Virtual Family Room: Bridging the Physical Distance with Virtual Reality

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ABSTRACT

The efficacy of VR in training applications is well documented in the simulation community, and VR efficacy is being increasingly demonstrated in other applications such as mental health therapy, industrial design, and other collaborative activities. This paper describes a collaborative application of VR that has a positive impact on warfighter readiness outside of the training environment.

The Virtual Family Room provides deployed warfighters with the opportunity for meaningful interactions with family members who are at physically remote locations back home. The deployed warfighter shares the same virtual environment as their family members and plays family-oriented games (e.g., block builder), shares recreational activities (e.g., mini-golf), or engages in collaborative work (e.g., homework). The Virtual Family Room has an advantage over passive communication technologies, like video chat, because it provides an increased sense of participation and engagement, as well as allowing the whole family to share experiences rather than passive information. These effects are particularly important for young children who might not wish to engage in complex verbal communication.

The efficacy of the Virtual Family Room was assessed with a military family at a United States installation. The participant was not deployed, but was preparing for deployment, and he had prior deployment experiences. After initial system training, the family could participate in any of the virtual activities of their choosing. The family members were physically separated in different rooms during the sessions to mimic the family's distribution during deployment of the warfighter, and the sessions were recorded. Data were collected on the perceptions of the overall experience, enjoyment of the virtual activities, and input on possible improvements. The results indicated that the family interactions were more "realistic" than video chat and that the virtual activities provided more memorable experiences for the families. The Virtual Family Room demonstrates the usefulness of VR in bridging the gap between families during deployments and, thereby, increasing warfighter readiness.

ABOUT THE AUTHORS

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INTRODUCTION

As modern warfare rapidly evolves, warfighters are exposed to volatile, uncertain, complex, and ambiguous (VUCA) environments. Any achievable competitive advantage must be made available to warfighters to increase their readiness and resiliency on the battlefield. Training is the single most important factor when it comes to warfighter preparedness. However, recent studies show that, besides physiological factors, psychological factors are responsible for warfighter resilience. In fact, overtraining has been shown to degrade performance in a Stroop test (Hynynen, Uusitalo, Konttinen, & Rusko, 2008). Resiliency is the ability to recover from a setback or adversity. Warriors need to be resilient if they are to weather the attrition in a VUCA environment and to stay relaxed in the face of the high emotional stress that warfighters experience when risking life and limb for their country. Virtual Reality (VR) has shown great promise when used to simulate military exercises. In addition to allowing rapid prototyping and customization of the exercises, VR provides a cost-effective alternative to some types of training – which is important in the face of budget restrictions. One of the major components of VR research is showing that it maintains a sense of realism and that the users feel 'present' in the virtual environment (VE). For any VR application to be successful, it requires a well-designed VE that limits simulator sickness while increasing the sense of presence. In this work, we focus on building a high-quality multi-user virtual environment that brings warfighters and their families together in a realistic way. We propose that by maintaining close and life-like interactions with their families, warfighters are more at ease with affairs back home and, consequently, can be more resilient in the battlefield.

The intricate global political climate has led to hostilities and alliances between nations, frequently leading to the deployment of military personnel to strategic locations. The Defense Manpower Data Center (DMDC) puts the number of active-duty military personnel in the United States military at 1.34 million as of November 30, 2019: 228,121 of whom are female - this translates to 17.06% of the total active-duty personnel. This is in addition to the 0.8 million reservists. The literature on military families spans several decades. Earlier studies showed that in military families with an early beginning absence of the father, some male children tend to be more aggressive and show increased dependency while some girls show decreased quantitative ability (Hillenbrand, 1976). Recent findings indicate that military children might suffer substantiated maltreatment at higher rates than children in non-military families (Rentz et al., 2007; Taylor et al., 2016). Other findings show that parental deployment has residual and cumulative effects on the children and spouses - effects that do not go away even after the deployed parent returns home (Lester et al., 2010); Surprisingly, the most stressful part of the deployment cycle is not the long months of separations but the post-deployment period (Lester & Flake, 2013).

