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Ragdoll Recovery: Manipulating Virtual Mannequins to Aid Action Sequence Proficiency

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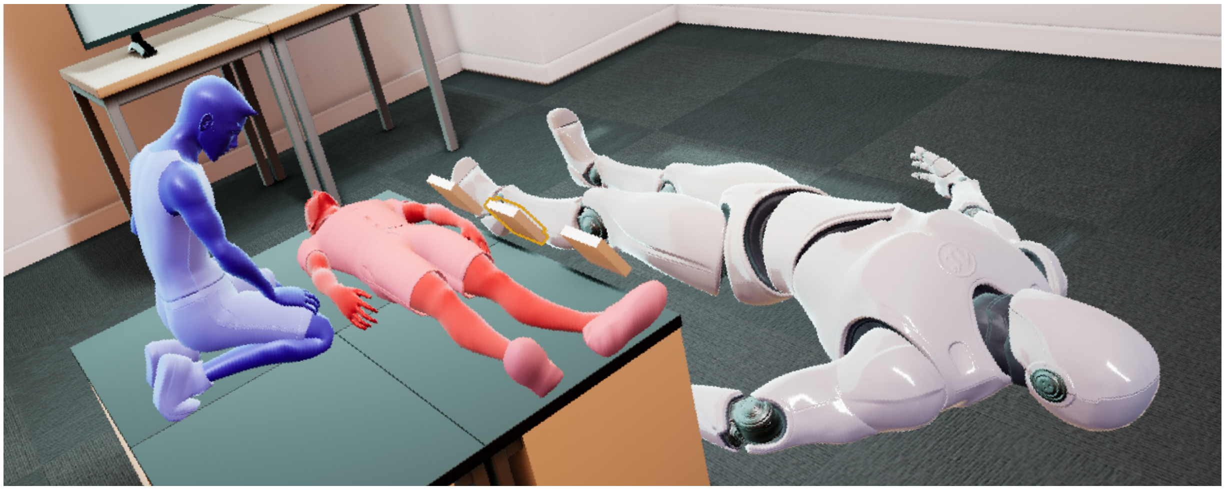

Figure 1: On the left of the image, two virtual avatars demonstrate the recovery position sequence. In front of them is the mannequin with ragdoll physics for the learner to practice the observed movements.

ABSTRACT

In this paper, we present a Virtual Reality (VR) prototype to support the demonstration and practice of the First Aid recovery position. When someone is unconscious and awaiting medical attention, they are placed in the recovery position to keep their airways clear. The recovery position is a commonly taught action sequence for medical professionals and trained first-aiders across industries. VR is a potential pathway for recovery position training as it can deliver spatial information of a demonstrated action for a subsequent copy. However, due to limits of physical interaction with virtual avatars, the practice of this motor sequence is normally performed in the real world on training partners and body mannequins. This limits remote practice, a key strength of any digital, educational resource. We present Ragdoll Recovery (RR), a VR prototype designed to aid training of the recovery position through avatar demonstration and virtual practice mannequins. Users can view the recovery position sequence by walking around two demonstrator avatars. Observed motor skill sequence can then be practised on a virtual mannequin that uses ragdoll physics for realistic and real-time limb behaviour. RR enables remote access to motor skill training that bridges the gap between knowledge of a demonstrated action sequence and real-world performance. We aim to use this prototype to test the viability of action sequence training within a VR educational space.

Index Terms:

Human-centered computing—Virtual reality; Human-centered computing—Interaction techniques

1 INTRODUCTION

The recovery position is performed on a person when they are unconscious, still breathing and do not have any other life-threatening conditions or injuries that would stop them from being moved [6]. It is part of standard first aid procedures that can help prevent further harm and death by keeping airways open whilst waiting for emergency services. Any medical professional or industry employee with first aid responsibilities will have been taught the sequence of steps required to place an individual into this position. It is also taught to school children and families to help those who may be prone to falling unconscious for a variety of medical reasons (for example epilepsy). Due to the breadth of people being taught this action sequence, recovery position training would benefit from many different tools to aid skill acquisition. It is important that those trained in the recovery position can perform the action sequence with some automaticity so that in an emergency, the cognitive load of the motor skills does not interfere with scenario judgements.

To attain proficiency and automaticity of learnt actions, Fitts and Posner [4] describe three typical stages of development: cognitive, associative, and automatic. At the beginning of motor-skill knowledge, cognitive representations are required to outline spatial positioning of movements and goals. Once a critical mass of understanding for the motor skills is understood, it is now important to translate this representation into procedural (motor) knowledge, normally through physical practice. Early on, movement takes time to execute as an individual is checking their motions against the cognitive representation. After much practice, movements are largely automatic with minimal cognitive load. Learners can then strategise around the use of the motor skill as movement is largely automatic. The common requirements throughout these stages of development are establishing a cognitive representation, developing procedural memory through practice, and feedback to adjust motor skills and refine cognitive representation.

