Exploring Web-Based VR for Participatory Robot Design

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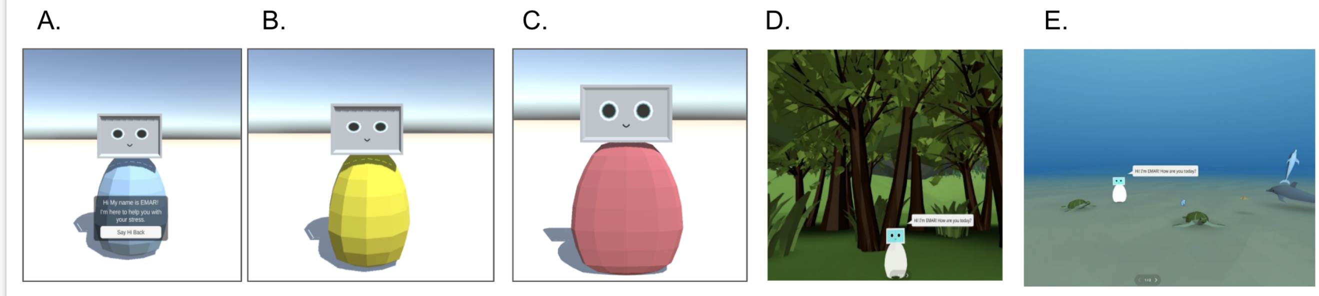

Figure 1: Snapshots from Web-based VR tools, WebXR robot interaction prototypes (A-C). In figure A, the robot prompts, *"Hi, I'm EMAR! How are you today? Say Hi Back"*. CoSpaces Edu robot environments designed by teens, where the robot prompted, *"Hi, I'm EMAR! How are you today?"* (D & E)

ABSTRACT

With the pandemic preventing access to universities and consequently limiting in-person user studies, it is imperative to explore other mediums for conducting user studies for human-robot interaction. Virtual reality (VR) presents a novel and promising research platform that can potentially offer a creative and accessible environment for HRI studies. Despite access to VR being limited given its hardware requirements (e.g. need for headsets), web-based VR offers universal access to VR utilities through web browsers. In this paper, we present a participatory design pilot study, aimed at exploring the use of co-design of a robot using web-based VR. Results seem to show that web-based VR environments are engaging and accessible research platforms to gather environment and interaction data in HRI.

CCS CONCEPTS

• **Human-centered computing → Participatory design**; *User studies.*

KEYWORDS

Robot design, Virtual Reality, Web-based VR, co-design

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1 INTRODUCTION

Virtual Reality (VR) is an attractive alternative for interacting with simulated robots because it affords a more immersive experience by better creating visual cues of real environments [11]. A few recent studies [10, 19] have shown the benefits of using VR as a prototyping and experimental tool for Human-Robot Interaction (HRI). However, access to VR is limited given its hardware requirements. Web-based VR is a technology that offers a 3D experience similar to immersive VR. However, web-based VR does not require VR equipment and can be accessed through a web browser offering an accessible platform to emulate physical embodiment conditions and interaction possibilities. Given the restrictions of remote co-design due to the COVID-19 pandemic and the lack of access to VR equipment, our study explored the use of a web-based VR platform to conduct participatory, co-design sessions with teens. Specifically, teens were invited to design a robot for social interactions using web-based VR.

The goal of this study was to determine the feasibility and accessibility of web-based VR tools as a novel research platform to facilitate participatory, remote design sessions with teens exploring behaviors and environments for a social robot interaction. The focus was for teens to participate, regardless of their location while giving the benefits of higher customization and control to the researcher. These design sessions suggest that teens find the web-based VR environment accessible and engaging. Additionally, we found web-based VR to provide successful and feasible tools for engaging teens in social robot co-design activities.

