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DESIGNING MODELING AND SIMULATION USER EXPERIENCES: AN EMPIRICAL STUDY USING VIRTUAL ART CREATION

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ABSTRACT

For decades, users have been interacting with software through graphical user interfaces. This is also true for modeling and simulation (M&S) tools, a paradigm that affects how models are built and simulated. It also impacts how results are presented, 1) preventing non-experts from using M&S tools, and 2) excluding people who are atypical on a sensory spectrum. This paper focuses on the exploration of key factors contributing to designing M&S user experiences as an approach to mitigate existing thresholds and establish M&S as a means to improving people's lives. We perform an empirical study with artists, who express creative skill and imagination in a visual form, creating in virtual environments. We report on results of a user experience survey completed after a creative session in virtual environments. Finally, we discuss how these results can benefit M&S tool development.

1 INTRODUCTION

M&S has proven itself to be a scientific discipline (Padilla et al. 2011; Gore et al. 2016), but it is also an emerging approach that can improve people's lives. In order to make M&S truly relevant to people's lives, we should embrace the concept of universal design and strive to enable all people to have equal opportunity and access to M&S tools regardless of their socio-economic status, sensory needs, or physical and mental disabilities (Rose and Meyer 2002). Currently, M&S tools often assume that the user is at least an aspiring M&S professional which limits the access to the power of the discipline. Already, there are efforts focused on making some M&S paradigms more accessible to non-experts by (1) lowering the threshold posed by cost and computational requirements (Padilla et al. 2014), (2) making the M&S process entertaining while teaching young learners (Padilla et al. 2016), and (3) using sensory stimuli other than vision as a potential path to making simulation more accessible (Deuro et al. 2017).While these approaches constitute a good starting point, they still require some M&S knowledge to build models, set simulation parameters, and analyze results. In order to make M&S truly relevant to non-simulation experts and foster a radical change in the way we consume models and simulations, we have to venture beyond simply extending traditional graphical user interfaces (GUI).

One potential direction is to explore and leverage narratives in M&S. Narratives have a high symbolic value for comprehension and are more engaging than traditional scientific communication (Dahlstrom

2014; Padilla et al. 2017). Furthermore, narratives are effective in M&S because they follow cause and effect relationships so prevalent in M&S paradigms and allow audiences to understand concepts that extend beyond "human scale" (Dahlstrom and Ritland 2012). As a result, we need to look for means to create and experience narratives in the M&S context. Instead of interacting with models and simulations through an interface, audiences will experience them through their senses, a process which is a more natural way of generating engagement and insight and a process more in tune with how humans have evolved over thousands of years.

After years of research and technological development, Virtual Reality (VR) has reached a level of maturity that makes it useful across multiple domains including the Arts. Visual artists generate creative compositions that they want the public to appreciate for its beauty or emotional power (Art 2017). Artistic VR users follow two major paradigms: an artist creating content, such as a movie or a building outside the VR environment then presenting it to the viewer during an exhibition via a VR form-factor (a head-mounted display for instance) (Schwartz 2017); and using VR as the environment where artists can use their creative skills and imagination to create an artifact they can share with an audience through the same form factor (*Tilt Brush*).

As VR tools evolve and improve, the keyboard, mouse and stylus are increasingly being replaced by gestures and other human-computer interfaces such as voice or gaze. In the near future, it is expected that VR will be the perfect storytelling tool not only for artists but also for archeologists, healthcare professionals, and educators, among others. To design and develop VR tools that are useful to artists, designers must better understand the creative process in VR in order to observe and analyze how artists adapt to this new creative medium. For instance, a VR tool's user interface (UI) needs to be flexible and intuitive to allow a seamless translation of artist's skills into the VR environment. In addition, artists' perceptions and responses must reflect and engage the use or anticipated use of the system (Ergonomics 2010), also known as user experience (UX). UX includes user's emotions, beliefs, preferences, perceptions, physical and psychological responses, behavior and accomplishments that occur before, during and after use.