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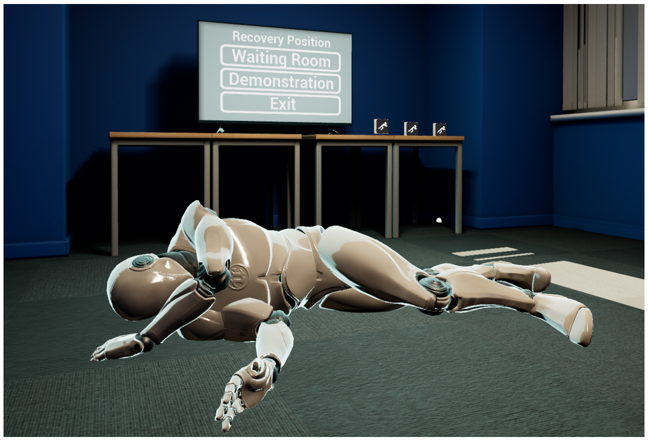

Figure 2: In this room, the learner does not have the benefit of avatar demonstration, and is challenged to apply the recovery position to the mannequin from a variety of starting poses.The learner is free to navigate back to the demonstration room if they feel they need more practice.

Mobile VR has been used to deliver observational learning of the recovery position [11]. By simply watching two virtual avatars perform the sequence, subjects were able to recall much of the steps and perceived to have better knowledge of the action sequence. This suggests that the immersive virtual world was able to help develop some cognitive representation of the action sequence through observation alone.

Once a base cognitive representation of an action sequence is established, then physical practice will help develop procedural (muscle) memory, knowledge of how to apply the action sequence to a given scenario, and enable feedback on performance. However, practising movements that interact with virtual content, commonly requires extra bespoke, real-world hardware. For example, in ITI VR industrial vehicle training [10], users can learn how to operate a variety of cranes. ITI VR also supplies physical controllers based on crane controls to provide realistic haptic feedback for procedural memory, transferable to the real world. Although effective, this adds significant expense to the training system and reduces accessibility beyond dedicated training centres. Similarly, when exploring mixed reality training for emergency responders via helicopter, the VR platform can reduce the cost by simulating the audio and visual input for the training scenario. However, dedicated hardware is required to provide the haptic feedback of the helicopter vibrations, surrounding objects and interactions with the injured personnel [8]. The recovery position is a relatively simple set of movements, and due to the breadth of people who may need to develop this skill, finding accessible approaches to training can help achieve proficiency for the many. To progress training past a cognitive representation within a VR space, we created the prototype, Ragdoll Recovery (RR). In this application, learners can observe the recovery position action sequence from two virtual avatars going through each step. Learners can then apply these movements to a virtual mannequin with ragdoll physics.

Ragdoll physics are a simulation [9] that calculates the realistic weight and joint movement of a virtual avatar's body parts, in response to physical interaction or collision. A set of rigid bodies will approximate the volumes of an object for simulated collisions. For example, a sphere rigid body will roll and bounce around virtual geometry according to the force used and physical attributes of "bounciness". This volume will also have a defined weight. A ragdoll will require many rigid bodies to represent the entire virtual avatar. For example, the upper arm and the lower arm may use a capsule volume, see Figure 3. Simplified shapes are required so that the simulation can be calculated in real-time. Between two rigid bodies, is a constraint that acts as a joint. The constraint will have angle limits for movement as well as dampening to reduce movement over time. These properties can be supplied across individual axes of movement, meaning both hinged (elbow) and rotator (hip) joints can be sufficiently replicated. Ragdoll physics are commonly used in computer games when a character is shot or propelled by an explosion. At the point of impact, the character switches to ragdoll physics and the body will respond like a human "ragdoll" with dynamic, physically simulated movement. In RR, the ragdoll physics applied to a virtual dummy creates a "limp" body to reposition. When a body part is lifted or moved, the rest of the dummy will follow the movement similar to a real-world body. For example, when moving an arm, the relative weight and joint constraints are calculated to inform the effect on the entire body as well as the interaction of the virtual floor.

