My Background

CAN HIGH DEFINITION TRANSCRANIAL DIRECT CURRENT STIMULATION (HD-TDCS) ENHANCE COGNITIVE TRAINING AND TRANSFER?

BY

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DISSERTATION

Submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy in Psychology
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2016

Urbana, Illinois

Doctoral Committee:

   Professor Arthur Kramer, Chair
   Assistant Professor Aron Barbey
   Professor Neal Cohen
   Professor Frances Wang
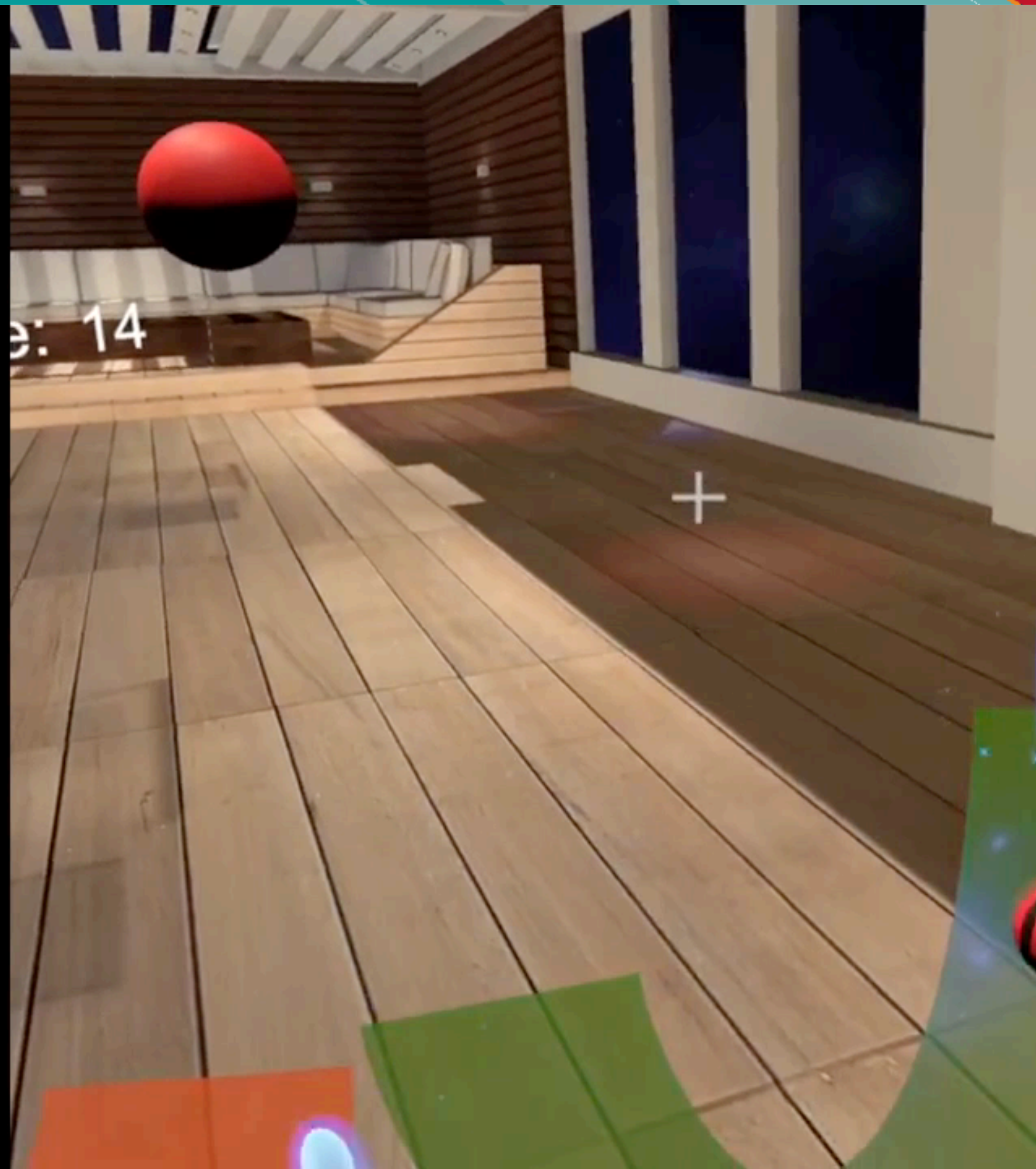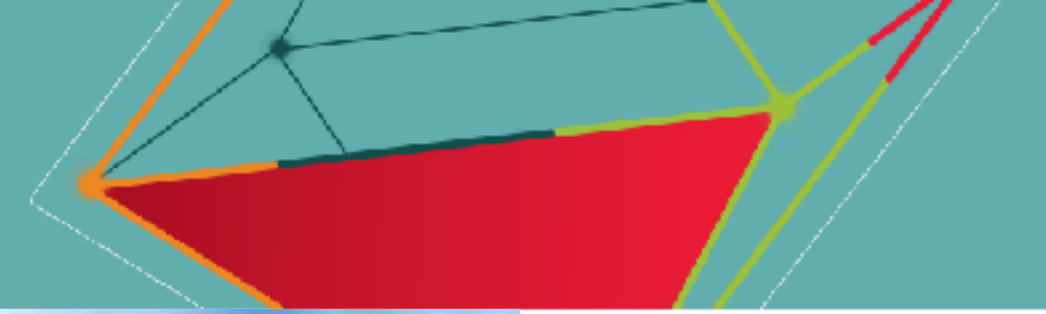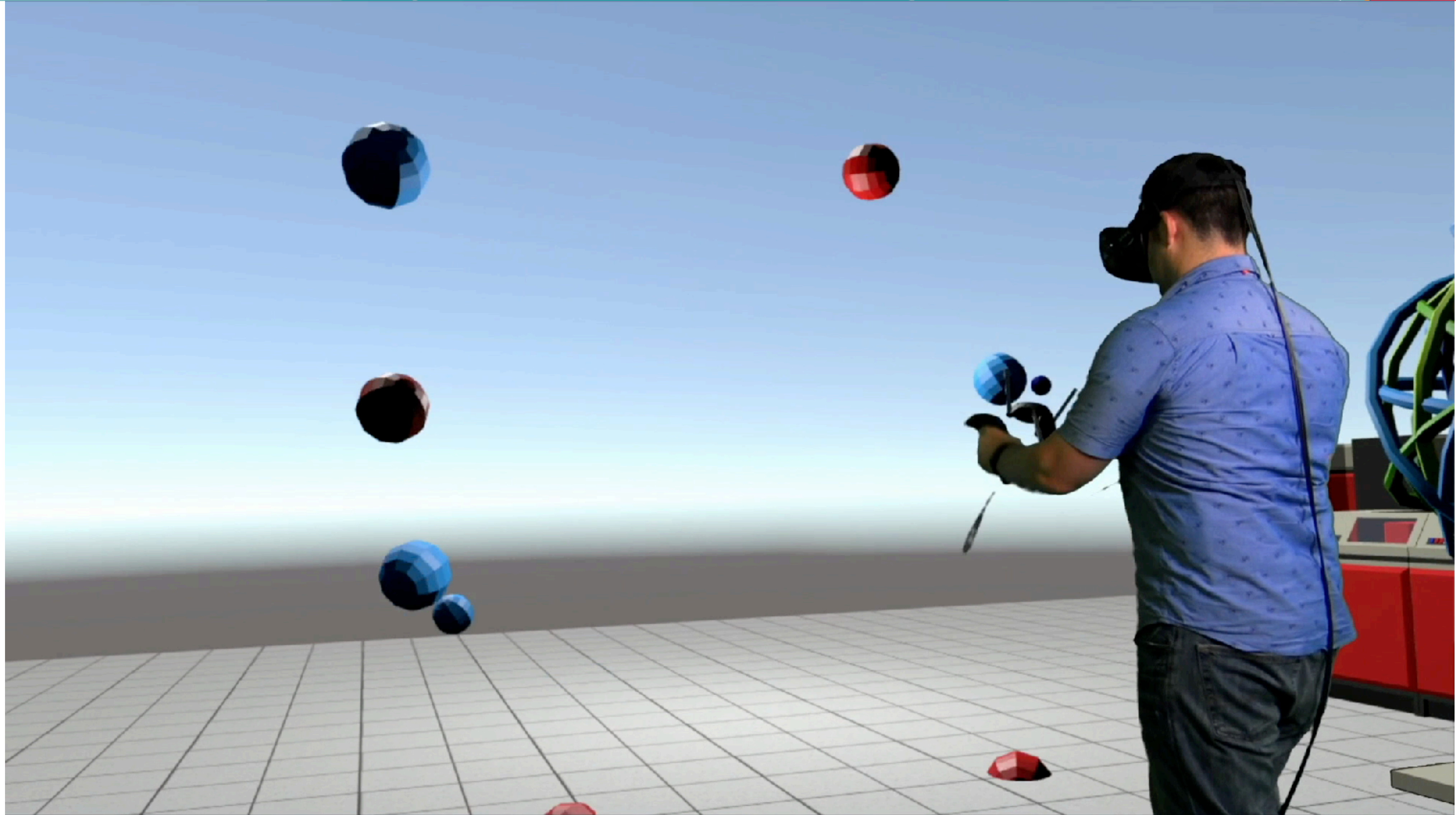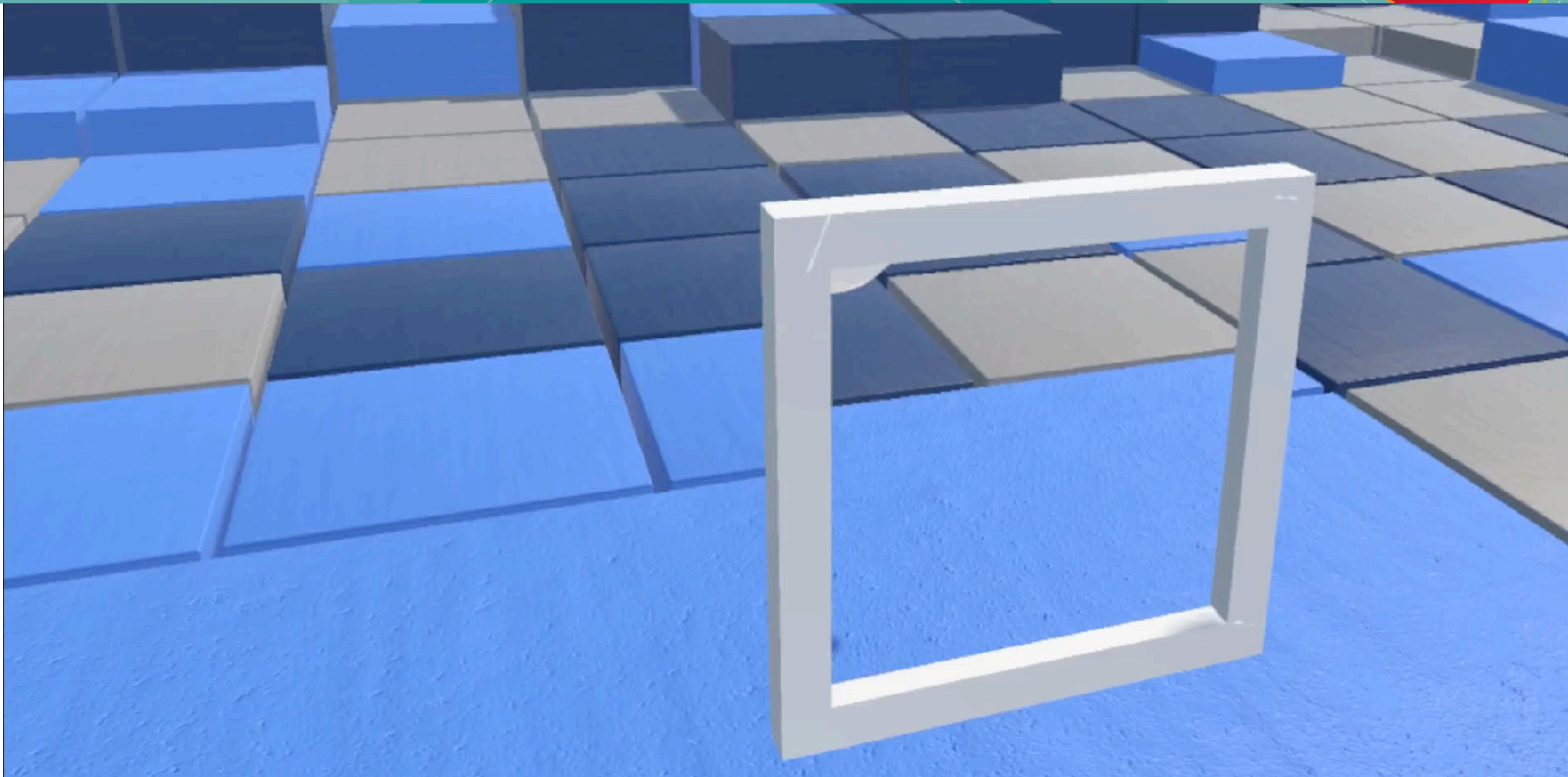   Professor Charles Hillman
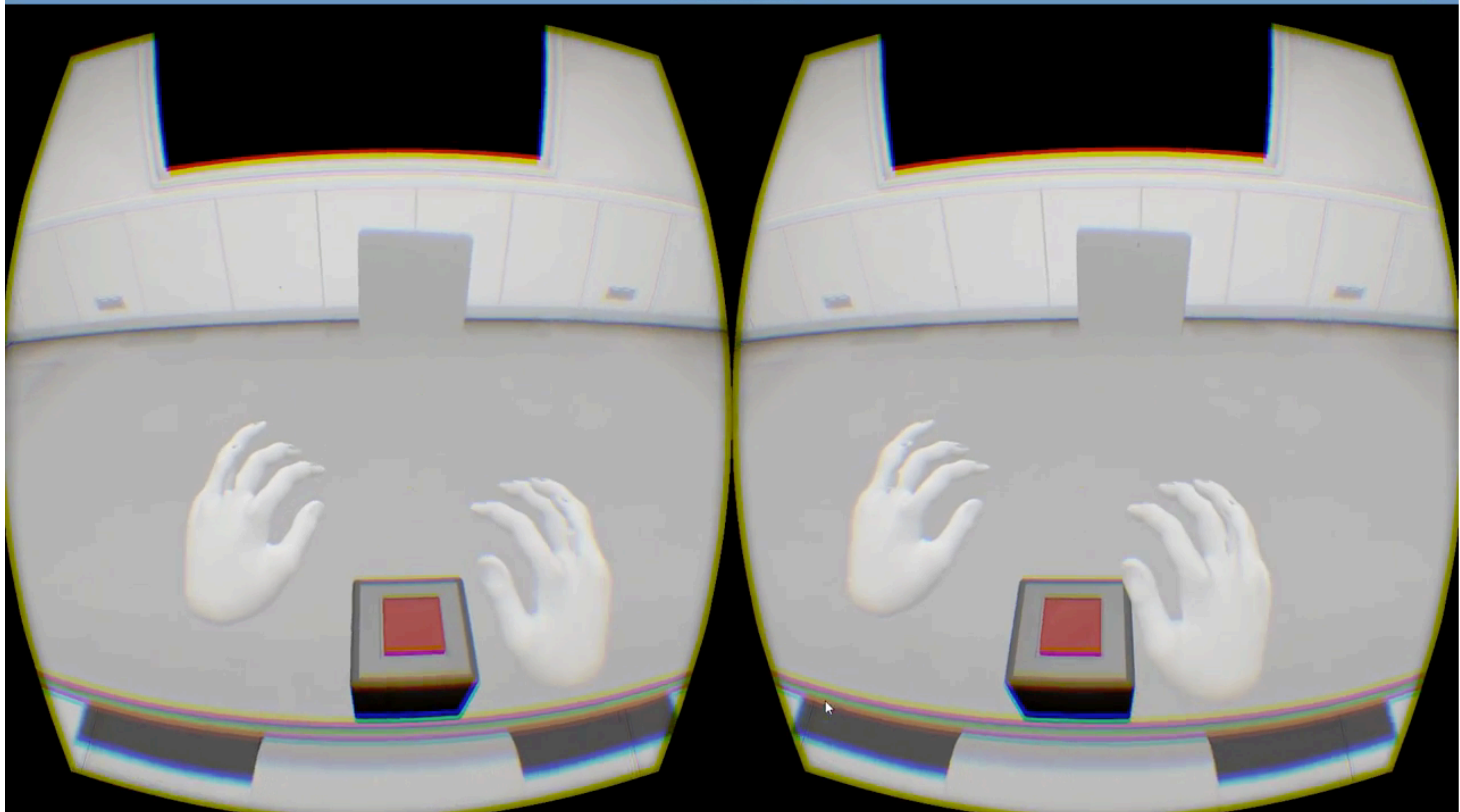
Immersive Cognition Lab

