EMOTE: An interactive online tool for designing real-time emotional AR visualizations

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Figure 1: An example visualization generated by the presented online tool featuring silhouettes of 3 people and dots above them representing the group's emotional state, assuming that their emotional states can be detected by their behavior or physiological responses and synchronously visualized.

ABSTRACT

In a future when augmented vision becomes a part of our daily lives, some might want or need to highlight their emotions by visuals on or around their bodies like wearing a prosthesis or an expressive make-up. This might especially be useful for situations where one cannot express their own emotions or read others'. To help the design process of affective augmentations, we developed EMOTE; an online interactive tool that presents a framework to guide designers while designing emotion visualizations for AR. We conducted an online workshop with 24 participants to evaluate the framework and the online tool. In this paper, we share insights on user experience with this tool, the effect of framework on the design process and how the framework can be expanded.

CCS CONCEPTS

• **Human-centered computing** → **Visualization design and evaluation methods**; **Visualization toolkits**; Empirical studies in visualization; **Mixed / augmented reality**.

KEYWORDS

emotion visualization, Augmented Reality, design framework, interactive online tool

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1 INTRODUCTION

History shows that imaginations of creative people, as narrated in science fiction media content often become a reality when the technological background is ready. While AR (Augmented Reality) is still a rapidly growing field, augmented vision in daily life has been a part of fictional works for a long while now. Speculating on a future when augmented vision becomes integrated into our daily lives, we may deliberate on two questions: what kinds of

information can be displayed, and how might we visualize such information? We believe these are interesting and relevant questions for design researchers and practitioners, as new design patterns need to evolve and adapt to such new modalities for effective presentation of information and creating pleasing user experiences.

In the near future, we believe that affective information might be represented in augmented vision. In a recent work on including emotion-based AR filters in video chats, we saw that affective augmentations might respond to the needs of people in unique cases; such as when they cannot express or read emotions in ways the general population does, when communicating with people from other cultures, or during remote communication when video or audio transmission is not possible. It was also observed that these augmentations could improve emotion communication by providing users a novel way of expressing themselves. In this regard, affective augmentations might correspond to a general human need, relatedness, the sense of closeness and connectedness to other people; incidentally, expressivity is identified as a design strategy for relatedness [11]. However, how affective information should be visualized in AR is not as clear. There is a variety of works on emotion representation in the HCI literature (some examples are [3, 31, 37]), designed to be integrated with existing applications and 2D interfaces [5], or conceptualized as wearables [1], but they are not targeted for AR. This paper focuses on the design space of expressive emotion visualizations that can appear around one's body as they experience the referenced emotional states. As a basis for our work, we refer to a framework on emotion visualization for AR [29], which outlines some essential steps in the design process, including parameters to track, visual attributes that can be used, and the placement of visuals.

It is often challenging for designers to produce work when they encounter design briefs related to new paradigms or mediums they have not designed for or even used themselves before. Comprehensive design patterns, guidelines, and frameworks have always helped designers have a better grasp of the bigger picture. Although the existing literature presents findings on emotion visualization, most of it is in written format reporting specific use cases; this makes it hard for design practitioners to dilute the information they can use during the design process, besides academic resources not being very accessible. With the motivation of filling this gap and providing an accessible online resource for designers, we developed a website that builds upon the framework mentioned above [29]. The website features an interactive tool that visualizes design choices presented by the framework to make them easier to understand. We evaluated the framework and the tool via an online workshop with 24 participants on designing emotion-based AR filters for people who cannot naturally express their emotions. We share insights on our participants' experiences with this tool, the effect of the framework on the design process, and how it can be expanded. This paper contributes to the XR literature with a discussion on important aspects of emotion visualization, suggesting improvements for an existing framework [29] and presents an online tool that might inform and inspire designers and researchers alike.

2 RELATED WORK

Here, we review work on emotion visualization in HCI and reflect on the increasing popularity of AR filters. Following, we summarize emotion models and the emotion visualization framework that this study is based upon.