2 RELATED WORK

With the pandemic shutting down labs and preventing in-person user studies, it is imperative to explore other mediums of conducting interaction studies for HRI. VR has become a popular platform, with previous studies using it to replicate HRI user studies as well as to test human-robot collaboration [17–19]. Research has shown that VR can greatly benefit the field of HRI as a tool to effectively iterate across robot designs. Wijnen et al. [18] found that VR can provide access to a wider variety of environments, scenarios, and robot embodiments for researchers to conduct studies. Kim et al. [10] successfully used VR as a methodology to collaboratively design a virtual reality game for teen-robot interactions. Their findings suggest that VR can increase collaboration and communication among participants while co-designing robots using virtual reality. However, VR is often difficult to implement for research purposes given the limitations of headsets, physical spaces, and cross-platform support.

In contrast, web-based VR simplifies users' access to this platform by being available through most devices with web browsers to experience immersive content [7]. Web-based VR is a compelling solution facilitating"universal" access to VR without needing additional software requirements [4]. For accessing web-based VR on mobile devices, orientation sensors help position the visualization accordingly, while on desktops, one can move around using the mouse or trackpad [15]. This increased accessibility provides the potential for accelerating the design process of robots using web-based VR, as compared to traditional VR. Web-based VR is especially useful given both the diminished costs and lower hardware requirements involved in using VR during the COVID-19 pandemic and otherwise. This pilot study explored the feasibility of using a web-based VR platform to gather data for robot behavior design and to explore an interactive environment for an immersive experience of teen-robot interactions.

3 METHODS

3.1 Participatory Design

This exploratory usability study employed a Participatory Design (PD) approach [14], given that it is an appropriate method to engage vulnerable populations (such as teens)[1] in the design of social robots [2]. A PD methodology was beneficial as it prioritized the perspectives of the participants, by voicing their needs and concerns towards the design requirements of the social robot. Given teens are a vulnerable population, we relied on a co-design method [2] where teens collaborated in the process of designing the virtual social robot. This meant teens guided each design session and directly informed feedback process and further iterations.

3.2 Technology

With the goal of the study to determine the feasibility and accessibility of web-based VR tools as a novel research platform, we replicated the design of physical social robot embodiment in an immersive medium, while giving access to this medium to teens across the country, without the constraints of a VR headset. In exploring various web-based VR platforms, we came across WebXR and CoSpaces Edu as appropriate tools for the different purposes of our design sessions. Below we discuss these two web-based VR platforms used for this study.

3.2.1 WebXR. Given that most teens in our studies have access to a laptop and the internet, WebXR was chosen as the medium for prototyping the various combinations of the social robot's interactive prototypes. WebXR [5] provides the functionality to combine the necessary features of both Augmented Reality (AR) and VR to the web. To build the three different combinations of the social robot's sound, facial expressions, and colors, the research team used Unity and Blender for building the prototype and animations respectively and later published using the WebXR API, which was then accessed by the teens on their web browsers.

In WebXR, different variations of the robot focused on distinct features, namely (1) Color, (2) Sound, (3) Facial Expressions such as smile and blinking, were built by the research team. To emulate a common component in HRI, we focused on the greeting interaction, that is, the participant's first interaction with the social robot. For designing color that illuminated from the robot's body, we tested out dynamic color changes, based on findings from previous studies [16] with HRI that were not tested with teens before. To design sounds, we used the sound library available [9] for social robot interactions, and picked sounds appropriate for a greeting interaction. For designing facial expressions, we tested two distinct features that would show notable change [8] if absent, and thus chose smiling and blinking.

3.2.2 CoSpaces Edu. To provide participants with a virtual engaging participatory design process, the research team used CoSpaces Edu [3], an educational 3D creation web and app-based classroom tool that allows students to create 3D augmented and VR environments. Previous studies [6, 12, 20] have shown that CoSpaces Edu helped inculcate interest in STEM and VR within students. CoSpaces Edu also allows for a school-like classroom environment, where research assigns each participant their individual blank "creative rooms" while observing the participants' work real-time.

A custom 3D model of the social robot, built using Blender [13] was uploaded to each participants' personal CoSpaces Edu library. See Figure 4 for a snapshot of the 3D object library.