CUBICLE NINJAS
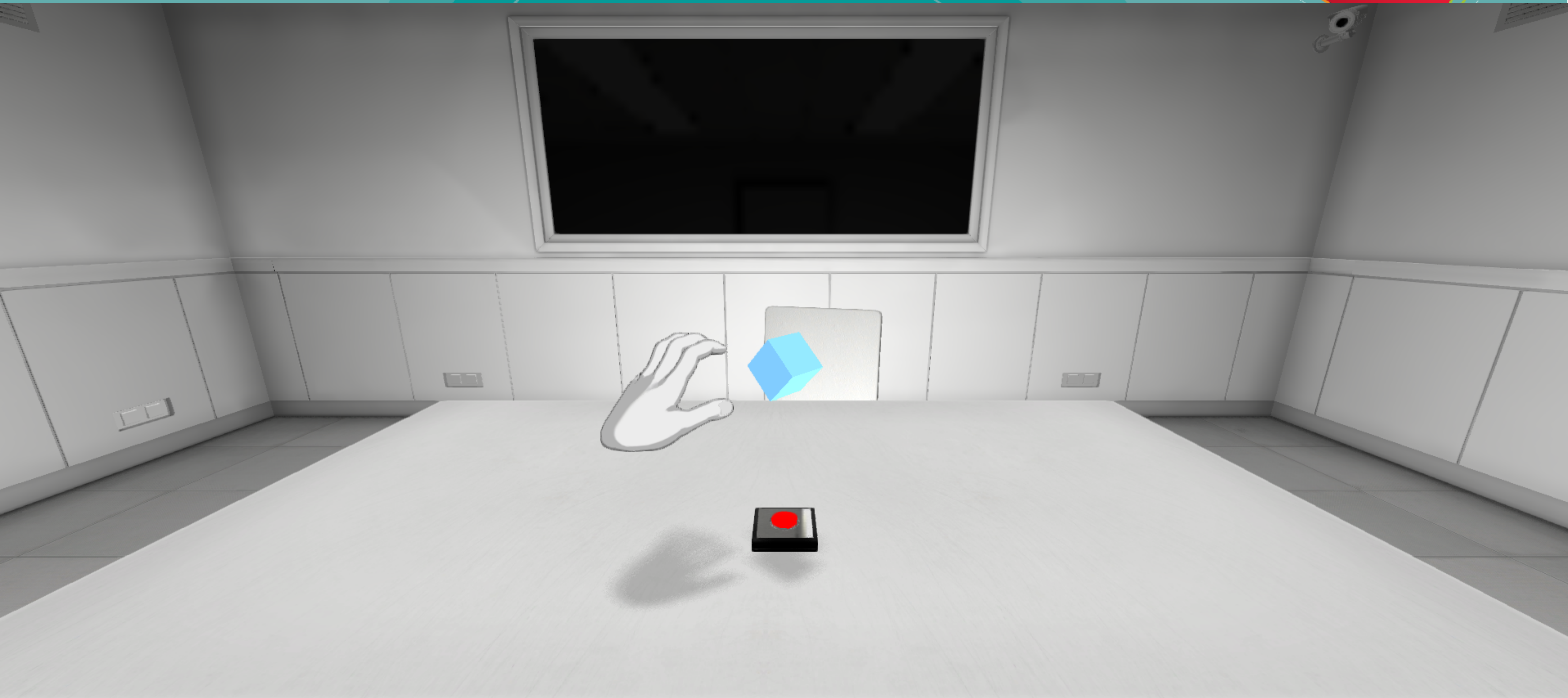
Virtual Reality
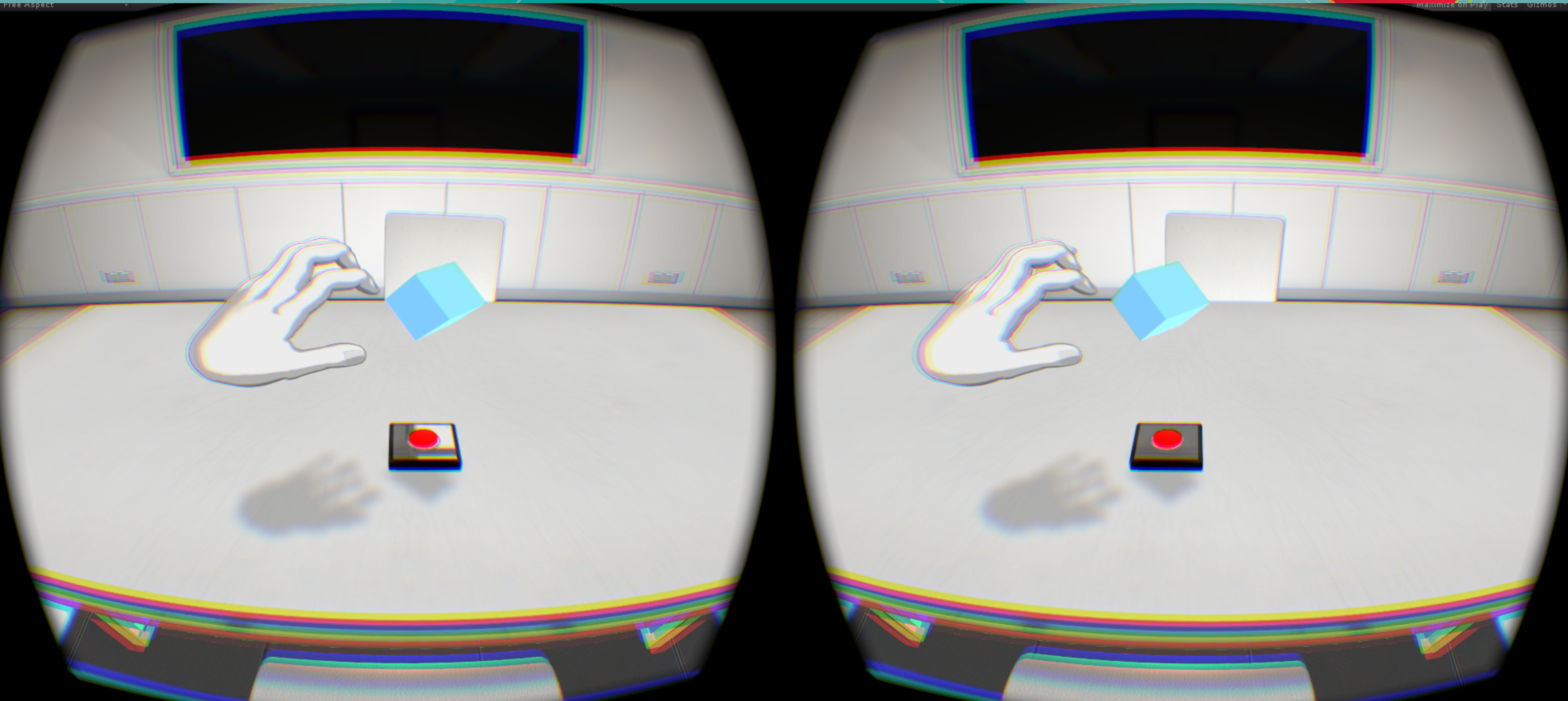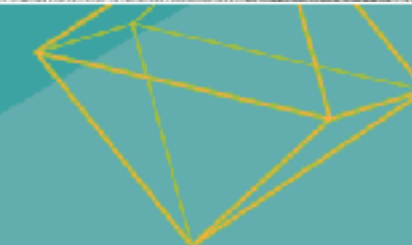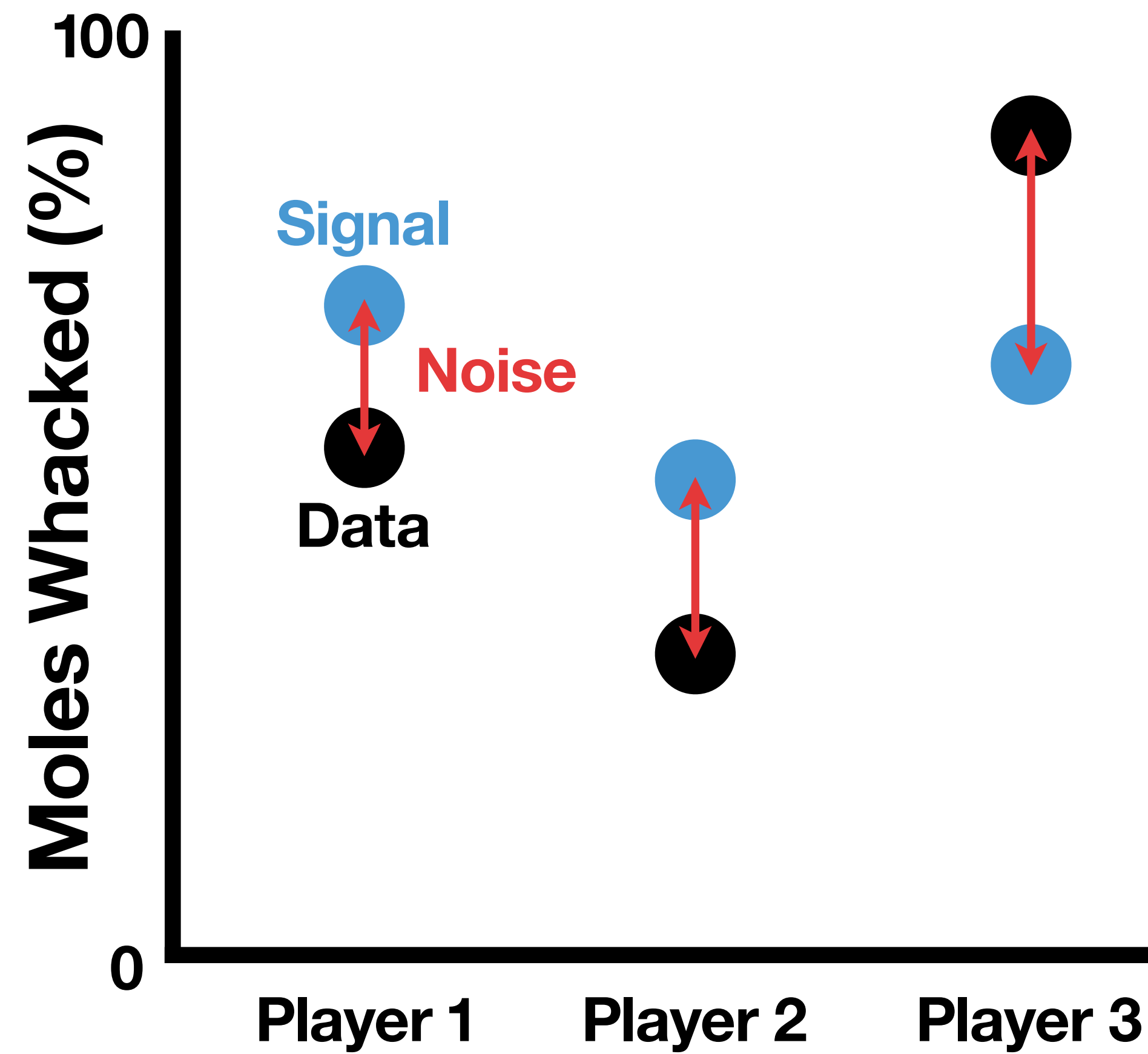
Augmented Reality

Mixed / Merged Reality

Signal vs Noise

Science:

Collecting **data** to measure stuff (**signal**)
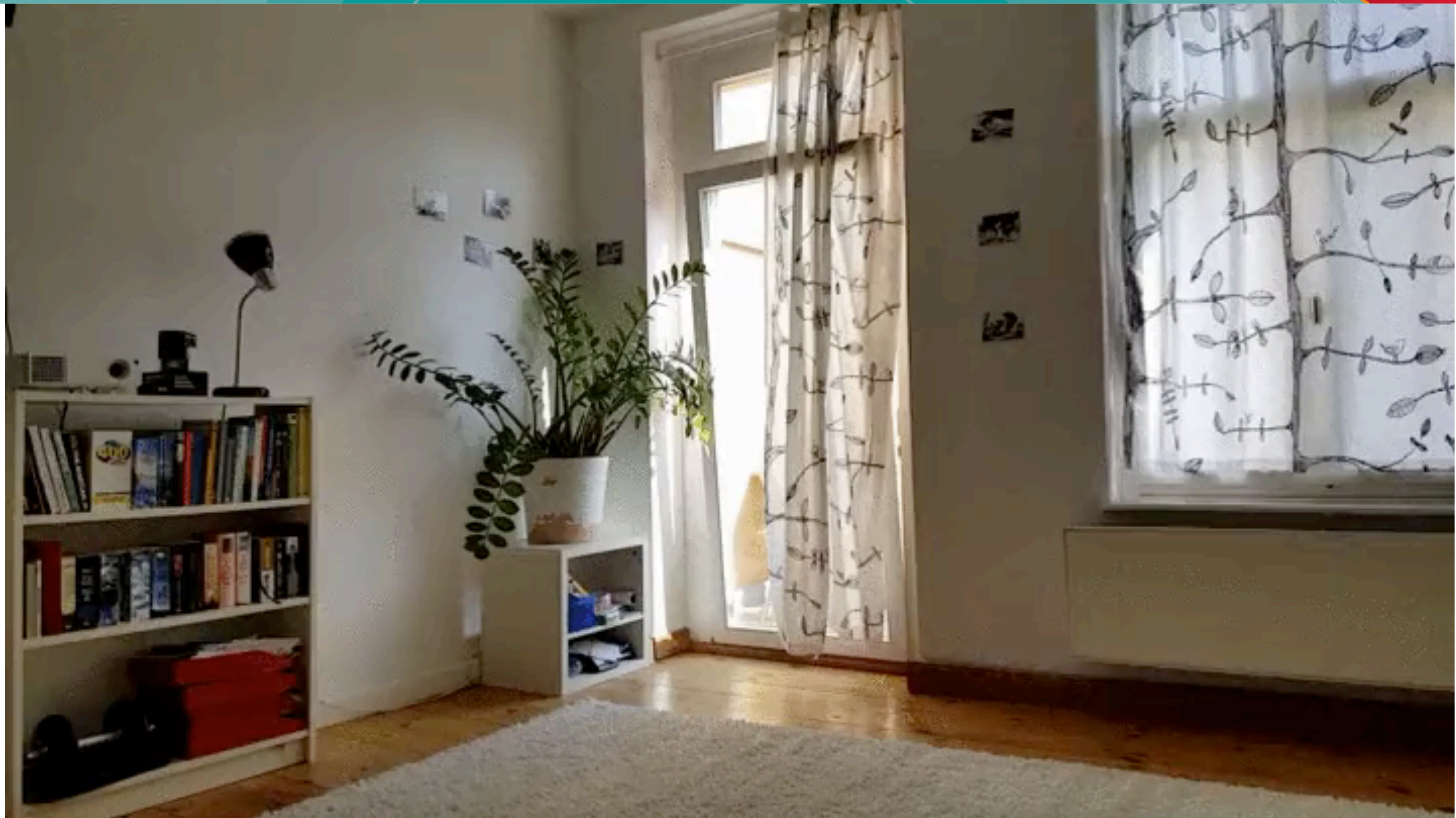while trying not to measure other stuff (**noise**)

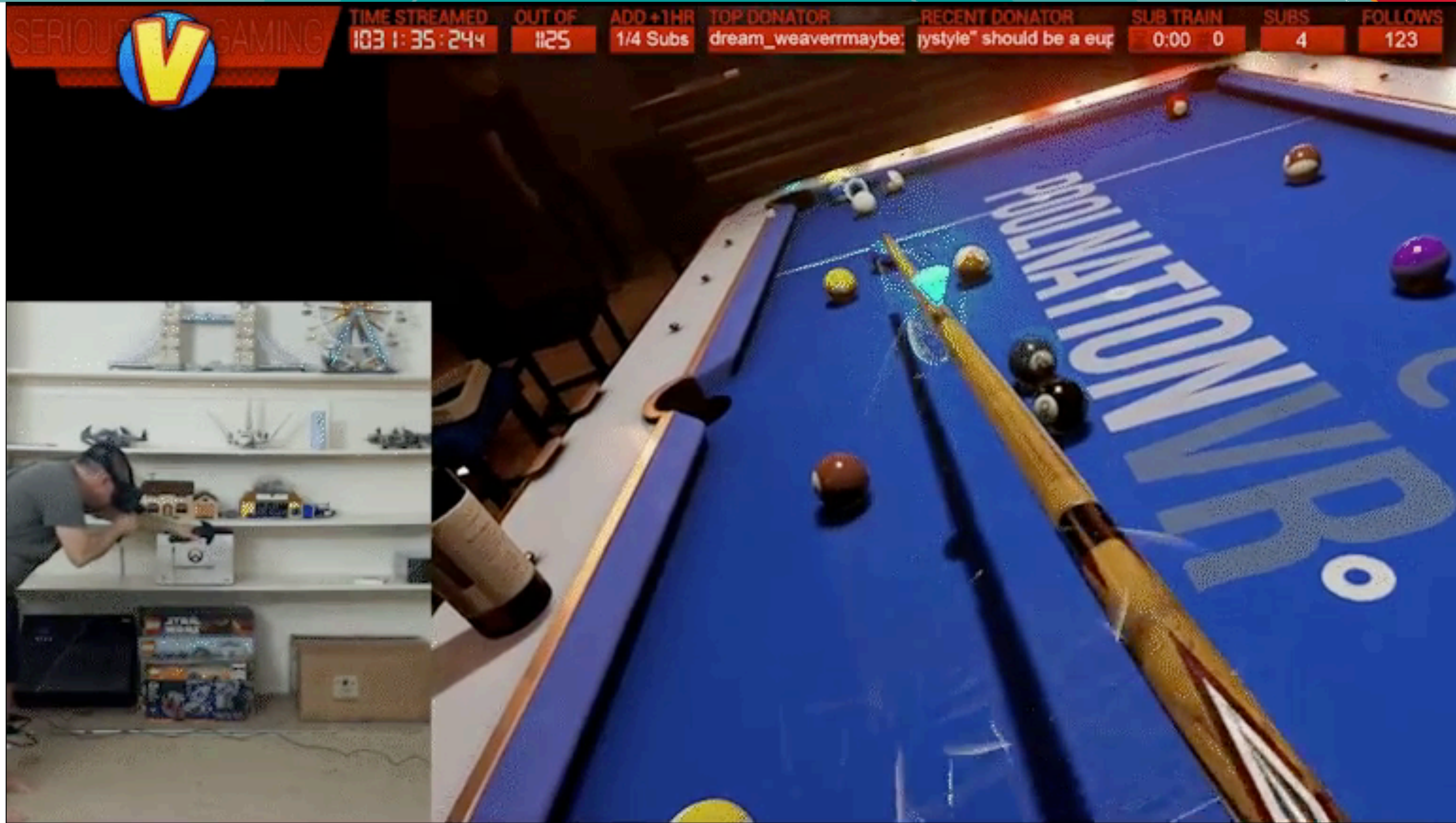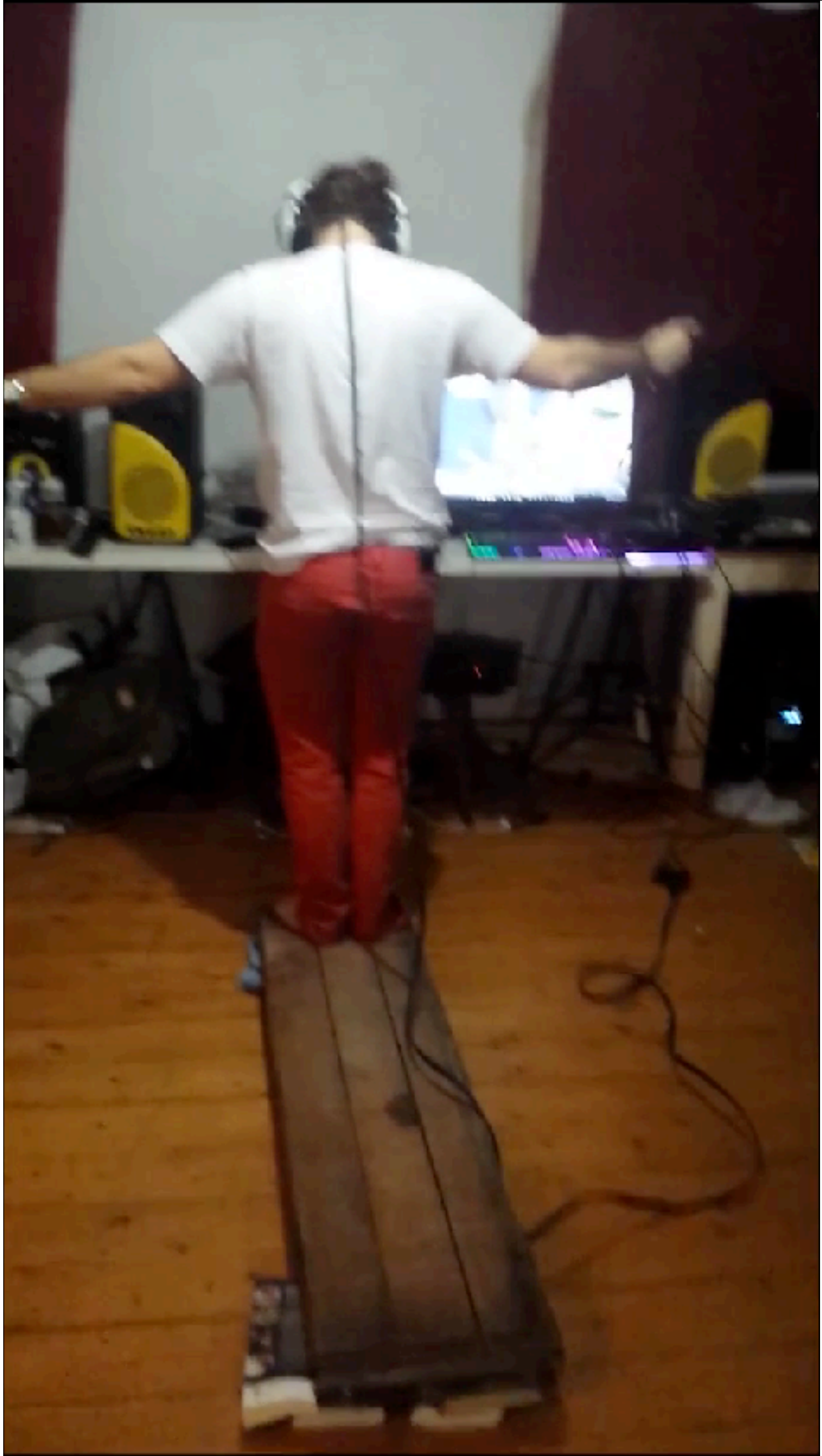# Why VR is Good for Science