Through the manipulation of a virtual mannequin, a learner can gather feedback on whether or not they have met the goals of each step in the sequence. This will help inform the learner of what they need to focus on to improve their performance. They will also gain an understanding of how another person's body will react to the push and pull of being repositioned. Each action in a sequence needs to adjust to the limb behaviour and constraints of another's body to reach the goal of each step. This will be different for everyone that is repositioned, due to variation in weight distribution, limb length, and starting position. With the addition of a ragdoll virtual dummy to practise, learners can progress past a cognitive representation through feedback and motor skill application within an appropriate context, see Figure 2.

2 DESIGN

RR has been initially developed for the Oculus Quest [7]. This platform uses an HMD and two controllers that are tracked in 3D space. The tracking of the HMD and controllers is performed by the HMD so no other hardware is required to supply the VR learning space. The Unreal Engine (4.26) [5] was used to develop the application. Its visual scripting "blueprint" system was used to script logic and interactions. The set up of rigid bodies and constraints for the ragdoll interactions use the "physics asset" [2] tools native to the Unreal Engine.

The design of RR is informed by four main aims:

1. Develop a cognitive representation of the recovery position through observational learning.

2. Develop procedural memory of the recovery position that is applicable to real-world practice.

3. Provide feedback to the user on the ability to perform the recovery position

4. Develop application that does not require more resources than room-scale VR hardware and the ability to download the application

To refine these aims into an implementable feature set, the development was guided by work that explored best practices for motor skill training in medical scenarios [12]. This work outlines four strategies that improve efficiency and performance of motor skill acquisition that supports the stages of development outlined by Fitts and Posner: Observational practice, Focus of attention, feedback, self-controlled practice.

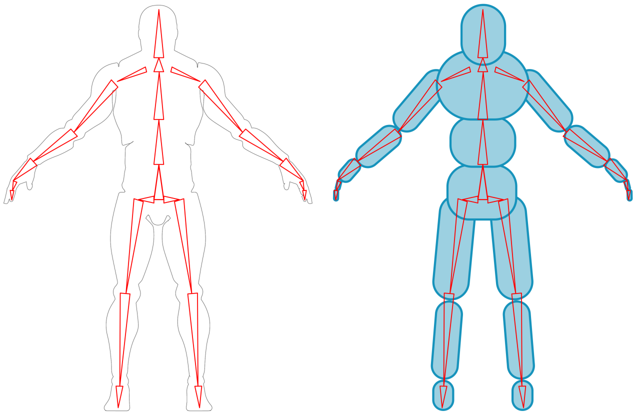

Figure 3: The set up of ”ragdoll Physics” on a virtual mannequin to achieve real-time, physics-simulated movement. The left-hand image shows the 3D form of the mannequin. The middle image shows the skeletal rig, a set of ”bones” with joints in between. Each bone will have control over a portion of the 3D mesh. As the bones move, the mesh will follow. The right-hand image shows a set of simplified rigid body volumes attached to each bone. When using physical simulation, the bones will be controlled by the collision and interactions with each rigid body. The joint movement is then controlled by the physics constraint between each volume.

2.1 Observational practice

Observing demonstrations of motor skills develops the cognitive representation and goals of actions. There is neural overlap between the perception of movement and its execution [3]. A classic example would entail an instructor performing a sequence of movements for the student to then copy. However, the efficiency of how an individual may copy a demonstrator depends on how easily they can mentally rotate an observed movement onto their own body position. For this reason, being able to see an action from multiple angles can aid cognitive representation for a broader audience. RR demonstrates the recovery position action sequence through two virtual avatars. Learners can walk around this demonstration They can view each step from an angle that best informs their cognitive representation. They can also find an angle that is easiest to mentally rotate the demonstration onto their own body position.

2.2 Focus of attention

When describing a movement, and giving feedback, it is more important to focus on the goal (external foci) rather than the details of the movement (internal foci). It is cognitively far easier to describe an action as “Push the button to turn the light on”, than “extend your arm, point your index finger and press it against the base of that switch until you feel and hear the button activating the lightbulb”. Using external foci compared to internal increases the efficiency of movement acquisition and goal comprehension). RR uses an accompanying voice-over to explain the movement goal for each step. The language used describes external foci where possible.

2.3 Feedback

Mechanisms for feedback are an essential reference point to analyse and adjust own performance in all stages of motor skill learning. A classic example would have an instructor appraise a student’s copy of a movement previously demonstrated. However, students can also gather feedback from the results of their actions or view their own movements for self-appraisal. RR enables users to position a virtual body which acts as feedback for whether each step goal is achieved. This virtual body can be repositioned whilst watching the demonstration to provide feedback on the accuracy of repositioning throughout the sequence. This virtual body position can be reset so the learner can focus on a particular phase in the sequence.

