How Are Your Participants Feeling Today? Accounting For and Assessing Emotions in Virtual Reality

Rivu Radiah
University of the Bundeswehr
Munich, Germany
sheikh.rivu@unibw.de

Pia Prodan
LMU Munich
Munich, Germany

Ville Mäkelä
University of Waterloo
Waterloo, Canada
ville.makela@uwaterloo.ca

Pascal Knierim
University of the Bundeswehr
Munich, Germany
University of Innsbruck
Innsbruck, Austria
pascal.knierim@uibk.ac.at

Florian Alt
University of the Bundeswehr
Munich, Germany
florian.alt@unibw.de

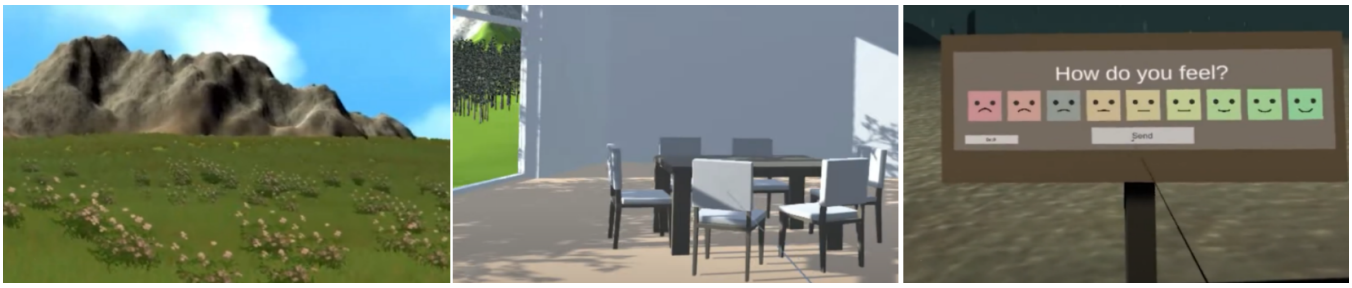

Figure 1: EmotionEditor is a tool to support researchers in designing/accounting for emotions in VR studies. It provides outdoor (left) and indoor (center) environments to support emotions as well as VR questionnaires (right) for emotion assessment.

ABSTRACT

Emotions affect our perception, attention, and behavior. Hereby, the emotional state is greatly affected by the surrounding environment that can seamlessly be designed in Virtual Reality (VR). However, research typically does not account for the influence of the environment on participants' emotions, even if this influence might alter acquired data. To mitigate the impact, we formulated a design space that explains how the creation of virtual environments influences emotions. Furthermore, we present EmotionEditor, a toolbox that assists researchers in rapidly developing virtual environments that influence and asses the users' emotional state. We evaluated the capability of EmotionEditor to elicit emotions in a lab study (n=30). Based on interviews with VR experts (n=13), we investigate how they consider the effect of emotions in their research, how the EmotionEditor can prospectively support them, and analyze prevalent challenges in the design as well as development of VR user studies.

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CCS CONCEPTS

• **Human-centered computing** → **User studies**; **VR**.

KEYWORDS

virtual reality, user studies, emotions, virtual environments

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1 INTRODUCTION

Emotions affect many aspects of human behavior, perception, and attention [7]. As a result, emotions, both positive and negative, can be expected to have a substantial influence on users' behavior in human-computer interaction studies. For example, prior work showed that negative emotions, such as depression, reduce attention and memory [40]. Likewise, emotionally arousing stimuli might influence how easily people can learn using a novel user interface or how well they can memorize information [25]. Also, qualitative feedback might be biased by participants' current emotional state. Despite the influence of emotions on human perception, attention, and behavior, emotions have only received little attention as a contributing factor in user studies. Collecting data about emotions in the context of a user study may be worthwhile since, to a great extent, our actions are controlled by our emotional state [73].

Researchers often more or less consciously account for this as they are trying to create a pleasant study environment where participants feel comfortable [50]. At the same time, for studies entailing virtual reality (VR), researchers often do not consider the potential influence the virtual environment (VE) might have on the participants' emotions. We believe the reason for this to be twofold. Firstly, researchers might be used to accepting the fact that in the real world, many aspects of the study environment are challenging to change. While the interior decoration could be changed, even though it is inconvenient and time-consuming, many other aspects like the room size, window size, or the weather are mostly not in the researcher's control. Secondly, and more importantly, researchers might not be aware of the potential influence or lack the knowledge on how they could design and control a virtual environment that optimally supports the desired emotional state participants should be in during a study. Even though controlling or manipulating the real-world environment is cumbersome, this process is far more straightforward in studies where participants are in a virtual world [42]. Since researchers can control almost any property within the VR, we believe this can be leveraged to assess and control the emotions of the VR users.

Currently, the research community lacks an in-depth understanding of how a virtual environment's design can affect and manipulate users' emotional states. In addition, versatile and functional tools are unavailable to rapidly design VE to elicit and asses emotions.

This work makes two contributions to close these gaps. First, we sketch a *design space* for creating VEs that support particular emotions. More specifically, we focus on three emotions commonly used in HCI, that is 'happiness', 'sadness', and 'fear'. Based on a thorough literature review, we derive environmental factors that are known to affect emotions. Examples include but are not limited to the use of colors [37], ambient sounds, the layout of architectural space [59, 63], and weather conditions. In addition to the *design space*, we present and evaluate *EmotionEditor*, a tool to assist researchers in the design of environments accounting for the desired emotional state of participants. Specifically, the EmotionEditor provides a set of six virtual environments to elicit or manipulate the emotional state of participants and a questionnaire asset, allowing the emotional state to be assessed within the VE. This asset also includes the ability to incorporate further study-related questions rapidly. To show the value of the EmotionEditor, we evaluated our design with 30 participants in a within-subject study and provide findings from qualitative feedback from 13 expert VR researchers. We asked VR experts to reflect on how their work could benefit from the design space and EmotionEditor. Furthermore, we asked them for feedback on how the editor could be enhanced. We synthesize the results of our investigations into four themes as follows: (1) the importance of emotions, (2) prerequisites to using EmotionEditor, (3) the benefits of EmotionEditor, and (4) design suggestions. We elaborate on the themes further in this paper. The evaluation of study participants shows that the EmotionEditor can successfully elicit the desired emotions in different virtual environments.

The following three research questions guided our work:

- **RQ1:** What is the design space for eliciting emotions through virtual environments?
- **RQ2:** What are the requirements for a general-purpose VR system that controls and assesses the users' emotions?
- **RQ3:** How do researchers perceive controlling and assessing emotions in VR studies?