3.3 Sample

The pilot sample consisted of 10 teens, between ages of 13 to 18 years ($M = 15.5$). Participants self-reported their gender, which was evenly distributed among males ($n = 5$) and females ($n = 5$). All participants currently lived in North America (United States ($n = 9$) and Mexico ($n = 1$)). Teens also self-reported their ethnicity, as Pakistani ($n = 3$), Chinese ($n = 2$), Asian ($n = 2$), Latino ($n = 1$), White ($n = 1$) and Pacific Islander ($n = 1$). These teens were assigned two groups based on their preferred times for attending the design sessions.

3.4 Design Sessions

Each design session was conducted via Zoom, organizing participants in groups of 5 teens. Each session had a duration of one hour.

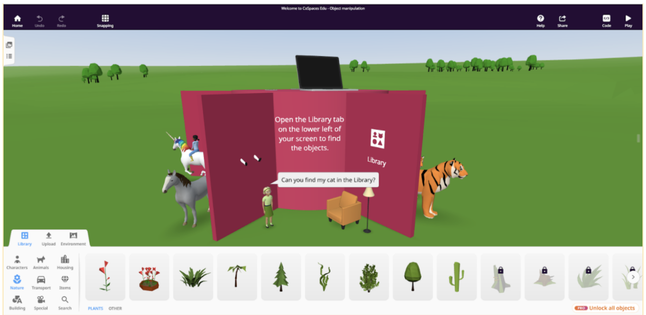

Figure 2: Screenshot of the CoSpaces Edu Library of 3D objects with the prompt "*Open the Library tab on the lower left of your screen to find objects.*"

See Figure 3 for more details on the study design and participants’ distribution. Teens were recruited using a digital flyer that was shared on social media websites accessible to parents and teens, and this study was approved by the University IRB. As an inclusion criterion, teens needed to have access to a laptop with internet access as this was needed to run WebXR and CoSpaces Edu during the design sessions. Prior to the design sessions, participants consented to participate and be recorded in Zoom. Their parents/guardians were informed of the teens’ participation, as well.

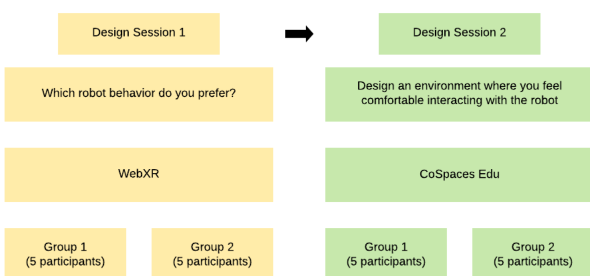

Figure 3: Design session purposes

3.4.1 Robot Behavior. In design session 1, we asked teens to compare two greeting behaviors elicited by the robot, in WebXR. For details on the two greeting behaviors, see Figure 1 for how the color changes from Figure 1 A (initial state) to Figure 1 B, and Figure 1 C (respective final states), along with differences in sound and facial expressions. The researchers shared the web-links of the WebXR platform that hosted the two separate robot behaviors. One teen was asked to volunteer to share their web screen with the group and interact with one WebXR robot behavior option at a time. After interacting with the first robot behavior, the research team asked the teens what they thought the first robot behavior communicated to them. After that, the volunteering teen switched to the second robot behavior WebXR link. The teens were then asked to share what the second robot behavior was communicating to them. Next, the research team asked the teens to compare the two robot behaviors, in terms of color change, facial expression, and sound, and share with the group, which one they preferred and why. Some of the questions that the research team asked were, *“Which scenario felt more welcoming or warm?”*, *“Which instance would you prefer between the two?”* and *“Was [robot]’s reaction what you were expecting in both instances?”*

