Research Experiences for Teachers

Virtual Avatar Simulator for Human-Robot Collaboration Training in Construction

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Introduction

1. Construction industry suffers from safety issues and has a high number of fatalities.
2. The industry also has productivity issues.
3. It is facing labor challenges and an aging workforce: Median age – 41.

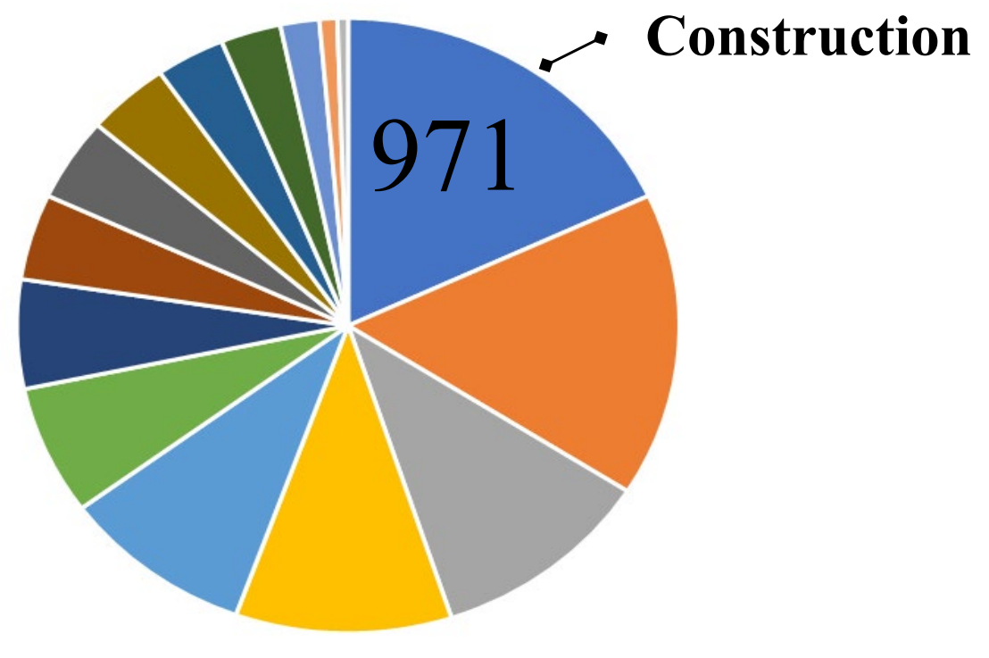


Figure 1: Number of fatal occupational injuries in industry sector (BLS 2017).

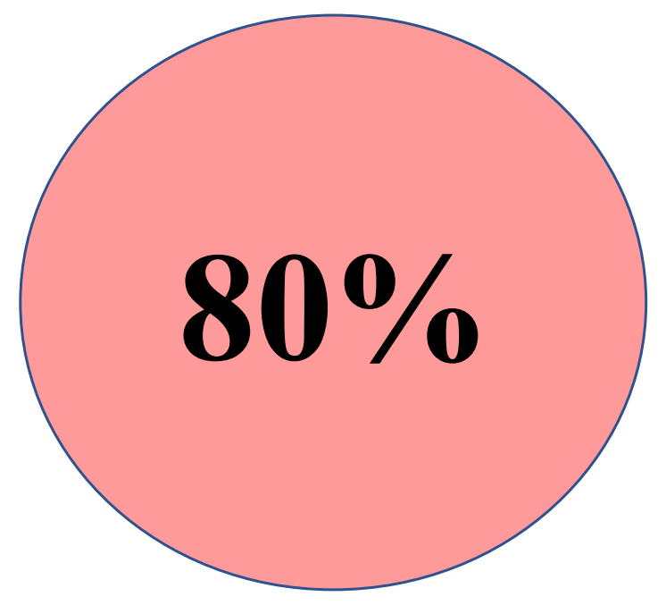


Figure 2: Percentage of companies are suffering from labor shortage.