This work is valuable to researchers as we provide a ready-to-use Unity editor, capable of eliciting and assessing emotions prior to VR user studies. The design space allows designers and practitioners to make informed decisions when certain emotions should be invoked in VR. For example, VR designers can use our design space to create VR games in a way that certain desired emotions are elicited as part of the user experience.

2 RELATED WORK

Our work draws from previous research on the effects of emotions, emotions in VR, and VR authoring tools.

2.1 Effect of Emotions

Research on emotions received considerable attention in the past. Having traditionally been a research field of interest to psychology and medicine, more recently also computer science and HCI tried to understand emotions and their effect on behavior and cognition.

Literature shows that emotions influence different types of *behavior* [53, 55]. Prior work also showed that emotions have an influence on users' *motivation and performance*. For example, Kiefer and Briner [32] investigated both the causes and consequences of emotions experienced in workplaces. In particular, they found that negative emotions lead to people putting less effort in their tasks. Fiori et al. [18] manipulate emotions to understand their effect on *decision-making*. They found a significant difference between the emotional reactions in the context of economic decision-making. Positive emotions led to more accurate predictions and negative emotions made users take more risky decisions. Schwarz et al. [57] investigated the influence of moods and emotions on decision-making and highlight the complex interplay of emotion, cognition, and decision-making that affects our everyday life.

From these examples, it becomes already clear that emotions are likely to influence many aspects of human behavior, many of which play an important role in studies in Human-Computer Interaction.

2.2 Emotions in Virtual Reality

While most research on how emotions influence human behavior has been focused on the real world, there is also work suggesting similar effects in VR. Generally, two streams can be distinguished: (1) understanding the effect of the virtual environment on emotions and (2) the use of VR to elicit and manipulate emotions.

Regarding the *understanding of emotions*, Dey et al. [12] investigate the effect of manipulating physiological feedback in VR on emotions. They found that altering such feedback can change the emotions within immersive environments. Mood Worlds allows users to self-create virtual environments visualizing their emotions [66]. Xue et al. showed how 360 degree VR videos can be annotated regarding emotions [70].

Regarding *emotion elicitation and manipulation*, Chirico et al. [8] argue that VR could generate complex stimuli that can elicit "awe". Researchers also investigated how various emotions such as happiness, sadness, anger, and fear fare in VR compared to the real world [52] and also how different emotions can be manipulated. Particularly, the focus has been on understanding different stimuli

that can generate emotions in VR. These stimuli mostly adapt approaches and materials used in the real world, such as audio and video materials [27, 52], and at times virtual reality itself [17]. Dozer et al. presented a design methodology for affective VR, presenting different scenarios to elicit particular emotions [13]. Marcolin et al. explain how different design aspects and features can be used to create virtual experiences impacting human emotions [43]. Recently, Jicol et al. [29] investigated the effects of emotions, more precisely fear and happiness, on presence. They found that fear can easier be induced when visual realism is high.

From this, we learn that researchers should think about how the design of the VR environment used in their study will influence participants' emotions and, hence, their results. With our work, we aim to better understand and help mitigate such effects. At the same time, despite not being a main motivation, our approach might also be useful in emotion elicitation. We reflect on this in the discussion.

2.3 Virtual Reality Authoring Tools

Researchers investigated the challenges of VR authoring tools [26, 46]. Ashtari et al. [2] explored the challenges faced by VR designers and researchers. Their findings show that the users mostly face difficulty in designing or implementing VR environments that can easily integrate human motion, gesture, and audio. Many are also unable to create natural VR experiences. A part of the problem is also the lack of design guidelines provided by these platforms.

Currently, there are various authoring tools to mitigate the abovementioned challenges [5, 67, 72]. While these authoring tools do provide easy implementation and easy blending of dynamic virtual scenes, they do not provide features specifically designed to help researchers in conducting user studies. We address to this by providing a tool assisting in dealing with aspects related to emotions.

2.4 Summary

Previous research showed the importance of considering the emotional state when conducting user studies. While prior work investigates emotion elicitation techniques and emotions individually, we extend this work by focusing on creating environments that support both eliciting and preserving emotions. We sketch which characteristics of a VR environment are likely to influence emotions and describe the design space. There exists no VR authoring tool for researchers considering emotion elicitation, emotion preservation, and assessment of emotional state. Based on the proposed design space and by building upon VR authoring tools, we address this unavailability and create EmotionEditor.

3 DESIGN SPACE FOR ELICITING EMOTIONS

Multiple factors contribute to our emotional state. Based on a literature review, we provide an overview of significant works focusing on emotion elicitation and manipulation, and sketch a design space for eliciting emotions through VEs.

3.1 Approach

We used Google Scholar to identify relevant publications related to emotions. We included peer-reviewed papers that showed clear relevance to factors affecting or eliciting emotions. Publications were included if they reported on the influences of the environment on the emotional state of people. All selected papers were reviewed in detail, and influencing factors were extracted and categorized. We present the design space below, along with relevant literature. We limit the scope of this work to three of the six basic emotions as derived by Ekman [15], as these are most commonly used in HCI studies (e.g., [17, 22, 52]) and they can be consistently detected (e.g., [52]). These include the emotions covered by the circumplex model of affect [54], namely happiness, sadness, and fear. Future work could extend the design space to cover additional emotions as well.

3.2 Dimensions for Eliciting Emotions

Our literature review shows that the environment can have an influence on how we feel. We argue that the virtual environment can be similarly designed to elicit emotions. To achieve this goal and support future designs, we present a design space for eliciting emotions in a virtual environment. To establish our design space, we categorized the dimensions according to typical design decisions made when building VR environments. Our design space features both indoor and outdoor environments and comprises five dimensions derived from the literature that influence each other. The dimensions are (1) layout of the space, (2) color theme, (3) ambient sound, (4) decorations, and (5) weather. We visualize the dimensions in relation to the emotional states of happiness, sadness, and fear in Figure 2. In the following we provide more details on the dimensions and relevant literature.

3.2.1 Layout of Space. Architectural design choices impact human perception and affective states. Some studies have investigated the relationship between architectural form and emotion [4, 11, 41, 59]. Prior research associates curved lines with feelings such as "serene" and "tender-sentimental" whereas angles are associated with "robust" and "vigorous". Banaei et al. [3] investigated the effect of different architectural shapes on valence, arousal, and dominance. Their findings suggest a correlation between affective states and various geometries. Particularly, curvature forms lead to a positive affective state. Dazkir and Read [11] had similar results, finding that curved forms generated more positive valence than angular forms. Therefore, the use of round objects, such as a couch or table with rounded corners, is recommended to elicit happiness.

