Designing Virtual Reality Tools: making simulated interventions feel and act like their real counterparts

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ABSTRACT

While global leaders in Virtual Reality (VR) simulation maintain a strong presence in use-of-force scenarios, their VR systems are consumer-oriented. This leads to compromises that lack crucial qualities such as appropriate pistol weights and missing magazine clips, which military personnel train to recognize and control through muscle memory. Using consumer-oriented equipment for training could contribute to hazards and reaction errors in the field.

Training officers in scenario-based decision making simulations is integral to preparing cadets for service; however, it is challenging to simulate the significance of real-life scenarios. The University of Regina and Royal Canadian Mounted Police (RCMP) have partnered to resolve this by building effective tools to train the paramilitary. VR promises more life-like visuals and complex situations, which require the trainee to use their body as they would in the target scenario. Yet, the use of VR risks gamifying the situation and trivializing the consequences of the trainee's choices. Making a simulated decision bear the weight of the real-world is a multifaceted problem, but one crucial aspect is ensuring simulated interventions feel and act like their real counterparts.

We present two prototype VR weapons based on the service pistol and the Conducted Electrical Weapon (CEW) of the RCMP. Using the SteamVR hardware development kit, with 3D printed and original manufacturer parts, we have produced synchronized virtual weapons. By reproducing the feel of these tools and matching them with their visual representation in VR we are taking initial steps towards decision-making simulation that begins to adequately represent the real-world objects and situations it simulates. Guidelines arising from the development process can help further the development of physically reproduced forms of interaction for VR training. The project advances research-creation practices, adds critically designed tools to a use-of-force training industry, and forms a unique network for co-creating innovative research focused on improving the safety of Canadians.

ABOUT THE AUTHORS

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INTRODUCTION

Virtual Reality (VR) systems enable a sense of presence in simulated environments through multisensory immersion. Presence, or what Slater more specifically calls place illusion, is the sense of "being there" in the simulated environment (Slater, 2009; Steuer, 1992; Witmer & Singer, 1998). VR experiences are commonly accessed using a specialized headset and are made interactive through the use of handheld remote controls or movements tracked by sensors in the headset, on the body, or installed in the room.

Global leaders in VR simulation, such as Oculus, Valve, and HTC, are focused on the consumer-oriented gaming industry. While this industry maintains a strong presence in use-of-force scenarios, their VR tools are marketed for gamers and designed to be as general-purpose as possible. Off-the-shelf controllers therefore conflict with important physical qualities of the virtual weapons used in training. The controllers lack features such as appropriate pistol weights and magazine clips, which the RCMP are trained to recognize and control through muscle memory gesture. As a result, using consumer generated tools for RCMP training could reduce training effectiveness and increase the potential for hazards through reaction errors in the field. To resolve this issue, we have formed a research-creation partnership to develop more effective VR tools to train the paramilitary in Canada. As the gaming industry harnesses the benefits of VR for economic gains (Christensen et al, 2016), it is crucial that academia and the paramilitary contribute more focused and critical designs to better understand the systems in use, and to enable leadership in developing best practices for their use.

The research investigates restricted use-of-force tools identified by the Simulations, Training and Innovation Unit at the Royal Canadian Mounted Police (RCMP) Depot in Regina, SK. The tools currently used by the RCMP to perform their duties are a Smith & Wesson pistol, a Conductive Electronic Weapon (CEW), Oleoresin Capsicum (OC) Spray, and a C8 Carbine rifle. Our research begins by reproducing the form and feel of these tools to customize them as VR peripherals which will be applied within VR training installations, using multi-user networked interfaces, electroencephalogram (EEG), and biosensing feedback systems. In addition, we are designing appropriate smart props and we aim to further develop the system to include additional sensory technologies such as active haptic feedback and olfactory systems to test, trial and design effective training situations that expand knowledge in the field of training and simulation using VR.