Ecological Validity

- Behavioral

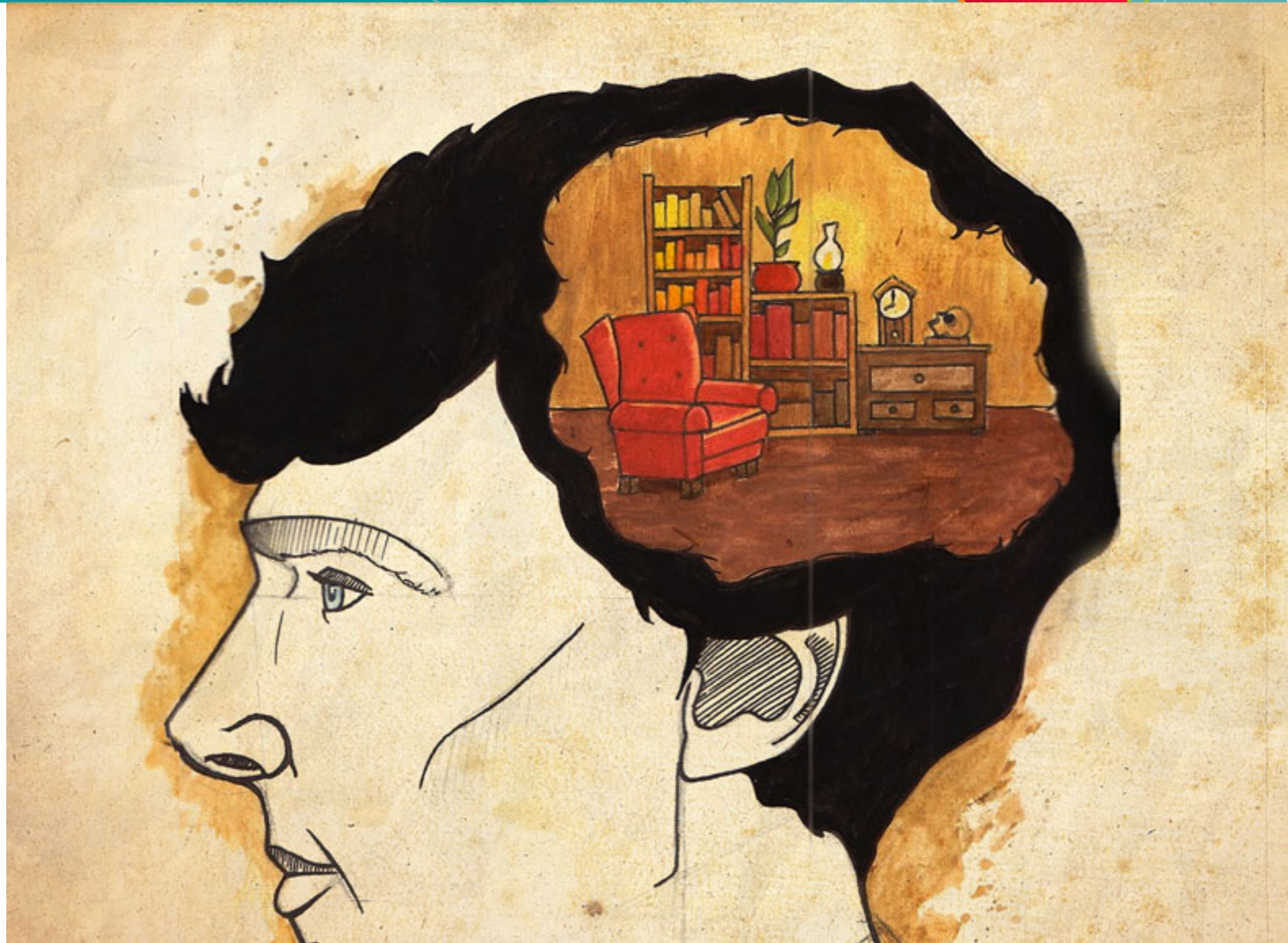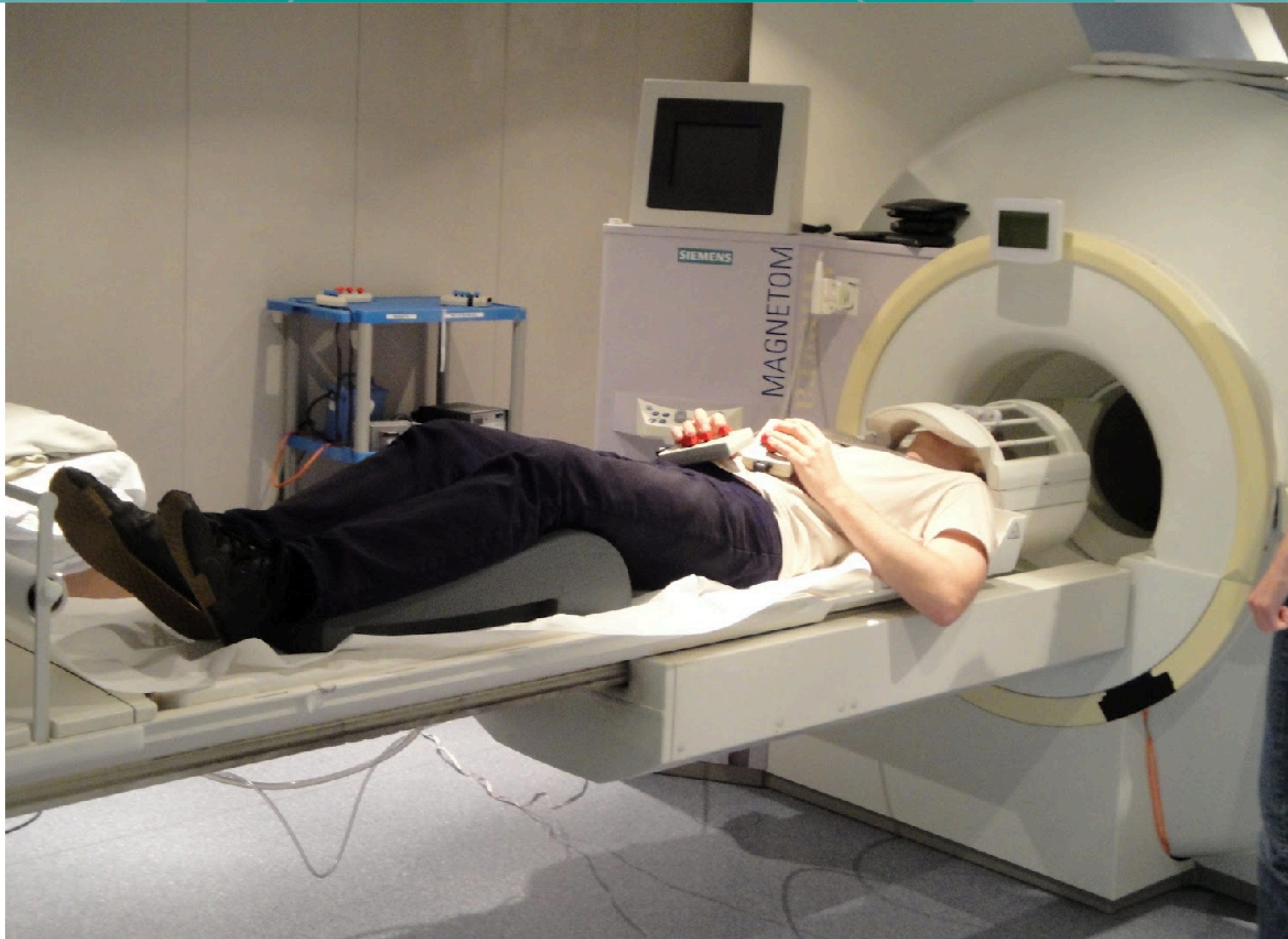# Ecological Validity

- Behavioral
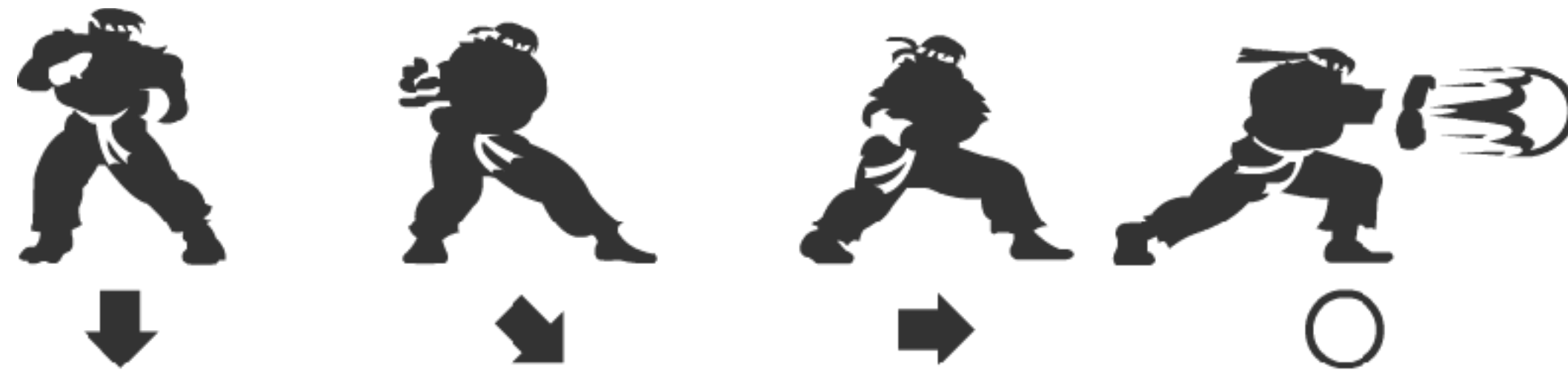
- Physiological

- Cognitive

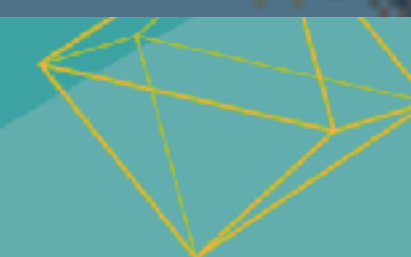# Pressing Buttons
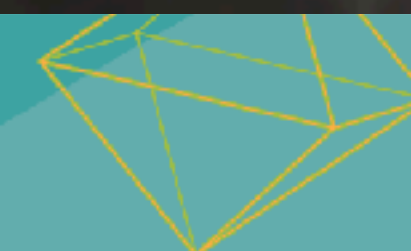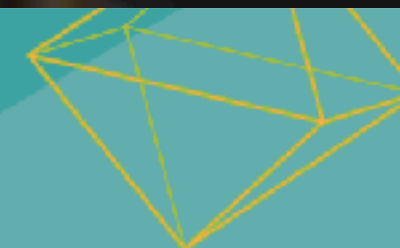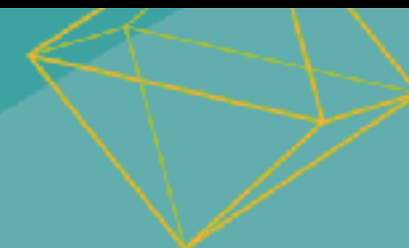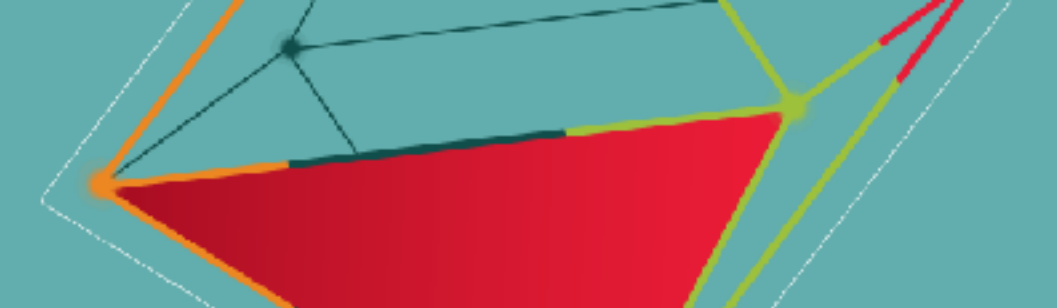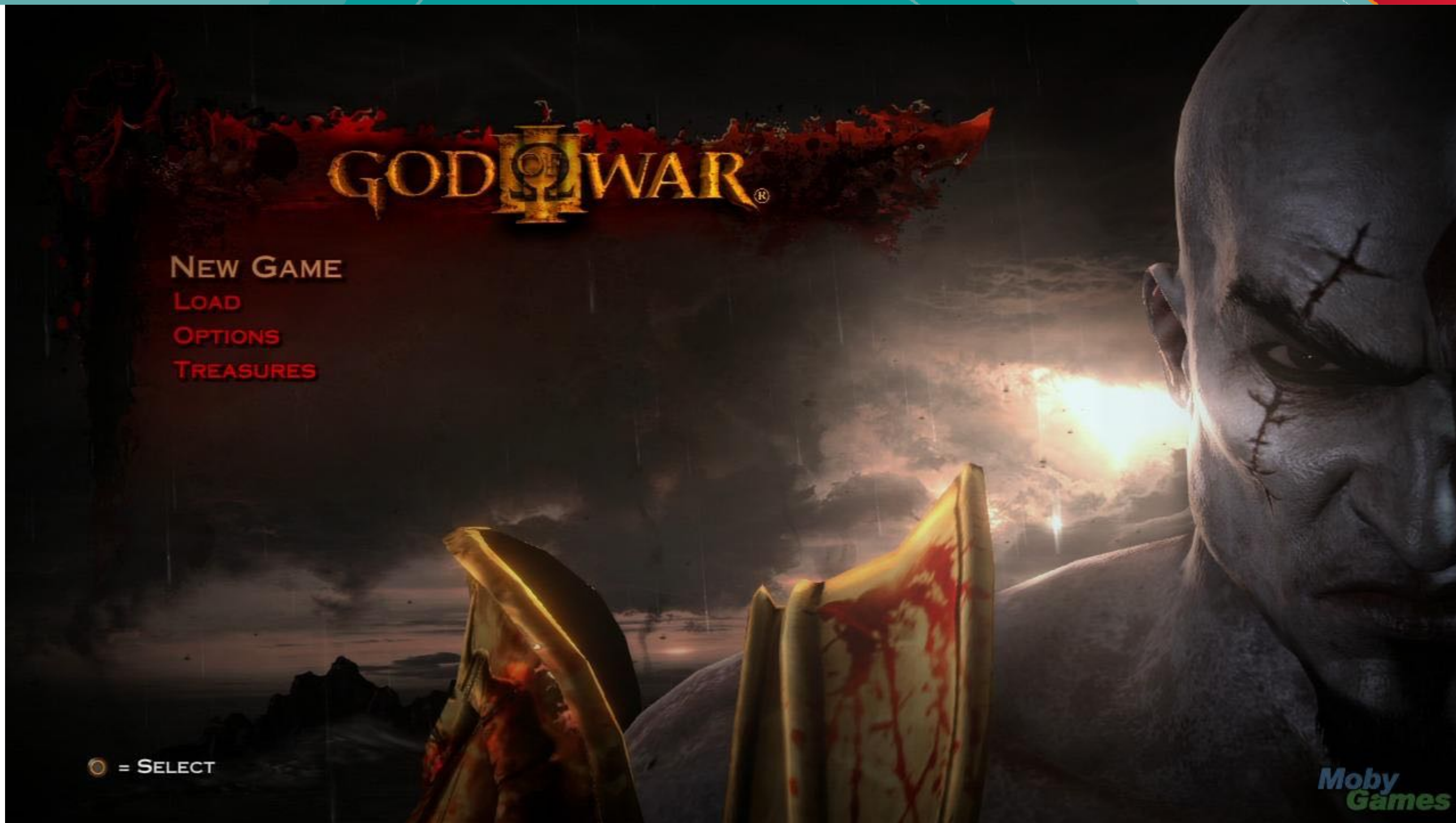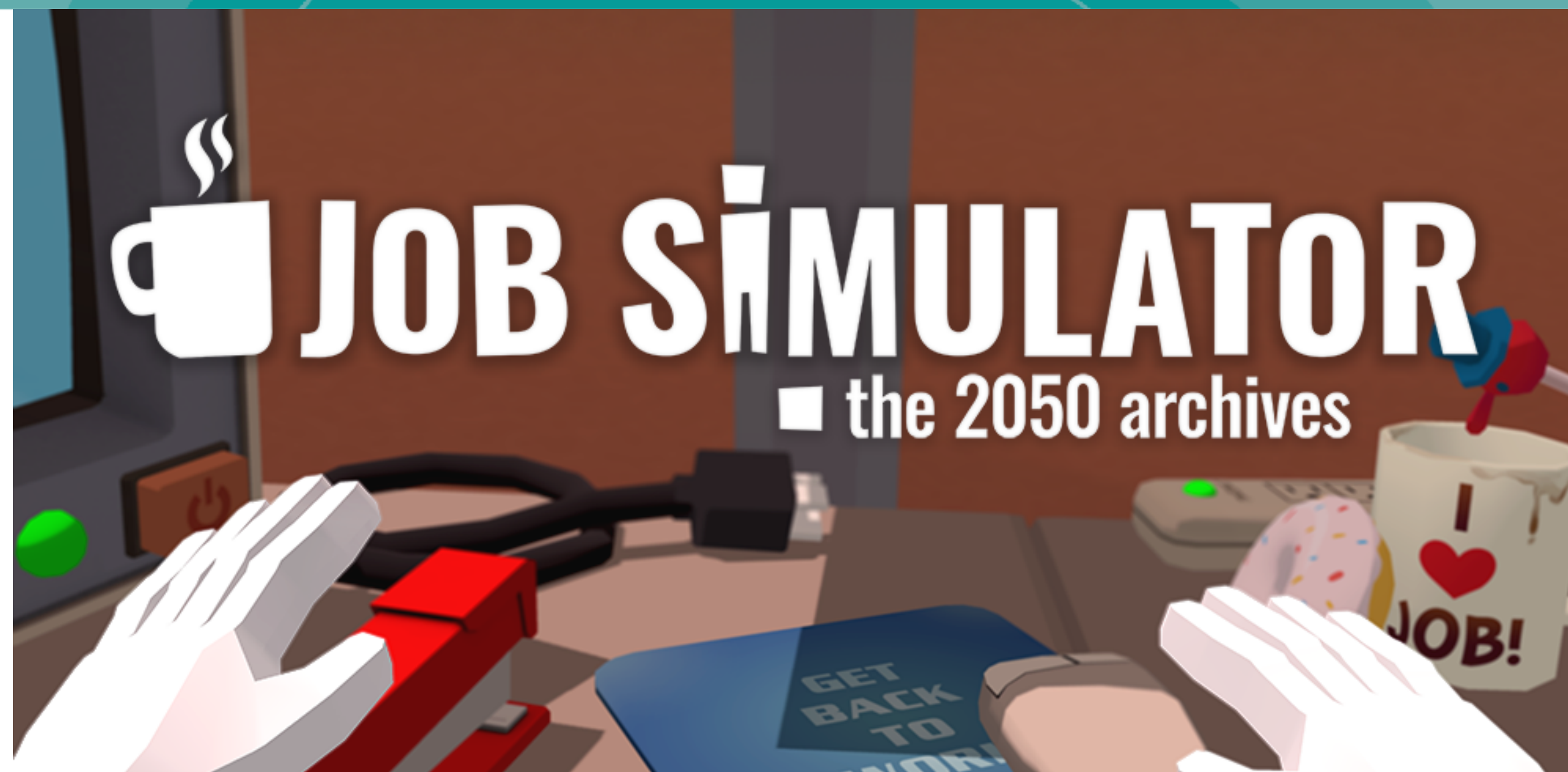
B

L3   R3

Real Life   Change the environment

Augmented Reality   **Add** visual input

Virtual Reality   **Add** visual input
                                 Remove visual input

Virtual Ball
+
Predicted Target

Virtual Ball
+
Predicted Trajectory and Target
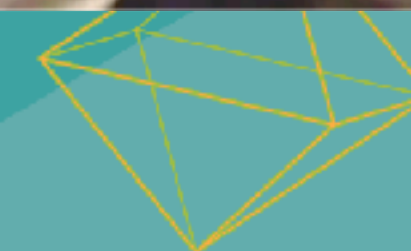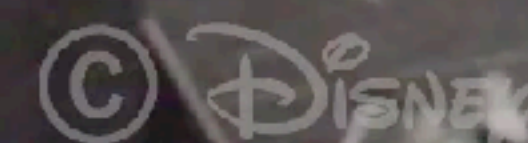
VR enables behavior that would be impossible IRL