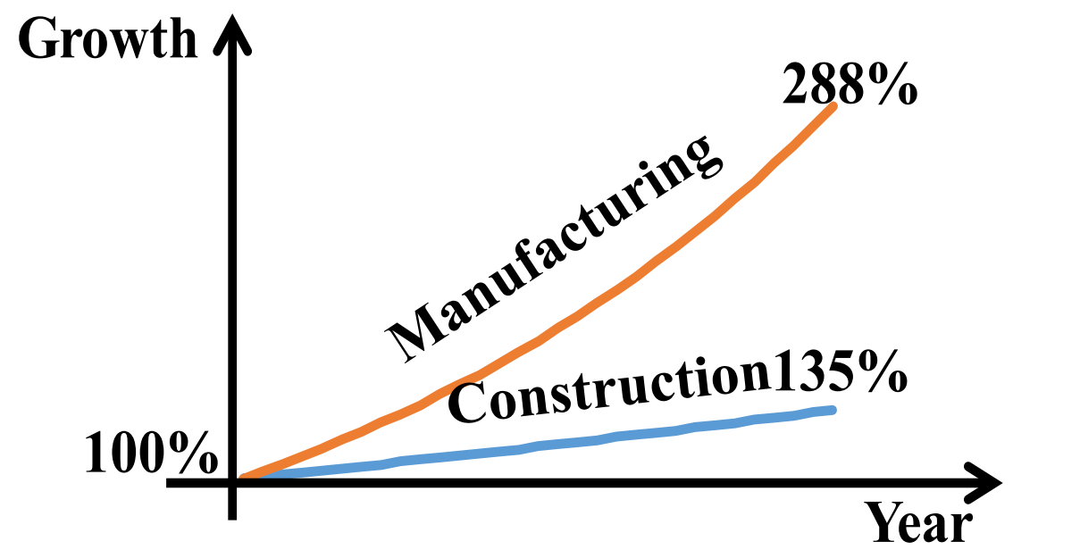


Figure 3: Labor-productivity growth in construction vs. manufacturing.

Robotics in Construction Sites

Figure 4: Construction Robots.

Challenges

1. Current construction robots may raise new safety challenges
2. Current construction workers need additional training with robots in the construction field while focused on safety.

Primary Objectives

1. Create **virtual environments** that adequately train the required skills of collaborating with robots in construction jobsites.
2. Test virtual avatar-based simulations as an improvement from the traditional use of controllers while training for human-robot collaboration.