This research project is invested in critical design methods (Dunne & Raby, 2007) that apply experimental approaches to VR training and simulation scenarios. We aim to develop creative practice-based solutions through a critical making process to effectively and physically engage with use-of-force VR technologies beyond the simulated environment into an augmented experience. Garnet Hertz describes critical making as: "mobilizing approaches from experimental media art, critically engaged industrial design and computer science interaction research that take cultural production and humanities-oriented inquiry seriously within the context of building functional technologies." (2016) Working through this lens enables our team to not only develop the necessary technology, but to engage with it critically and fully consider the ethical implications of its development throughout that process. A critical approach is essential to ensuring that we contribute to a responsible future for VR training technology that enables better decision-making and saves lives. This will also serve to improve the relationship between security forces and the public through increased transparency and trust in servicemembers' decision-making capabilities.

Innovating Situational Training

A report from Public Safety Canada, 'Dialogue on Handguns and Assault Weapons,' states that "firearm-related violent crime has increased in recent years, despite the fact that the rate of violent crime, generally, has modestly decreased" (2018, p. 4). The RCMP is charged with ensuring its officers can respond to a variety of situations with the best training possible. To do so, they regularly update their training to keep pace with the evolving demands of police work across the country. They deliver situation-based training scenarios that simulate the specifics of the job within Canadian society. The cadet training program is governed by legal policy, and analysed for effectiveness and appropriateness using thorough testing and review methods (RCMP Cadet Training Program, 2017).

The bulk of cadet training happens on-site at the RCMP Academy, situated at Depot Division in Regina, Canada. Scripted scenarios are produced on-site or subcontracted. This model requires a large investment in equipment, software, and hardware licensing. Cadets and officers from all over the country must travel to the centralized RCMP Depot for training. As the cost of VR technology continues to lower and performance improves, we have the opportunity to build a networked VR kit that can be distributed to RCMP divisions across the country. This would allow the RCMP to increase access to training across the force and simultaneously reduce costs. An example of a time-sensitive and effective networked training module, which could be distributed through these means, is the new marijuana detection policy methods as a VR scenario. All officers would be required to fulfill the training module with their on-site VR kit. The training could then be experienced in a rich and enhanced method in a timely and cost-efficient way across the country, providing continual training throughout servicemembers' careers. Most importantly, these new tools will help the Royal Canadian Mounted Police achieve innovative methods to improve training and reduce risk to officers and the public in the field. By improving the speed, frequency, efficiency, and quality of training, the quality of life and safety of Canadians can be increased across the country.

The current situational training at RCMP Depot uses a large footprint media installation, housing a non-immersive system in which situational videos are projected life-size on a screen. The video is played and the trainee must decide how to respond. An observer controls simple decision points in the narrative to keep the experience from being overly predictable. While this system uses a modified version of the actual service-weapon and real actors in the video, it lacks the level of presence that VR is capable of delivering. By replacing this system with VR simulation, not only will the system be made more portable and ubiquitous, but also it will improve the quality and value of the training by improving presence and encouraging trainees to behave as they would in a real scenario. The VR scenarios further allows for greater variance and branching structures which requires cadets to respond to the scenarios in a more realistic fashion that better represents the unpredictable nature of their line of work.

Lackey et al. showed that levels of stress and workload in live training can be reduced through VR training (2015). This suggests VR situational training is useful for reducing stress and workload in subsequent live training and potentially in actual scenarios in the field, giving officers a clearer mind to make better decisions. To properly transfer skills to subsequent live training and field operation requires that the simulation sufficiently match the physical and psychological characteristics of the actual scenario.

Presence in VR-based Situational Training

Essential to reproducing the psychological demands of the scenario is the trainee's presence in the virtual scenario. Steuer defines the mediated presence found in VR, telepresence, as "the extent to which one feels present in the mediated environment rather than in the immediate physical environment" (1992, p. 76). He suggests that it is affected by dimensions of vividness, divided into breadth and depth, and interactivity, divided into speed, range, and mapping. Vividness is the result of sensory breadth, or the number of sensory dimensions presented, and depth, or the resolution of those modulated senses (Steuer, 1992).