A major question is how to measure UX in the VR art creation process and how to design the UI in a way that makes it intuitive to the user and provides the right balance between the level of interactivity provided by the tool and the experience that artists are trying to share. One possible set of answers can be found in exploring usability which is part of UX (Ergonomics 2010). However, there are few methods for evaluating the usability of VR systems. Standard evaluation methods such as Nielsen's heuristics (Nielsen 1994), cognitive walkthroughs (Wharton et al. 1994), or cooperative evaluations with users to diagnose problems (Monk et al. 1993) do not address comprehensively all aspects associated with VR. An attempt to accommodate the usability of VR systems was made by Sutcliff and Deol Kaur (2008) which was based on a theory of interaction for VR and complex 3D graphical UI (Kaur 1997) stemming from the concepts introduced by Norman, in Cognitive Engineering (1986). Yet the aforementioned study (Sutcliff and Deol Kaur 2008) does not focus on immersive VR, such as head-mounted displays, and the methods mentioned above are aimed at traditional applications of VR, such as training that assume the existence of 3D content in the environment rather than applications wherein an artist is the creator in the VR environment.

Chertoff et al. (2010) propose a virtual experience test to measure holistic virtual environment experiences based on five dimensions: sensation, cognition, affect, actions, and relations. The questionnaire is oriented towards the evaluation of the particular software rather than the general user experience in VR as a creative tool. Gabbard et al. (1999) apply a mixed method approach (heuristic and formative usability evaluation) focusing mainly on user interfaces in virtual environments, while Di Giornimo et al. (2013) define a synthetic usability index on the basis of multi criteria decision analysis (MCDA) and the Saaty's analytic hierarchy process (1980). However, the study relies on weights assigned by participant matters experts only. Burbules (2004), providing a framework that focuses on aspects of immersion such as interest, involvement, imagination, and interaction, understands the virtual to be, instead of a product or a simulation imposed on us as passive audience, a context of active engagement. This active participation is as much immersion and reality as is our understanding of the real world, with no distinction. In reconceptualizing

VR particularly in educational contexts, the importance of such immersive experiences comes with direct action and responses not constrained only to perception and cognition. Acts of joint participation become networked settings that operate as functional components essential to crafting new spaces for social imagination.

In this paper, we investigate factors that contribute to designing modeling and simulation user experiences rather than mere interaction through traditional UI to generate insight. Instead of turning to engineers, scientists, and M&S professionals, we designed a study with people who express creative skill and imagination in a visual form. A group of visual artists, mostly associated with the Chrysler Museum Glass Studio in Norfolk, VA, was recruited to perform in a virtual reality environment. The balance of the paper is as follows: Section 2 introduces our methodology used in this study. Section 3 describes the data collected during the experiment and presents the analysis performed on the subset of the data collected followed by the discussion in Section 4. Section 5 concludes the paper.

2 METHODOLOGY

In order to understand how to design a simulation experience, we recruited nineteen visual artists from the Hampton Roads region in Southeastern Virginia. To qualify as an artist, a participant had to attest by signing a statement of credentials that they hold at least a Bachelor of Fine Arts degree or had their art pieces displayed in an art gallery setting. Each artist had to consent to participate in the study following a research protocol approved by the Old Dominion University Institutional Review Board (ODU IRB# 17-151). Because the study involves VR, each participant has to fill the Golding Motion Sickness Susceptibility Questionnaire (GMSSQ) (Golding 1998). This questionnaire is designed to find out how susceptible to motion sickness a person is, and what sorts of motion are most effective in causing that sickness. In this context, sickness means feeling queasy or nauseated or actually vomiting. Two artists were excluded from the study by scoring 20 or more on the GMSSQ reduced the number of participants to seventeen.

We selected the Oculus Medium made by Oculus VR of Menlo Park, CA as the means for creation because it is a freeform 3D sculpting tool that allows the user to create in a VR environment. Oculus Medium is oriented on the whole artistic spectrum, from beginners to professional artists. It uses Oculus Rift Touch controllers to enable hand gestures and movement for a tactile experience. The Oculus Rift is a VR headset equipped with an OLED display characterized by 1080×1200 resolution per eye, a 90 Hz refresh rate, and 110° field-of-view (FOV). It has integrated headphones that provide a spatial audio effect. The headset also has the capability of rotational and positional tracking. The tracking system relies on stationary infrared (IR) sensors that detect light emitted by IR LEDs built into the head-mounted display. This creates a volume in which the user can perform, walk, or sit [9]. The whole experience was run on a computer equipped with Intel® Core™ i7-7700K CPU @ 4.20GHz with 32GB RAM, Nvidia GeForce GTX 1080 graphics card, and Windows 10 operating system.