The size and shape of the space (e.g., a room) can similarly influence emotions. A study conducted in VR compared arousal and valence ratings of rooms of different sizes. It found that a room of dimension $4\,\text{m} \times 5\,\text{m} \times 3.5\,\text{m}$, a size commonly found in domestic spaces such as bedrooms, had a consistent positive valence rating relating to happiness. Meanwhile, smaller rooms had negative valence ratings relating to fear [56]. Furthermore, they found that a room with small windows but of great volume makes it seem empty, affecting people negatively [56]. The study also considered room proportions. While room size proportions within the range of 1:1 to 1:1.5 were rated positively, the valence ratings dropped quickly after 1:1.5 was reached. This means that rooms that have a long shape provide rather negative feelings and can be useful when designing the indoor version of the "sad" environments. Similar findings were produced by several others studies [45, 49, 61].

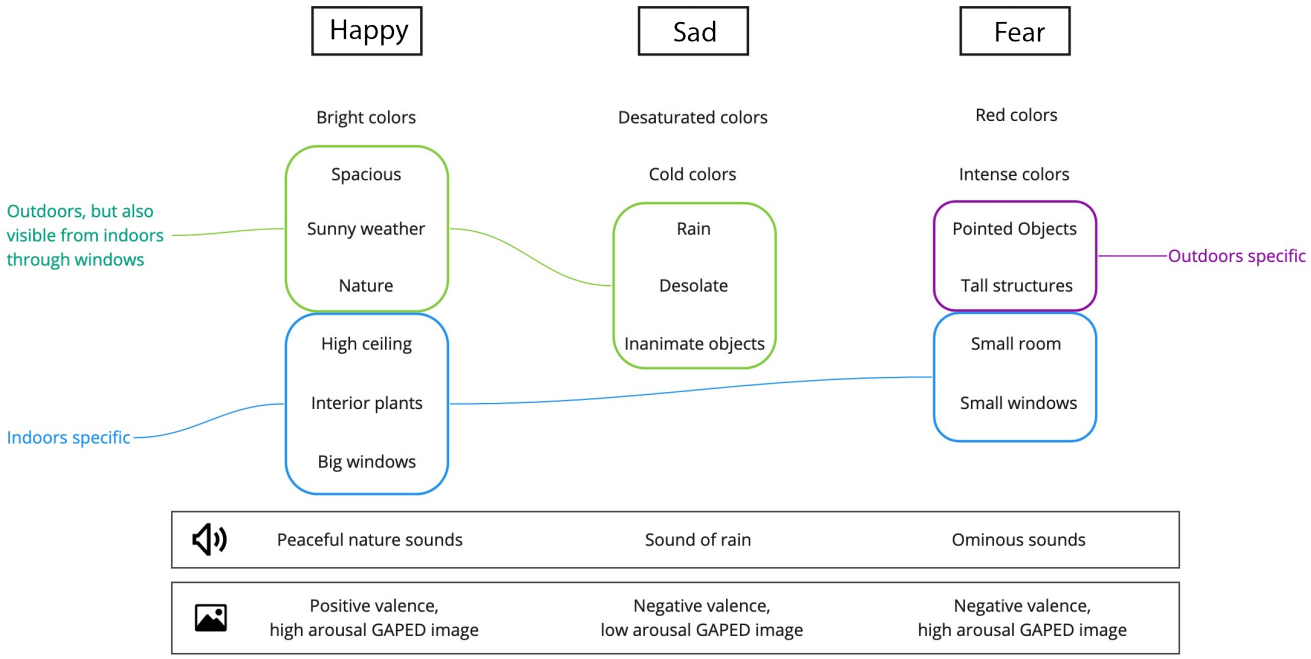

Figure 2: Design space for a virtual environment capable of eliciting emotions among users.

3.2.2 Color Themes. The psychological effects of color have been researched extensively. Color can affect, among other things, our attention, alertness, and intellectual performance [16], and is an important factor in assessing emotions [48, 69]. Color was also investigated by Lipson-Smith et al. [37], who used VR to study mood responses to colors in three different contexts. Similar research by Gil and Bigot [20] shows a positive association with emotions.

Colors influence how we feel although the link between specific colors and emotions is not well fully established [20, 30]. When placed in an indoor environment, the color of the surrounding walls can influence its effect on the subject [34]. Bright and chromatic colors elicit emotional responses of higher valence (happiness) than dark colors (sadness/ fear) [68], and people working in brighter lighting conditions experience better moods than people working in dark lighting conditions. There is also evidence that the presence of colorful objects in a room can have a positive impact on people. Generally, achromatic colors induce feelings of lower valence than chromatic colors, increasing with the brightness of the color. Therefore, darker, grayish shades are preferable when eliciting negative emotional states (sadness /fear) [48, 68].

3.2.3 Ambient Sound. Sounds are present in any real-life environment and can contribute to the affective atmosphere of it [19, 24, 71]. In the case of virtual environments, they can also help amplify the sense of presence of users inside the environment [36].

Sounds can be used to support emotions. Ambient sounds are mostly non-musical and non-linguistic and are known as "every day" sounds. Everyday sounds are generally more complex than musical sounds, noisy and often provide a great deal of information about their sources. It describes its source and the environment around it, such as when rainfall on a tree produces different sounds compared to when it falls on a tin roof. These types of sounds are capable of eliciting emotions even when isolated from their sources. The sounds of rain can elicit a melancholic atmosphere and peaceful sounds from nature can elicit happiness. According to Grey [23], stimuli can have several factors creating fear, among them intensity and novelty. Intense conditions can be loud noises or objects approaching at a high speed.

3.2.4 Decoration. Prior work has also investigated how objects in the environment may affect our emotions. In an experiment carried out by Roger Ulrich, a set of patients were examined during their hospital stay, with half of the patients being allocated in rooms with windows looking out at natural scenery and the other half in rooms with windows facing a brick wall. On average, patients with a view of a natural scene recovered earlier, and were observed to be in significantly better spirits than patients facing a brick wall, who were often observed to be upset and requiring encouragement. These results suggest that a room with a natural view has a positive influence on the people situated in it [65] and can elicit happiness. Findings of another study indicated that people who work in an office with plants and windows feel better about their job, job performance, and overall quality of life [14]. Even physical discomfort can be reduced by the presence of plants: participants of a study by Lohr were more willing to keep their hand submerged in ice water if they were in a room with plants than if they were in a room without plants [38]. The level of detail in an immersive environment can also affect our emotional state, e.g., the graphical quality [35].

It has also been found that people have more positive emotional responses to the view of trees than when looking at inanimate objects like urban scenes without vegetation [39]. Therefore, the designs of sadness-inducing environments are rather blank and with fewer stimuli. Elements like water can be affect emotions both positively and negatively, depending on the context. Water can also be used to induce fear, for example, in scenarios where the user is on a boat in the middle of a turbulent ocean with giant waves [44].