2.1 Emotion Visualization

Creating emotion visualizations is a well-investigated research topic in HCI. Researchers have worked with various mediums for presenting visualizations; integrated into apps [5, 13, 21], wearables [1, 20], fashion pieces [30, 32], using both 2D [5, 13, 21] and 3D [3, 19, 23, 28, 31, 33] visualizations.

With the increasing popularity and availability of AR and VR technologies, research has expanded from physical space [19, 23, 31, 33] to virtual space [3, 13, 21, 28] during the last decade. In most cases, visualizations are static, representing one emotional state at a time, and have contextual associations (i.e. UI elements [5], location and time [13], digital behavior such as tasks [21]). The focus on real-time emotion visualization is limited. All in all, emotion visualization in HCI generally focuses on specific contexts, such as self-tracking [33], emotion awareness and regulation [13], therapy support [8], and a generalizable approach is lacking. A recent approach towards a generalizable, design-focused visualization framework is [29]. With this work, we aim to validate this framework for emotion visualization in AR and provide suggestions for its improvement and future use.

2.2 Affective AR

Affective computing is an evolving field; and research has made it possible to identify emotions using multiple modalities such as facial expressions [17], brain waves [15], heart rate [8], speech [6] and skin conductance [12, 34]. Emotion detection from facial expressions has become commercially available (Microsoft [24], Affectiva [22]), and wearables such as Apple Watch also provide affective state detection from physiological signals. In another vein, AR technologies are now a part of our daily lives through the AR filters provided by popular platforms such as Instagram, Snapchat, Zoom. Immersive Mixed Reality tools such as HoloLens can also be expected to meet with the general population in the upcoming years. On top of developer tools such as ARKit, ARCore, Vuforia, software such as SparkAR and LensStudio enables users to create their AR filters without (or with minimal) programming.

Despite its potential, HCI literature has not yet fully explored Affective AR. As mentioned earlier, immersive Mixed Reality is about to enter our daily lives, and it will bring the possibility of associating affective computing output with the physical body through AR visualizations. There is limited research on body and AR; one example is a body-based device-agnostic AR toolkit, BodyLayARs developed by Pohl et al. [25]. One example application they present relevant to our work is attaching emotion-based visuals above people's heads [25]. Similarly, demos for providing emotional information [10] and spatial manipulation based on emotions [26] have been presented. Our work addresses the gap in the literature on body-related affective augmentations by presenting an emotion visualization framework targeted for AR that considers positioning visuals in relation to the body through EMOTE.

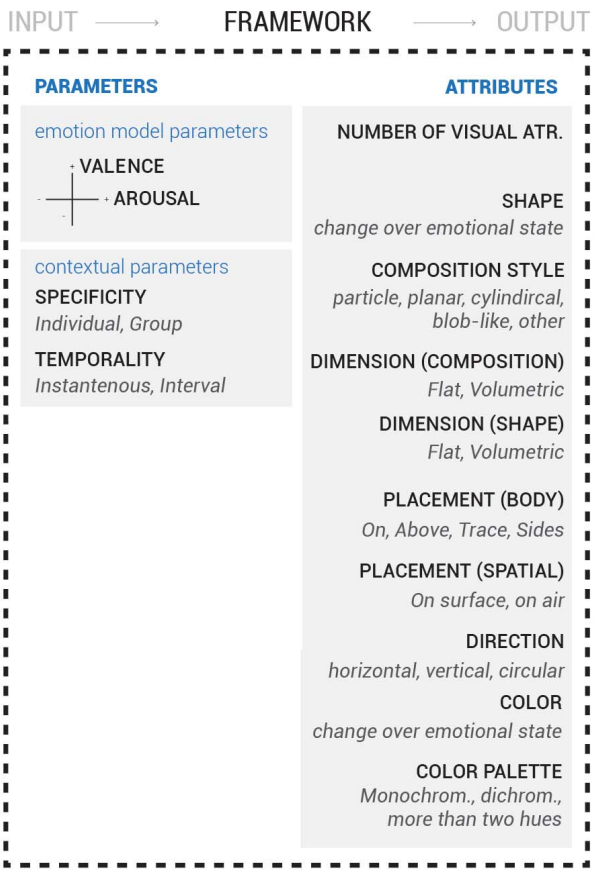


Figure 2: A diagram summarizing the AR emotion visualization framework.