We assumed that artists participating in the study were not familiar with VR and Medium. Therefore, each participant was allowed to complete a 20-minute training session assisted by a researcher. The purpose of this session was for the artists to become familiar with the VR environment and input devices. We also measured the time each participant spent on training in the Simulator Sickness Questionnaire (SSQ) (Kennedy et al. 1993) at the end of each session. Participants experiencing "severe" symptoms were excluded from the study. For this study, no participant was excluded due to training sickness.

An assessment phase followed the training session where each participant had to accomplish an identical task developed by the subject matter expert (SME) – create a flying creature and use at least two colors (Figure 1). Each participant was given up to 10 minutes to complete the assessment phase. When all participants completed the creation of a flying creature, we measured the actual time needed to accomplish the task. Then the SME reviewed and scored the resulting artifact on a 10-point scale, adding additional points based on three key factors participants were taught in the tutorial: use of multiple colors, additive and subtractive sculpting, and use of multiple tools. The artists scored on average 7.1.

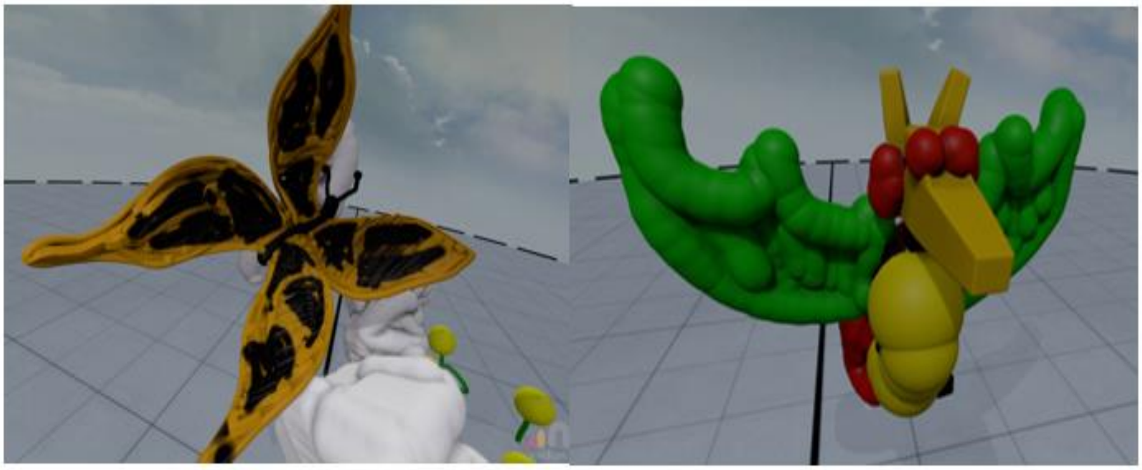

Figure 1: Flying creatures created during the assessment phase.

Upon completion of the assessment session, each participant was given the identical theme of "ocean" and asked to create an artifact for no more than two hours (Figure 2). During this phase, the participant was asked to think aloud, which was recorded, while working in the environment. Each participant's voice and movement were recorded by a video camera. Additionally, the position and orientation of the participant's head, input controllers, and the state of each button throughout the session were stored in a log file. Participants were not provided any assistance during this phase unless they felt sick and wanted to stop the experience. Every 20 minutes, the participants were required to take a break and submit to the SSQ. Again, participants experiencing "severe" symptoms would have been excluded from the study. The artists spent in total 1474 minutes creating, resulting in an average of 86.71 minutes per participant, with three participants spending over 100 minutes in the environment.

Figure 2: An artist with a head-mounted display and handheld controllers creating in the VR environment (left) and a virtual sculpture (right).

Upon completion of the creative phase, participants were administered the user experience questionnaire (link) before being interviewed by a researcher (link). Participants maintained the copyrights to the VR pieces of art created during the session and gave permission to use images representing the VR piece of art in scientific publications.