3d-Printed VR Roomba Basketball
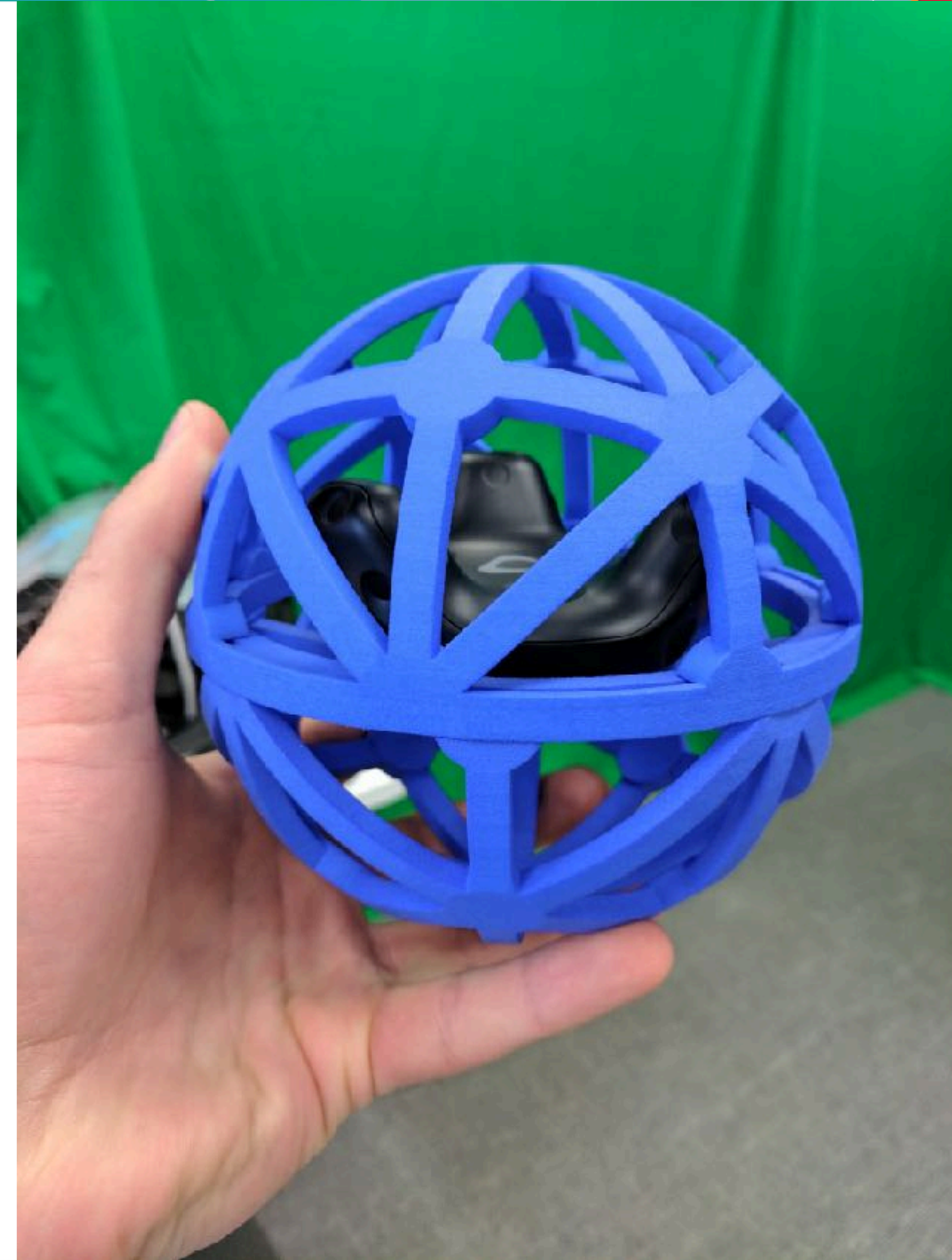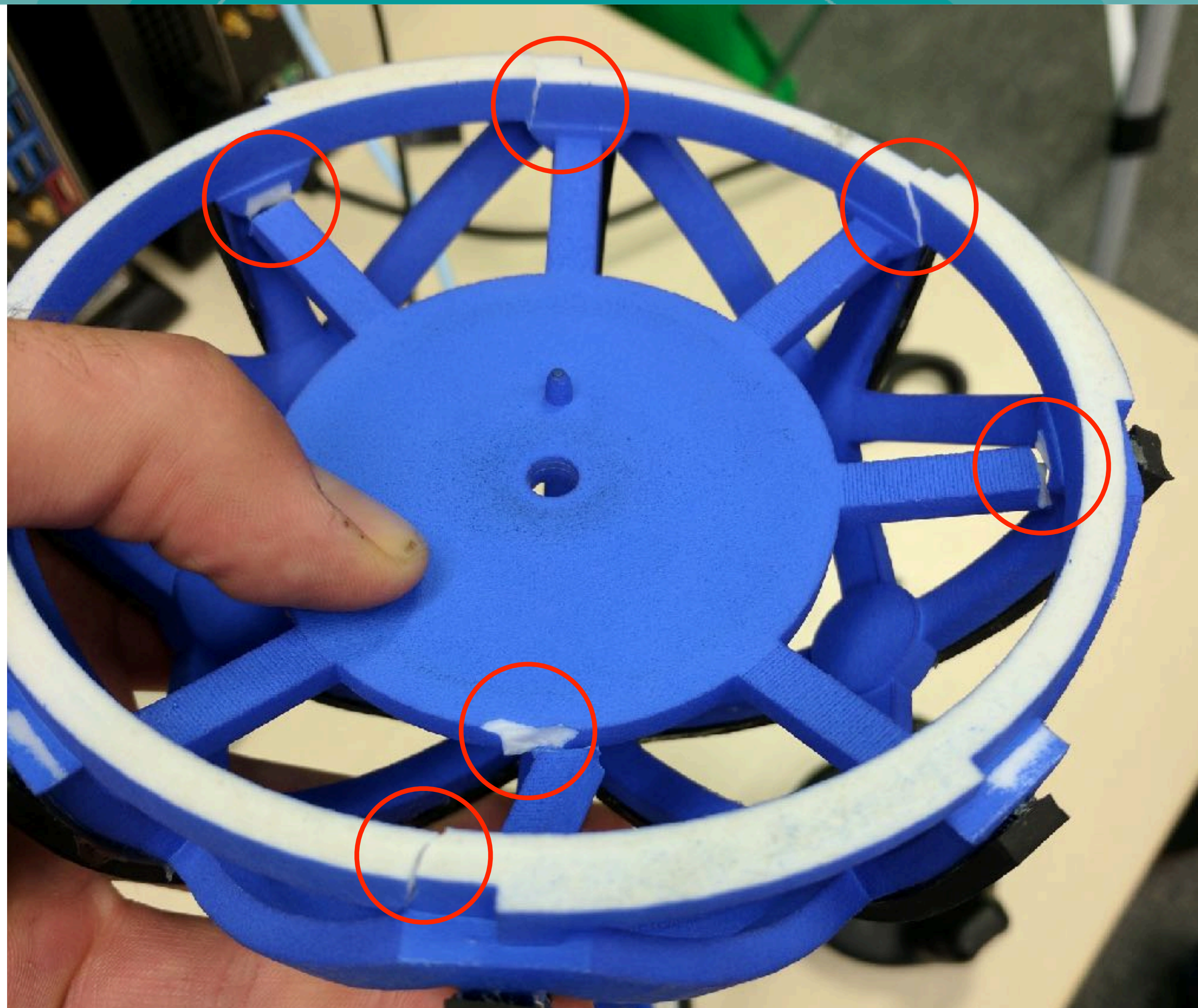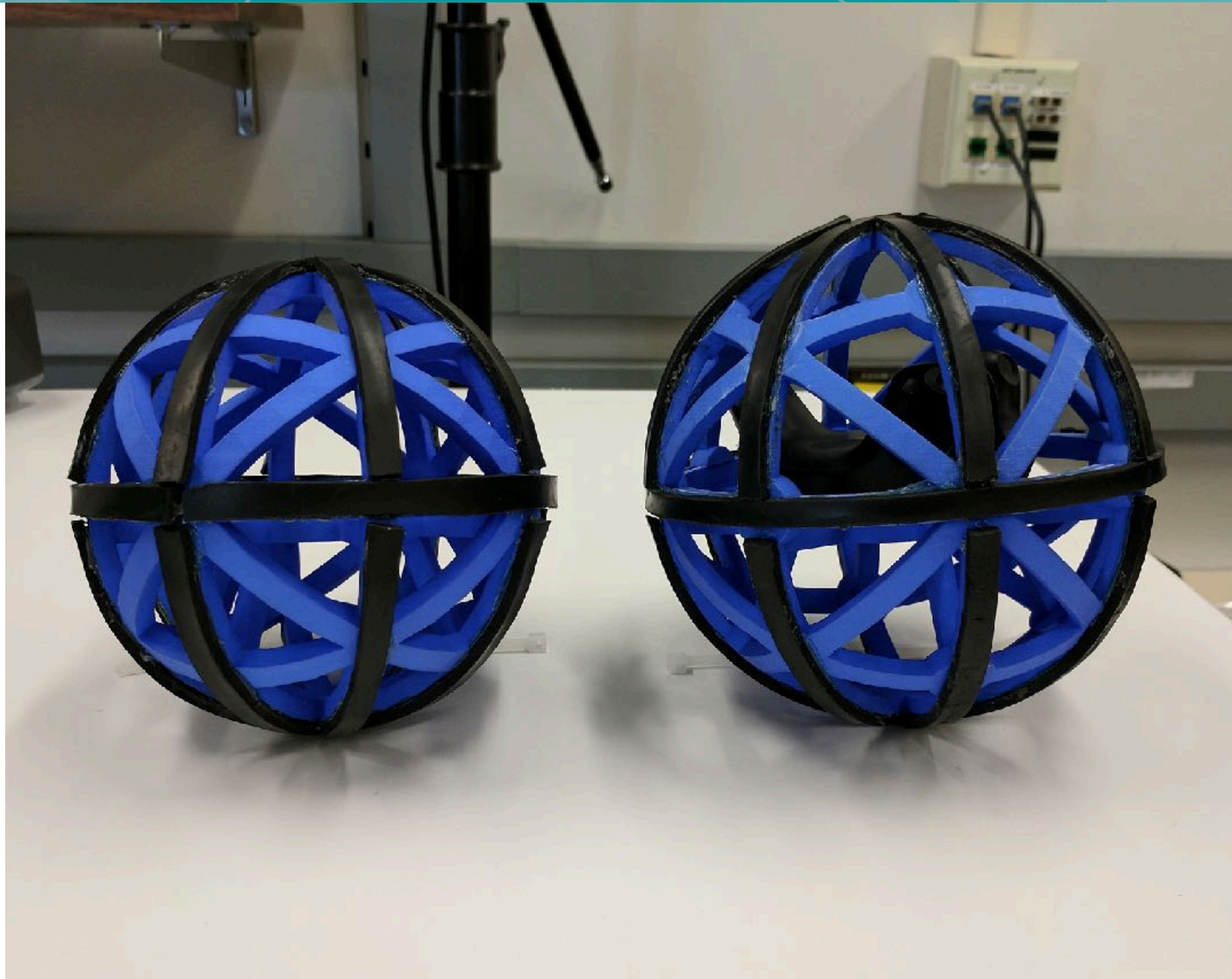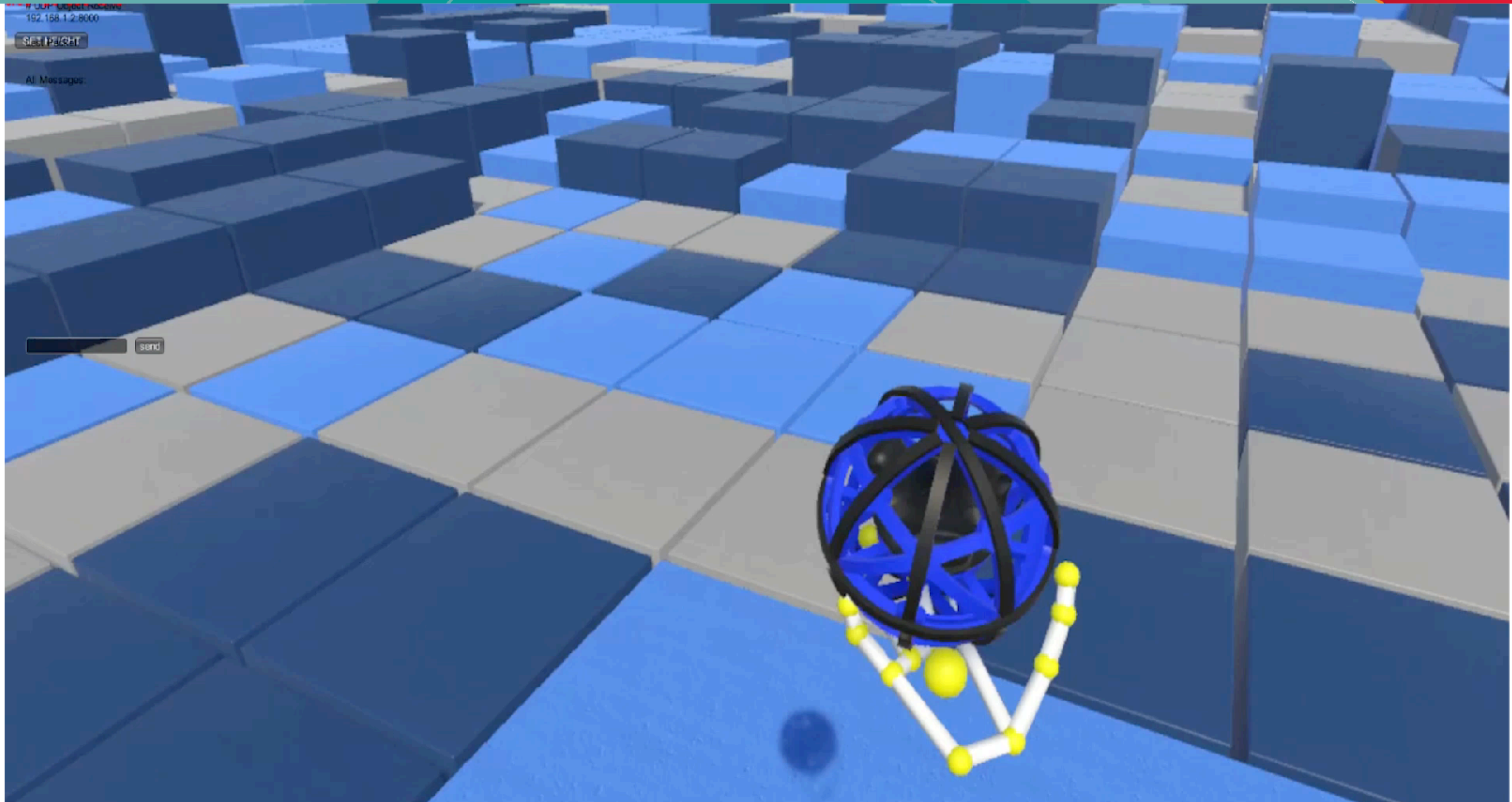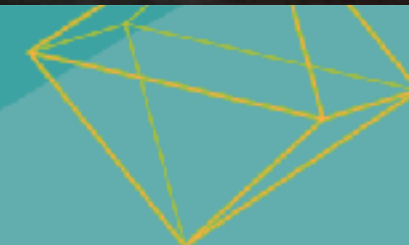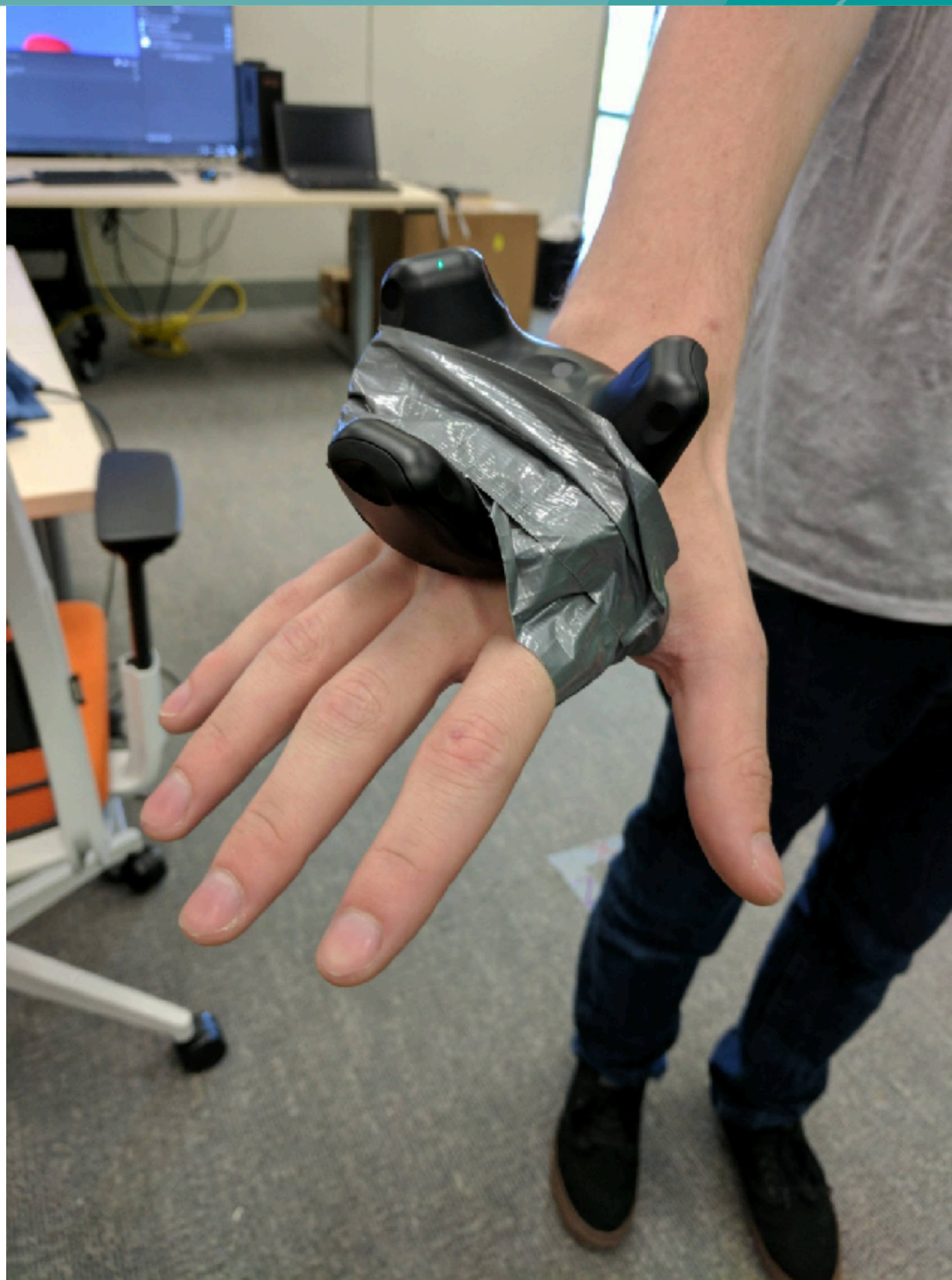
Tomato Presence

" …hand presence can be maintained using a stand-in object in VR and that the brain will intuitively accept it."