Previously, deployed parents (mostly fathers) attempted to maintain close psychological connections with their children via telephone calls, letters, and tape recordings (Hillenbrand, 1976; Hinojosa, Hinojosa, & Högnäs, 2012). The situation only got a little better with the advent of video conferencing and mobile phones. Video calls and phone calls typify the almost passive interaction between family members in separate geographical locations (Greene, Buckman, Dandeker, & Greenberg, 2010). The disadvantage of these kinds of interaction is that they are inherently passive and usually require long-winded gesturing and other forms of compensation to resemble anything close to face-to-face interactions in the real world. This is compounded when it comes to children because they may not engage very well with communication that limits action possibilities.

Research also demonstrates that intuitive, non-verbal communication fosters deep neurological connections between children and their parents (Schore & Schore, 2008). The worry for the deployed parent, especially if they are gone for a substantial amount of time, is that they cannot actively and physically participate in raising their children.

Consequently, this might lead to a weakening of the parent-child bond, which is difficult to rebuild even after the end of the deployment cycle. In addition, the spouse at home might feel like they are bearing the brunt of raising the children on their own thus introducing strife in the relationship. All these factors might linger in the mind of a warfighter, leading to decreased resiliency. Thus, to mitigate the negative impact of physical distance among family members during deployment, having a platform that offers a way for warfighters to interact with their children as they would in the real world, actively, jovially, and naturally, while physically separated would be advantageous for warfighter resilience.

The Virtual Family Room (VFR) is a VE meant to seamlessly bring together members of a family separated by distance. It includes many of the common fun games that parents would normally play with their children at home. More competitive games are included for adults. Also, it includes tools that will facilitate parent-children collaboration in tackling tasks together, such as solving homework problems. Each of the family members will have a head-mounted display (HMD) and hand-based controllers to interact with objects in the virtual environment. Upon loading the VFR application, the user is presented with the main menu that has two options:

- **Tutorial**: In this VE, the user is taken through the different aspects of locomotion and interaction necessary to enjoy their VFR experience such as teleporting, writing, grabbing, and customization. This is primarily designed for first-time users because the users need to know how to be productive while in the VFR.

- **Family Room**: In subsequent visits, and once they are comfortable with the controls, the user is encouraged to skip straight to Family Room which has several games and activities. Most of these are collaborative and are designed to imitate real-world interactions thus encouraging bonding between parents and their children. The Family Room has two main components - the backyard and the living room.

Collaborative virtual environments (CVE) are usually evaluated on the following aspects: cohesion between team members, implicit communication, and task performance (Sarmiento, Maciel, Nedel, & Collazos, 2014). To fully describe a virtual meeting room, the following topics must be covered: awareness of periphery, navigation and locomotion, persistence, and usability of metaphors (Frécon & Nöu, 1998). The VFR is a high-quality CVE which addresses all these points while remaining accessible to both children and adults. It builds on previous efforts to design a virtual family room (Rukangu et al., 2020).

VR is on the cusp of going mainstream with the introduction of affordable wireless headsets with touch controllers for interaction, for example, Oculus Quest, HTC Vive Cosmos, and the Pico among others. This has led to optimism that VR is about to make a major breakthrough into the consumer market. At the recently held IEEE-VR conference, which was the first major conference to be hosted online due to the COVID-19 pandemic, Mozilla Hubs was used in conjunction with video conferencing to overcome the travel restrictions.

RELATED WORKS

Resilience can be looked at through a variety of domains that enhance the readiness, lethality, and modernization of the armed forces. The level of a warfighter's resiliency can be affected by physiology, psychology, sex differences, physical training, and nature (Nindl et al., 2018). Although performance is heavily dependent upon physiology, it can be enhanced by developing psychological coping mechanisms. Some research has gone towards developing a comprehensive resilience model that shows how resiliency during the deployment cycle could depend on the whole family (Riggs & Riggs, 2011). In addition to the warfighter's unit and their personal traits, their families play a leading role in the psychological well-being of the warrior, as evidenced in a thorough literature review (Meredith et al., 2011). VR has been used in military training exercises and, in some cases, has been shown to beat traditional live-fire training in learning motivation and final performance (Bhagat, Liou, & Chang, 2016).