3 DATA AND ANALYSIS

For the purpose of this paper, we focus on the user experience (UX) questionnaire that participants took at the end of their sessions. The questionnaire has a total of 20 questions, with some questions adopted from existing surveys and the rest created by the authors to address the creativity of visual artists and the use of VR environments as a creative tool. Participants were asked to characterize their experiences in the environment, by marking an appropriate number on the 7-point scale, in accordance with the question content and descriptive labels. They were encouraged to consider the entire scale when making their responses, as the intermediate levels may apply. Each question is meant to address a specific aspect of the experience outlined in the third column of Table 1.

Table 1: List of post-experiment survey questions with link to source for cited questions. Questions with a star followed by -1 (* -1) will have their responses multiplied by -1 during analysis to align with the interpretation (negative to positive) of the correlation with other questions.

#	Question	Aspect (Label)	Lowest	Medium	Highest
1.	Have you ever experienced Virtual Reality before?	Past Experience Modeling ***(PEM)***	Not at all	Sometimes	Often
2.	While in the Virtual Environment, did you have a sense of "being there"? (Rechowicz et al. 2018)	Sense of Being There ***(SBT)***	Fully Disagree	---	Fully Agree
3.	Did you experience any delays while using the software? (* -1)	Delay Using Software (DUS)	Not at all	Sometimes	Often
4.	How important to you is being able to use more than one color while creating?	Use of More than one Color ***(UMC)***	Not at all	Somewhat	Very important
5.	How important is the ability to record the narrative while creating?	Ability to Record Narrative (***ARN)***	Not at all	Somewhat	Very important
6.	How important is the ability for the viewer to see all the creative steps you took?	Ability for Viewer to see all Steps ***(AVS)***	Not at all	Somewhat	Very important
7.	Did you feel that you could construct a story about your actions in the virtual environment? (Chertoff et al. 2010)	Sense of Constructing a Story **(SCS)**	Fully disagree	--------	Fully agree
8.	How natural was the mechanism which controlled movement through the environment?	Movement Control Mechanism (***MCM)***	Extremely artificial	Borderline	Completely natural
9.	How much did your experiences in the virtual environment seem consistent with your real-world experiences?	Consistency with Real World ***(CRW)***	Not consistent	Moderately consistent	Very consistent

10.	How involved were you in the virtual environment experience?	Amount of Involvement ***(AOI)***	Not involved	Mildly involved	Completely engrossed
11.	How much did the visual display quality interfere or distract you from performing in the virtual environment? (* -1)	Quality of Display ***(QOD)***	Not at all	Interfered	Prevented performance
12.	How much did the control devices interfere with the creative process? (* -1)	Quality of Controls ***(QOC)***	Not at all	Interfered somewhat	Interfered
13.	How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?	Concentration on Task ***(COT)***	Not at all	Somewhat	Completely
14.	How much did the auditory aspects of the environment involve you?	Level of Auditory Involvement ***(LAI)***	Not at all	Somewhat	Completely
15.	How much did absence of tactile feedback interfere with your ability to control the virtual tools? (*-1)	Lack of Tactile Feedback ***(LTF)***	Not at all	Interfered somewhat	Interfered
16.	How helpful were the audio cues while working with the creative tools?	Helpfulness of Audio Cues ***(HAC)***	Not at all	Somewhat helpful	Very helpful
17.	How complex was access to the creation tools? *(* -1)*	Level of Access Complexity ***(LAC)***	Not at all	Somewhat complex	Complex
18.	Did the result of your creative process in the Virtual Environment correspond to your initial vision?	Correspondence with vision ***(CWV)***	Not at all	Somewhat	Completely
19.	If you had access to Virtual Reality, would you incorporate this form of art into your portfolio?	Incorporation in Portfolio ***(IIP)***	Not at all	Probably	Definitely
20.	Were the depth cues provided by the virtual lighting adequate?	Adequacy of Depth Cues ***(ADC)***	Not at all	--------	Completely

Fourteen of the seventeen participants fully completed the post-experiment survey with the average participant reporting to have little to no previous experience with virtual reality. Despite this relative lack of experience, 89% of users described having a sense of presence with 24% of users fully agreeing that they had a sense of "being there" when they created in virtual worlds. Only 12% percent of users report to having experienced no delays while using the software, while a majority of users (65%) felt it is important to be able to use more than color. Users were split on the ability to record a narrative, with 47% feeling it is not important and 42% saying it is somewhat to very important. However, users agreed that it is important to tell a story (44% fully agree) and it is important for viewers to see all the creative paths they took (60%).