2.4 Self-controlled practice

Translating the cognitive representation to procedural memory (muscle memory) is key to automatic performance. This is best achieved through physical practice. Additionally, incorporating varied scenarios to apply motor skill knowledge aids the efficiency of learning and performance. This also promotes external focus on movement goals based on the presented scenario [1]. Giving learners some control over the flow of information to inform their movements (both demonstrations and feedback) can be more effective than externally controlling for these. This facilitates more relevant information for the user throughout motor skill acquisition. RR gives control to the user over the flow of information. They can select to see the next step in the recovery position sequence or go back a step. The voice-over and visual animation are repeated when going forward or back through the sequence. Learners can choose to practise on a virtual dummy in a variety of starting positions. This adds variation to the application of the sequence which fosters strategic judgements in a learner for the best application of the recovery position within different scenarios.

2.5 Ragdoll Recovery Interactions

One button is required for all interactions within the RR application. Firstly a ”laser pointer” paradigm is used for general menu navigation. A raycast is fired from the front of the controller and activates menu selections when hovering over them in 3D space. This paradigm is represented by a disappearing line emitted from the front of the controller and a dot that lands on the virtual environment to show where the ”laser” is pointing. For mannequin interactions, a raycast is emitted in a sphere shape around the controller. When the sphere cast overlaps with a rigid body of the mannequin, this location is used as a ”grabbing” point. This grabbing is activated by the trigger button.

3 DEMONSTRATION

RR is comprised of three main rooms. The demonstration will showcase each room to highlight the key features. The first room acts as a navigation point for where the learner would like to progress in their training. From here they can navigate to either the Demonstration Room or the Practice Room. In the “Demonstration Room”, users will be able to watch the virtual avatars perform the recovery position with control over which step is performed. They will be able to move around the demonstrators as they see fit. They will also have the option of practising what they observe on a virtual dummy. In the “Practice Room”, users will be able to perform the recovery position on a virtual dummy without the aid of observing the demonstration. In this room, the virtual dummy will have a variety of starting positions.

4 DISCUSSION AND FUTURE WORK

RR applies a novel use of ragdoll physics to enable the physical manipulation of a virtual mannequin. This approach affords the practice of moving another’s limbs and body position, which aligns to action sequence training like the recovery position. Therefore RR could extend the learning progression from cognitive representation through to physical practice and feedback of that practice. It should be noted that there are limits to the physical practice of this approach. Since the mannequin has no physical weight, there are elements of skill left unpracticed, compared to the real world. For example, adjusting own body position to account for the weight of another. The more weight that is required in a movement (for example lifting an entire body), then the less applicable to real-world performance.

However, even in this scenario, a learner will be able to practice the sequential order of movements and gather feedback. Therefore, this application would still benefit as an extra tool for revision, priming, or early knowledge acquisition within a training course.

Accessibility is an important concern for the RR project, as those who want to learn, may not be able to within the timescales and locations of training programs. RR requires a basic room-scale VR set-up: An immersive display and two controllers that are tracked in 3D space. RR and the approach taken are accessible as many VR platforms supply this base hardware as standard. It is a noteworthy point that RR was built for the Oculus Quest, a VR platform that does not require an expensive PC to power the graphics. The Quest would be described as a low powered device with limitations for rendering and processing similar to mobile phones. Therefore RR can be built for a wide variety of room-scale VR platforms.

We hope this work helps to guide modern affordances of VR technology for physical interaction with virtual avatars. We also hope our work can be used as a template towards good practice of educational concepts identified for motor skill learning. However, we do not see this form of virtual interaction solely used for education. It has the potential to be applied to concepts for interactive & collaborative spaces where a physical connection between users and other virtual avatars is required.

The current implementation of RR uses a basic ragdoll set-up supplied through the Unreal Engine. We feel there is scope for a large number of improvements that can further be explored to make the interaction more natural and nuanced. One such improvement is related to the fact that we are currently using controllers with a simple grab input for manipulation. A next step would then be to apply best practices in the use of virtual hands for the many grasping positions required for the mannequin interactions.

Additionally, there are other systems in animation that could be leveraged to gather more control of the manipulations such as contextually limiting body movements resulting in a focus on individual limbs, or using Inverse Kinematics for more control when grabbing the hands or feet.

The current version of RR relies on the learner analysing their own progression and performance. A possible extension could be providing more sophisticated approaches to feedback to help inform the learner of their performance against certain benchmarks. For example, the accuracy of ragdoll position at each step, viewing the virtual recordings of own performance and collaborative spaces for feedback.

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