Slater calls this sense of "being there" place illusion and claims that this illusion is the result of the VR system's capacity to support sensorimotor contingencies (2009). Sensorimotor contingencies are "the actions we know to carry out in order to perceive." (Slater, 2009, p. 3550) For example, a Head Mounted Display that restricts the user to head rotation, such as the Samsung GearVR, restricts the available sensorimotor contingencies and will therefore have a significantly lower place illusion than a system which supports 6 degree-of-freedom movement in the virtual space. The senses are intertwined and constantly compared, particularly that of vision, proprioception, and touch (Fuchs, Moreau, & Guitton, 2011, p. 12; Jerald, 2016, p. 122). In the above example, sensorimotor contingencies are satisfied through the linking of the proprioceptive and visual senses in moving about the space; however, in most VR experiences, when the user reaches out to touch and interact with objects in the virtual environment, they find the tactility expected to be lacking as they reach through empty space, breaking the place illusion and potentially reducing their immersion and sense of presence.

Including real objects (Hoffman, 1998) and passive haptics (Meehan et al., 2002) in VR experiences has been shown to increase the user's sense of presence. Based on Steuer's dimensions determining telepresence, these tracked, synchronized physical objects increase the vividness of the experience by extending the breadth and depth of the senses engaged. First, they broaden the engaged senses, allowing the user to touch and feel an object in the virtual environment. Second, including real objects increases the depth of the sensory stimuli presented. Ordinary VR controllers are designed to represent a variety of things and as such their weight, texture, and physical appearance do not match that of the objects they represent. By simply including tracked real objects, the depth of sensory stimuli matches the object represented, maximizing the contribution of touch and proprioception to the sense of presence. In terms of Slater's place illusion, the object satisfies the proprioceptive and tactile sensorimotor contingencies, an illusion which may have the capacity to extend out into the surrounding environment as suggested by research in this area (Hoffman, 1998; Meehan et al., 2002; Desnoyers-Stewart et al. 2018).

Including real physical objects in VR simulations is not always feasible. Particularly with movable and interactive objects, it requires some level of modification to include the sensors and electronics required for tracking and representation in the virtual environment. As such, reproductions of real objects with compromises in levels of fidelity are needed to produce cost-effective and consistently satisfactory tangible experiences. The aforementioned concepts of presence are user-centered and focus on their perception of the virtual environment as a whole. To better understand the object's capacity to expand the breadth and depth of the VR sensory experience and therein contribute to place illusion and create a sense of presence, the focus of presence needs to be shifted from the user to the object itself.

Object Presence

The concept of object presence has been used to describe the sense of presence attributed to virtual objects displayed using augmented reality systems (Stevens et al., 2002; Poretski et al., 2019). Stevens and Jerrams-Smith define object presence as "the subjective experience that a particular object exists in a user's environment, even when that object does not." (2001) Of course, as in the case of a VR controller, the object shown does, to some varying degree, exist in the user's environment; however, the perceived object is not that which is physically present. While object presence is not typically used in the context of VR, the term nonetheless serves as an ideal way to describe the sense of presence attributed to a tangible object in the virtual environment.

Moreover, the actual physical appearance of the controller is likely to have an effect on the sense of presence and behaviour of the trainee. As Steinicke et al. suggest, gradual transitions to the virtual world increase presence (2009). In their study they began their VR experience in a virtual replica of the surrounding physical environment to transition from the physical space into the simulation and enhance the user's sense of presence. Similarly, presence, particularly object presence, can be enhanced by matching the physical and virtual representation of the VR weapon. In this way a similar transition effect might be achieved through the persistence of the object within the virtual environment.

For example, in the existing non-immersive simulation, the use of the actual service-weapon creates this sense of object presence despite the system's limited immersive capacity, yet the trainee is still aware this is not an actual loaded weapon. As Stevens et al. suggest, the environmental, social, and personal dimensions of presence can also contribute to object presence and vice versa (2002). In the current RCMP scenario training, there is a strong social aspect of presence since the weapon must be treated as a real one, with the same rules regarding disarming, storage, and use of the weapon regardless of its physical inertness. This creates a loop between the social presence and object presence of the training scenario leading to greater overall presence in the scenario.