In terms of usability, 53% of users say that the mechanisms that control movement were between borderline and somewhat natural. In addition, 41% of users reported that their experience in the virtual world is moderately consistent with their real world experience. Despite this lack of consistency, 59% of users said they were completely involved in the virtual environment experience. The quality of display hindered 36% of users with 12% reporting that it prevented them from performing in the environment.

Similarly, control devices interfered with the creative process for 42%, but all users claimed to be somewhat or completely able to concentrate on their tasks rather than the tool. In terms of multi-sensory involvement, 50% of users felt that they were somewhat involved by the auditory aspects of the environment, 88% reported that audio cues were between somewhat and very helpful and 63% agreed that the depth cues provided by lighting were adequate. However, 47% claimed that the lack of tactile feedback interfered with their ability to control the virtual tools and 53% stated that access to the creation tools was somewhat complex.

Overall, all users reported that the results of the creative process in the virtual environment did correspond to their initial vision (41% somewhat and 18% completely) and 24% said they would definitely incorporate virtual reality into their work if they had access to it.

At the beginning of the creative phase, participants were presented with an environment that was essentially a blank canvas. As they progressed through the task, the space filled with their creations. With auditory stimuli, a high level of presence was achieved. The results show that auditory stimuli were a contributing factor to the achievement of a high level of presence. Auditory stimuli indicate that a modeling tool is being used, assuring the user that the current action has impact on the modeling environment.

Delays are correlated with the complexity of the sculptures triangle-wise, an indication that modeling in VR environment should not generate 3D objects that are rich in triangles. 3D models should be simplified and, if possible, textures and bump maps should be used to show detailed virtual models. An M&S user should also be able to use various colors during the modeling process for better understanding of the components that are part of the model.

Although the results show that almost half of the artists felt that recording the narrative was not really an important feature, being able to tell a story and record all the steps needed to complete the sculpture were found to be of high interest. These results indicate that M&S environments should provide an opportunity for the modeler to fashion a narrative about the model and the steps taken to build the model.

Concerning interactions, the current movement controls seem to be at least sufficient to keep the user engaged with the virtual environment and less than half of the group found the experience moderately consistent with the real world counterpart. This means that the mechanism can be reused in M&S applications without significantly affecting the level of involvement, meaning also that the user can experience in the virtual environment in ways familiar within the real world. Despite the moderate performance of the movement control mechanism and the correspondence between the VE and the real world, most of the users were able to achieve higher levels of proficiency in the virtual environment. This is an important indication for how to design modeling environments to allow an M&S user to become quickly familiar with the tool.

The quality of display impacted negatively over a third of the group and some were completely prevented from performing. The construction of a head-mounted display (HMD) creates suboptimal experiences for people with lower vision and those who wear glasses. Correct mounting on the person's head also had an impact in quality of display. Text presented in the virtual environment was also found to be too small and blurry. Despite control devices interfering with the creative process in almost half of the cases, almost all of them were able to concentrate on their task rather than the tool, a promising result for M&S user experiences. One of the most common VR form factors and associated controls – HMD and handheld controllers – do not prevent the user from focusing on a task. To mitigate other interfering factors, an appropriate text size should be chosen or text should be avoided when M&S user experience is being developed.

From the multi-sensory involvement point-of-view, auditory aspects of the virtual environment are involving and should be part of M&S user experience, specifically because almost all artists found them useful in the creative process. The results show the artists expected tactile feedback, and we argue that this factor would also be true for most M&S user experiences. Tactile feedback is important for perception point-of-view especially in 3D environments where depth perception can be decreased. A typical M&S user should be able to know when he or she engages with a model or menu through the virtual representation of the control devices. Since almost all artists indicated that the result of their creative process matched their initial vision, we can expect the same would be true for M&S user experience. Modeling experiences should improve if we apply these indicated changes to the environment.