2.3 Emotion Models

Choosing an emotional model is crucial to forming a basis while designing emotion visualizations. There are two approaches to emotion modeling that are adopted in HCI: categorical models and dimensional models [14]. Categorical models define emotions discretely. One example is Ekman's definition of six basic emotions: fear, anger, joy, sadness, disgust, and surprise [7]. On the other hand, dimensional models define emotions through their values in specific dimensions. The most common dimensional model is Russell's circumplex model of affect [27]. The circumplex model defines a two-dimensional space with valence and arousal axes. Valence refers to the pleasantness of emotional states, and arousal refers to how active the related physical experiences are. Dominance is commonly added as the third dimension to this model [36]. We will be referring to categorical and dimensional emotion models throughout the paper.

2.4 Emotion Visualization Framework

Our work is heavily based on an emotion visualization framework [29], which provides design decisions that were found to help design emotion visualizations to be displayed in AR environments. It is developed based on the authors' analysis of emotion visualizations formed during a series of workshops. They propose using Russell's circumplex model of affect [27] to define emotional states and suggest visualizations to change parametrically based on its dimensions: valence and arousal. There are two decisions to set the context: *specificity* prompts designers to choose whether an individual's or a group of people's emotions will be visualized; *temporality* prompts them to choose whether the system will present visualizations of instantaneous emotions or emotions that are experienced over a time interval. An AR-related choice is *placement*, which includes two categories. They suggest that visualizations can either be placed in relation to the users' bodies (on, above, tracing, sides) or the space users are in (on surface, on air). These three choices are rather systemic, and the rest deals with the visual properties. Four decisions affect the visual composition: style (particle, planar, cylindrical, blob-like, other), dimension of the composition (flat, volumetric), dimension of the visual elements (flat, volumetric), color palette (monochromatic, dichromatic, more than two hues). Two more specific choices are on which colors will be used and the form of the shapes that make up the composition. They suggest that color and shape can change based on valence and arousal. Some suitable ways of approaching this are changing the saturation and brightness for color and changing the shapes' size, complexity, or smoothness. Finally, if the visualizations are designed to be dynamic, there is one decision related to motion: *direction* to define whether the movements will be horizontal, vertical, or circular. A visual summary can be seen in Figure 2.

3 INTRODUCING THE TOOL: EMOTE

We built a website [1] that introduces the emotion visualization framework [29] and features an online tool that dynamically renders affective visualizations based on the framework's parameters. There are three static pages; (1) introduction to relevant concepts (AR, emotion models, parametric visualization), (2) explanation of the framework and (3) presentation of some example visuals. The remaining page includes the interactive tool built using three.js, a JavaScript library for creating 3D visuals. This tool generates visualizations based on the following choices as suggested by the framework:

Emotions: Users can select how color and shape relate to valence and arousal. Mapping color to valence (brightness increases with it) and shape to arousal (size increases with it); or mapping shape to valence (shapes become more organic with it); color to arousal (saturation increases with it).

Specificity: The two choices are *individual* and *group*. When *individual* is selected, only one person and their emotional state is represented; when *group* is selected, three people and their emotional states are represented.

Temporality: *Instantaneous* represents an emotional state at a given time and renders one emotional state per person, *Interval* represents emotions experienced over time and renders three different emotional states per person.