Riva et al. also show that there can be a cyclical relationship between affect and presence (2007). They showed that the emotional state of the user contributed to the sense of presence, and the sense of presence contributed to the capacity of the VR environment to evoke a particular emotion. While the mechanism behind the connection between presence and emotion is not yet clear, a review by Diemer et. al showed a consistent correlation across a variety of studies (2015). Affect is an important component in training as the trainee must learn to perform in the presence of the strong, complex emotions present in a real-world situation. The interrelation between affect and presence suggests that enhancing object presence could better induce those emotions and lead to more realistic behavior in the training scenario. Furthermore, those emotions may contribute to a greater sense of presence, further compounding the effect.

We designed the VR weapons for use in situational training around these concepts of presence, endeavouring to create as realistic an experience as possible to ensure the emotions experienced and actions taken in the simulation matched those of the real world situation as much as possible. In the following sections we describe the development process, the current implementation of the training tools, and discuss the insights gained thus far and resulting future work.

DEVELOPMENT PROCESS

The development of these VR weapons followed an iterative and experimental research-through-design process. We used rapid prototyping techniques such as 3D printing to quickly develop each iteration and improve on the previous one. The design became more complex and iteration cycles lengthened as the product became more and more refined. With development beginning in March 2017, our team was able to produce a proof of concept in less than a month and a fully functional prototype pistol in just one year. We were able to integrate the knowledge developed through prototyping into a second design, which emulated the RCMP CEW, taking another year of development to refine to the point presented in this paper.

This iterative method also allowed us to continually adapt to the rapid progression of VR as new technologies were developed and products released. The systems used for tracking and integration in the finished product were not yet released at the outset of this project and were quickly integrated as soon as they became available.

In artistic research, the process of creation itself plays a critical role in the production of knowledge. According to Borgdorff, “the creative process forms the pathway (or part of it) through which new insights, understandings and products come into being.” (2010, p. 46) Those insights and understandings become embodied and embedded within the product created and documented in the notes, photographs and design documents produced along the way. In describing their model of research through design for interaction design research, Zimmerman et al. state that, “through an active process of ideating, iterating, and, critiquing potential solutions, design researchers continually reframe the problem as they attempt to make the *right* thing.” (2007, p. 497)

Our team included artist-researchers, engineers, and creative technologists supported by the RCMP technical development and training staff. We met regularly to discuss challenges, to evaluate the prototype in its current form, and to design and develop the next iteration. While the detailed design was often done individually, larger design decisions were made collaboratively through a hands-on process where tools and materials were available for prototyping along with the current and previous prototypes. We had access to VR software to test and evaluate the functionality as a team and troubleshoot design problems as they arose. When not working together, we collaborated via Freedcamp[1] project management software, which allowed us to continue progress between meetings, organize design tasks, and capture notes and reflections on the design. Iterations of the prototype were handed off to stakeholders at the RCMP, demonstrated at research partner meetings, and showcased at conferences where feedback could be gathered to inform the next iteration of the prototype. This project was conducted concurrently with the development of a mixed reality MIDI keyboard instrument (Desnoyers-Stewart et al. 2018), allowing the two projects to build off of one another.

Figure 1. HTC Vive Controller Mockup

[1] https://freedcamp.com/

Version 0.1: HTC Vive Controller Mockup

We began the creative development process with a simplistic mockup to quickly verify the need for controllers that evoked a greater sense of object presence. We modified a Red Gun, a tool regularly carried by cadets to become accustom to the Smith & Wesson pistol weight. We cut away a section of this solid rubber pistol prop and attached it to an HTC Vive controller to align with the virtual weapon. Even with this basic modification we noticed a significant improvement over the controller's believability as a pistol. The weight, shape, and center of mass all better matched the weapon displayed in the HMD, creating a greater sense of object presence. The shape of the controller, feel of the trigger, and presence of other controls still distracted from the sense that this was a pistol however, prompting the need to progress towards replacing the controller entirely.