4 DISCUSSION

In order to gain deeper insight into this dataset, we conducted a spearman rank correlation test of the post-modeling data. We used the spearman test because the data is ordinal and we make no assumptions about its distribution. After calculating the spearman coefficient, we clustered the resulting correlation matrix hierarchically using the "hclust" library in R. Table 2 shows the four major clusters emerging from the matrix when we used a 95 percent confidence level (p= 0.05).

Table 2: Themes for UX Design in M&S.

Themes	Questions
Quality of Presence: This cluster captures the quality of presence provided by the tool. A high presence environment that meets user's expectations increases the suspension of disbelief with the necessary number of auditory stimuli;	Sense of Being There **(SBT)**, Correspondence with vision **(CWV),** Adequacy of Depth Cues **(ADC),** Past Experience Modeling **(PEM),** Amount of Involvement **(AOI)**
Quality of Experience: This cluster contains variables that capture the tool's ability to convey the user's intent. Users who feel that the tool is able to capture and convey their story tend to want to include it in their portfolio and share it with the public;	Ability for Viewer to see all Steps **(AVS),** Sense of Constructing a Story **(SCS),** Lack of Tactile Feedback **(LTF),** Incorporation in Portfolio **(IIP),** Ability to Record Narrative (**ARN),** Consistency with Real World **(CRW)**
Quality of Interaction: This cluster indicates how users rate the quality of interactions with the tool. Users that feel hindered by the quality of displays and controls tend to feel that their ability to access creation tools was complex;	Concentration on Task **(COT),** Quality of Controls **(QOC),** Quality of Display **(QOD),** Use of More than one Color **(UMC),** Level of Access Complexity **(LAC)**
Quality of Involvement: This cluster captures the user's involvement while developing their model. Users that can feel engaged visually, auditory and control their movement tend to find that the model they build with the tool is able to convey their vision;	Delay Using Software **(DUS),** Level of Auditory Involvement **(LAI),** Movement Control Mechanism (**MCM),** Helpfulness of Audio Cues **(HAC)**

Simulation tools and their interfaces need to exhibit a Sense of Being to be universal. Accordingly, the tool should allow users to most naturally express their vision while optimally accommodating their sensory, educational, etc. needs. Depth cues also impact modeling in relation to the ability to orient within a modeling environment. Intuitively, past modeling experience is also a factor influencing Quality of Presence. As we become more comfortable with the tool and its UI through increasing level of proficiency, our amount of involvement with the modeling process should be positively correlated. In this case, the user can focus more on engagement rather than the modeling tool itself.

For M&S tools to provide intent conveyance capabilities, there must be a high level of Quality of Experience. Some variables contributing to the experience focus on being able to construct a story around the model and simulation. The story should take into account modeler's and end user's preferences regarding the modality of how the story is told. The choice should be as rich as possible to accommodate people with various educational, sensory, social needs, etc. Ultimately, M&S tools should fluidly operate between various modalities of storytelling. To provide an example, a modeler builds a story in the audio form and the end user would see an animation conveying the same story.

In UX, the narrator is the framer of events, adding an agentive component to locating intention. Narrative is understood as composed of personal perception and constructed cultural meaning, both negotiating what kind of expectations and assumptions the narrative allows and constrains. Narrative fidelity (a reliable story) and narrative probability (a story's personal coherence) can be used as a guide in VR UX to investigate how content and form operate with functional components for the user to appeal to emotional, cognitive, and imaginative processes through narratives as presented and constructed (Barbatsis 2005). In the case of visual compositions, the user moves between content and fidelity of expression simultaneously to make meaning as guided by spatial awareness and the focus of events as the eye moves through sequencing the story *and* the environment to fashion meaning through Quality of Experience.

Additionally, the Quality of Experience is also influenced by allowing the modeler to record a narrative and the user to see all the modeling steps. Recording a narrative can benefit a modeler and an end user at the same time by providing the modeler's explanation and intent, as well as the context. This capability is especially useful when people representing different domains work with the model as each person can record their narrative enriching the model and enabling insight generation. Viewing all steps would add tremendous value in an educational wherein emphasizing narrative for a student could teach model development in the context within which it was professionally built.