Collaboration in VR is not a new concept and VR has been used in industrial settings to facilitate collaboration on projects. Pick et al., describe a framework that would overcome the cost and distance challenges brought about by the back-and-forth correspondence involved in design reviews in factory layout planning. They use an asymmetric set-up (Pick, Gebhardt, Weyers, Hentschel, & Kuhlen, 2014). Cecil et al. developed a CVE where an experienced surgeon could remotely teach and evaluate a student (Cecil, Ramanathan, Rahneshin, Prakash, & Pirela-Cruz, 2013). Non-verbal cues, for example, gaze interactions are known to play a role in communication. Bailesnson et al., found that

head orientation is useful for transmitting important information even for tasks that had some form of verbal communication (Bailenson, Beall, & Blascovich, 2002). Spatial audio has been explored in different areas like in remote collaboration where Regenbrrecht et al., used spatial audio for three participants arranged around a table (Regenbrecht et al., 2004), while Gortzel et al., test the effectiveness of spatial audio in distance estimation in VR when used in conjunction with visual cues, concluding that there was a limit to our ability to detect audio-visual distance incongruence (Gorzel, Corrigan, Kearney, Squires, & Boland, 2012). Kim et al., show that spatialized audio is capable of presenting critical and noncritical information in spatially separated locations because aircraft control operators had a better response time when using spatialized audio (Kim, Miller, Rusnock, & Elshaw, 2018).

DESIGN OF THE VFR

Hardware

The VFR is targeted for the wireless Oculus Quest headset which has inside out tracking, a per-eye resolution of 1440x1600, and a 100° Field of View (FOV). Since the VFR Quest set-up requires nothing beyond the usual set-up required for other apps and games (normally, it's setting up of guardian boundaries), any user can quickly and consistently set up for any indoor location. The VFR application is flexible and supports both teleportation and walking metaphors thus allowing it to be used with a wired headset like the Oculus Rift-S. The only limit is that the amount of walking for the wired headset is limited by the length of the cord connecting the computer and the Head Mounted Display (HMD).

Software

The VFR was designed using the Unity3D game engine, and the environment was modeled using Blender software. The software runs on Oculus Quest HMD with a high frames per second (FPS) to minimize the chances of inducing visual-based motion sickness.

The main software requirement for the VFR was that it needed to be a Collaborative Virtual Environment (CVE). However, since it's used in a family setting, it needed the following additional features:

- customizable avatars.
- persistence between sessions.
- several fun activities and games.
- synced video viewing and control.