Primary Case Study

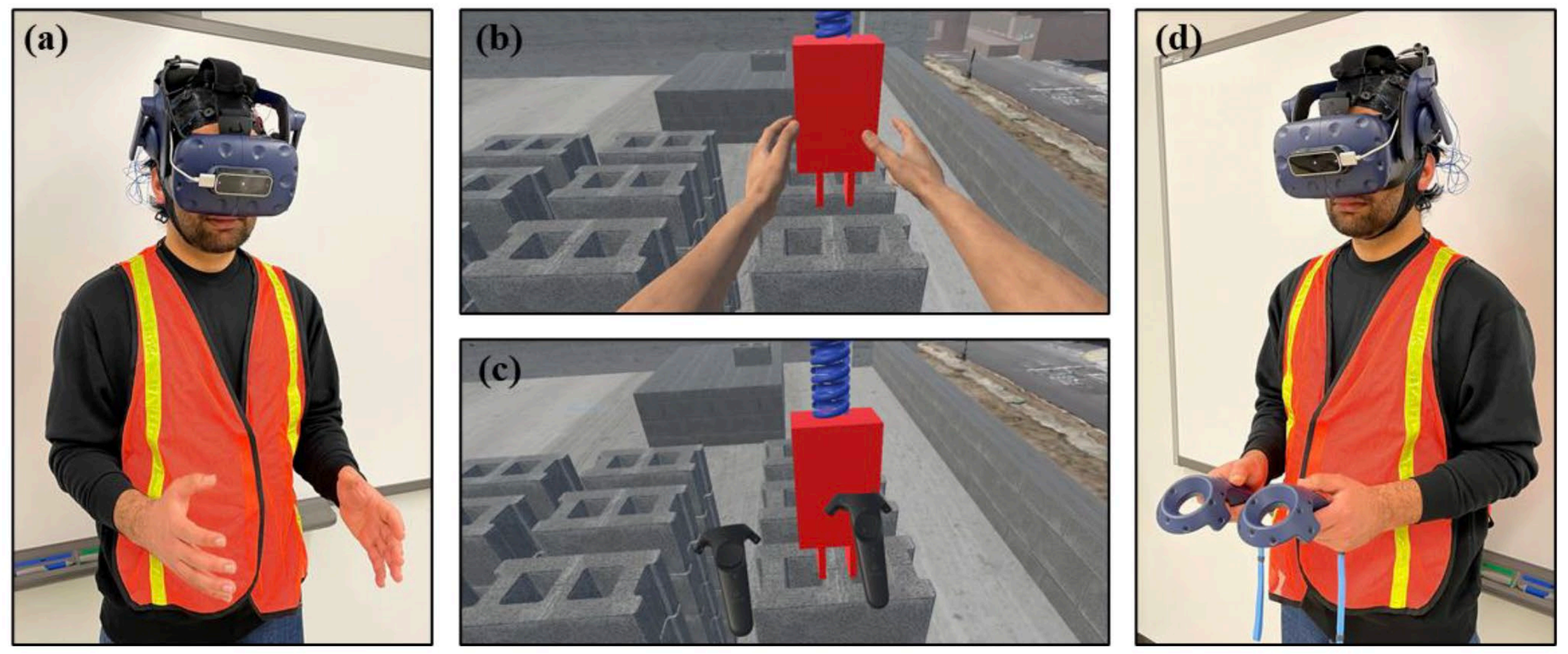
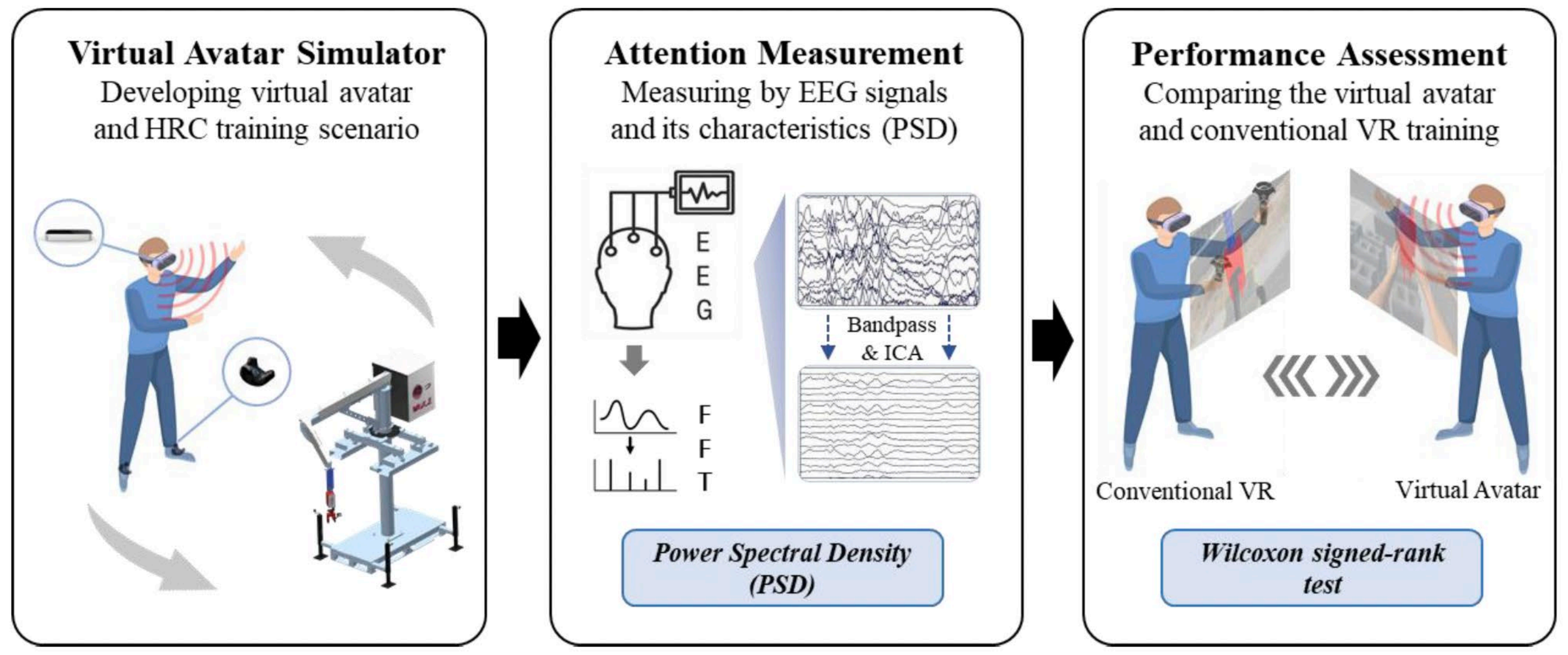