Creative people tend to share their experiences in forms of painting collections, music albums, 3D models or code repositories. If we approach the M&S process as an experience, incorporating it within the modeler's portfolio would also increase the level of Quality of Experience for an end user. An end user would be able to follow modeler's work in the same way we follow our favorite artist, creating a feedback loop between the creator and the user. This would allow us to recognize whether the modeler's story and intent has been conveyed, and, if not fully realized, what changes need to be made to improve storytelling techniques.

UX contends that, when we first interact with an object or a person, we have certain presumptions based on our experiences, past and present; we expect them to behave in a consistent way. This expectation must be transferred to M&S tools. If the experience in a modeling environment is not consistent with the real world experience, the overall Quality of Experience will be hindered. A negative impact of this Quality of Experience variable will be even greater if the model or the end user is atypical when it comes to sensory needs.

In order for simulation tools to be interactive, a high level of Quality of Interaction needs to be present. Here, the quality of displays plays an important role, especially considering display is not only visual but also a stimulant of any of the five classical senses in a deeply aesthetic way that engages with cognition. Therefore to ensure universal access, displays cannot hinder access to creation tools. Quality of controls must also be considered in this same multisensory context. If the quality of controls and displays is suboptimal, simulation users will be distracted from the task at hand, negatively impacting the Quality of Interaction. The Quality of Interaction is also affected by the ability to use more than one color. However, we need to consider *color* in the multisensory manner. If we consider a blind user, the color would correspond to a tone, force magnitude, scent, or taste. For simulation tools to comply with the universal access principles, we need to provide multiple levels of sensory stimuli and, hence, increase the Quality of Interaction.

VR experiences are powerful because users' active engagement is highest through involvement. To achieve high levels of Quality of Involvement in simulation tools, we need to ensure that there are no noticeable delays while using M&S tools. Delays prevent the user from interacting with the model as their attention can be redirected to other tasks. Our levels of involvement typically decrease as we move between unrelated tasks. This also indicates that a user of M&S should be presented an environment with very few items in the surrounding area, allowing them to focus on the modeling task at hand. Likewise, our involvement in almost any experience depends on how stimulating it is. Although in our experiment the visual artists were asked about the level of auditory involvement, we project the answers onto multisensory involvement. Similarly, we argue that multisensory cues contribute to the level of involvement with simulation software.

5 CONCLUSIONS

We live on a spectrum that requires us to rethink how we engage, interact, digest, and explore digital information in new ways and through new modalities. Keeping these principles in mind, the M&S community needs to embrace the role simulation can play in improving people's lives. We propose that this can be achieved by making M&S tools an experience for the modeler and the end user. This experience should take into account how we perceive information depending on our sensory and physical needs, cultural and social backgrounds, life experiences, and education levels to provide experiences for all individuals. Before it happens, we need to plan for implementing universal access into simulation and investigate how various groups of creative people convey ideas and narratives. To explore key factors for designing M&S user experiences via simulation software, we conducted a study to understand how visual artists create and interact in and with VR, what changes to the decision-making process the artists need to communicate the same idea through a virtual tool rather than conventional media, and how they convey a narrative to the viewer rather than simply presenting simulation results. Based on data collected, we identify four themes: Quality of Presence, Interaction, Involvement, and Experience. Subsequently, we propose the Presence-Interaction-Involvement-Experience (PIIE) model for designing simulation software that generates the M&S process as a shared experience. The model underlines the importance of equipping simulation tools with multisensory stimuli and leveraging the concept of digital senses (Rechowicz et al. 2018). Although the data collected involves artists performing in a virtual environment with mostly visual stimuli, we recognize that the environments going forward should address needs of people on the whole sensory spectrum in order to seek methods that allow for delivery and diversity of M&S experiences through an arbitrary or mixed sensory channel, which will ultimately contribute to the advancement of universal access in simulation tools. Combining these results, we are guided toward creating M&S user experiences rather than computer applications with traditional graphical user interfaces.

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