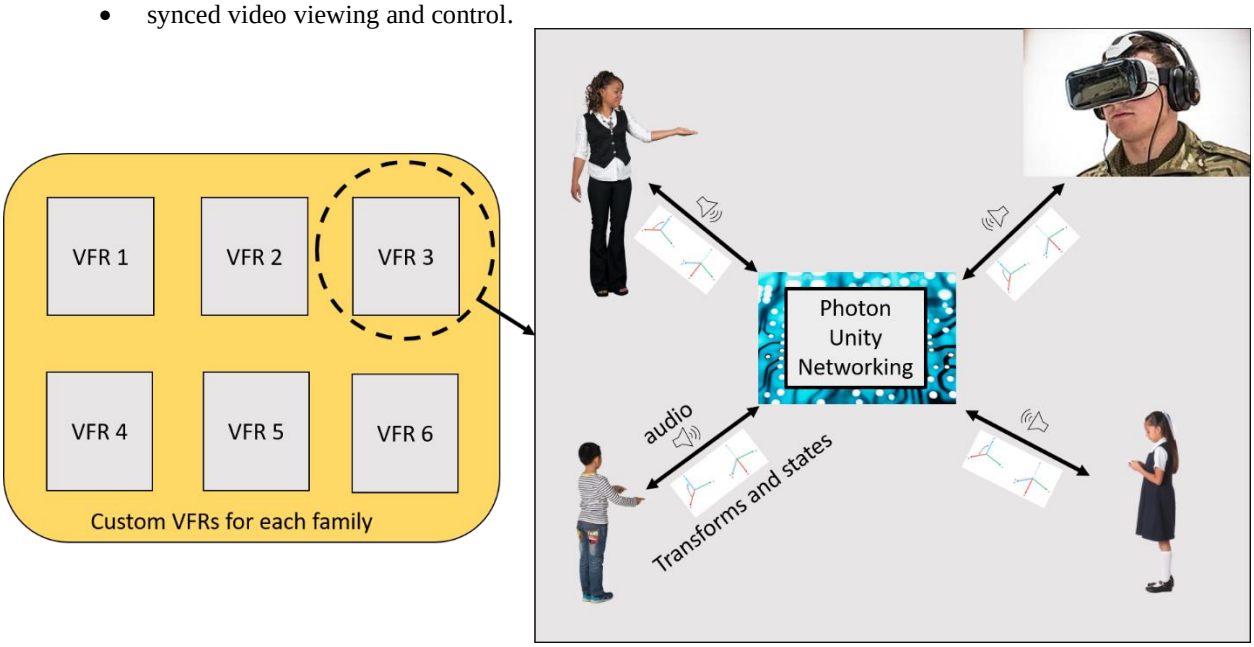

Figure 1 Overview of the VFR system. On the left, are several unique VFRs for different military families, while on the right, we highlight the use of Photon Unity Networking to transmit and synchronize data between family members.

The Family Room

On launching the VFR application, the user is allowed to select whether they want to go straight to the Family Room or whether they would rather go through a tutorial first. The Family Room is the platform for all multiplayer interactions.

Multi-player Design

We leveraged the Photon Unity Network (PUN) framework to implement the multiplayer feature of the VFR. PUN hosts the VFR in its globally distributed Photon Cloud to guarantee low-latency and the shortest round-trip times for each of the family members. Figure 1 above shows the multiple VFRs and how PUN stitches everything together. Each family is assigned a unique room number which allows them to get into the same room concurrently and prevents users from accidentally joining another family room. The family room number was used to implement state persistence in the family rooms by saving the state of the Immersive Virtual Environment (IVE) in a server. Then, during the subsequent loading of a scene, we instantiate the necessary objects to take the application to the saved state. Figure 2 below shows how different family members can get together to participate in activities.