Placement: This choice determines where the visualization is positioned in relation to the displayed bodies and the space. The choices are *above the body, on the body, tracing the body, sides of the*

[1] the website can be accessed at https://emotion-visualizer.herokuapp.com/about

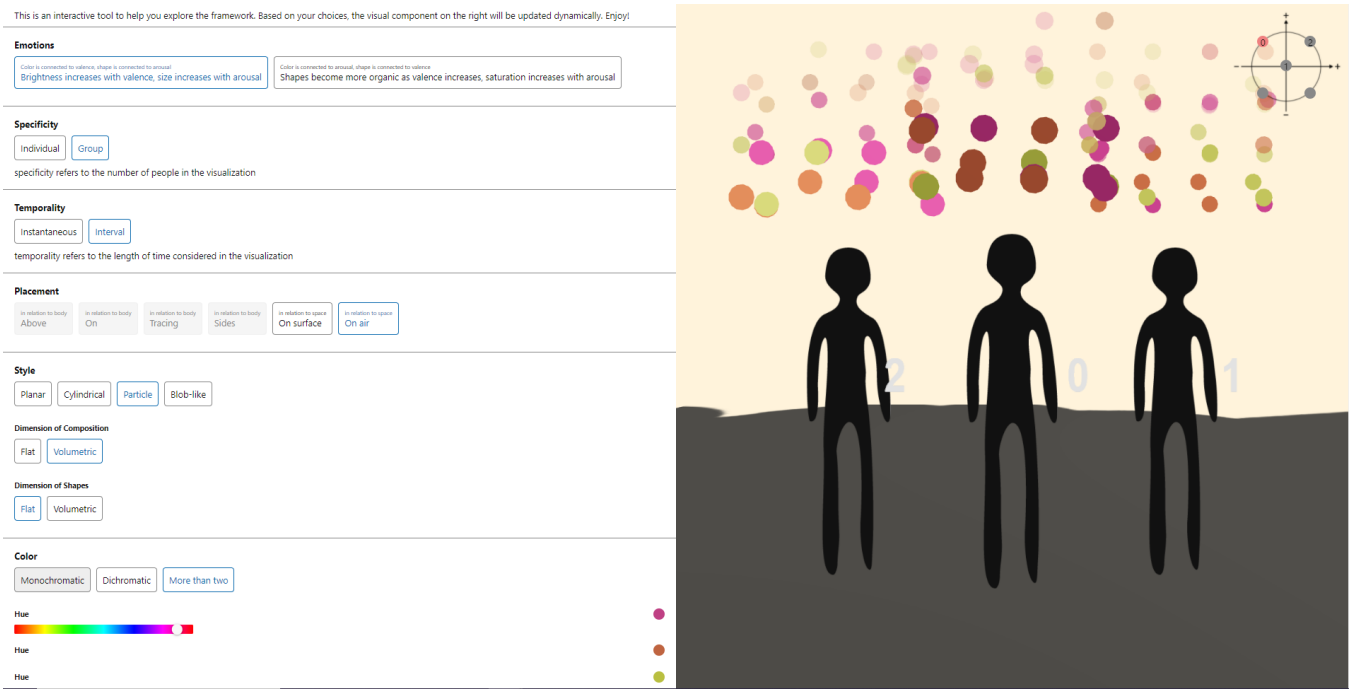


Figure 3: A screenshot from the interactive tool

body, on surface, on air. When *group* is selected in specificity, only the latter two choices are selectable.

Style: We implemented the pre-defined style choices: *planar, cylindrical, particle, blob-like.* In terms of development simplicity, we have a particle based structure for all styles, but we approximated relevant visual output for the other three choices.

Dimension: Both for composition and shapes there are two choices: *flat* or *volumetric.* For composition, choosing *volumetric* positions visual elements in different positions with respect to the z-axis. Choosing *volumetric* in shapes makes the visual elements 3D, whereas choosing *flat* makes them 2D.

Color: There are three choices: monochromatic, di-chromatic, and more than two hues. Users are prompted to pick one, two, or three hues according to their selection. Particles are colored randomly using the selected hues.