Figure 5: Experimental setting and training scenario: (a) and (b) subject using the virtual avatar simulator, (c) and (d) subject using the conventional VR.

Primary Methodology



Virtual Avatar Simulator
Developing virtual avatar and HRC training scenario

Attention Measurement
Measuring by EEG signals and its characteristics (PSD)

Power Spectral Density (PSD)

Performance Assessment
Comparing the virtual avatar and conventional VR training

Wilcoxon signed-rank test

Primary Data Analysis

#	Scenario	O1 $\left[10\log\left(\frac{\mu V^2}{Hz}\right)\right]$	O2 $\left[10\log\left(\frac{\mu V^2}{Hz}\right)\right]$	T7 $\left[10\log\left(\frac{\mu V^2}{Hz}\right)\right]$	T8 $\left[10\log\left(\frac{\mu V^2}{Hz}\right)\right]$
1	VR	2.13	7.99	5.08	7.24
	Virtual Avatar	8.29	6.98	7.16	9.02
2	VR	8.6	-1.36	-4.12	-0.66
	Virtual Avatar	11.94	4.29	8.78	8.44
3	VR	8.58	11.93	7.59	10.84
	Virtual Avatar	18.42	14.36	14.32	16.05
4	VR	1.39	3.13	3.11	6.55
	Virtual Avatar	12.69	10.56	5.16	12.31
5	VR	3.62	4.97	-0.18	6.29
	Virtual Avatar	12.98	9.65	8.15	12.34
6	VR	2.48	0.6	-0.79	2.51
	Virtual Avatar	6.81	3.67	0.63	3.06

Figure 7:Calculated means PSD values in beta frequency range for selected EEG channels

1. Based on the statistical analysis, the virtual avatar-based training platform induced higher sustained attention in subjects than conventional Virtual Reality.
2. This increase can be attributed to the higher sense of presence, usually experienced in virtual avatar-based simulations.
3. The other reason can be the virtual avatar's interaction mechanism in the immersive environment since the subjects were more cautious during the task performance to accomplish the task.

Primary Conclusion

1. This study investigated the feasibility of virtual avatar-based simulation as an enhanced training platform for human-robot collaboration in construction.
2. Subjects' sustained attention was measured using continuously captured EEG signals throughout the training process.
3. EEG power spectral density was used as a metric to identify levels of attention.
4. The statistical analysis revealed that the level of sustained attention is significantly higher in the proposed training method.
5. The findings highlight the feasibility of the proposed virtual avatar-based platform for human-robot collaboration training in dynamic construction workplaces.
6. Therefore, this study can pave the way for developing more efficient training practices for human-robot collaboration in construction.

Secondary Objectives

1. Use virtual reality to create highly realistic scenarios to improve safety, education, and offer otherwise impossible opportunities, including 3D tours, simulations, and games that have a high scientific value and are made available at no cost for educational use.
2. Compare controllers versus real hands during VR simulations.