3.2.5 Weather. *Weather*-related features, such as haze [64] and natural lighting conditions [17] can affect our emotions (e.g., darker environments tend to have a negative effect). A study with five virtual parks which were used to elicit emotions in VR concluded that the supposed neutral environment filled with dead trees and devoid of other stimuli was better at inducing sadness than an environment consisting of trees, dimmed lights, and people with umbrellas quickly moving on a rainy day [17]. Another interesting factor that can influence a person's affective state is haze. The results from the study showed that the presence of haze, which has increasingly become a climate phenomenon in many cities, is not only a threat to citizens' physical health but can also have an impact on people's emotional states. Especially when the weather is colder such as in late autumn and winter, people's emotions can be negatively affected by the presence of haze [64].

4 EMOTION EDITOR

Our design space comprises five dimensions that contribute to the manipulation, control, and elicitation of emotional states. To effortlessly support researchers in assessing and controlling emotions during VR studies we propose EmotionEditor, a general-purpose VR tool controls and assesses the users' emotions.

4.1 System Architecture and Requirements

EmotionEditor is currently available for the Unity3D game engine version 2020.1.17f1 or higher. It contains six scenes, one for each emotion (happiness|sadness|fear) and location(indoor|outdoor). Users can choose which environment will be loaded and adjust the settings of those VEs according to their needs.

4.2 Approach

To identify features needed in an editor, we discussed and identified key areas which researchers and designers need to consider before any development or evaluation. The authors discussed these over several sessions, drawing upon their own research experience and prior work. We eventually focused on the following four aspects:

Setting Most real-world studies are conducted in a controlled lab setting. For VR studies, one has an advantage as VR can be used to simulate any kind of setting. We consider two types of settings (indoor and outdoor).

Emotion Assessment Not only should the editor be able to elicit emotions, but also assess the emotions of the participants. Emotions can be assessed using both subjective measurements and physiological measurements. For subjective measurements, the SAM scale is a widely accepted and reliable method, and thus we implemented it in our editor [6]. The SAM scale is an inexpensive, easy method to quickly assess emotions and can be used without the need for additional measuring instruments.

Data Collection User studies typically include collecting data through questionnaires (demographic information, feedback on the tested application, etc.). As questionnaires are an integral part of studies in HCI, we implemented a feature to include demographic questionnaires and post-study questionnaires as part of our editor.

4.3 Premade Virtual Environments

We included six VEs in the editor (Figure 3), which elicit different emotions. The VEs were designed according to our design space, and we offer both indoor and outdoor sample scenes.

The outdoor environment meant to elicit happiness consists of a beautiful, lively natural scene made of hills with trees close to a mountain range. The sky shines in a saturated blue and is slightly covered with white clouds. The user spawns on an earthy pathway, close to a farmhouse. The surroundings are filled with green trees, grass, bushes, and colorful flowers (Figure 3a). The corresponding indoor version consists of a room with objects predominantly formed with round edges, among them a couch, two chairs, a table, and potted plants. The windows provide a view of the landscape that has been described in the outdoor version (Figure 3b).

The outdoor version to elicit sadness consists of a barren landscape, with tree stumps and dead trees being the only objects visible. The vision is impaired by a dark gray haze and the sky is dark and covered in heavy clouds (Figure 3c). The corresponding indoor version was built with as few stimuli. The size of the room and windows was chosen based on the study with virtual rooms, which found that big rooms with a ratio of 1:2 lengthwise and tiny windows induce the most negative valence (Figure 3d).

The outdoor version for inducing fear consists of a dark forest made of tall pine trees and bushes. Apart from the lack of light, dark red fog strongly impairs the vision of the user (Figure 3e). With the factor of disorientation in mind, the indoor version of the fear-inducing environments was created as an endless maze in the dark, with deformed walls and strongly impaired vision (Figure 3f).

4.4 Questionnaires and Data Collection

Emotions are usually assessed using the self-assessment manikin [6] (Figure 1 right). Apart from this feature we also provide a built-in demographics form and a post-study questionnaire. Questionnaires are used in most studies, and having such a feature available in VR would save implementation time and effort on the researcher's end. In addition, EmotionEditor provides a set of assets to create additional questionnaires that can be directly answered within VR. All data can be collected using our editor and exported as a spreadsheet in an online platform.

4.5 Application of the EmotionEditor

Our goal was to provide researchers with a VR authoring tool, enabling them to assess the emotional states of their study participants and conduct user studies in VR. Generally, the editor is intended to save time in the implementation phase, as it helps with setting up the VE as well as the functionality needed for the study. Researchers can further implement features specific to their needs in our editor. With this in mind, we did not tailor the editor to suit one specific research direction, rather all researchers conducting studies in VR can use the prototype. Researchers can choose to use our editor at the beginning of the study to elicit or assess emotions only or use our editor throughout the entire study duration.

5 STUDY I: ELICITING EMOTIONS

To evaluate the capability of the developed VEs to elicit emotions, we conducted a within-subject user study with 30 participants.