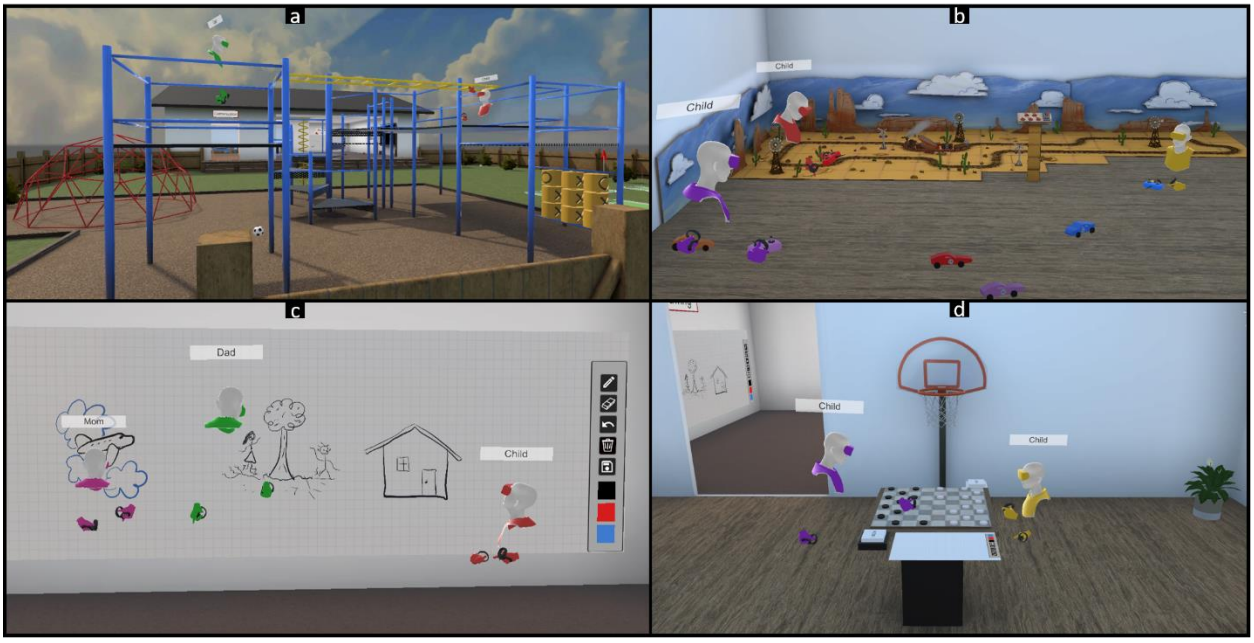

Figure 2 shows multiple family members taking part in activities concurrently. The participants were in different physical locations. a) child playing with father in the backyard. b) children racing their remote-controlled cars. c) the family drawing on the whiteboard. d) playing checkers

Avatar Customization and Mirroring

To differentiate between the users in the VFR, the users are allowed to customize their avatars. At the moment, the VFR avatar consists of the head, torso, and hands. The users can change the colors and names of their avatars. The names are displayed prominently on top of the avatar's head making it easy to discern between the users. There is provision for eight different colors for customization. We included a miniature 3D mirror of the user's avatar right by the customization area; the users' changes are reflected in real-time on the avatar. Though further research needs to go into this, preliminary interactions in the VFR among the developers showed that they could easily tie an avatar to the owner; the height differences and the mannerisms exhibited by their respective avatars were easily discernible.

Locomotion and the Watch Interface

The VFR supports arc-teleporting and physical walking by the users. The only requirement for physical walking is that the users set-up the guardian bounds - this prevents them from walking into objects in the real world. A watch interface, chosen because a watch is easily accessible, was designed to facilitate movement between scenes through menu selection. The watch is activated by a ray-cast from the touch controllers or by a tap from the user's index finger.

Once activated, a menu is displayed that allows the users to flit between the scenes, for instance between the tutorial and the backyard, as shown in Figure 3. The watch interface also shows the room number/name that the user is currently in, the people in the same room, and the available rooms - allowing it to serve as a useful troubleshooting tool. In addition, the interface lets users exit the application.

Figure 3 The watch interface can be used to teleport between scenes. Either of the controllers may be used to teleport within scenes

Living-room and Backyard Activities

Several games were implemented to equip the VFR with a realistic representation of activities that a parent would play with their children in real life, e.g. basketball, soccer, and golf. We also implemented some activities that would require strategic thinking by children like checkers, lego builder, and tic-tac-toe. The video and whiteboard will serve as tools for interactive learning and demonstration, or just as a means to increase the bond between the family members.

Writing and Drawing

An expansive whiteboard that covers one wall of the VFR allows the users to do collaborative writing and drawing. The board will serve as a useful tool for several activities such as brainstorming or expounding ideas and concepts. A user can hold one of several tools in their hands including a marker and eraser. We placed a menu on both sides of the whiteboard which allows the user to select the tool that they want to use, change the color of their markers , save their drawings/writing or even undo their last action. To draw or erase something on the board, the user needs to be close to the whiteboard at which point the tool in their hands becomes visible. The whiteboard is a crucial part of the VFR because the parents and children have another dimension to express themselves, through drawing and writing. The drawings can be saved and retrieved from the devices for offline use, to be printed out for example.

Strategy Games

The lego-builder features weightless blocks of different shapes that may be arranged strategically to take different forms. The family members would need to communicate a collaborative strategy and hand out different roles to reach a final building goal. A recycling bin that deletes lego blocks from the scene is provided, and three infinite lego block spawners are included as well. When grabbed, these spawners generate a new lego block identical to it in the users' hands. Three paint buckets are provided along the edge of the table to allow the users to change the color of the lego blocks. Dipping a block into a paint bucket changes the block's color into the color contained in the paint bucket.

Checkers is a two-player game that calls upon the wits and competitive spirit of the family members. It has a reset button that resets the board and the checkers' pieces. The pieces themselves can be handled, moved, and even thrown about like any other object in the scene. The checkers board-game can be seen in Figure 4c. A 3D version of Tic-tac-toe is available in the VFR and is shown in the background of Figure 2a. It consists of nine cylindrical wood pieces

that have an 'X' and an 'O' on either side of them; they are each mounted on a cylindrical joint. Two players take turns to roll the pieces by grabbing and pulling on each of the pieces until it turns.