Secondary Case Study

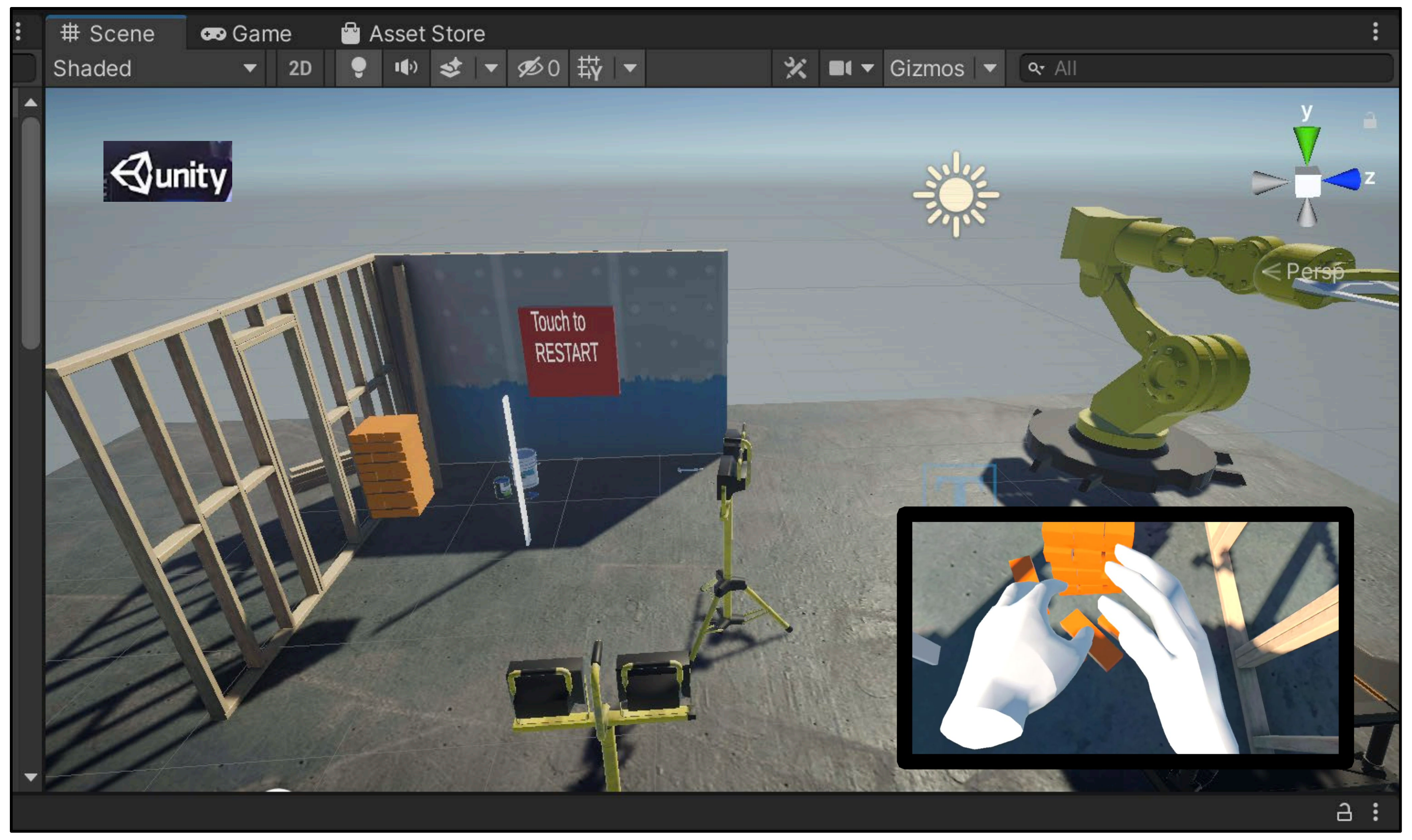


Figure 8: Unity game created by Deborah Armstrong to teach forces. Using C# coding scripts, it is possible to move the concrete blocks. Physics is used so gravity, mass, and friction are present.