Figure 2. Testing LeapMotion based infrared tracked pistol

Version 1.1: Bluetooth + Leap Motion Infrared Tracking

Next, we developed a prototype using a 3D print of the model used in the VR experience. Due to the limited options available for integrated object tracking we initially decided to track the weapon using infrared LEDs and the Leap Motion. We began by modifying a script found on the Leap Motion forum (Zalo, 2014) and used a Teensy development board to control the LEDs and send trigger controls to the VR simulation. This implementation functioned as long as the weapon was in sight; however, the Leap Motion was not able to properly render the hand pose while holding the weapon. As such, we abandoned the Leap Motion in favor of more reliable and better supported tracking methods which would continue to track the weapon when outside of the user's field of view.

Version 1.2: Bluetooth + HTC Vive Tracker

We developed the next version following the release of the HTC Vive Tracker. While the tracker altered the overall physical form of the weapon, it provided an opportunity to quickly adapt our existing design to the new system. We were able to situate it outside of the area where the weapon would be held, limiting its interference in the user's presence. The tracker enabled us to better integrate the weapon within the HTC Vive tracking system already used to track the user's head and display the VR environment via the HMD. This iteration was another functional improvement, yet the low resolution of the reference model and texture of the 3D printed plastic impeded its effectiveness. Stakeholders and informal feedback from conference attendance suggested our design was on the right track but still felt more like a toy than a service weapon.

Figure 3. HTC Vive Tracker Pistol

Version 2.1: SteamVR Hardware Development Kit

In Spring 2017, the SteamVR Hardware Development Kit (HDK) became available from Triad Semiconductor[2]. With the concept proven in version 2.1, we moved forward in the next iteration by deepening our design detail. We painstakingly measured every aspect of the service-weapon's exterior in an attempt to reproduce it in as high-resolution as possible. We modeled it in 3D Computer Aided Design (CAD) software to mock up the mechanisms and ensure reproducibility. Since the 3D printed plastic we were working with could not reproduce the texture of the grip and trigger we instead opted to use these components from an actual service-weapon. We measured the trigger force and sought to reproduce it in the space available considering the weapon would be full of electronics. While we could not reproduce the weight of the actual service-weapon in 3D printed plastic, we opted to retain this material for ease in prototyping. In place of the ammunition cartridge we used a large button in the shape of the cartridge to simulate loading the pistol. The size of the development board required the addition of a small hump towards the rear of the pistol to fit all of the necessary components. We minimized its impact on presence by blending its form with that of the weapon and keeping its profile flush with the sides of the weapon and outside of the areas primarily interacted with. Once satisfied with the overall design we began integrating the optical sensors based on the documentation provided by Valve, the developer of the SteamVR tracking system used in the HTC Vive (Valve, n.d.).

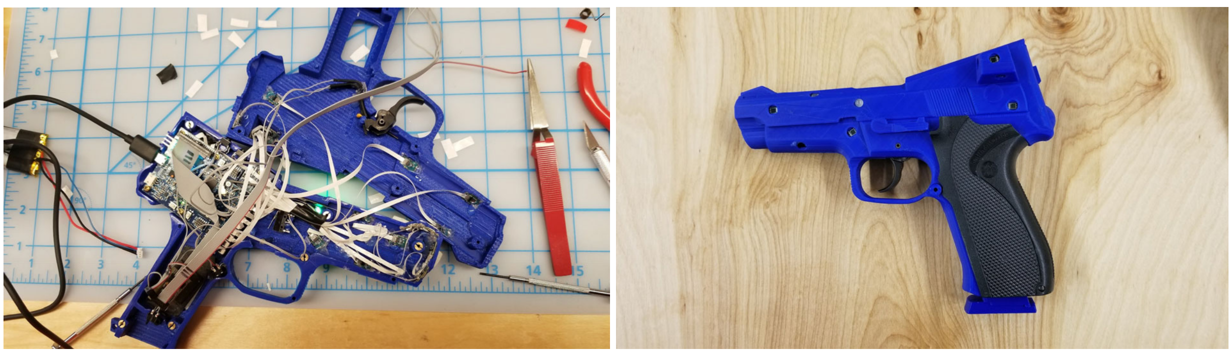

Figure 4. The SteamVR HDK tracked pistol (Left: internals, Right: assembled).