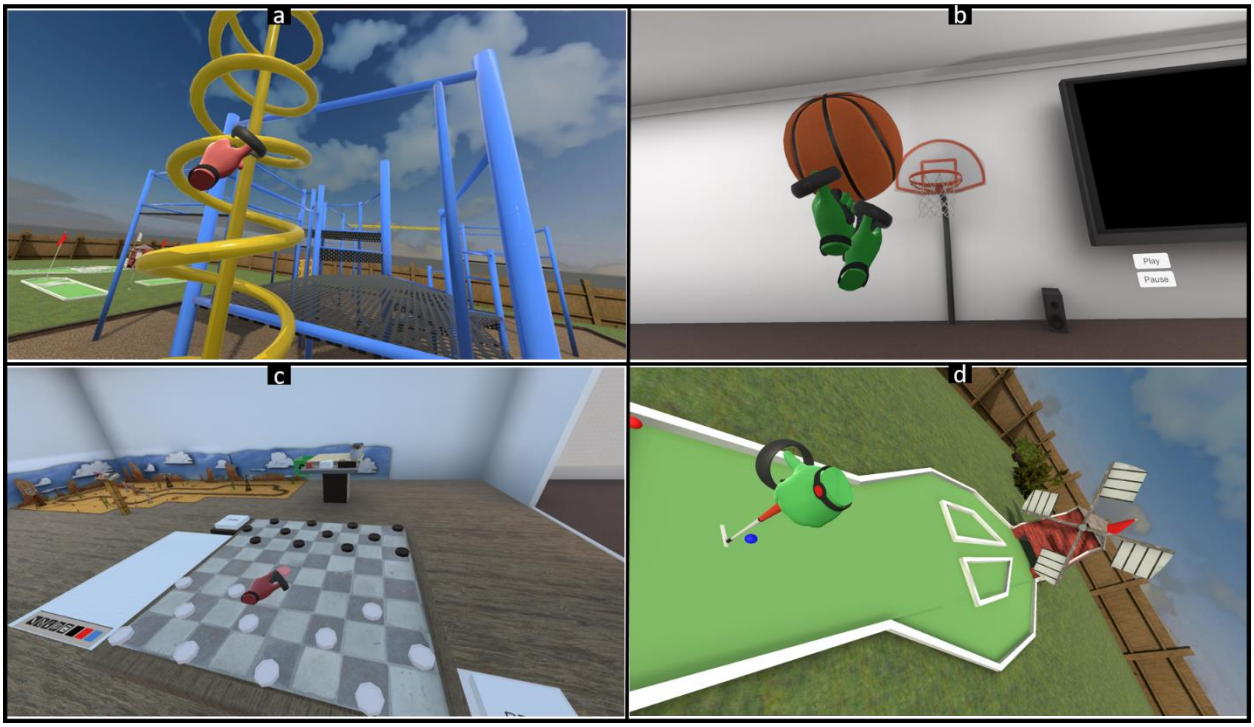

Figure 4 shows a first-person view of some of the activities and locations in the VFR. a) playground. b) living room. c) checkers board with the train in the background. d) mini-golf course

Fun Games

The Mini-golf game consists of three courses whereby the system spawns a ball periodically to ensure that the game is played perpetually. A golf club is provided for each course. The clubs act like grabbable objects and can be swung by using the same motion that would be used in the real world. As with all the games in the VFR, it was left to the family members to keep a record of the score. An automatic trainset, shown in the background of Figure 4c, that runs around a predetermined course allows the users to get on the train and ride it. A basketball hoop and two basketballs are included in the living room. An elaborate playground is located outdoors - this adds to the realistic view of the VFR while giving the children a chance to swing on the rails like in a jungle gym. The way this works is that the user grabs one of the rungs on the ladder and pulls their hand towards them. This makes their virtual body move forward. Remote controlled cars are included, and the family can race each other in the family room.