iRobot Create 2

Raspberry Pi

+
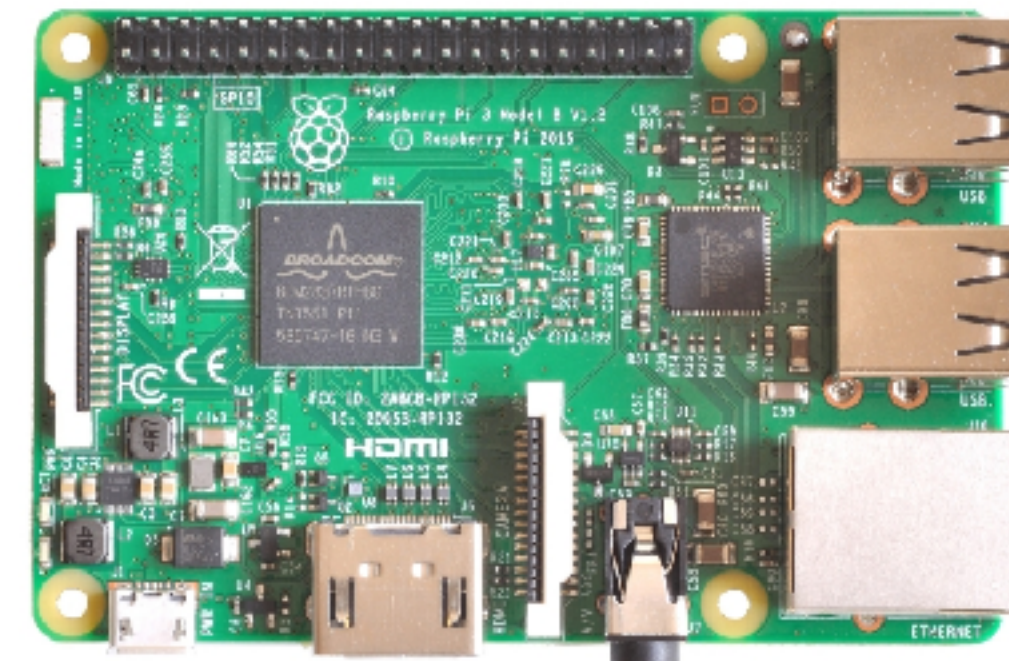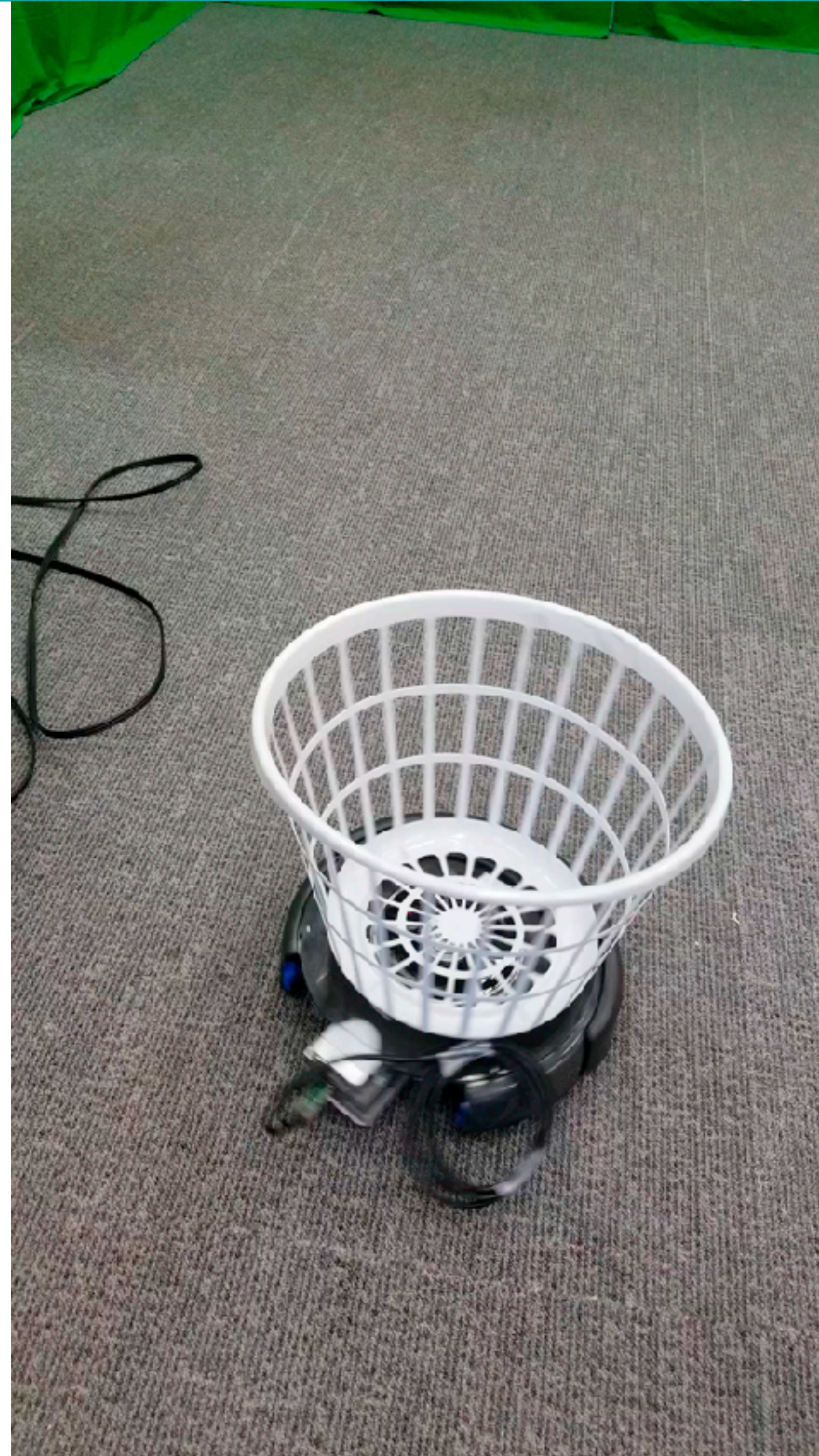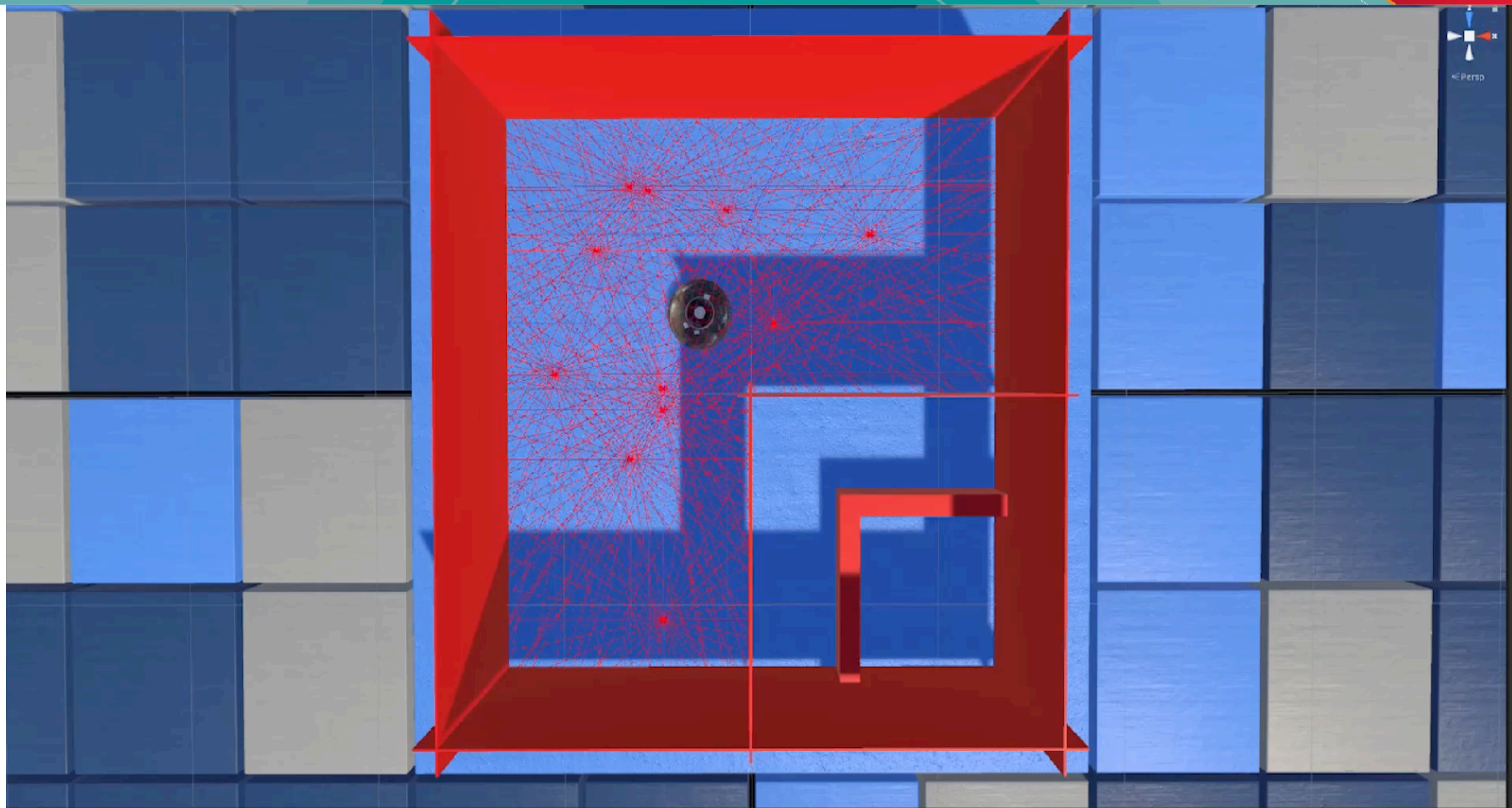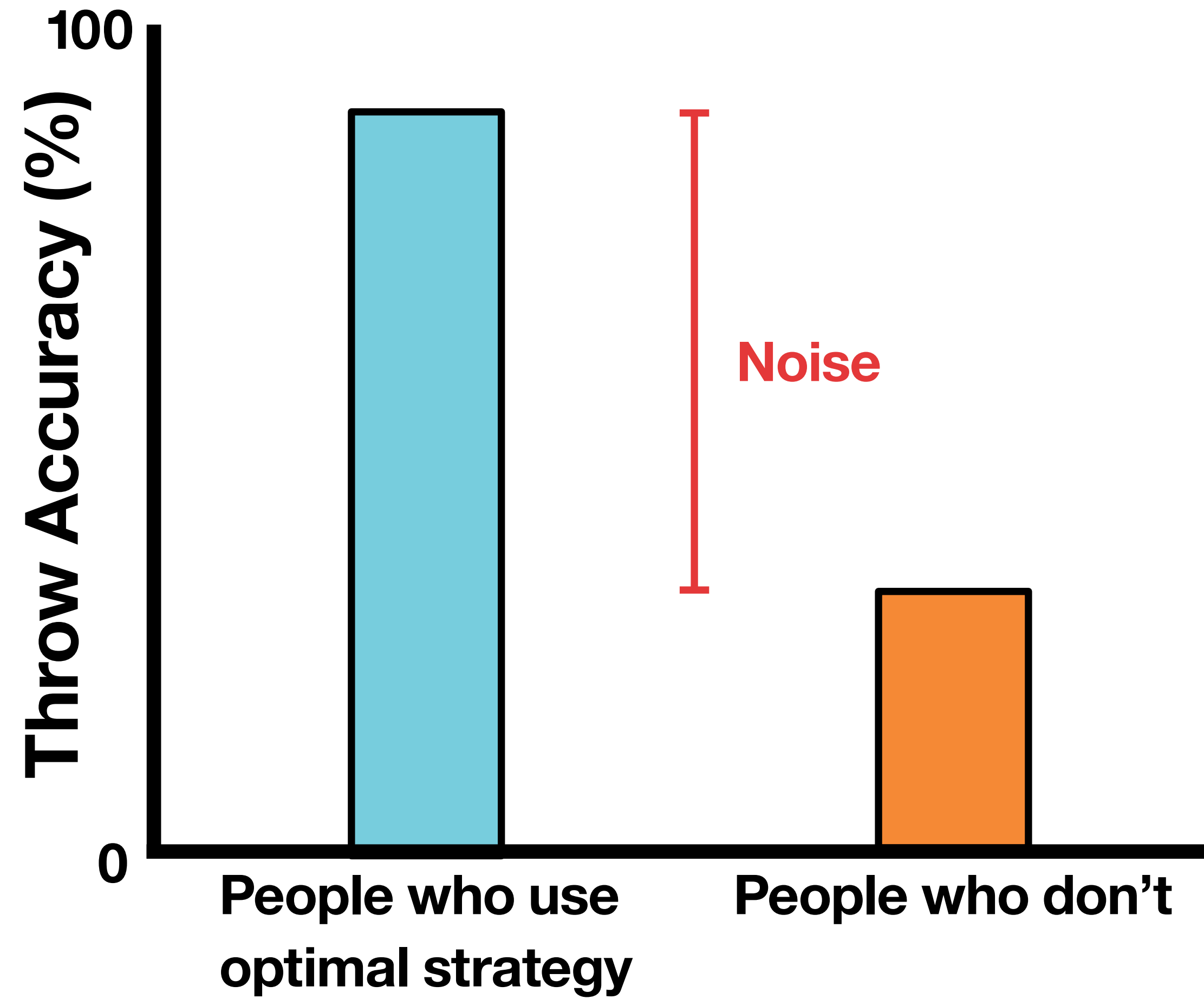
Nerf VR Targeting
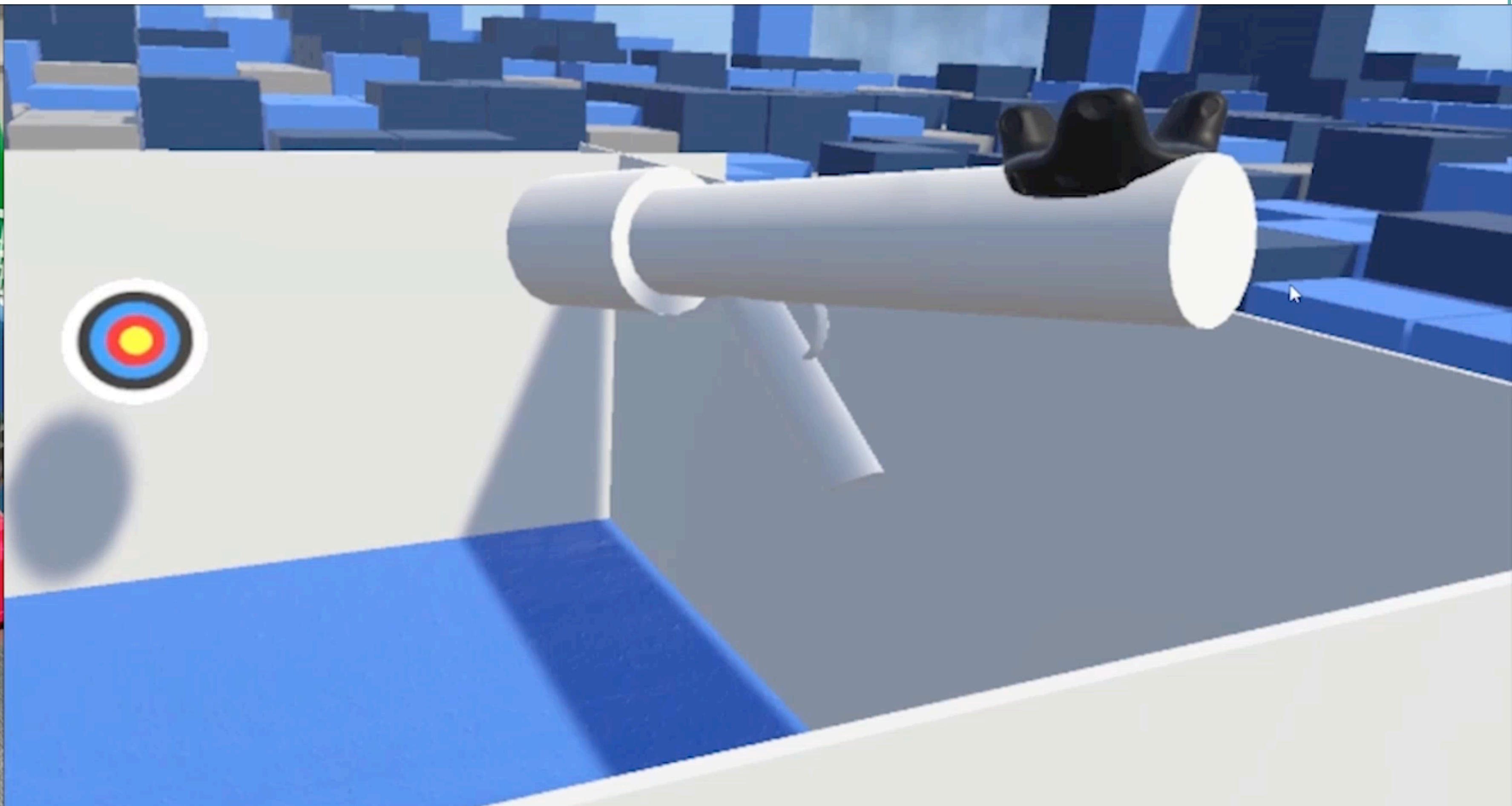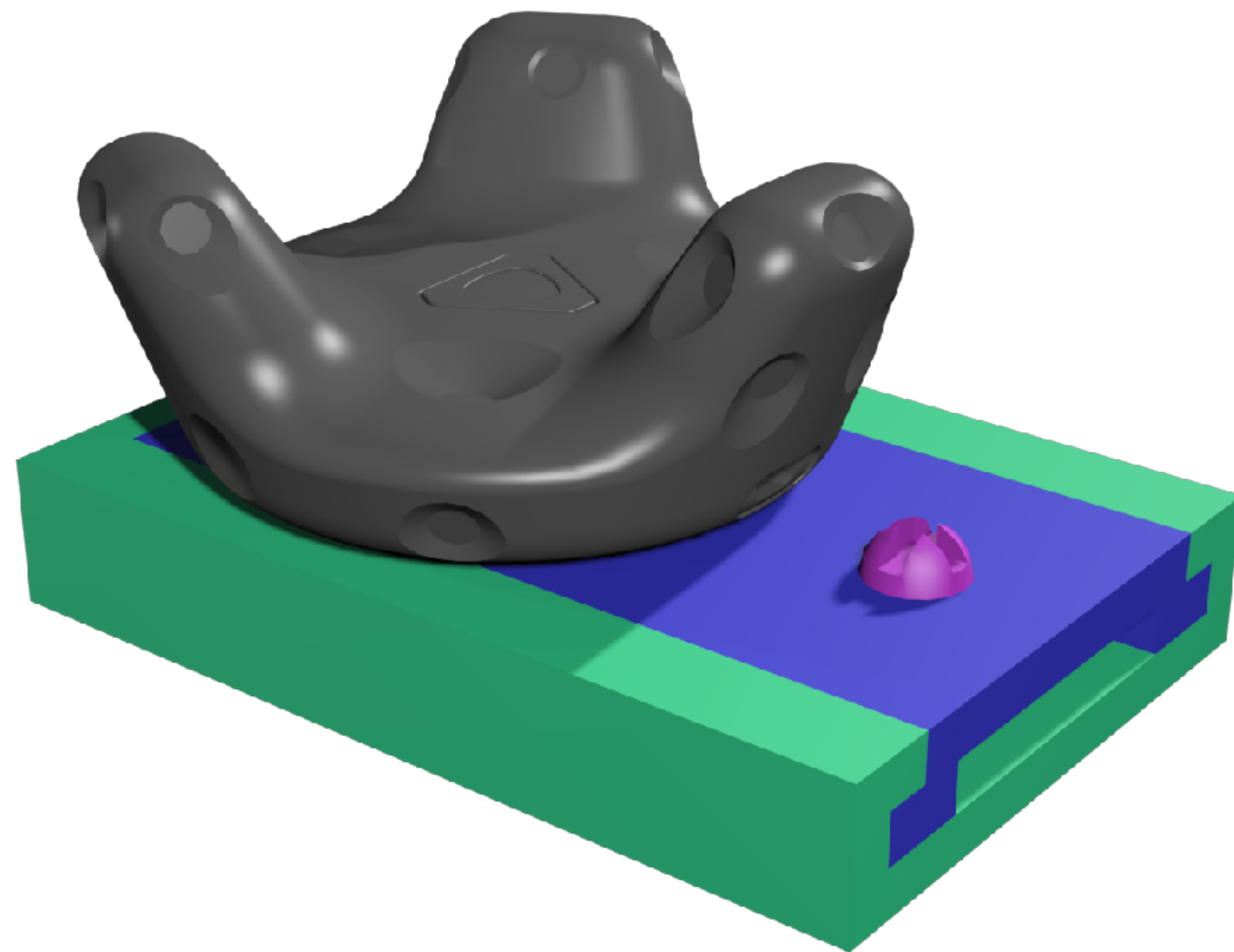
3 Conditions