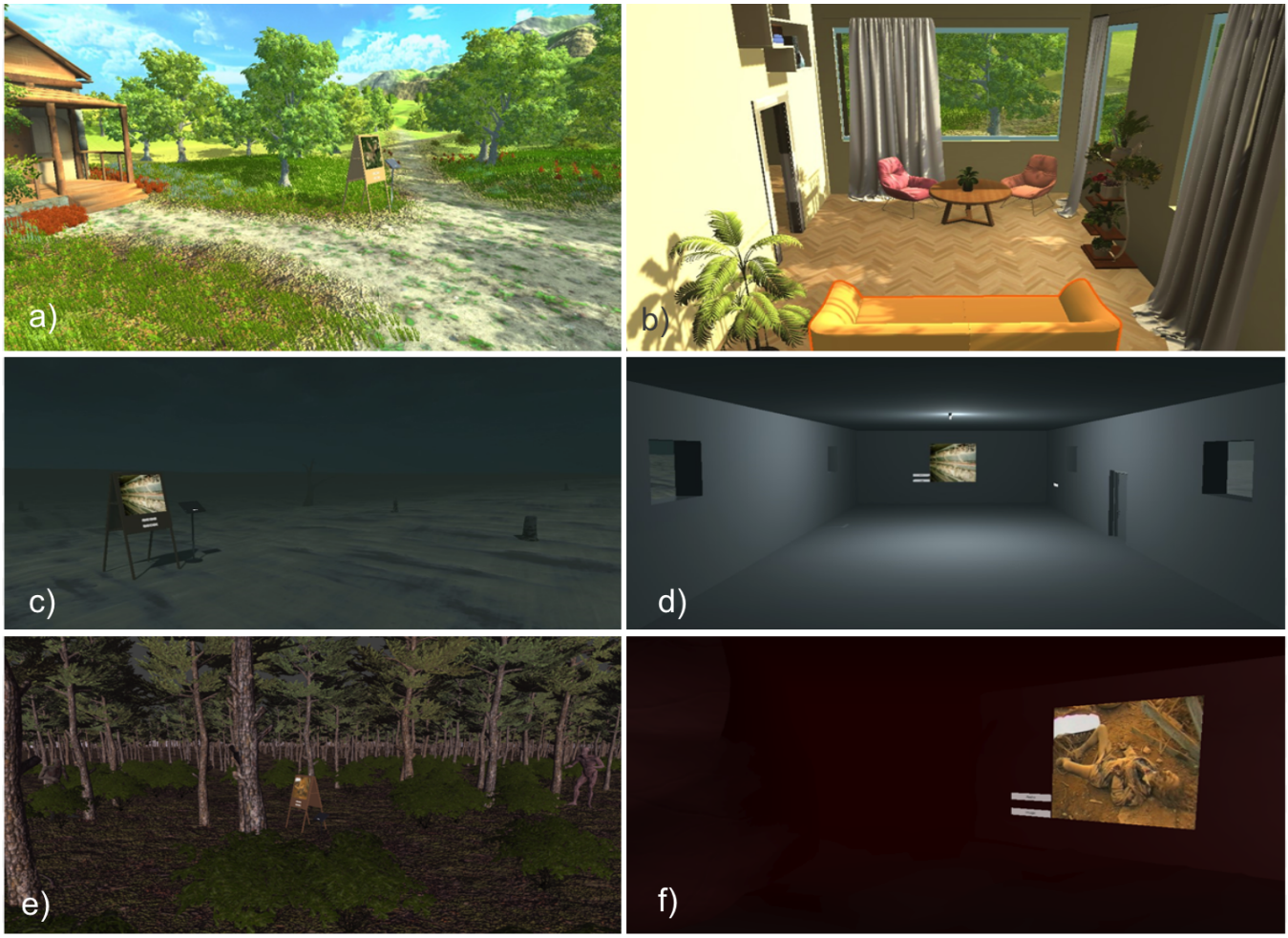

Figure 3: The set of virtual scenes available in the EmotionEditor, that were built based on our design space. The scenes elicit *happiness* (a, b), *sadness* (c, d), and *fear* (e, f), in selectable indoor and outdoor environments.

5.1 Measures

In our user study, we collected the following measures:

Demographics We assessed gender, age, occupation, education, and relevant experience with VR (no experience, have heard or seen it, have used it a few times, have used it several times, use it a lot), and a self-assessment of personality (Extroverted, Critical, Sympathetic, Anxious, Reserved, Emotionally stable).

Self Assessment Manikin (SAM) The SAM scale consists of the dimensions valence, arousal, and dominance. Valence indicates whether the emotion is positive or negative; arousal indicates the intensity of the emotion or whether the emotion is aroused; and dominance indicates whether the user is in control of the situation [6]. SAM is a subjective measure allowing users to evaluate their emotions on a 9-Point scale.

VR Task Completion Timek Participants were asked to stack cubes in each of the VEs. There are four cubes in each scene that need to be put together vertically. The time taken to complete this task is recorded for subsequent analysis.

Post-study Interview The experimenter asked whether each environment elicited or altered the participant's emotions and whether the cube-stacking task interfered with the corresponding mood. Participants were also asked whether being indoors and outdoors produced different feelings in the same emotion-evoking environment. Finally, participants elaborated on their feelings about the different VEs.

5.2 Task

In each virtual environment, the participants were asked to stack four cubes vertically using the VR controller. The participants needed to touch the cubes with their virtual hand (which followed the position of the VR controllers), illustrated by a yellow outline around the cube (Figure 4). Once the cube was selected, the participants could press and hold the controller key to pick up and hold on to the cube and release the key to let go of the cube.

5.3 Procedure

After welcoming the participants, we kindly asked them to sign the consent form. Next, the experimenter explained the study process,

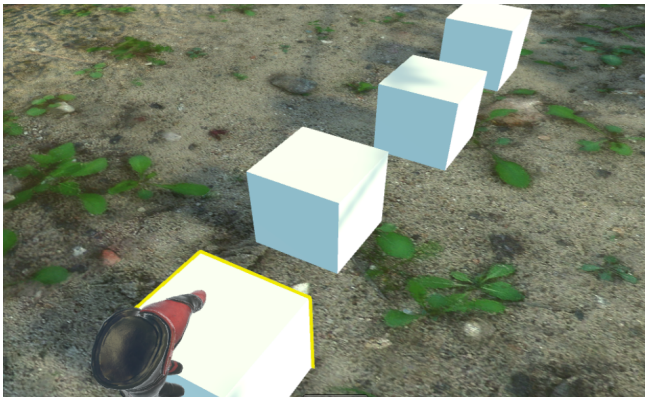

Figure 4: Participants were asked to stack the cubes virtually using the controller.

task, SAM scale, and how to fill it. Participants then entered the virtual world and experienced the six premade VEs. Immediately after entering the scene, they filled in the SAM scale once. In each of the VR scenes, participants could see three panels. The leftmost panel contained a picture selected from the Geneva Affective Picture Database (GAPED) [10] to elicit the targeted emotion. Participants were encouraged to explore the environment without any time restrictions. They could choose at any time to begin the cube-stacking task. After finishing the cube-stacking task, they filled in the SAM scale for the second time. Finally, after a 30-second interval, they entered the SAME scale for the last time. This completed one emotion eliciting VE, and subsequently, the participants were transitioned to the next scene, experiencing a different environment. The order of the VE was counterbalanced based on Latin Square.

5.4 Participants

We recruited 30 participants (14 men, 16 women) aged 20–29 (M = 23.73, SD = 2.04). Twenty-nine participants were students, and one was employed. Twenty-eight participants had a bachelor's degree, and two had a graduate degree. Sixteen participants had used VR a few times, 2 had used VR several times, 2 used VR a lot, 4 had seen or heard of it, and 6 had no prior experience. The mean value with VR experience was 2.67 (1=no VR experience, 5 frequent VR use).

5.5 Results

We compared the SAM values in different environments with different levels of VR experience, age, gender, and personality. The results indicated no significant differences between these factors.

5.5.1 Emotion Elicitation. Our findings suggest that the environments could evoke changes in arousal, valence, and dominance for elicited emotions. For happiness and fear, the environments were more successful, leading to larger changes in the SAM (cf. Figure 5).

