layout that placed the most recent 3D model of their concept in the centre of the cube, and dedicated surrounding areas to inspiration images and snapshots of earlier design phases (e.g., sketches, preliminary models, etc.). P04 also expressed excitement about using the cube as both a space for collecting research ideas, and as a presentation medium at a project's conclusion.

Creating an Immersive 3D Scene (P02, P05, P07). Three participants created a cohesive three-dimensional scene that is akin to 3D game world environments or physical space counterparts. P02 recreated a scene they were about to film, paying attention to aspects such as lighting, while still having other reference materials on the walls. P07 embraced the cube as an environment to envision the approximate layout of a store design. The scene included wallpaper and carpet textures, alongside furniture positioned to encourage socialization and browsing merchandise in the space.

Quick Layout by Scaffolding (P02, P04, P07). Three participants demonstrated use of scaffolding in the creation process. P02 placed a sketched top-down view of the room they would be filming onto the MoodCube floor, then used the sketch as a guide for placing 3D objects in the space (Figure 9). Meanwhile, P04 combined different primitives shapes to create a fake product (see middle object in Figure 7-D), and P07 used primitives decomposed from imported materials to create displays for the store concept.

Lighting for Mood Setting (P01, P02, P03, P04, P05, P06, P07). Almost all participants emphasized the importance of the lighting as it was often brought up as a key feature of the MoodCubes system. P05 expressed: *"I move in all the lights and now it's just changed even the color and all of the objects. It adds more perspective"*. Lighting was used to accentuate parts of the MoodCubes, and as an element of simulation in the case of P02 and P07.

The Role of Audio (P02, P03). P02 and P03 mentioned the importance of incorporating audio into the scene . P02 especially advocated for the feature, stating *"I would for sure use audio… at the pre-production stage, everything you want is to cheat now… you want to get as close as possible to the tone and mood. I just want to*

explain things fast… I can see myself just putting like hummingbirds in the morning, whatever sound or, you know, just imagine if this scene, I just put a heavy metal song, you would change completely the feel of whatever I'm looking at".

6.3 Learning Curve

Even though all participants created a MoodCube and use the interface with relative ease, four participants (P01, P05, P06, P08) expressed difficulties with 3D navigation. The main challenge is navigating and manipulating the workspace, as expressed by P06: *"I struggle doing 3D manipulations, and then for people who are even less technically inclined is like a lot of trouble"* (P06). This was a sentiment shared by P01, pointing that adoption of a tool like MoodCubes would depend on collaborators, who might be resistant to new software. Moreover, it can be difficult for novices to understand three-dimensional space on the screen: *"I'm not pro in 3D, I don't see 3D, so sometimes it's hard to organize my head"* (P05). In contrast to these challenges, participants that were comfortable with three-dimensional navigation (P02, P03, P04, P07) commended MoodCubes for being similar to some of their familiar applications such as other CAD software while still offering more simplicity: *"it would be a nice tool for someone that doesn't know how to 3D model. It's kind of easy to understand, especially if you know, CAD or any other program for 3D or drafting"* (P07).

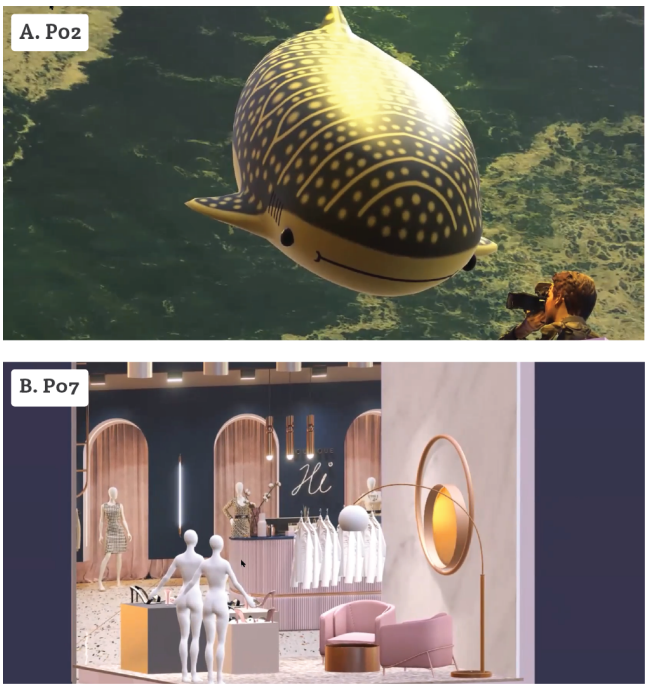

Figure 8: Participants in our study used MoodCubes for different storytelling purposes. P02 (above) frequently reoriented the camera to alter the mise-en-scène and convey different visual themes. P07 (below) created a storefront environment, using the cube to tell stories about how potential visitors might interact with different areas of the shop.