To see the representation of different emotional states, users can also pick from some predefined points on a diagram representing Russell's circumplex model of affect [27]. A screenshot from the online tool can be found in Figure 3 and sample visualizations formed with it can be found in Figure 5.

4 EVALUATION: ONLINE WORKSHOP

To assess the online tool's usability and the framework's contribution to the design process, we conducted an online workshop using Zoom and Miro software.

4.1 Procedure

The workshop consisted of 4 phases: initial ideation, website exploration, second ideation, and answering open-ended questions and the SUS (System Usability Scale) questionnaire [4]. First, we gave the following design prompt:

> Imagine AR devices have become very common and highly developed; and we can use AR filters to augment our daily vision. You, as someone who lives in this world, cannot express your emotions through your facial expressions, body language, etc. due to a mental condition and this has caused some hardships in your life. Now, you have a tool that lets you design AR filters and you want to design one to show your emotions to other people during your daily life.

After giving our participants 15 minutes to work on the prompt, we asked them to examine the framework and the interactive tool on our website for 10 minutes. Following this, we asked them to improve their design concept or develop a new one. The design concepts were collected via sketches (see Figure 4 for some of them), which were drawn in Miro, prepared using other software, or by hand (then uploaded to the platform). We also collected verbal responses: description of the design concepts, their impression of the framework and the online tool, the challenges they faced while designing, and whether the framework responded to those challenges. Afterward, we sent them a survey with follow-up questions and the SUS questionnaire [4].

4.2 Participants and Analysis

We invited a group of design students to the workshop to evaluate the online tool and the framework. The reason behind inviting design students was that they would be potential users of the framework as designers and are more likely to be familiar with AR filters

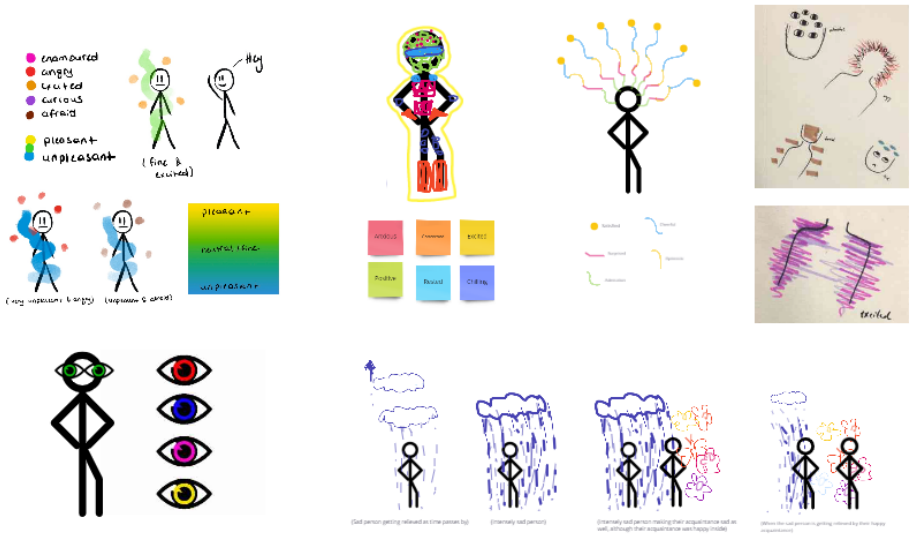


Figure 4: Some of the visuals from the online workshop

due to their age. 24 participants (16 female, 5 male, 1 preferred not to say; mean age: 21.85), joined the study. 13 of them (9 female, 3 male, 1 preferred not to say; mean age: 21.62) filled the follow-up survey. We thematically coded the answers to open-ended questions and the visual elements. Mean scores and standard deviations were computed for quantitative questions, and SUS scores were calculated as instructed [4].

5 RESULTS

In this section, we present the results of the online workshop. We first report the SUS score [4], then share the insights based our analysis of the produced visuals and on the answers to open-ended questions. Then, we report the results of the quantitative questions included in the survey and the suggested use cases for affective augmentations.