Version 3.1: Virtual Builds

The next version developed was designed to match the form of the RCMP's Conductive Electrical Weapon (CEW). For this version a more compact development kit became available from Virtual Builds,[3] which allowed us to fully integrate the design into the form of the actual weapon. Once again we 3D printed the intervention; however since the CEW is plastic and relatively lightweight, we were able to reproduce its form without including components from the actual CEW.

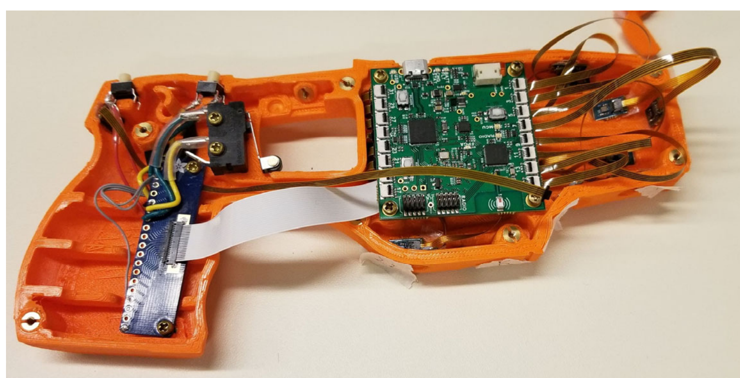

Figure 5. Internals of CEW featuring Virtual Builds HDK

SYSTEM DESCRIPTION

This project has thus far produced two prototype tools for use in VR situational training: a service-pistol and a CEW. Each of these systems are integrated into the SteamVR tracking and controller system at the hardware level, allowing them to be interchanged with off-the-shelf controllers such as those used for the HTC Vive so they can be integrated with the RCMP's custom scenarios as well as any other program using SteamVR hardware.

[2] https://www.triadsemi.com/steamvr-tracking/
[3] https://www.virtualbuilds.com/

Service-Pistol

The current version of the VR service-pistol, shown in figure 6, uses the SteamVR HDK package from Triad Semiconductor. It features a working trigger, which tracks the rotation of the trigger and sends a button press signal when fully depressed. In addition, the weapon can be reloaded by pushing in the large bumper designed to match the form of the ammunition cartridge. The USB connection and home and auxiliary buttons are integrated on the hump at the rear, outside of the actual representative surfaces to maximize fidelity with the real object and prevent their interference in the training simulation.

Figure 6. SteamVR HDK based 3D Printed Pistol

Conducted Electrical Weapon

The CEW better matches its real counterpart. It features the Virtual Builds development board, which has a smaller form factor and lower cost than Triad Semiconductor. The form of the CEW is also more conducive to the sensor placement requirements of the SteamVR tracking system due to the larger bulbous shape of the front of the weapon. This tool includes a working trigger, safety, and buttons as well as haptic feedback integrated within the handle. The haptic feedback can be customized in the training scenario application software.

Figure 7. SteamVR HDK based 3D Printed CEW

DISCUSSION

Object Presence of the Mixed Reality Weapons

In the early stages of the research project, the pistol body was entirely 3D printed. While this enabled our team to rapidly change the form factor to adjust to the space requirements and technical demands of the technologies inside the pistol, the simplified form and plastic texture repeatedly broke the plausibility illusion and reduced presence for users trying the system in a demonstration. The factors that contributed to breaking presence were symptomatic of the simplistic early design, including the use of an imprecise pistol model meant for use in a game rather than for replication in 3D printing, but suited our initial fast prototyping requirements.

Imperfections that affected the look and feel of the object including printing pistol walls that were too thin, making the object feel fragile in the user's hands; plastic components that added unnatural friction between surfaces; and the VR tool was significantly lighter than the real object. Though the functionality of the plastic object simulated the real object, we found the VR tool did not have sufficient physical resemblance in the hands of our team members, who were experienced users, to convince them that they were holding a pistol. We could at this stage speculate that before the user entered the VR environment, they would already be doubting the functionality of the product. Based on our own testing of the tool, the physical imperfections transferred through functionality and touch into the VR environment where we felt that the use of the tool would inhibit the users' ability to feel present in the virtual environment, preventing them from focusing on the task and feeling the real weight of the simulated situation.