6.4 Comparison to Other Software

Participants, regardless of their 3D experience, brought up similar software and contrasted different aspects. Interestingly, MoodCubes was compared both to specialized professional software and to more accessible games that are easy to use and have a general audience.

Lighting and Rendering Comparison (P01, P02, P07). P01 described how the lighting in MoodCubes stands out due to its accessible nature, as it can be difficult to work with models in theatre as *"it depends on how the theatre model is made"*. P01 highlighted how theatres often have an AutoCAD model, which they cannot access, while lighting design is often done in VectorWorks. MoodCubes can act as a starting for experimentation: *"[MoodCubes is] a nice way to have some preliminary ideas about lights… I could play around with where I want the lights to hit"* (P01). P07 noted how the advantage of MoodCubes compared to other CAD software (e.g., Google SketchUp, Autodesk Revit, Autodesk AutoCAD) is the live rendering, which other tools decouple from the editor: *"you can actually see how lamps interact with the sketch"* (P07).

Games (P04, P05). P05 was reminded of the Sims, whereas P04 saw a parallel with Animal Crossing and used the comparison to ground their critique. P04 noted how the cube shape can be limiting: *"In Animal Crossing the rooms, aren't cubes, they're room shaped, right? They're wider than they are tall… this space feel a little bit less constrained because when I see [MoodCubes], I see an eight foot ceiling… so I interpret this as a fairly small space… I have to make my stuff smaller"* (P04). Moreover, P04 contrasted the highly curated nature of these games making the application more accessible.

Need for Basic Tools (P04, P06, P07). Given their high proficiency in 3D modeling, P04 and P07 wanted additional tools that could speed up or facilitate their workflow, such as snapping objects to walls or to each other, clipboard support, cropping tools for images, layers, etc. P04 and P06 expressed wanting to type long form notes: *"I like to annotate my collections... so I remember why I grabbed them and why I think they're important… I like to be able to write on the wall, or in my sketchbook"* (P06).

7 DISCUSSION

With the creation of MoodCubes as an artifact, our own experiences in creating MoodCubes, and observing practitioners try the system, we are able to reflect our approach and expand with lessons learned.

7.1 Revisiting the Design Rationale

Earlier in §3 we described the goals and decisions that drove the design of MoodCubes from the early stages of its ideation. We can now look back and reflect on the extent that these goals were met.

R1. Enabling Different Types of Media. MoodCubes presents a three-dimensional space from which practitioners can drag and drop media files (e.g., images, video, 3D models, audio) that can be freely positioned in the environment. The user study showed how practitioners enjoyed the variety of media they could work with and how they can come together. It is very easy to, for instance, forget about audio as being part of the collection process given the visual nature of traditional mood boards. Yet, audio can have a profound impact in mood setting and evoking certain responses, whether it is a soundscape, music, or even a narration one might want to keep in mind. Videos can show more complex

Figure 9: P02 strategy to recreate room model by importing a sketch into MoodCubes.

amounts of information given their dynamic nature, and can create visual stimulation throughout. While most study participants did not mention collecting 3D models in their everyday practice, the MoodCubes environment and the integration of 3D models in the suggestions invited participants to think differently about their creation. Perhaps part of why 3D models were not commonly collected by our participants was that they did not have a place to collect them and see them. The suggested 3D models that had built-in animations consistently evoked verbal responses, surprise and more explorations. MoodCubes' novelty in terms of media lies in how media elements are treated – looping videos as part of the scene, providing spatial audio, turning images into 3D planes, and enabling different kinds of decomposition, transformations and suggestions. This creates a new set of raw materials that creative practitioners can work with when creating new moods.

R2. Providing a Virtual Space to Centralize Collections. Practitioners can arrange collected materials into a MoodCube to create a cohesive aesthetic that can guide the creative project forward. While prior work argues for juxtaposition as a key element of creative processes [6, 22, 24, 32, 35], the three-dimensional representation makes for unique visual interactions between the objects in the MoodCube. For instance, the cinematographer (P02) collected inspiration material by adding images from other movies with key camera angles or relevant colours for a colour palette. They also created a miniature set to explore spatial dimensions of their project before carrying site visits. Interestingly, MoodCubes acted both as a space to simulate the set, while also being a place where all materials were present. P04 wanting to create galleries with progress suggests how files in the file system may perhaps miss some of the historical stages of a design. Participants' immersion came in the form of anecdotes and storytelling (Figure 8), hinting a sense of feeling a connection with the space. Looking at the resulting cubes, it could be that the system invited a deliberate use of the three-dimensional space, creating arrangements to simplify perception as well as having dynamics to simplify their own internal computation [25]. For all participants, the space, and it sections always had a meaning.