Synced Video

A virtual video screen is provided on one of the walls in the living room. Play and pause buttons that are activated by raycasts allow control of video-play. The video-sharing feature could be a useful tool for sharing experiences and bonding. It could be useful for tutoring sessions where the appropriate video would get pulled up and the parents would walk the children through a concept by playing and pausing the video as necessary. When a video is played or paused by any user, the pause/play action is updated in all the videos in all other remote virtual environments, this allows for real-time syncing of video. The same applies to the situation where a user selects a different video: the selected video is loaded in all other VEs. The next step with the video-sharing platform is to allow for custom video uploads. For instance, videos about memorable moments about the kids' or parents' days, for example, a goal scored by a child can be uploaded and watched together. Figure 5 shows the location of the video player in the VE.

Figure 5 The family watching a video in the living room. Synced video allows any user to pause, play, and select videos, upon which their commands are propagated to all other videos in the other users' virtual environments.

Spatial Audio

Audio feedback is the second most popular response in virtual environments. We implemented spatial audio using Dissonance in conjunction with PUN. Also, whenever a user speaks in the VFR, a speaker icon appears above their head thus acting as an identifier of the source of the sound.

Tutorials and Avatar Demonstration

The VFR is meant to be used by people of differing comfort with using virtual reality gear and with varying degrees of familiarity with gaming. We felt that it was important to include a self-contained tutorial that would guide first-time users on how to interact with objects, how to customize their avatars, and how to move around in the virtual environment. The tutorial needed to be self-contained since the VFR system is meant to ship to users who did not have easy access to the developers, if at all. Abundant help texts and directions were placed strategically on the walls and the controllers. The tutorial was split into 5 stages. By design, the user had to successfully get through the previous stage before they could proceed to the next one. This was enforced by translucent walls between the stages that would not allow the user to walk or teleport through to the next step. The system played a short congratulatory sound and removed the blocking walls whenever each stage was completed. In the first stage, the user was asked to teleport to a marked location by pushing on the appropriate joystick on their controller.

In the second stage, the user needed to type in a preferred nickname using a virtual keyboard that resided on the wall. It was in this stage that they also selected a color for their avatar. The following stage showed the user how to grab and move an object. We included an avatar agent that detected when the user got to this stage; the avatar would then demonstrate the steps to grab an object, and how to swing a lever that would clear the intersecting wall to the next stage. The user learns how to write in the next stage which has an avatar demonstration too. Finally, in the final stage, the users gained familiarity with the watch interface, finishing the tutorial by teleporting to the backyard by interacting with the watch interface menu.

USER EVALUATION

The User Evaluation plan involved collecting data from military families. The families would be identified through the National Military Family Association. Each family would use the VFR to complete a series of virtual interactions

and then be given "free play" time. Data on the ease of use, perceptions of interactivity, and overall impressions of the system were to be collected as well as any feedback to improve VFR over several months. However, the complete user evaluation of VFR was suspended in March 2020 due to COVID-19 restrictions. As a consequence, the only data available at this point comes from an initial user feedback session. Only that data is reported here.

We had a military family comprising the husband (a soon to be deployed airforce officer), the wife and two children aged 3 and 6 respectively try an earlier version of the VFR. The 3-year old was too young to independently use the VFR (the Oculus Quest is rated for ages 13 years and up), and initially, he was supposed to watch from the sidelines. However, he was so enthusiastic about taking part in the fun that the decision was made to include him too. One of the researchers held the Quest in a comfortable position to counterbalance the force on his head and neck. Also, he would occasionally request to be teleported to where the rest of the family was located in the VFR. This necessitated a simple transfer of the HMD from the boy to the researcher and back again. The session was run in three separate spaces to simulate geographic separation - the three family members might as well have been on three different continents. Two researchers were present in the VFR with the family, but they kept a respectful distance between themselves and the family at all times. We recorded videos and pictures of the interaction and had an open session afterward, during which the family gave us feedback on their experience while in the VFR. Their experience was very positive and they indicated that the VFR platform was quite realistic compared to skype video calls and phone calls - which is how they usually communicate. They particularly liked the "catch" and basketball games because they were similar to things that do together normally at home. We also garnered useful feedback and plan on implementing their suggestions in future iterations of the VFR. We implemented the assisted teleport feature where the users could teleport each other in the VE after receiving feedback from the family. We are in the process of implementing augmented virtuality, which brings a view of the surroundings into the virtual world.