While deciding to continue to print in plastic so that our team could adapt to the rapidly evolving technologies available to us, we made three major decisions that affected the believability of the VR tool: (1) precise reproduction, (2) integrating real components, and (3) realistic physical appearance.

The first major shift was adopting a more precise reproduction method. Instead of relying on design files that were provided to us through the paramilitary, we leveraged our partnership to work directly with the RCMP Armory to reverse engineer their service pistol. We recreated the object in a 3D Computer Aided Design (CAD) platform to full specification. This enabled us to build a more true-to-life replica that worked to convince the user that they were holding an actual pistol.

The second decision was to integrate real components from the pistol. Working again with the Armory, we looked at what features of the Smith & Wesson pistol could be blended into the new design to improve realism without compromising cost. We identified the metal trigger and grip as the most critical tangible aspects and integrated those components from the actual service weapon into our design. These two elements of the real pistol immediately altered both the acceptability of the object outside of VR and within VR. We chose to use these components as they were the most significant tangible attributes of the pistol and the grip also contributed to its appearance outside of VR. These small but significant changes allowed us to retain the flexibility of a 3D print while making the finished product feel as real as possible. These new elements elicited visual and tactile (outside VR) and mental and tactile (within VR) prompts that worked to activate the users sense that they were holding a weapon.

The third decision was to ensure an overall realistic physical appearance. This research stems from observations made in-house between our team while testing the functionality of our tools. Once we had a functional device that incorporated a real trigger and a grip, we had a tool that, at first glance, resembled a service pistol. This was an important feature that affected the use of the tool. Based on efficiency of explaining the project to members of our research team and to our research partners, we developed a pattern of handing the user the device, which resembled their service pistol, before they put their HMD on. This helped them visually and tangibly understand that they could use the trigger and re-load the magazine on the VR tool, before they put on the HMD where they then would have to work from muscle memory within the VR simulation. This short introduction prior to the HMD experience seemed to enhance their journey into believing they were holding an actual weapon. We then would take the device from the participant, have them put on the HMD where they were given approximately 30 seconds to adjust to the VR environment, and then hand the tool back to them. The VR situation they experienced was either a Shooting Range where they could perform target practice, or a cityscape scenario where they were tasked with de-escalating an active shooter situation.

While the weight of the object still did not come close to the actual pistol weight, the users were no longer distracted by the detail of holding a plastic pistol. Instead they became immersed in the simulation and used their tools to engage with the VR training scenario. We were able to integrate these design decisions into the CEW training tool, as we were better able to match the physical characteristics of the mostly plastic device, which only differs from the reference CEW in its internals and the need for tracking sensors. This improvement will offer us an opportunity to evaluate the significance of an exact match in contrast with an approximate one and provide some insight into what level of object presence is sufficient.

This preliminary research is directing us towards future investigation of mixed reality design methods. Results so far align with previous research suggesting that the incorporation of tactile clues in the VR environment help to retain the user's sense of presence and immersion within the experience (Hoffman, 1998; Meehan et al., 2002; Desnoyers-Stewart et al. 2018). Through our hands-on design process we have found that object presence seems to be an important factor in the overall training experience. In training the paramilitary and military we are also conscious that placing a tool that does not convince the user of its effectiveness could have significant detrimental effects towards the proper use of the real tool. These aspects of the simulated intervention designs will be studied commencing Fall 2019, investigating how object presence can play a part in designing an enhanced VR environment for situational training.

Guidelines for Developing Mixed Reality Tools to Enhance Object Presence

Based on the virtual weapons produced through this critical design process we found several aspects of the design that seem to be critical to object presence in VR training. We propose the following preliminary set of guidelines for the development of such hardware for use in VR scenario-based training which will be evaluated and refined through a series of user studies.