5.5.2 Task Completion. Participants needed more time to complete the task in the outdoor (outdoor happiness: mean = 20.6 s; sadness = 24.7 s; fear = 21.3 s) than in the indoor environments (indoor happiness mean = 15.2 s; sadness = 16.5 s; fear = 22.5 s). The conducted statistical significance tests did not yield significant results.

5.5.3 Participant Feedback. Twenty-nine participants mentioned that they personally felt VEs could successfully generate emotions. Five said that the environments particularly evoked fear and made them feel scared and anxious. While four participants mentioned that the environments can elicit emotions but do not have a significant impact, only one did not feel the invoked emotions. Ten participants believed that for the same emotion, there was no difference in emotional intensity between indoor and outdoor environments. Nine participants felt that the outdoor environment could more successfully invoke emotions compared to the indoor environment.

6 STUDY II: EVALUATION OF THE EDITOR

We conducted a series of semi-structured interviews with 13 VR experts from the HCI community and industry (cf. RQ3). In the following, we describe the methodology, explain the interview structure, procedure, and analysis and, finally, summarize the results.

6.1 Methodology

6.1.1 Identification of VR Experts and Recruitment. For the interview study, we identified researchers and practitioners experienced in the field of VR. We also searched for interviewees who work at the intersection of virtual reality and emotional research, and cognitive and affective sciences. To compose a list of potential interviewees, we looked for suitable candidates among our personal contacts. In addition, we identified them from the scientific literature.

To recruit participants, we emailed the candidates with a brief introduction to our study and an invitation to participate in an interview session. 13 candidates responded, with whom we then scheduled a 60-minute online meeting.

6.1.2 Interview Structure. We designed a semi-structured interview. The session was divided into three phases:

(1) *Understanding the research strategies of the interviewee:* In this phase, we asked researchers about their recent work and if they considered the emotional state of the participants in prior work. We focused on their perspectives and the factors which are important for them when designing a user study.
(2) *Introducing the EmotionEditor:* We explained our work to the researchers and showed a video clip describing the features our tool provided. In addition, we showed a flowchart on how the tool can be used.
(3) *Assessing the EmotionEditor:* In this phase we asked for their opinion about the EmotionEditor and if they would consider assessing or eliciting certain emotions to their study participants. We also sought feedback about the existing features available in our editor as well as suggestions about additional features that could be implemented to enhance the tool.

To make efficient use of the interviewees' time we prepared for the interviews beforehand. As part of the preparation, we went through all participants' research profiles and publication lists. By making ourselves familiar with the work of the participants, we were able to ask more specific questions about how their work could have been improved/be supported by our work. This facilitated detailed discussions relevant to their field of work. Apart from a set of predefined questions, we allowed further discussion and feedback based on how the interviews progressed.

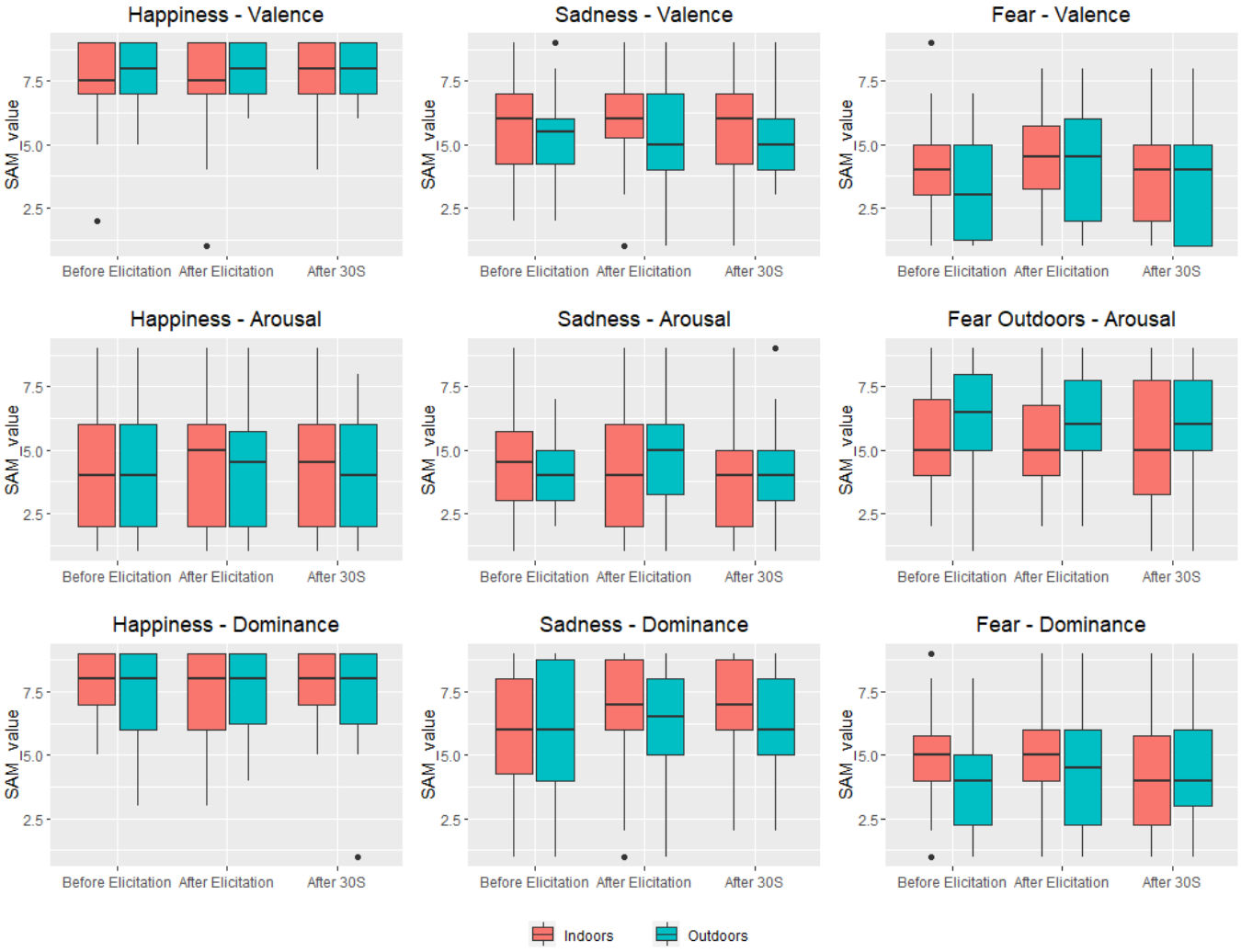

Figure 5: Box plots for an n = 30 sample from the three SAM tests separated by each selection. The whiskers of the box plots extend no further than 1.5 x IQR from each edge of the box.