RL
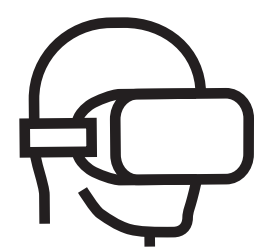
VR

3 Conditions

RL

VR
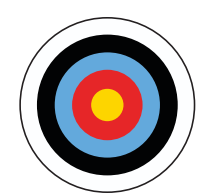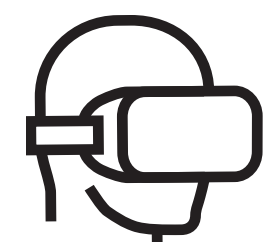
VR Targeting
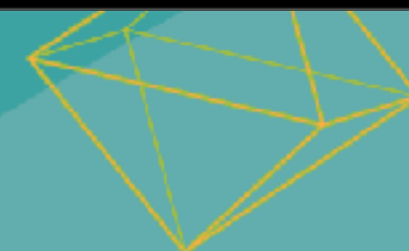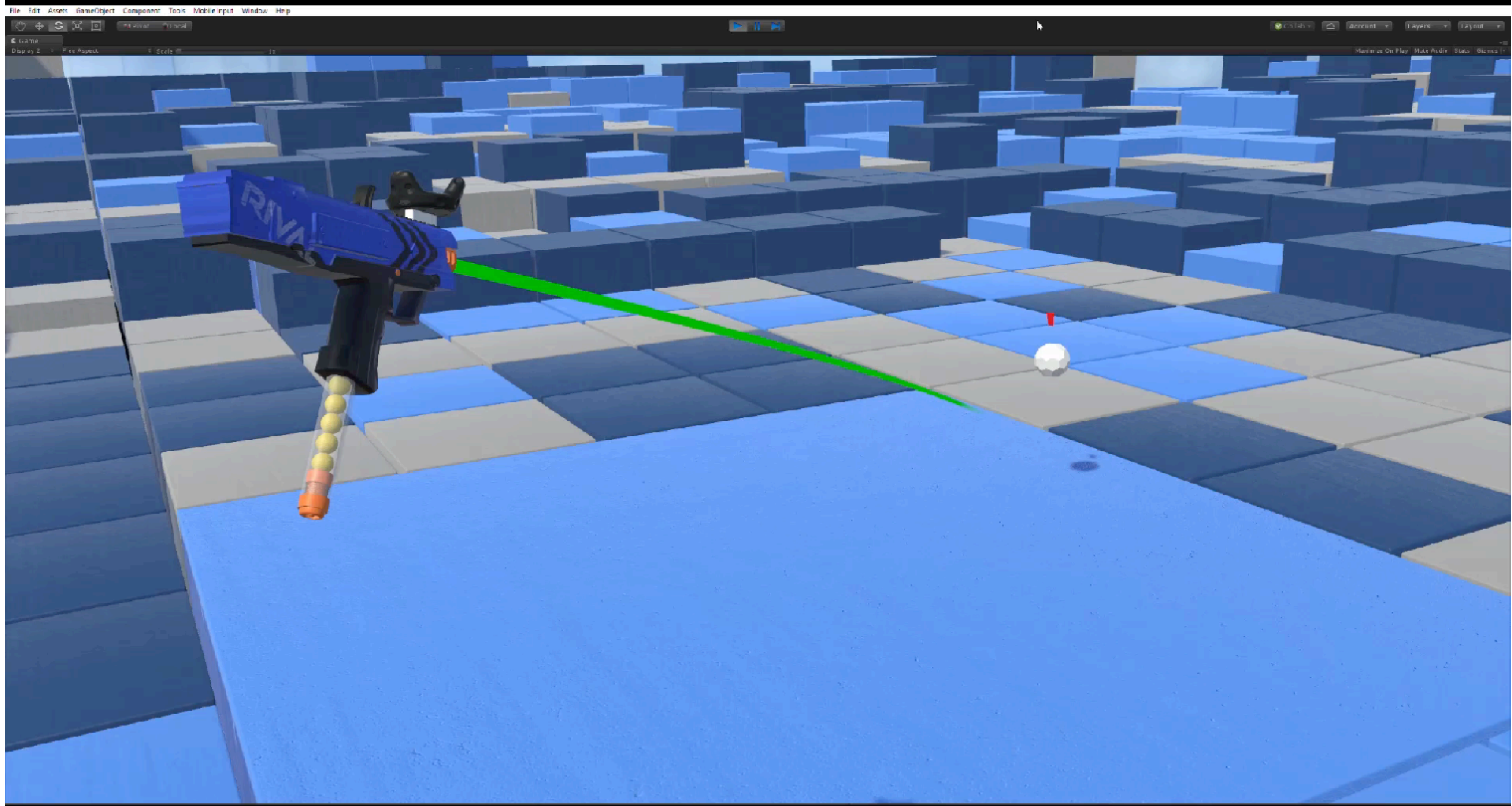
RL
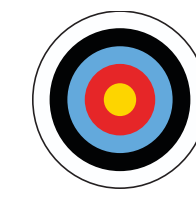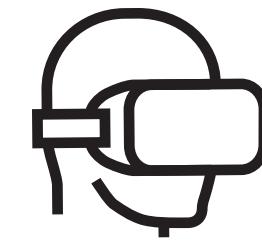
VR Targeting
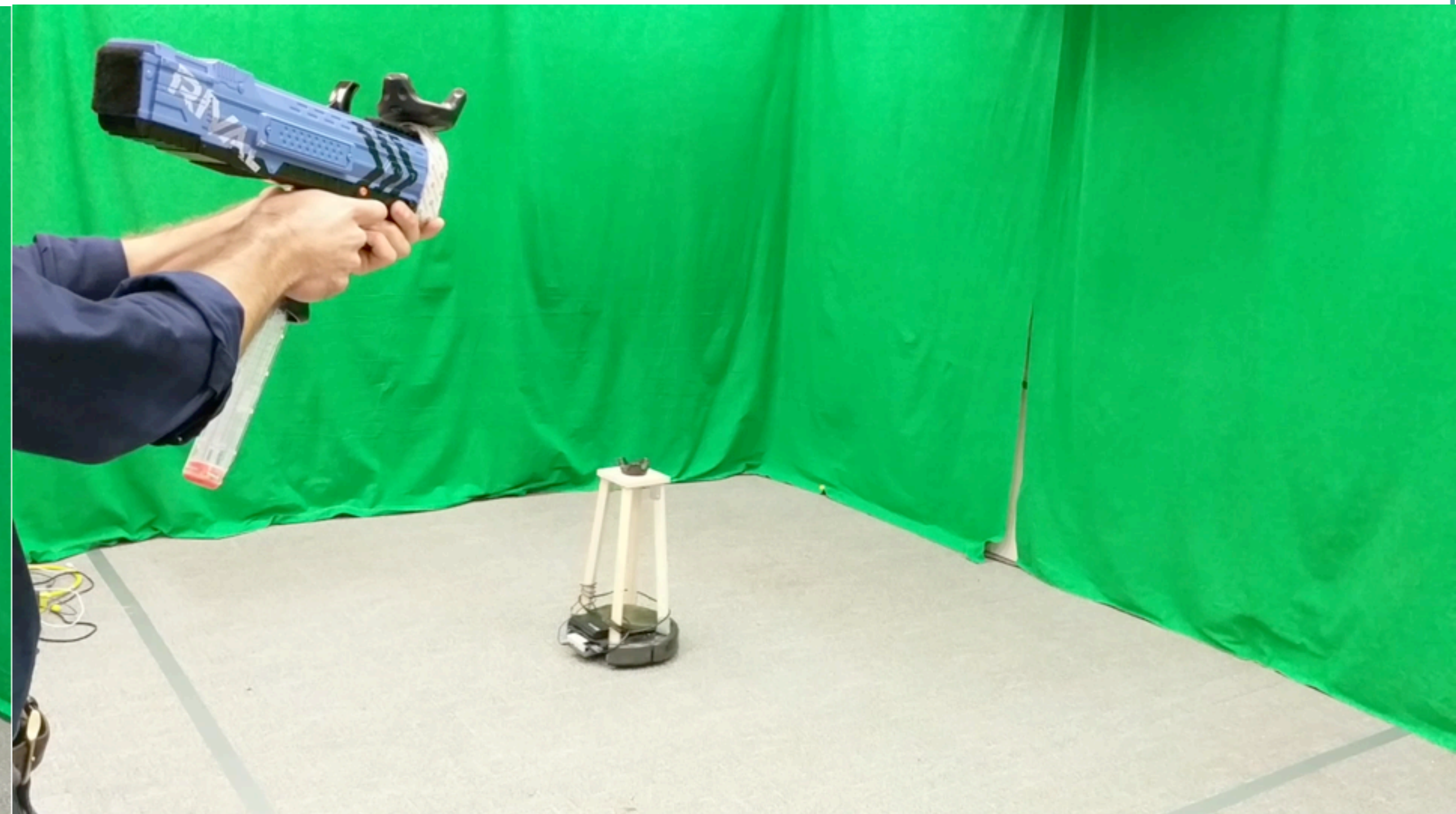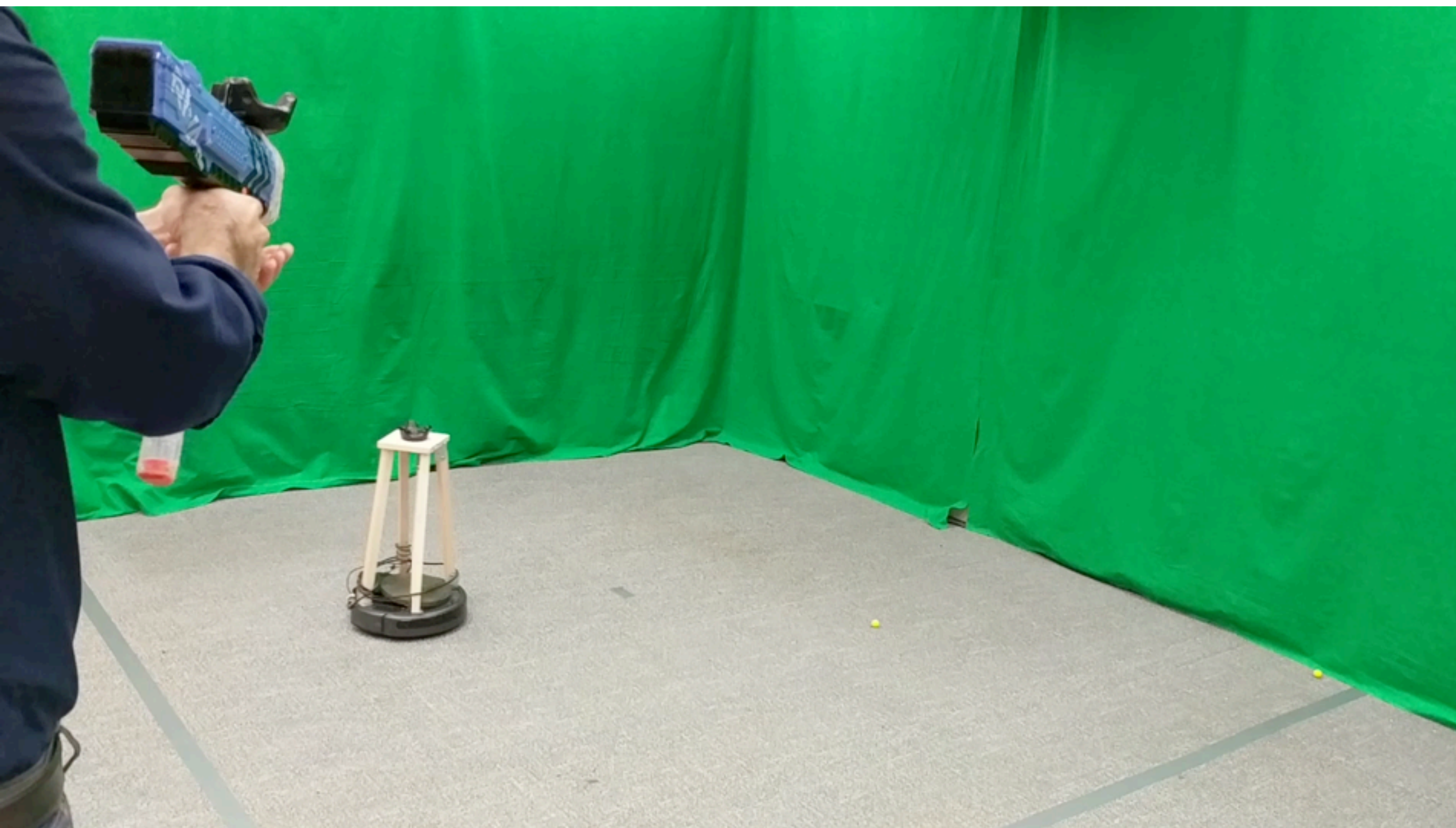
Hypotheses

1) VR Targeting will enhance accuracy

RL == VR < VR Targeting

2) VR Targeting will enhance **future** accuracy in both VR and RL

• Players will be more likely to use optimal strategy

Machine Learning
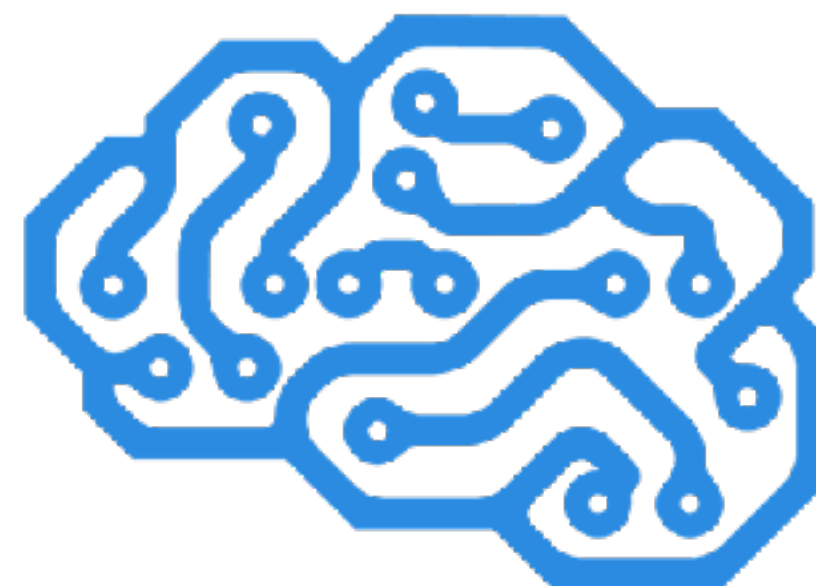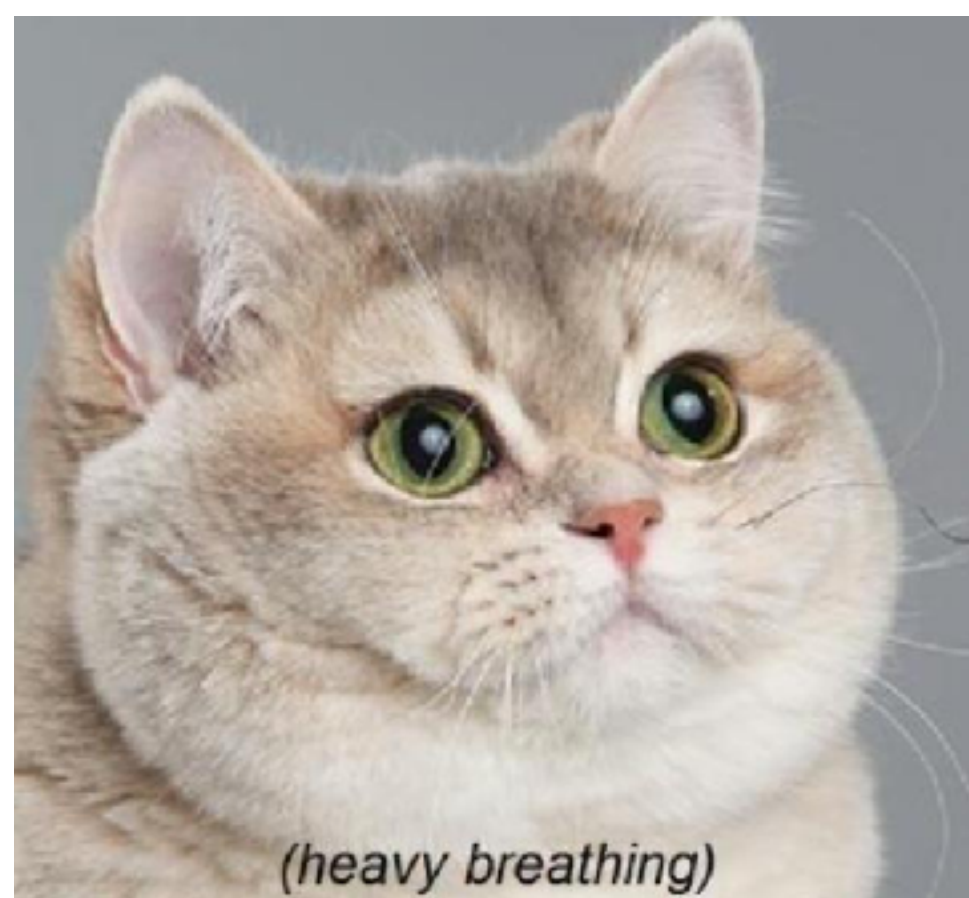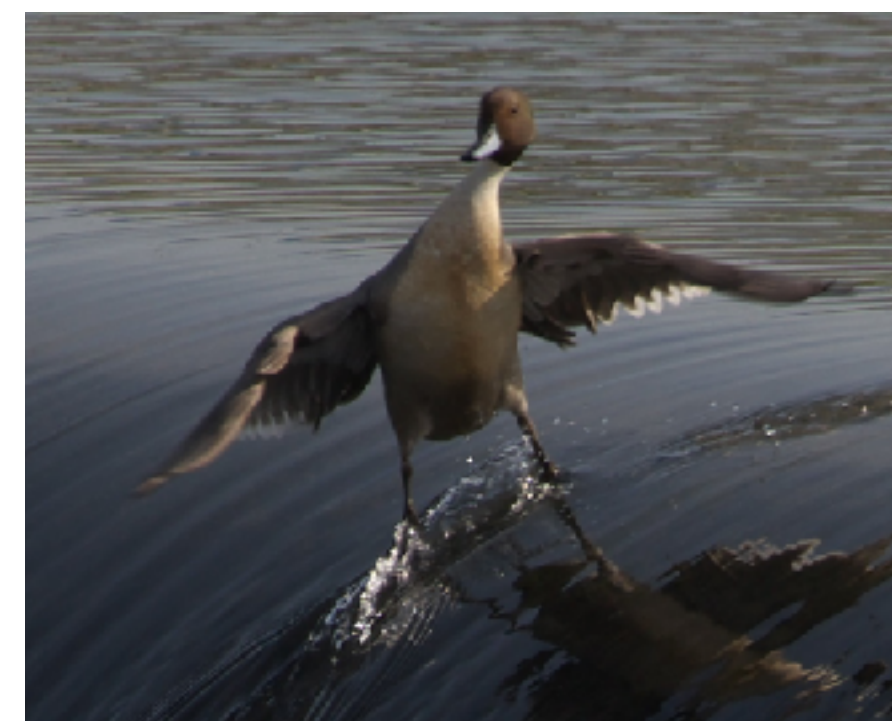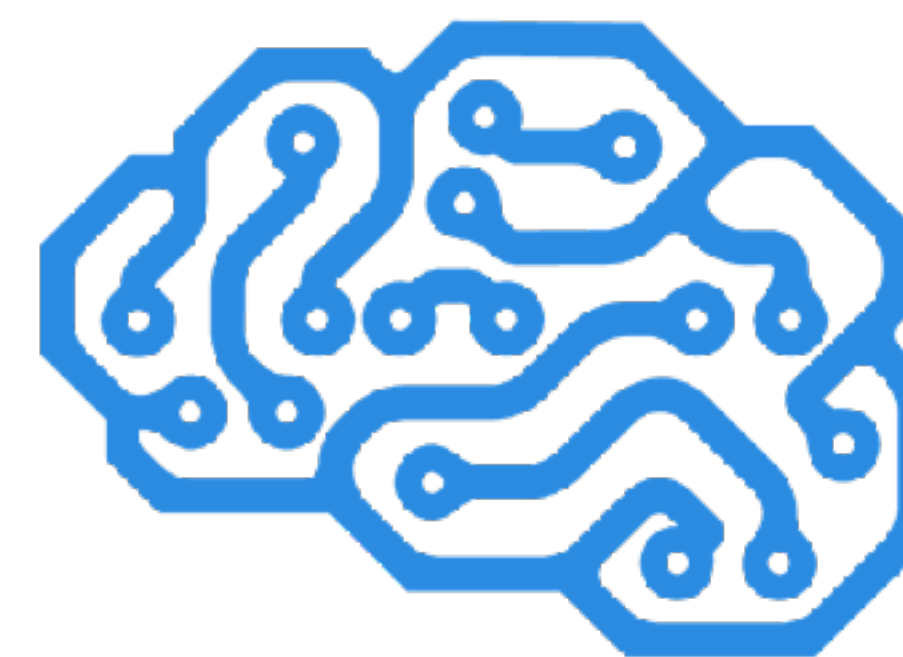
Cat = False (74% Confidence)