5.1 SUS

To assess the usability of the online website, we administered the SUS questionnaire [4] in the follow-up survey. The average score was 63.27 (*SD*=15.28). According to a study conducted by Bangor et al., this score falls into the third quartile, which is mapped to the adjective *good*, describing the user experience (the adjectives were other quartiles were *OK, excellent, best imaginable*) [2].

5.2 Insights from the Analysis of Visual Outputs in the Workshop

We analyzed the resulting visuals and compared the ones produced before participants were instructed to examine the website to those produced afterwards. Among the 24 participants, 2 did not design visuals for the second task, 6 represented new ideas, and 16 improved their previous design concepts. One observation we made was that the concepts became more abstract; some of the participants moved away from the use of verbal expressions, emojis, and illustrations of facial expressions, which were present in their earlier visualizations. Initially some of the participants had focused on placing the visuals on the face and around the head area; during the second task, visualizations were mainly positioned in relation to the entire body. The variety of shapes and colors was increased in general. Some of the participants also added dynamic elements, visualizing how the representations would respond to changes in emotional intensity, interactions with others' emotional states, the transition from one emotional state to another. Lastly, some of them switched to visualizing emotions as defined by Russell's circumplex model of affect [27] instead of referring to emotions categorically.

5.3 Insights from Qualitative Questions

According to participants' responses to questions that we asked during the online workshop about 1) their impressions of the framework 2) how it affected their design process, the framework contributed by providing conceptual information, prompting them to think about visual attributes in more detail, helping them plan and articulate their ideas better.

5.3.1 Conceptual. After visiting the website and examining the framework, participants reflected on different aspects of emotional states. The option of visualizing emotional states of a group of people encouraged them to think about emotion-based interactions ("it reflects the fact that when we are in a group or a society, we share feelings and affect others' feelings too."), the experience of multiple emotions ("framework pushed me to think how the AR filter works in a multi-emotion field and group communication.") and how to represent different aspects of our emotional experiences ("it provided me a different perspective on how to express emotions on such AR filters regarding their continuity, intensity and more.")

5.3.2 Visual attributes. The framework shifted some of the participants' focus to visual attributes ("While I was thinking about the first task, I only thought about the expression ... never about

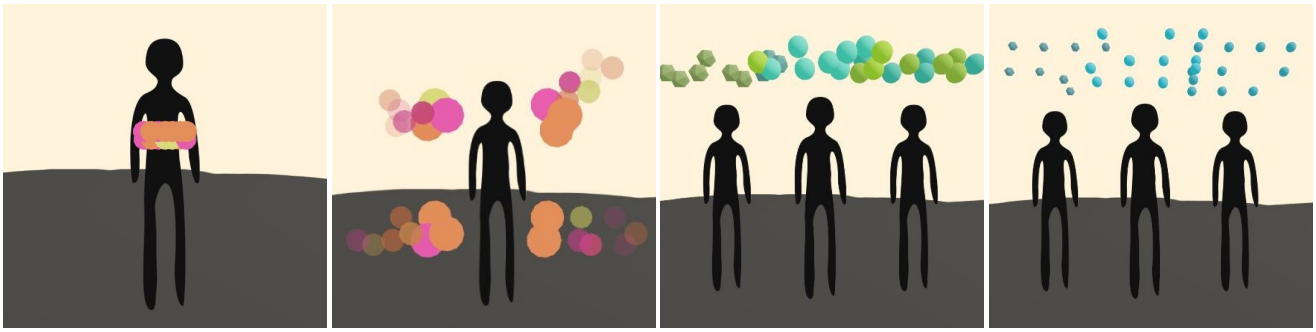


Figure 5: Visuals that illustrate some different choices from the framework.

the colors or the lines.", "the placement of the visuals became more important for me."), helped think about attributes in more detail ("appliance of color ... added a whole new understanding method for the viewer ... Different hues, saturation levels, strength in colors shape the meaning of the information much better. By also using shapes, it was clearer for the viewer as they could easily differentiate a smooth object from a rigid, sharp one") and tie the attributes to emotions conceptually ("I had a challenge representing the intensity of the emotion and wasn't sure which colors to use. The framework helped me with the circles, bubbles idea to represent where the emotion is felt or the duration of the emotion etc. Also, I solved the color choices problem I faced.", "The framework helps me understand how I can use color, shape, and placement in a more efficient way. At first, for me, it was hard to design how multiple emotions could appear simultaneously.")