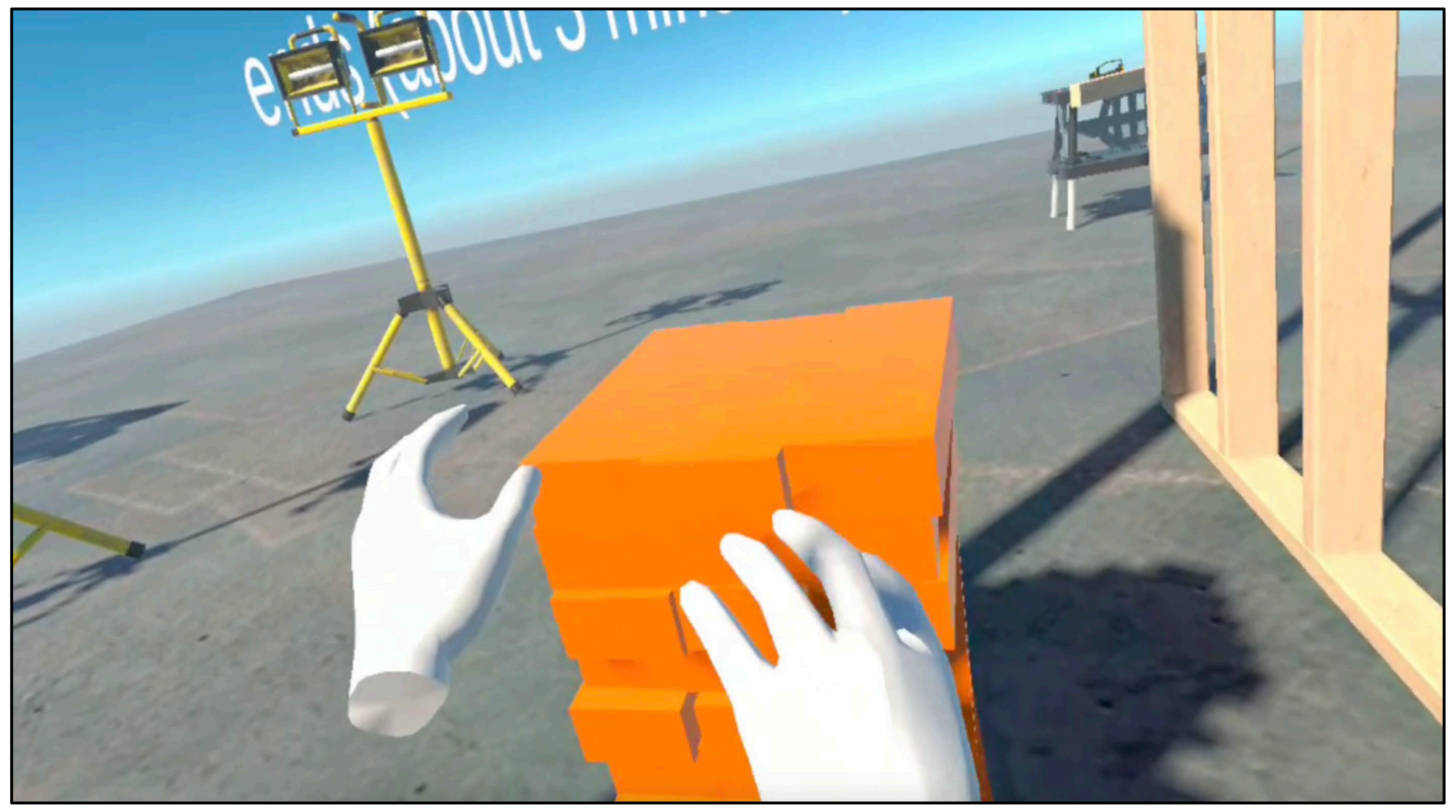


Figure 9: Unity games can be created to allow for the use of hands in Virtual Reality.

Conclusion/Results

1. The use of hands in place of controllers required more concentration and leads to higher learning skills and improves safety and training.
2. Through video tutorials over topics in Unity 3D, teachers and students will be able to create high quality educational experiences in VR at no cost.

Future Plans

1. Create safety "games" using Unity 3D that cover laboratory safety. In place of showing lab safety videos in classrooms, have VR simulations available.
2. Create "games" using Unity 3D that will be able to teach and reinforce science topics. Make these games and simulations free of cost.
3. Create simulations that use hands in place of controllers. Have students complete questionnaires based on their experiences.

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