1. **High-Fidelity Reproduction.** With VR simulation it can be tempting to use low-fidelity controllers in an effort to maximize the utility of a single device by allowing it to represent various objects; however, the fidelity of the physical device is highly noticeable, even when the device is not visible. As such it is essential to reproduce tools meant for training with specific devices to a high degree of fidelity to maximize object presence and transferability.
2. **Materials Matter.** While the opaque nature of VR headsets affords modifications to the physical device to support tracking or reduce cost, the materials used are critical to its object presence. 3D printed plastic reproductions can feel more like toys or game controllers than the weapons they represent. Real components should be integrated where possible to maximize the likeness to the represented weapon in texture, balance, and weight. Where real components are impractical, touched surfaces should be textured to match the represented object.
3. **Physical Appearance.** Despite VR blocking the user's view of the physical world, users may still have to interact with the physical object outside of the simulation. Reproducing the tool's physical appearance outside of VR remains important to the object's presence within VR. Since this may be the only physical aspect of the simulation interacted with outside of VR, its physicality may be essential in imbuing a greater sense of environmental and user presence within the scenario.
4. **Purposeful Transition.** As with the VR environments and scenarios themselves, a smooth, progressive transition of the physical object into VR may increase object presence. Similarly, this transition could help with the presence of the scenario as a whole as it ties the user to reality. As such, the handling of the physical tool should be purposeful, designed to encourage a smooth transition and enable the user to connect their VR experience with the outside world through the physicality of the object.

Future Work

We plan to evaluate these designs-as-prototypes through a series of user studies. We will investigate the object presence and their contribution to the overall experience of presence using Witmer & Singer's Presence Questionnaire (Witmer & Singer, 1998) behavioural measures (Reiner & Hecht, 2009) and physiological measures (Meehan, 2002). Through this study we will compare our method to the existing training system currently in use as well as to conventional VR controllers.

Further development of the pistol will continue to improve its likeness to the actual weapon. In future iterations we intend to use a metal body as this is the only feasible way to achieve the actual weight of the weapon with all of the electronics and sensors embedded into the device. We will also develop a fully weighted and tactile trigger linked to the cartridge ammunition in the software and strong haptic feedback to give a more realistic interaction when the trigger is pulled. We also aim to develop custom PCBs to facilitate assembly and better fit the electronics within the profile of both the pistol and CEW. Finally, we will extend this system to design other tools for application in training and simulation for the RCMP.

CONCLUSION

Through a collaborative, practice-based research grounded in design process we have developed new tools to better enable the use of VR for situational training. In addition, through this development process we uncovered knowledge about the importance of the physicality of such tools despite its typical compromise in favor of flexibility and cost savings for the consumer market. We have also demonstrated the capacity of artistic-research methods to contribute to the development of technology and the value of partnerships between law enforcement agencies and artists and creative technologists. While the prototypes produced through this process have yet to undergo a formal user study to validate their effectiveness, we have nonetheless made several important contributions.

VR seems to imply limitless possibilities; however, as we have found through our research, the physicality of tools used in VR training is essential, constraining the design of such objects. This is particularly important in the field of law enforcement where timely decision-making under pressure can save lives and prevent unnecessary harm. By presenting trainees with a stronger sense of object presence, these tools can provide a more representative experience that better aligns with and transfers to the real world scenarios being trained for.

Finally, this research builds avenues for knowledge mobilization between partners and creates a space for co-creating innovative research-based knowledge that is unique in Canada. It has an impact through the addition of critically designed tools to an industry currently led by the gaming business. It advances research creation practices and theoretical discourse within this field and will lead to the implementation of better training tools and methods at the RCMP and throughout law enforcement and military agencies, improving public relations through increased transparency and improved safety.

The project, through its unique partnership across art, engineering, psychology, and public safety is shifting methods of paramilitary research in Canada. The public distribution of the research is essential and this project will deliver the work in multiple ways. Progress reports are shared with the RCMP, the Faculty, the Collaborative Center for Justice & Safety, and the International Security Simulation Technologies Group. The results will be disseminated through conferences, and we are also looking at distribution through social media options. Importantly, we recognize that distributing geographically across RCMP stations in Canada can have the most impact. Therefore, we will produce a cost-efficient educational kit to disseminate training to the RCMP across Canada.

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