Serendipity via Automated Suggestions and Remixing. The system provides ways to discover new inspiration materials through automated suggestions. Both the decomposed and the retrieved assets invited participants to playfully explore. Many times participants would spot an image preview of a 3D model and wonder what it is, import it into the MoodCube and show surprise, either because the model was interesting to look at and unexpected, or because it happened to be the right fit for what they had in mind. This happened for instance with P03 when they found a mannequin, or when P02 found a green sofa that matched their site photo and sketch. As someone unfamiliar with 3D modeling, P05 was surprised by the suggestions and allowed them to shape the decisions and design of their MoodCube.

7.2 MoodCubes and the Creative Process

Our original vision was for MoodCubes to expand on what is possible with traditional mood boards. Because of this, we thought that the role of MoodCubes in the design process would be similar – one that remained highly conceptual and potentially abstract.

7.2.1 Problem Construction and Problem Solving Combined. We were surprised to see that participants saw further usage of the system to support simulation and even prototype or plan spaces with it. This could be due to 3D spaces lending themselves to more literal physical spaces, suggesting a higher expressive match [42].

The participant-generated MoodCubes often featured a mix of both literal and abstract elements. For instance, P02 included shots of previous films as images that showcased interesting angles and colours. They took advantage of the wall space to place the more abstract information, and the floor space to have the more literal information. The use of lighting enabled a different way of thinking about the space, as it sparked thoughts as to how lights might interact in a scene (especially in the context of P01's set design and P02's cinematography backgrounds). For P02, having the floor plan of the space they had sketched out generated accurate suggestions for the furniture. In the case of P05 and P07, the aesthetics and the creation were largely driven by the automated suggestions. Moreover, the related suggestions would sometimes yield results that fit within a similar aesthetic, which helped with the mood setting. At the same time, given that MoodCubes borrows existing search algorithms (e.g., from the Google vision API), the related suggestions are bound to be more literal (e.g., P04's lightning leading to 'storm' suggestions, rather than 'power').

The different participant results thus suggest that MoodCubes supports different degrees of both problem-construction and problem-solving, which perhaps could be tied to the 3D nature of the system and the type of practitioner. Professional domains such as theatre (P01), cinema (P02), and architecture (P07) are drawn to think spatially. Even some of the early exploration methods in these professions – such as location scouting, physical model-making, searching for props to create a set – imply a form of 3D spatiality similar to that which is provided by MoodCubes. The extent to

which more 2D-inclined practitioners might work with the 3D spatiality opens interesting future work explorations. In our study, we can already see how P05 for instance, while inexperienced with 3D, mixed elements of a literal space (e.g., a mannequin with curtains) together with colours, patterns, lights and moods.

7.2.2 MoodCubes and Its Mental Model. The ability to preview content in design time without requiring a rendering loop provided MoodCubes a higher dynamic responsiveness [43] compared to other tools. This appeared particularly apparent with the lighting effects, not only from light objects, but how objects in the space were able to reflect light and suggest their materials right away.

The mental model of MoodCubes is one that deliberately followed existing 3D modeling environments. This made it so it was similar to existing CAD tools, but simplified to the core features. Thus, it proved easy to use for people with experience with 3D modeling, but more challenging to 2D designers. This shows how similarity to other tools can influence how people get started with the tool [43]. Participants such as P05 were able to work with it without major setbacks in the context of 3D despite their limited 3D experience. Perhaps MoodCubes can incorporate means to facilitate usage for 3D CAD novices as inspired by the comparisons to video games – providing more curated set of starting items, as well as having additional tools to snap objects into the space and reduce the amount of 3D navigation.

One feature that might have made MoodCubes so accessible is the ability to enable quick start and experimentation [43], as practitioners get a blank canvas right away from which they can start importing assets. These assets also get a variety of suggestions instantly that invite a playful exploration and discovery which might help with problem construction. The MoodCubes environment encourages sampling the virtual world in a way that emulates existing practices [22, 32, 36]. Active manipulation and curation to encourage creative thinking through transforming both the individual media items, and the space surrounding it. This makes for a natural extension to suggestion and recombination approaches [23, 27, 28] recontextualized to also provide object decomposition and fit three dimensional spaces.

7.3 Limitations and Future Work

The current prototype had some minor technical limitations such as the lack of an undo function, and global scene operations. These affected the usability of the tool, and we do believe addressing these could have led to even more progress from our study participants.

Abstract Suggestions. The current version of MoodCubes relies on traditional algorithms to interpret imported content in terms of image segmentation and computer vision techniques. This means that the related results yielded tend to be more literal. Our study results showed that there is potential to explore more abstract interpretations for related suggestions (e.g., "sadness" showing images of rain, or blue tones).