Neural Signature of Memory
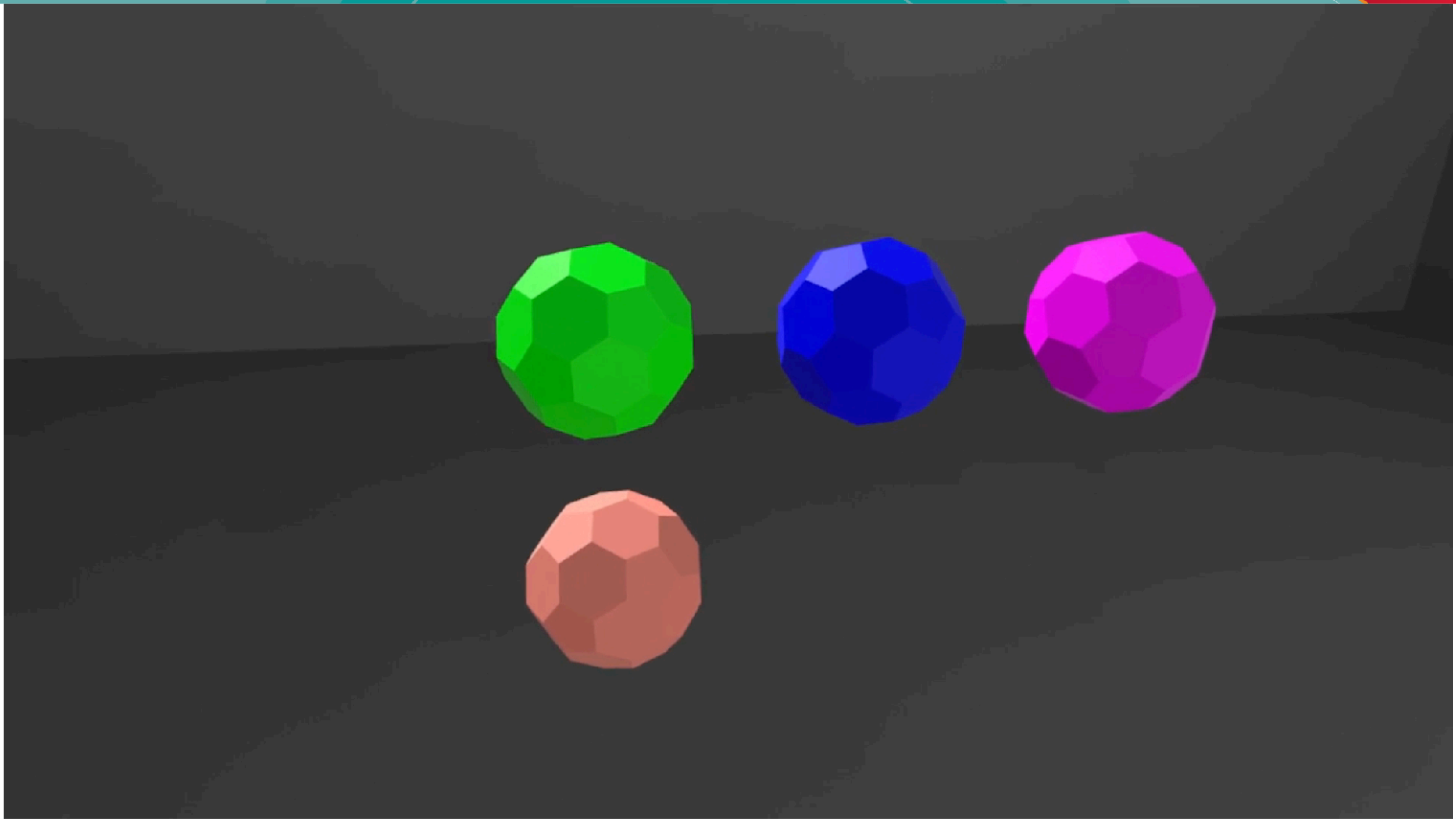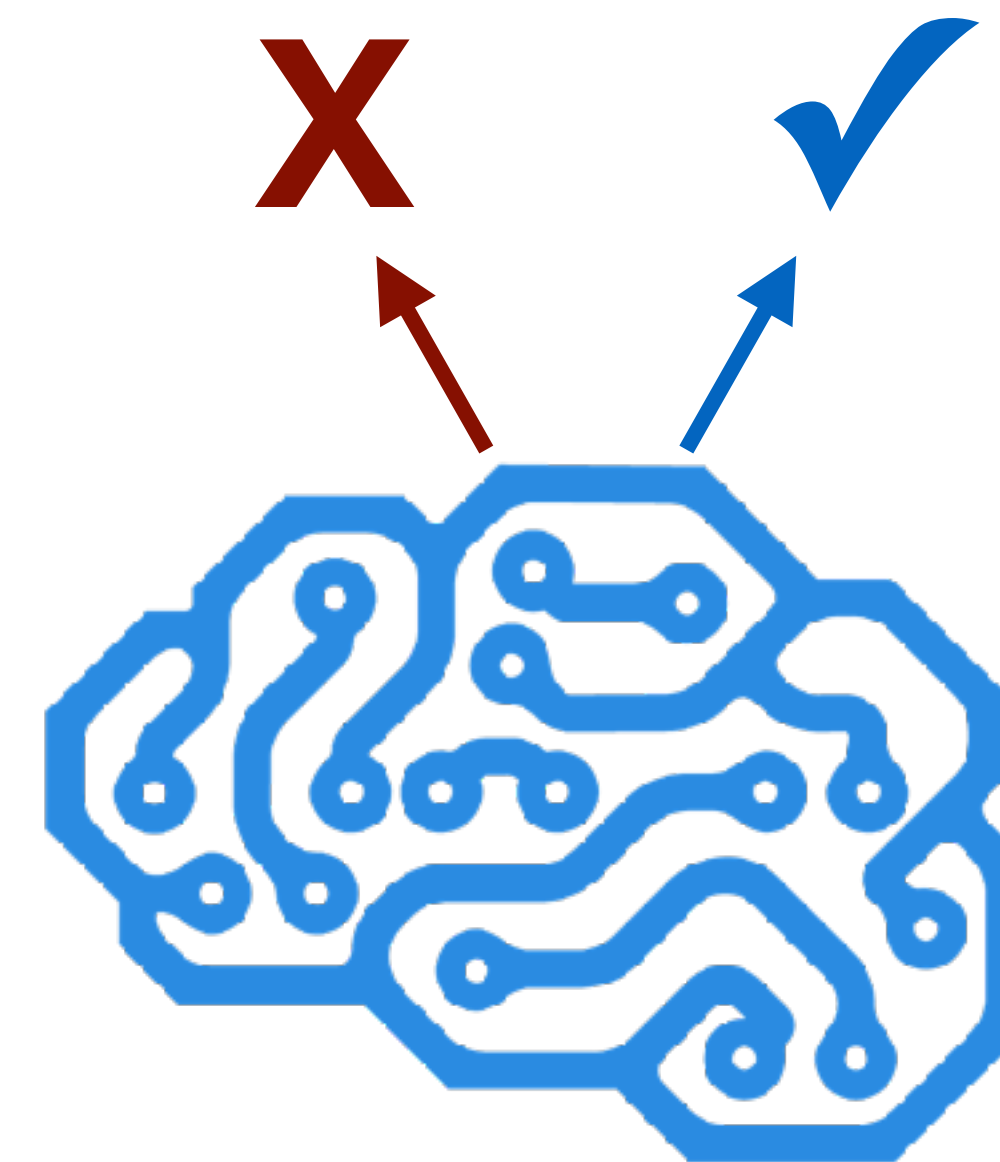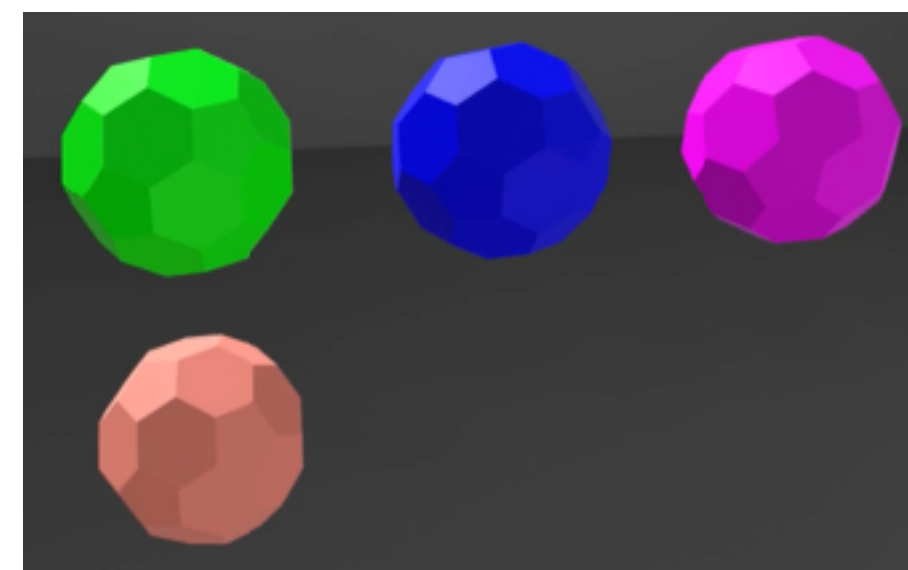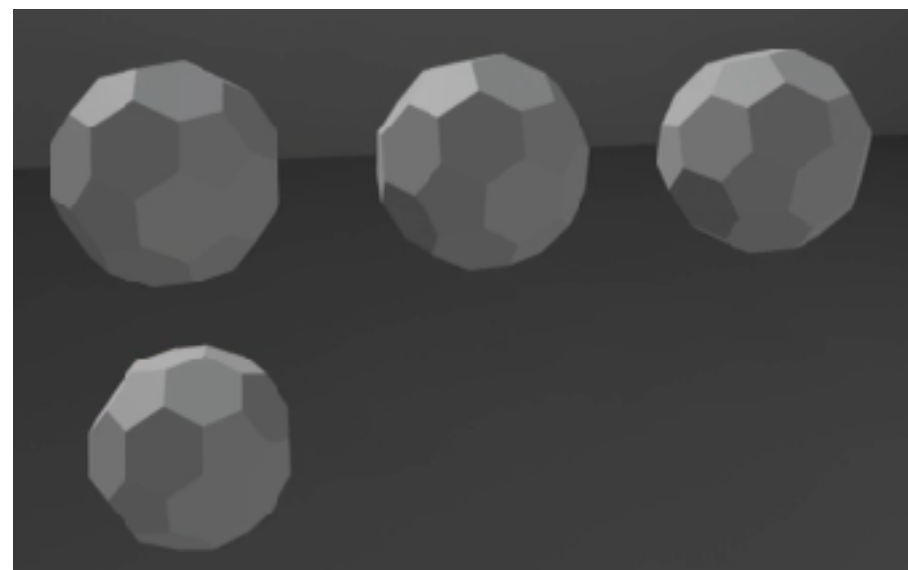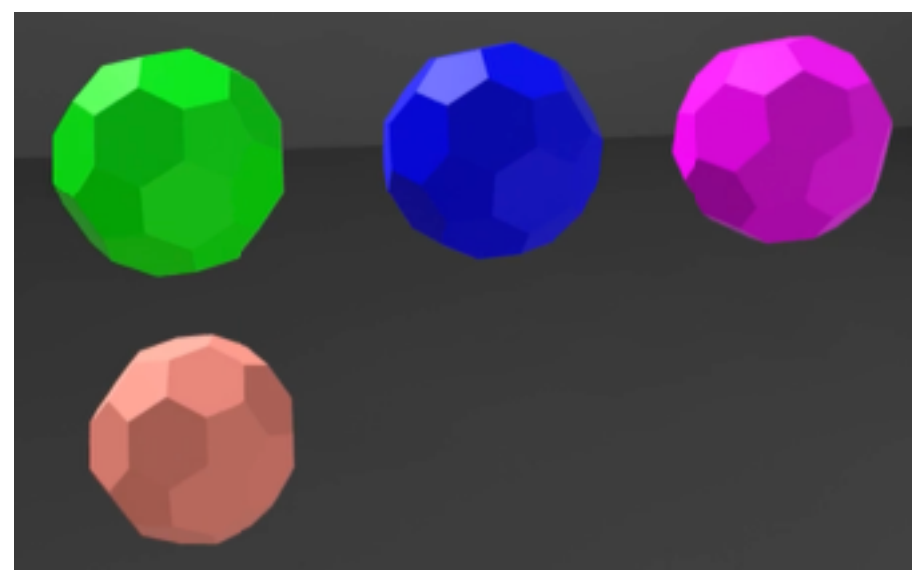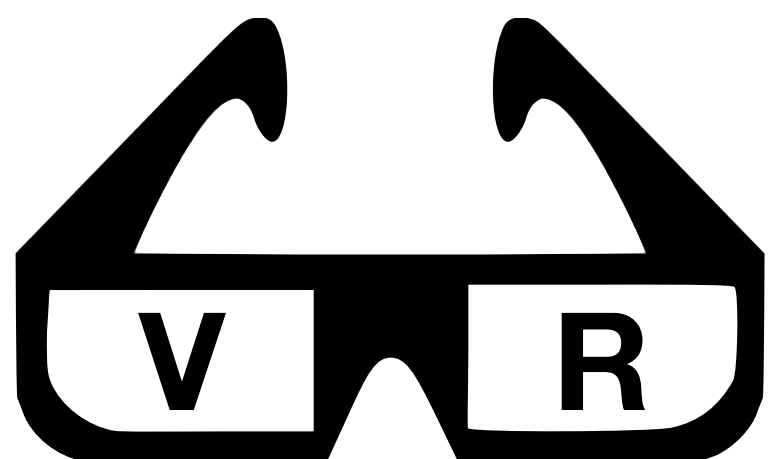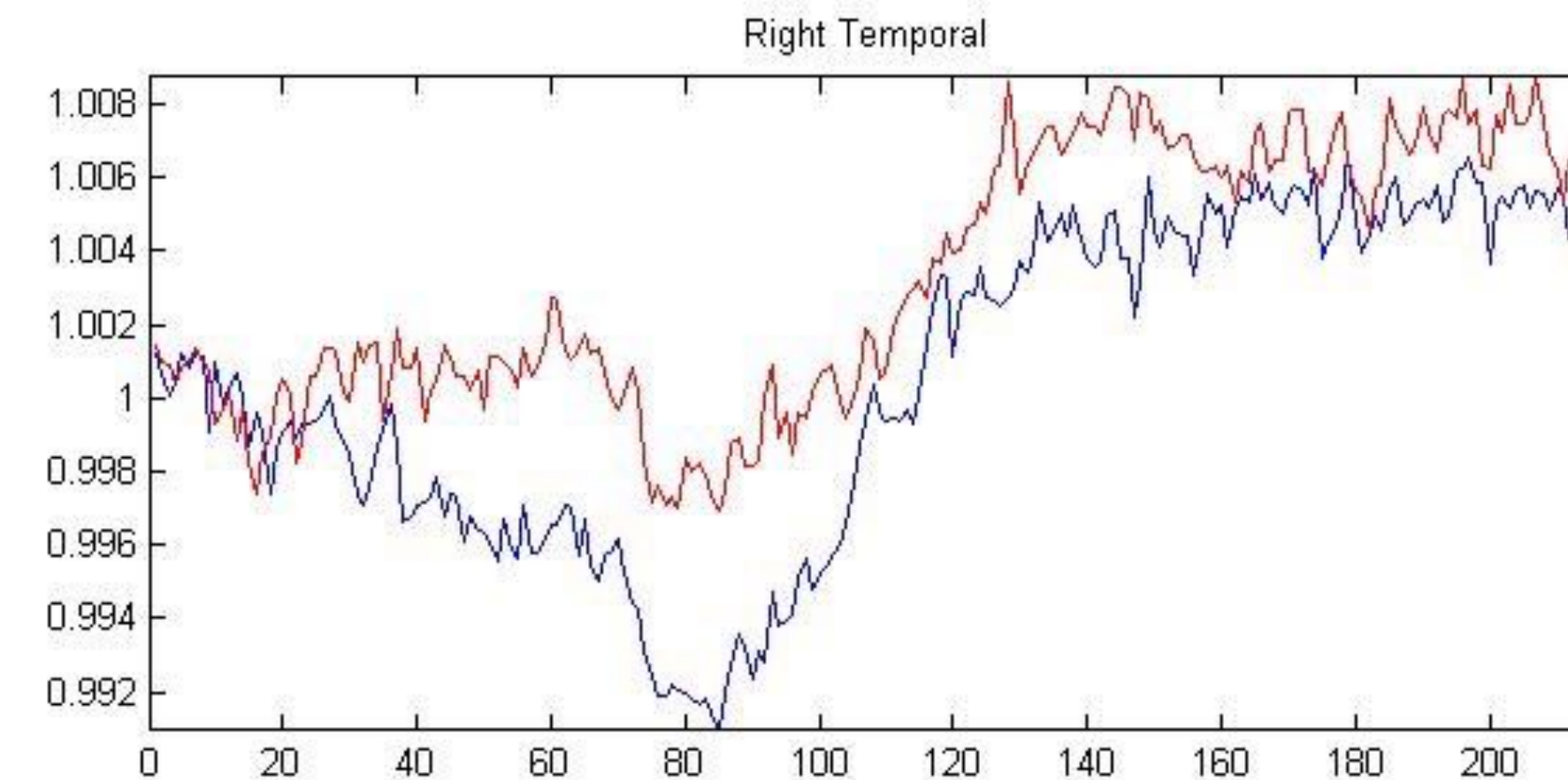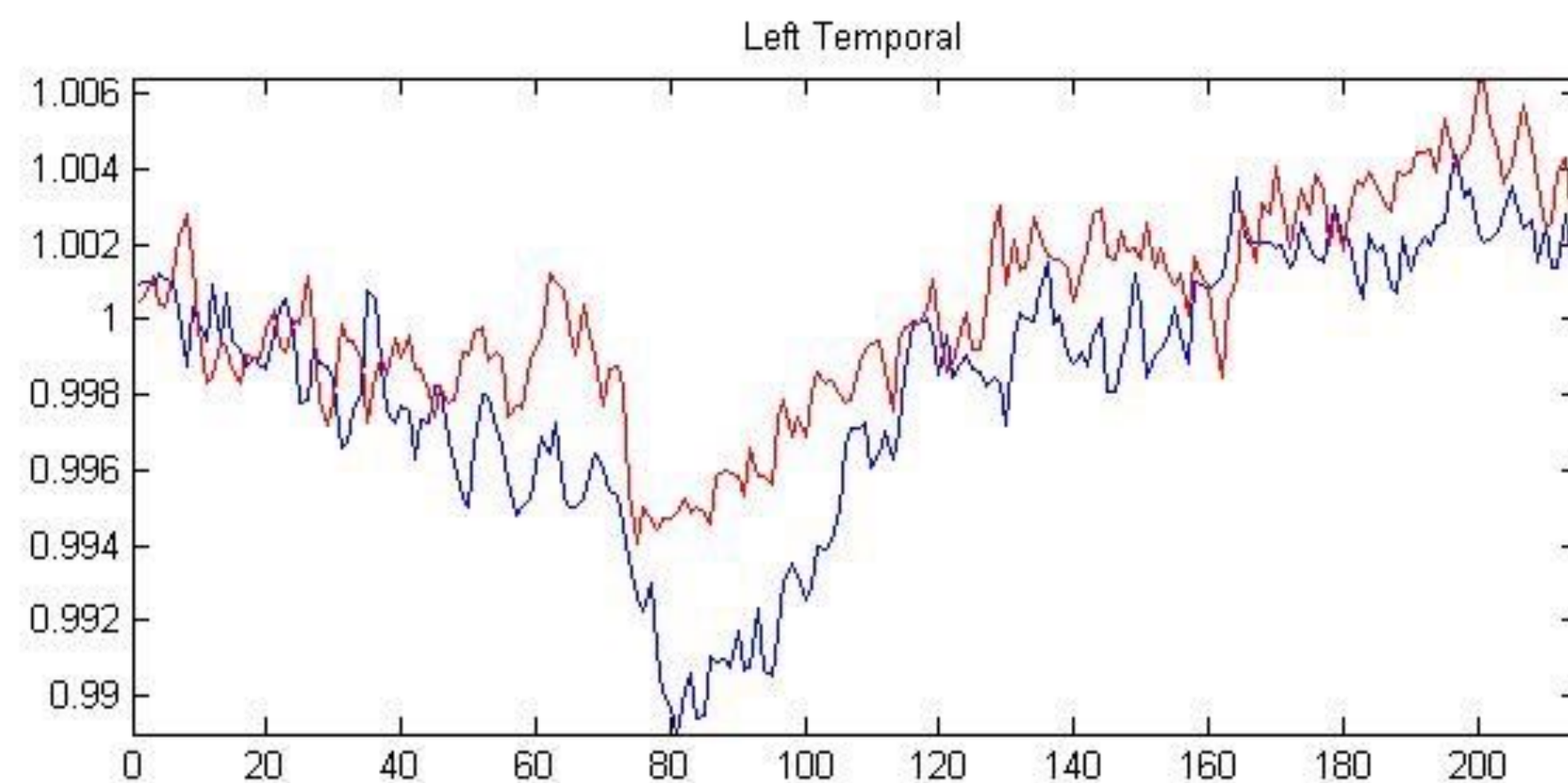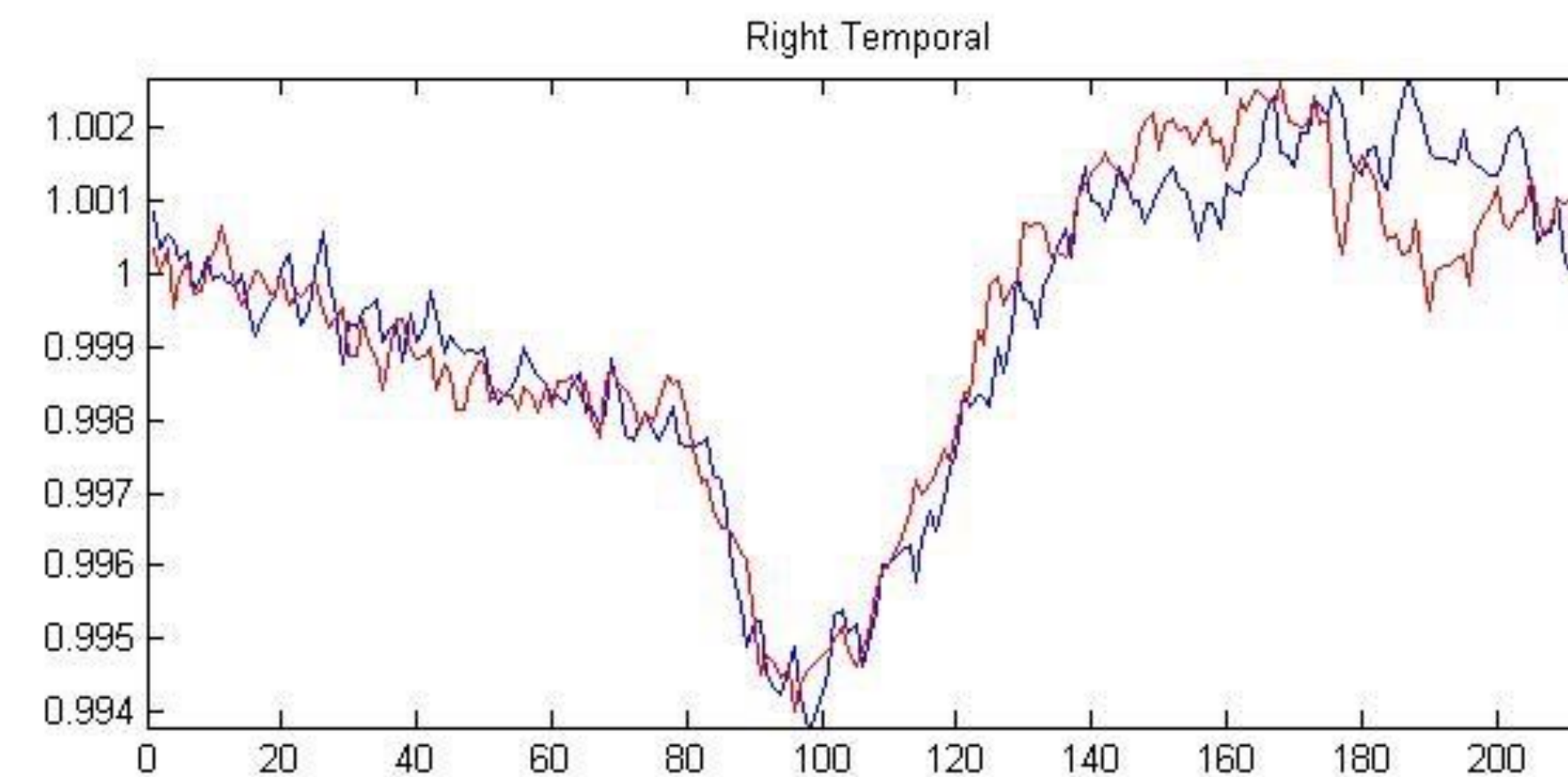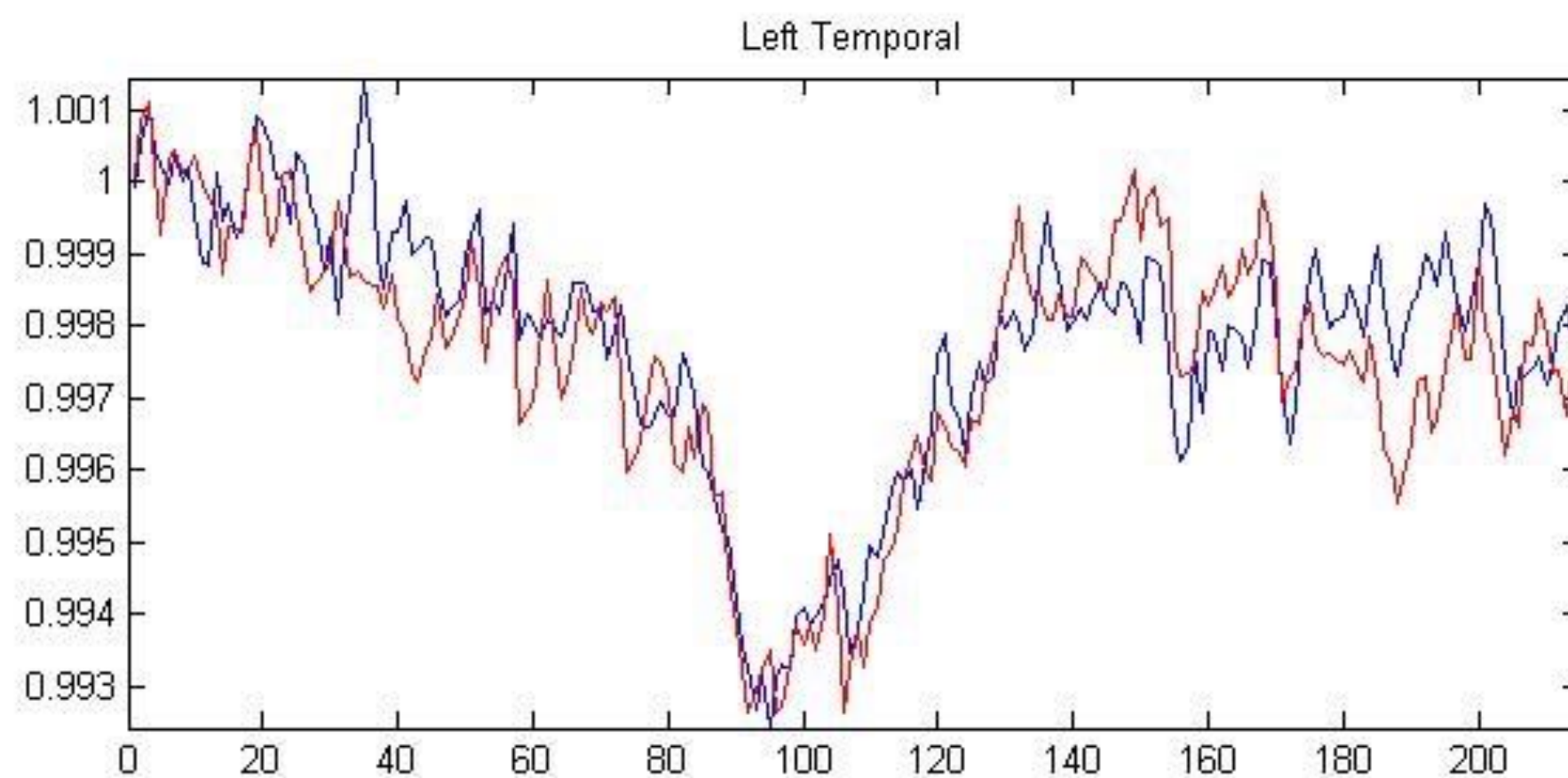
Puppy or bagel?
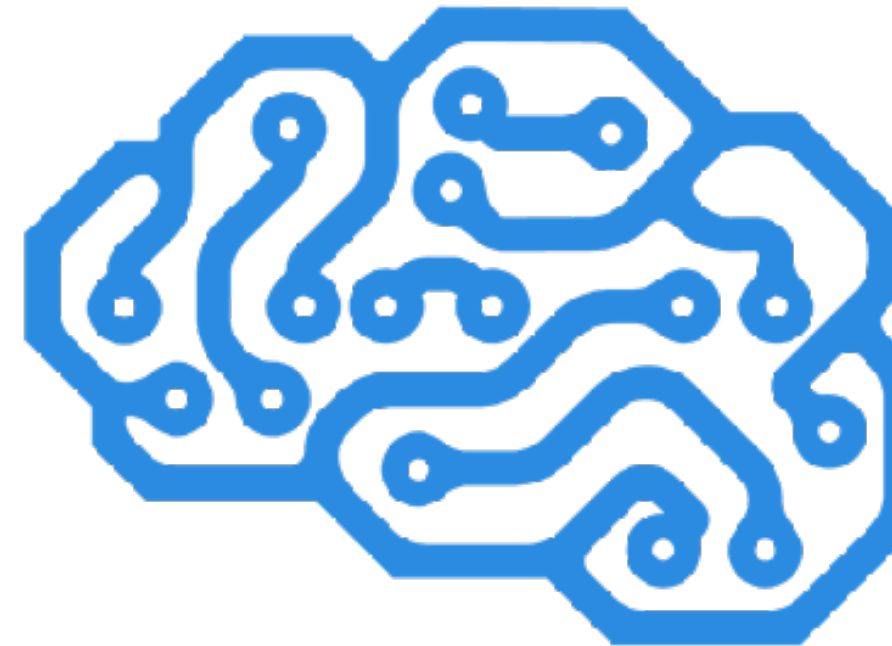
Puppy (54% confident)