6.1.3 Procedure. We recruited participants (N=13) for interview sessions through personal invitations. Interviews were conducted via the video conferencing platform Zoom. At the beginning of the interview, participants gave their consent to store data and record the video session. Before starting the actual interview, we provided a link to an online questionnaire to gather demographic data including age, gender, and experience with VR. Furthermore, we asked them to rate their expertise in the field of VR research. Then, we commenced the interview as explained previously. Each interview session lasted on average 30 minutes. An overview of their research profiles is provided in Table 1.

6.1.4 Data Analysis. We conducted a thorough qualitative analysis of the feedback obtained. We used thematic content analysis as a method. As a first step, we transcribed the audio files from the interview sessions. We open-coded the transcribed files which were grouped into keywords and then eventually refined into themes.

Table 1: Participant demographics (area of expertise, profession, self-rated VR expertise, number of years in research).

Gender	Male	9
	Female	4
Profession	PhD Candidate	5
	HCI Researchers	6
	Engineer	2
Area of Expertise	Usable Security	1
	Tangible Interaction in XR	1
	Multimodal Interaction in XR	2
	Human-Computer Interaction	2
	Emotions, Virtual Reality, Psychology	2
	Machine Learning and HCI	1
	Development in VR	4

Expertise	Expert	8
	Competent	4
	Limited	1
	None	0
# Years in Research	11 years	1
	10 years	1
	9 years	1
	8 years	2
	5 years	3
	4 years	2
	Less than 4 years	3

6.2 Results

In this section, we describe the results obtained through the conducted interview sessions. We conducted a thematic content analysis, resulting in the themes described below.

6.2.1 Importance of Considering Emotions in User Studies. All interviewees recognized the importance of considering emotions in users studies and similarly gave importance to environment design and how comfortable participants are.

When asked if they think emotions can affect the outcome of the study, most answered that they believe emotions can play a role in the outcome of the study. One interviewee (I074) stated, *"Yeah, I think it could have an effect. And that's probably something that should be taken into consideration when analyzing the results. But we don't really have any good models on how to do that at the moment. But I think that's definitely something that could affect the results"*. In addition, another interviewee (P05) stated, *"it's very relevant, especially if you have a manipulation. So you assume your participants to be equal in the two or more conditions regarding their emotions, but sometimes it's not so. So it's better to check it always before starting the study, and also to control for other potential intervening variables besides emotions"*.

Although most interviewees reported that they do not explicitly measure emotions in their studies, they do take into account the well-being of participants. For example, they ask participants to stop the experiment if they feel unwell. Most make an effort to ensure that participants feel relaxed, though they do not officially term it "emotion regulation". Researchers try to make the physical study room or location pleasant for participants and also make an effort to ensure that participants are not stressed. For example, one interviewee (I09) stated, *" In general, you want that the participants feel well, that they don't feel stressed. Of course, take care if they feel sick, or if they feel insecure"*. All interviewees strongly believe a good relationship between the participant and the experimenter to be vital for a valid study outcome.

All interviewees agreed that the VR environment is important, as is monitoring how participants feel. They also agreed that anger and other emotions can affect our cognitive states, which in turn may affect the performance of participants. Based on the answers of the interviewees and the effort they put in to ensure all participants are relaxed before starting a study, it seems that most researchers take into account the subtle effects of emotions to some extent.

6.2.2 Pre-requisite to using EmotionEditor. We asked researchers if they would consider the emotions of the participants for their future studies. Most interviewees were not aware of prior literature regarding emotions. For example, one interviewee (I02) stated, *"It would help if there is previous data that really suggests that the emotional state actually affects performance. If that's the case, then I would certainly consider this data, but I would really have to know previous studies or research that actually shows what type of data on what type of performance so emotional state actually has an effect"*.

A few of the interviewees were actively involved in emotional research and therefore most interviewees needed an explanation of how the literature is scattered across many different sources and there has been no attempt to combine them. Interviewees agreed that combining the scattered literature would be useful.

6.2.3 Why is the EmotionEditor Beneficial? All participants believed that our editor is beneficial and can facilitate conducting a user study. We asked participants to elaborate on reasons why they like our tool and would be willing to use it for their research purposes. The factors which appealed to them the most were:

Saving Time. Building 3D environments and implementing the required functionality is time-consuming. With the EmotionEditor, things like questionnaires, and emotion elicitation and assessment, are readily available. Saving time in the implementation phase is highly desirable and we find this to be a priority for researchers.

Data Export. Many participants stated that being able to export data is highly desirable. Several factors play a role here. Firstly, uncertain times such as the COVID-19 pandemic has initiated a need to conduct remote studies more frequently, and having the option to export data online is especially handy in these instances. This feature also helps colleagues to collaborate when geographically separated. One participant mentioned that in many cases they do not require heavy analysis using software like R or SPSS. (I04 stated, *"It will be extremely cool because sometimes it happens that you have this software or files that adopts different formats, so it's always a mess, but having it online instead would be perfect"*). In such cases, it is highly desirable to have the data exported as a spreadsheet which can allow a really quick analysis of the data for overviews. Many factors affect how data is to be analyzed. A few researchers admitted to prefer having data exported only in the local machine, especially in instances where the data is sensitive, such as medical data. However, having data available online to share among team members is a highly useful feature, especially during remote collaboration. But in cases of remote collaboration, almost everyone prefers to have data at a secure cloud service that complies with the data privacy and protection laws of the geographical location.

Ability to consider emotions. Many participants mentioned that most often researchers ignore the emotional state of the participants and simply assume to get a good outcome. This can bias the data in research areas where emotion may heavily determine the actions of the users. Most of them believe that balancing out everyone's emotional state would be highly useful before starting any user study. Our tool would ensure that researchers are aware of how participants feel before the start of the study. One interviewee stated (I05), *"We discovered that, to most of them "emotion" is an important criteria. We come to this conclusion based on the effort they take to ensure that thus we strongly believe there is a need to analyze emotions and we also highlight here that currently no good model exists to deal with emotional state of the participants"*.

6.2.4 Design Suggestions. Most participants found our tool to be beneficial and were convinced that they would like to use the editor in their own user studies. They provided suggestions that they believed would enhance the prototype.

Provide emotionally neutral virtual environments. Many believe that in addition to eliciting emotions like happiness or sadness, it would be beneficial to elicit a more "neutral" emotional state in participants. (I07 stated, *"It would be useful to get all of the participants on the same level"*). This would also ensure that participants are not too distracted by the virtual environment. We believe this feature is likely to benefit a broad range of studies.