Enabling Shapes Beyond the Cube. Given the participant explorations with versioning and simulation spaces, it seems MoodCubes might benefit from alternative layouts. It would be interesting to explore if other types of layouts might yield even more varieties of inspiration collections and simulations. For example, one might have different kinds of rooms or even create shifted walls and promote more abstract representations.

Modeling Tools and Controls. As a way to improve MoodCubes as an independent tool, it might be useful to add some basic 3D modeling options, such as drawing and grouping primitives, layers, etc. These, together with other layout tools such as snapping to the grid or to the walls might make the tool more inviting to 3D modeling novices and experts alike. In addition, having options to select multiple objects to apply lenses or scene-wide manipulations might also increase the system's expressive power.

Other Immersive Approaches. The current implementation of MoodCubes is set to the web browser. It would be interesting to see other representations, such as an independent applet that works across devices and applications on the desktop (similar to SurfaceFleet [5]), ways to see the MoodCube in AR, or even VR first-person navigations. With VR it is particularly interesting that one would be working with a potentially infinite space that gives room for new interactions and immersive experiences in first person.

8 CONCLUSION

The challenge of "problem construction" requires creative practitioners to collect inspiration materials to better understand the problem at hand. As an extension to mood boards, we created MoodCubes, a 3D environment for collecting inspiration materials that (1) enables multiple kinds of media beyond 2D images (including 3D models, videos, and audio); (2) provides a centralized collection space in a single cohesive view; and (3) enables serendipitous discoveries through automatic suggestions and visual remixing. Our current implementation opened up new ways to import materials, expand existing collections, and interact with the 3D environment. Observing creative practitioners carry out a first-use study shows that MoodCubes can be highly expressive with a low entry barrier and can potentially impact a variety of creative domains in many stages of the creative process. MoodCubes provides an immersive multimedia space that entices curiosity and playfulness while leveraging computational intelligence to empower creators to reframe open ended problems. Our explorations, as well as our study results point to many roles within the creative process, hinting towards a new generation of design methods.

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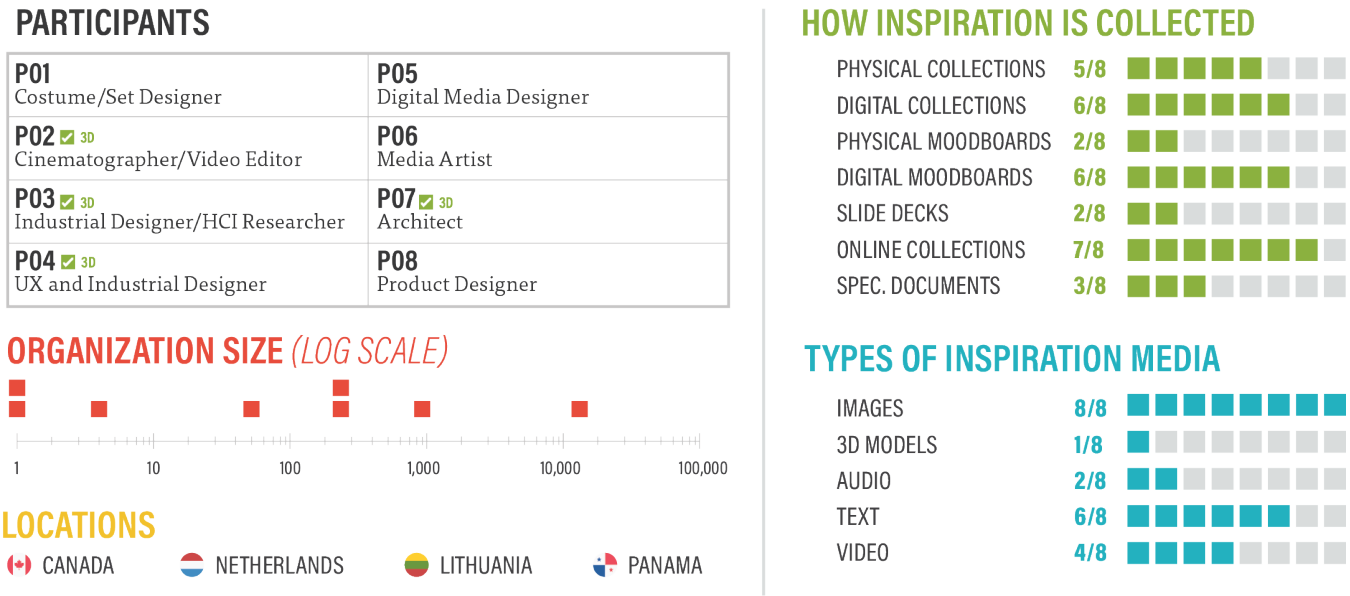

Figure 10: Summary of study participants. Figure shows the list of participants and their occupation, their organization size, locations for the remote study, how inspiration is collected and the types of media used when collecting inspiration.