3.4.2 Robot Environment. Given the teens’ emphasis on changing features about robot environments during design session 1, the research team decided to help teens express their ideas further by designing robot environments using CoSpaces Edu. To ensure free-form ideation and creation, we set up a classroom in CoSpaces Edu for the study and then provided each participant with their personal blank environment and a 3D model of the robot. After a tutorial on how to use CoSpaces Edu, teens were asked to design an environment where they would feel comfortable to interact with a robot, within 45 minutes. Researchers asked the participants questions about aspects as they worked on creating their environments, in real-time. Post designing, the research team asked each participant to explain their thought process of building and designing their respective environments, to the group. This discussion helped add context to the different facets of the robot environment. Some of the questions that the research team asked the teens were, *“Did you have an inspiration for it?”*, and *“What about the environment made it comforting?”*

4 FINDINGS

4.1 Engagement

Teens found the environment engaging and seemed to enjoy interacting with both the WebXR and Co-Spaces Edu platforms. The same group of teens participated in both design sessions, without any drop-outs in between. When asked about their experience of designing social robots in WebXR, teens emphasized the “escape from reality” this medium provided, especially during the stress of a pandemic. While sharing their preferences on robot behavior, teens discussed with one another the different features of the robot that led to a “warm” robot behavior. Teens described the color changing, blinking, and smiling respectively as “coming to life”, “human-like” and “welcoming”, all descriptions of “warm” robot behavior.

When designing their robot environments on CoSpaces Edu, most teens insisted on extending the session as they enjoyed interacting with the platform and wanted to continue their designs. Teens used 3D objects outside the standard environment library provided by CoSpaces Edu, to explain their environments’ themes, such as a floating backpack to represent adventure; or butterflies and bunnies to enhance the feel of nature and the outdoors. While most teens typically designed nature environments, either forested, or underwater (Fig. 1(D), 1(E), 4(A)), more abstract environments were also illustrated such as the surreal “futuristic, winter wonderland” scenario including a flying train (Fig. 4(B)). See Figure 4 for more details.

4.2 Feasibility

As researchers, these platforms were feasible to use and operate during design sessions. They provided the research team the ability to scale our study to multiple participants without changing the setup of the study. The tool allowed researchers to gather feedback

Figure 4: The teen designs of their social robot environments in CoSpaces Edu. A: Grassy field environment with strong nature elements; B:Futuristic winter wonderland; C: Indoor environment with elements of nature. In each figure, the robot is prompting, *"Hi, I'm EMAR? How are you today?"*

in real-time related to robot behaviors. For example, the research team heard mixed responses about specific color changes, but one participant suggested, *"If there's a way for [the robot] to change colors based on keywords from what we say that would also enhance the experience (like red to show anger, yellow for happiness, blue for calm) to substitute for human responses like when we talk with friend"*. When discussing the different sounds, teens stressed that they would like sounds that were more "robot-like". One teen also added, "If I seek a social robot I want to interact with a social robot, not a robot making realistic sounds". Moreover, some teens suggested additions such as (1) environment or background (e.g., "space" and "nature"), (2) movements (e.g., jumps), and (3) interactions (e.g., "voice" and "text"). The participants had no problem accessing or designing in these systems. The WebXR API led to faster prototyping of robot behavior, after listening to the wide range of feedback given by the teens.

5 DISCUSSION

Even though this was a pilot usability study, the participant feedback and experience demonstrated that web-based VR is promising in offering an accessible, web-based environment whereby participants can engage in co-design and interact with a social robot prototype and provide valuable feedback about their interaction experience. We plan to continue using web-based VR tools for prototyping different social robot features and environments, to collect more structured data for building design requirements. We also acknowledge the potential biases from participants who showed high interest in our project, the technology, and therefore revealed positive attitudes during the design process. In this exploratory study, all participants used standard screens for viewing the web-based VR platforms, however, future studies could explore these platforms on VR headsets or glasses with integrated augmented reality features.

Moving beyond the limitations, we recognize the effectiveness of web-based VR tools aiding not only the design process to provide efficient flow of feedback but also as engaging collaborative platforms for gathering interaction data from teens. These tools enabled immersive participatory design of our robot's features from teens from across the country, without difficulties of hardware. Given this potential, there are a multitude of possible future applications for robot design and HRI through web-based VR collaboration.

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