Support including physiological data. Many supported the view that in addition to SAM scale assessment, the system could integrate physiological measurements. This would mean that the data is taken implicitly without wasting time which is highly desirable for both researchers and participants.

Fully integrated plugin. Researchers want a tool that would do most of the work in the background and allow researchers to focus on the research question. Many said this would be best obtained if our prototype was available as a fully integrated plugin (for example in Unity) which would allow a smooth transition from the emotion assessment to the researcher's actual study.

Enhance graphical quality. One researcher commented that our current prototype may be suited for use by researchers or specifically academic research. However, when research is being conducted for industrial purposes, clients may actually need high graphical quality environments.

Implement out-of-VR questionnaires. Though research suggests that answering questionnaires in VR is beneficial [58], many interviewees believed there should also be the option to do this outside of VR. This is because participants may need a break from VR and also because filling questionnaires in VR can be time-consuming. This could work, for example, by having the editor open questionnaires automatically on the computer's default browser, as was done in one existing VR study [33].

7 DISCUSSION

We discuss how researchers and designers may benefit from a design space. We also discuss the importance of analyzing participants' emotional states in a user study by drawing upon the feedback obtained through our interviews. We discuss the advantages and challenges of our proposed prototype and reflect upon feedback.

7.1 Eliciting Emotional States vs. Preserving Emotional States

Goslin and Morie [21] argue that creating VEs using imagery and sound will enhance the sensation within a virtual environment and evoke an emotive response. Riva et al. [51] investigate the efficacy of VR as an affective medium. The authors created "relaxing" and "anxious" environments which successfully evoked anxiety and relaxation. Therefore, prior work argues that VR is an affective medium. However, prior work does not provide a design space to design virtual environments to evoke a particular emotion.

In line with this, we introduced a design space that can be leveraged to design VEs that elicit emotions in participants. The design space consists of five dimensions that can be manipulated in the VE: *Layout of Space*, *Color Themes*, *Sound*, *Decoration*, and *Weather* are dimensions to design for in affective virtual environments.

Prior work shows that traditional emotion elicitation methods from the real world can also effectively elicit emotions in VR. One may argue that if using solitary materials such as audio and video clips can elicit emotions, one does not need to design virtual environments to fulfill the same purpose. We firmly believe that not only is it important to elicit an emotion but one must take into account the intensity of the elicited emotions. A comparative study conducted by Rivu et al. [52] shows that even though elicitation may work, it is also likely that the emotions will quickly wear off. This can be mitigated by designing a virtual environment that does not use only one stimulus but rather a combination of strong stimuli to elicit emotions of higher intensity.

7.2 Benefits of the EmotionEditor

Discussions with researchers revealed that researchers to a great extent attempt to make the study participants comfortable during user studies. Therefore, it is important for any user study that the participants are physically and mentally well enough to participate and not bias the data. We have seen in prior work that at times researchers had to drop participant data due to the participant not doing tasks properly or because the participant left the study mid-way due to frustration [12, 47]. We believe that emotional assessment may prove to be helpful to avoid such instances. With our tool, researchers would also have the opportunity to elicit a desired emotion before starting the study.

Another reason why researchers appreciate the editor was that with the editor a great chunk of implementation would already be done, making it a time-efficient solution. This is beneficial to many researchers as this allows them to focus less on implementation and more on the study design and the research questions at hand. Most researchers stated that having a high-fidelity environment implemented from scratch is challenging and time-constraining which is why most of them opt to use available plugins from asset stores. Having a tailored environment for researchers use would be highly beneficial to the mass community of VR researchers.

All the interviewees thought that the features our tool provides are useful and needed. A few researchers mentioned that they typically have participants fill out questionnaires outside of VR, but with our tool, they would be happy to make use of the in-VR questionnaire feature to ensure that participants are fully immersed. There are cases though where out-of-VR questionnaires are warranted. For example, if the study lasts for a long time, participants might benefit from breaks where they can remove the HMD [33].

We asked interviewees how they would envision using our editor. Several researchers would use our tool at the very beginning of their studies to assess and elicit a desired emotion or neutral state of the participants and then continue with their own research questions. The rest preferred to use it throughout their studies. Our findings show that a top priority for researchers is to avoid additional effort. This is precisely what we did with our editor.

7.3 Ethical Considerations

Cumyn et al. discuss the importance of ethical conduct on part of researchers [9]. The existence of institutional review boards (IRB) is to verify the ethics of research and aid researchers to conduct their research ethically [28, 31]. At the end of the day, the responsibility of applying the ethical protocols rests on the researchers.

Ethics play an important role in VR research especially because human behavior is sensitive to environmental features. The effects of VR on the consumers' mental health and moral standards are still not sufficiently investigated [1, 60, 62]. Thus, we believe the ethical concerns of using VR has moral implications on the design of VR user studies.

When researchers use our design space to create emotion-evoking VEs, they must be aware of the ethical implications. Similarly, researchers using our EmotionEditor must also seek approval from their IRBs before conducting studies. We need to further explore the ethical implications of using virtual environments that can manipulate users' emotions. Particular care must be taken when studies are dealing with emotions that contain negative valence or arousal.

One must also consider participants' ethical rights. When designing VEs to evoke emotions, we may manipulate participants. Should we conduct only deceptive studies when dealing with emotions? If not, at which point do we disclose emotional states being manipulated? These open questions require further exploration.

7.4 Future Work

The interviewees revealed several design options that can enhance and enrich our current prototype. In the future, we will implement those proposed features to offer our environment a fully integrated plugin available for researchers. These include (1) building an environment capable of neutralizing emotions and (2) integrating physiological data.

8 CONCLUSION

In this paper, we explored the concept of controlling and eliciting emotions in virtual reality (VR) user studies through the displayed virtual environment. We formulated a design space for controlling and eliciting emotions through virtual environments based on a literature review. We introduced *EmotionEditor*, a freely available tool to help researchers conduct VR studies. The EmotionEditor fulfills the derived requirements, including emotion elicitation, real-time emotion assessment, and emotion regulation. Additionally, our tool supports the design of studies by providing flexible and customizable VEs and facilitating data collection and export.

We conducted a user study with 30 participants to evaluate the EmotionEditor's ability to elicit intended emotions. Results indicate that despite no significant difference, the virtual environments generally change the self-assessment manikin dimensions. Participant feedback resonates with the same results. Finally, we present the results from 13 expert interviews, discussing the importance of designing for emotions in VR studies. Experts generally agreed that controlling and assessing emotions in VR studies is important and believed that emotions could impact the outcomes of their studies. Overall, they find the concept of EmotionEditor beneficial, as it saves time when considering participants' emotions in user studies.

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