Some excerpts from the debriefing with the family sharing their thoughts on their experiences are shown below:

- Mom: "I think it's very cool because we can play catch… At home we always play sports"
- Dad: " And it's the same thing, you know, the same level of catch"
- Dad: "It's like if you're still there with them, you know? … I know it's virtual reality but you'll be able to at least, um, interact the way you do when you're home."
- Dad: "It's literally the same thing we do at home, we go back, like, to the backyard if it's raining we play catch inside…"
- Mom: "And you know, like he, taking the ball from me, like messing around, that's the how we have fun, like so, it's really accurate."
- Dad: "I threw the ball but she didn't catch it, so…that's what in reality happens."
- Daughter: "Um…I like that, choosing the color." The daughter liked the color-selection during avatar customization.

CONCLUSION AND FUTURE WORK

We have described the design of the Virtual Family Room, which is a collaborative virtual environment that lets geographically separated members of a family meet virtually; the family can collectively or competitively play common games. While in the VE, the users can physically walk or teleport. A group teleport feature allows the adults to teleport children swiftly and vice versa. Also, an on-demand menu called up by tapping on the wristwatch allows the users to teleport between scenes.

The design and conceptualization of the VFR were made possible by an interdisciplinary team drawn from several research labs at the University of Georgia, namely: Engineering, Sociology, Human Development, and Journalism and Mass Communication. Due to the COVID-19 pandemic, we were forced to delay a planned study and the project is still at the focus group stage where several military families are invited to try out the system while we iterate on the family room prototype. Feedback gathered from one military family led to the implementation of the assisted teleport and the addition of augmented virtuality to the system. They found the VFR experience to be more realistic and particularly helpful in connecting with the children who might not fully grasp why the parent was away and what they were doing. We also invited several chaplains from the Robins AFB in Warner Robins, Georgia to assess the VFR as

a preliminary step before rolling out the study in their base. They were all enthusiastic about the system and its potential to revolutionize communication for deployed warfighters and their families.

VFR has the potential to increase warfighter resiliency by helping them naturally connect with their families while deployed. The advantage of VFR is that it allows active interaction among family members as opposed to the passive interaction of voice or video chat. These advantages will be useful if the VFR grows, as intended, into a hub to lead to other VEs like workplaces and schools. The preliminary data supported these advantages and provided insight into other potential applications of VFR. In fact, the family who participated in the initial data collection was convinced that it was a better means of interaction compared to video and phone calls, particularly because it allowed the young children to participate wholly in the experience. Clearly, a complete evaluation is required before the full capabilities of VFR can be generalized. However, the application of virtual reality does seem to provide a new avenue for building warfighter resilience. The planned study will involve actively deployed personnel from all branches of the military and their families. They will be given a VR system consisting of an Oculus Quest headset and the related peripherals. As with any military technology, the pressing issue is the security of the system and the possibility of the introduction of vulnerabilities to military bases, or even the exposure of classified information. The VFR is built to run as an app in Quest with minimal permissions, thus it does not collect any location information. Furthermore, the app updates will be tightly controlled by the researchers.

The VFR focuses more on built-in play and accessibility to children as opposed to the currently available VR conferencing systems like Second Life, VRChat, Hubs, and Virbela. Though they all offer the ability to change customize avatars and join in special rooms, the VFR makes it easier for children to use these features. In addition, VFR offers family privacy controls that are vital when working with children. Moreover, the target user for the VFR is the small-group (family) and the VFR design is tailored to meet their expectations with everything placed in the virtual environment.

Finally, the next step in the VFR design is to make it accessible to other non-immersive platforms like computers and smartphones. This asymmetric interaction will allow for deployed warfighters to interact with their families when they do not have the space to set up their VR systems, or when they are short on time. With the unfortunate COVID-19 pandemic of 2020 forcing lengthy separations between family members, the VFR would be a great tool to bridge this physical gap within the DoD and civilian communities.

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