5.3.3 Planning and articulation. The framework also eased the planning process, helping them form a more systematic approach ("... now I understand that certain emotions and certain visuals should follow each other.", "In the previous frame, a more random and messy plan flashed in my mind ... I created some variables in my mind by matching them with each other.") and supporting their thought processes ("... the framework made it [design process] more tangible for me and made it easier to think about.", "It was more solid the second time I did it because I knew what to do and how to represent it [emotions] better.")

5.3.4 Improvements. We asked our participants whether they had improvement suggestions for the framework and the online tool in the follow-up survey. For the online tool, some participants suggested improving the interface and the visuals ("Maybe, the interface of the framework can be improved more.", "A real-life sketch, example, stronger illustrations would help us imagine the project better."). Suggestions for the framework were to distinguish emotions better ("I think it doesn't encompass the specificity of some emotions. There is a lot of difference between strong unpleasant feeling and anger, for example."), explain some aspects in more detail ("maybe explaining what do each color mean, same with the shapes. You needed to imagine some things.") and to make it more simple ("I would simplify the framework because it is very comprehensive but somewhat difficult to understand"). Considering some of them already found the framework too complex and hard to understand might point to differing levels of need for information and detail based on the experience of the designers.

5.4 Insights from Quantitative Questions

In the follow-up survey, we asked our participants to rate how helpful the framework was to their design process and how adequate they found it for the task. Both questions were presented as 5-point Likert scales. Helpfulness was rated in the range of *not at all - a great deal*, and the average response was 3.33 (*SD*=0.75), which means the framework was helpful more than a *moderate amount*, but not *a lot*. The adequacy was rated in the range of *extremely inadequate - extremely adequate*, and the average response was 3.92 (*SD*=0.47), which is close to *somewhat adequate*.

5.5 Potential Use Cases for Emotion Visualizations

In the follow-up survey, we also asked our participants in which cases emotion visualizations would be helpful. Daily-life related and general suggestions were situations where honesty and understanding are essential, during one-to-one communication, while having conflicts; to improve communication and empathy, overcome the language barrier, help understand emotions better; for entertainment purposes, for example in performing arts and exhibitions. Some suggestions were linked to professional settings: monitoring suspects and witnesses by police and law workers, during psychology research, when experienced emotions need to be communicated with health professionals. Two cases related to special groups were proposed: people who have difficulty describing and expressing emotions and animals. Finally, two participants had suggestions related to VR environments to represent non-visual sensory experiences and augment avatars.

6 DISCUSSION

Overall the design framework helped participants in terms of creativity, efficiency and abstraction by clarifying some concepts, broadening their perspectives, and inspiring different uses of visual attributes. Based on our analysis of the design choices made by our participants both before and after they were introduced to the framework, we identified some expansion possibilities for the framework:

6.1 Representation Style

The framework focuses on abstract visualizations; however, a representational approach can also be useful depending on the use case. Some of our participants used emojis, symbols, or images that allude to natural phenomena (such as weather conditions, flowers, fire) and body parts. Such representations might be more suitable for cases when the visuals need to be easily understandable and not so subtle. An example of this is the context of driving where users might want to get the information straight away [16]. A representational approach might not need as much visual guidance as an abstract one, but it can still be included as a choice in the framework.

6.2 Emotion Model

Even after our participants were introduced to Russell's circumplex model of affect [27], most of them preferred to keep on representing categorical emotions in their visualizations, and one of them combined the two approaches. Although dimensional models might be preferable for parametric designs, it is also possible to come up with state-based visualizations. This approach might also be useful while working with emotion recognition algorithms with categorical output, which is still more common than those producing dimensional output. Moreover, some participants included intensity as a dimension, which can be added as a dimension for both categorical and dimensional emotion modeling approaches. Therefore, it might be helpful to have the emotion model as a choice rather than providing only one to work with.

6.3 Multitude of Emotional States

Even though the framework does not mention visualizing multiple emotional states experienced simultaneously, it allows multiple states to be visualized over a time interval. Interval visualizations seem to have inspired our participants to visualize multiple emotional states for an instantaneous experience. The issue of having the experience of complex emotional states and experience of multiple emotions at once were also mentioned as challenges. Some of the participants designed visuals that show layers of emotions, often differentiating between the physical experience with the mental one, or separating the emotional experience of a person from the environmental effects. The choice of including layers can be useful based on the context and use-cases. Therefore, designers can also be prompted to think whether the system will visualize simple or complex emotional states, whether multiple states can be visualized simultaneously or whether they want to form a layered structure.

6.4 Data Source

Although our prompt did not include a question about how emotions should be recognized, many of our participants ideated on it. Some referred to physiological signals such as heart rate and brain signals, and many of them speculated on systems where users can input how they feel. Data source might fall out of the scope of a visual framework; however, defining it might help designers imagine the system in more detail, thus easing the design process. It might also be interesting for designers to conceptualize the visualizations based on the type of input used: i.e., the rhythmic patterns of heartbeats or wave-like structure of brain signals can inspire visual choices.

6.5 Output Modality

The framework is agnostic in how visualizations will be formed technologically, but it considers augmentations of the entire body. However, some of our participants placed their visualizations on panels, screens, or accessories (headband, bag), which do not need full augmentation of the vision, and their implementations are more plausible with today's technology. Accordingly, placement options can be extended, or at least possible output modalities can be mentioned.

6.6 Standardization

One recurring concern our participants experienced was whether everybody would be able to understand which emotional states are represented. Some participants suggested using predefined color codes; works on emotion and color mapping could be helpful in this direction [35]. There are also some works on measuring the effect of different shape and motion parameters (color, contour, pulse size, pulse rate) on emotion perception [37] which could guide the standardization of other parameters. We think that imposing standards would be too restricting for the designers; however, it could still be helpful to present relevant information.

6.7 Other Considerations

Here, we discuss two important points that arose from the results but do not contribute to the expansion of the framework.

Sensory modalities: A recurring feature outside the framework's scope was including emotion representations via other sensory modalities. Currently, most AR applications target visual modulation; however, as AR develops as a field, modulation of other senses is expected to become more common. Some existing work on representing emotions with audio and haptic cues [9, 18, 38] can inspire this area of exploration.

Comprehensibility: A significant problem was that some participants found the framework too complex and too hard to understand. Our motivation in building EMOTE was to ease this process; however, it can be developed further to present the framework more clearly and in a simpler way. As mentioned earlier, the average SUS score (63.27) points to room for improvement. If our suggestions for expansion were to be integrated, the framework would include even more decisions, making this task even more challenging.

7 CONCLUSION

In this paper, we presented EMOTE, an online tool that presents an emotion visualization framework that targets AR. Through an online workshop conducted with 24 participants, we evaluated the effect of the framework on the design process and saw that it provided a conceptual basis, helped them plan, articulate on and diversify their work, inspired them to think about aspects of emotion visualization that did not occur to them before. Moreover, based on their answers and analysis of the visual output, we identified some areas of expansion for the framework. We suggest inclusion of a representational approach along with the abstract one, supporting categorical emotion models as well as dimensional ones, allowing

the representation of multiple emotional states, providing information or choices on the data sources (based on which emotions will be detected), output modalities and the standardization of visuals. We think that the framework and the discussions provided in this paper can inform future academic work and help designers create affective augmentations.

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