Enhancing Learning Through Virtual Reality and Neurofeedback: A First Step

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ABSTRACT

Virtual reality presents exciting new prospects for the delivery of educational materials to students. By combining this technology with biological sensors, a student in a virtual educational environment can be monitored for physiological markers of engagement or more cognitive states of learning. With this information, the virtual reality environment can be adaptively altered to reflect the student's state, essentially creating a closed-loop feedback system. This paper explores these concepts, and presents preliminary data on a combined EEG-VR working memory experiment as a first step toward a broader implementation of an intelligent adaptive learning system. This first-pass neural time-series and oscillatory data suggest that while an EEG-based neurofeedback system is feasible, more work on removing artifacts and identifying relevant and important features will lead to higher prediction accuracy.

Categories and Subject Descriptors

• **Applied computing~Interactive learning environments** • *Applied computing~Biological networks* • *Applied computing~Computer-assisted instruction* • Applied computing~Psychology

Keywords

Virtual reality; EEG; Neurofeedback; Human-computer interaction

1. INTRODUCTION

One of the most important and foundational concepts of learning analytics is the necessity of feedback or intervention to improve education and learning. Since the early days of learning theory, such as Kolb's Experiential Learning Theory [1] and Bandura's Social Learning Theory [2], feedback to the learner has been considered to be an integral element of learning. A large amount of more modern empirical research has focused on the usefulness and appropriateness of different methods of feedback. In general, feedback seems to be more effective when it focuses the individual's attention on task-related information as opposed to self-related information or praise [3], and when it is immediate as

opposed to delayed, particularly when more real-world paradigms are used [4, 5, 6]. Additionally, the most successful feedback provides information on how to improve, not just the correct answer, while remaining relatively simple and easy for the learner to understand [7].

Campbell and Oblinger's five-step model of learning analytics [8] highlights the importance of tailoring interventions for learners in the Predict, Act, and Refine stages. By collecting data about individual learners, teachers can create personalized models that predict success in a particular course, lesson, or even question. If the model reports that a student is at risk for failure, the teacher can intervene to provide additional guidance to the student. Finally, the result of this intervention, and continued collection of data, can be used to refine and update the model for continued successful prediction. These ideas of effectively utilizing data to improve learning interventions are similarly expressed in other learning analytics models as well [9, 10].

Recently, Clow [11] expanded on the five-step model by introducing the Learning Analytics Cycle. Here, learners engage in some form of education material, leading to collection of data (which could be demographic, assessment-based, etc.) about the learner. These data are processed into metrics, outcome variables which provide insight into learning or predict success. The important last step is to use these metrics to intervene and alter the learning process, effectively creating a closed-loop system; the data output by the learner determines the intervention, which affects the input.

Under this framework, learning will be most improved when interventions are provided in real-time to the learner — as soon as some predictive metric is obtained that identifies the individual will fail, the system should intervene. Here, we propose a system to accomplish this goal that can provide rapid, informative intervention prior to the subject even responding. By measuring electroencephalography (EEG) signals, we can track the individual's learning state in real-time. Additionally, by providing instruction in a virtual reality (VR) environment, we can not only provide a more realistic learning environment, but also more easily and adaptively alter the learning environment to intervene based on the EEG signal, effectively closing the loop.
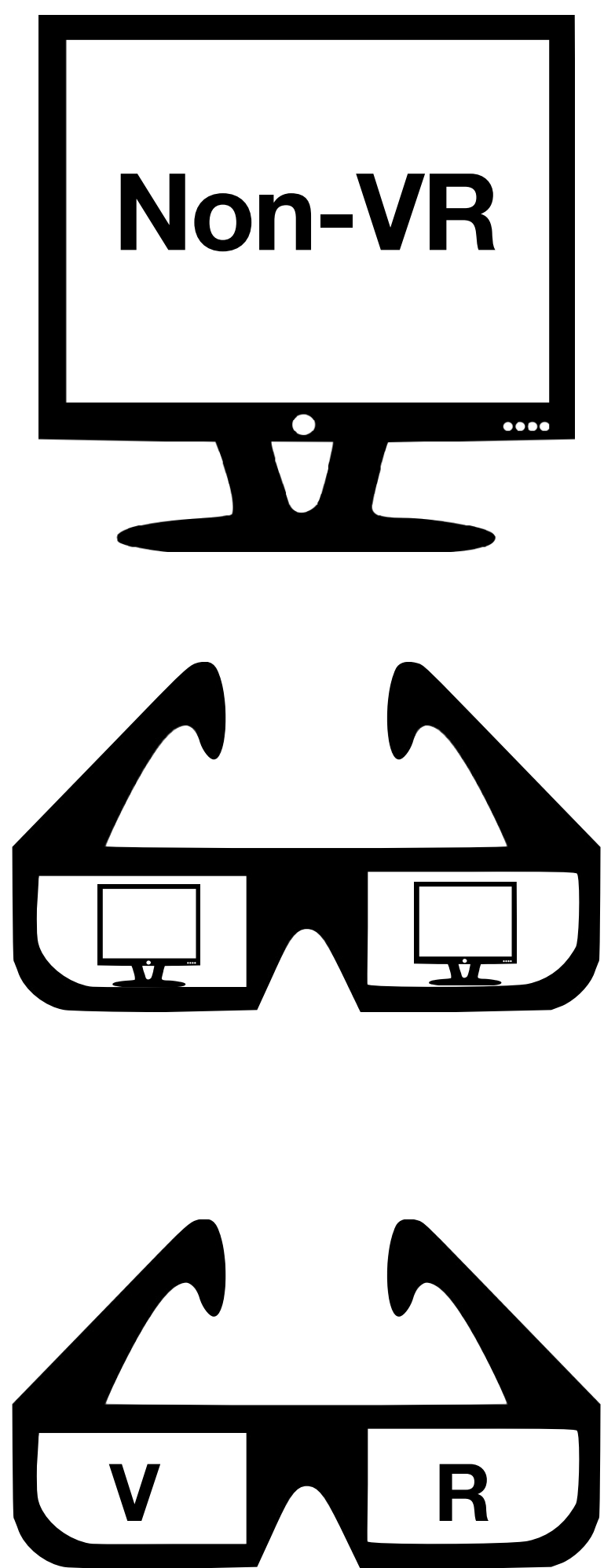
2. VIRTUAL REALITY

VR refers to technology that simulates a realistic three-dimensional environment for the user to interact with. This is typically and most successfully implemented as a headset, or head-mounted display, with a screen that the user wears. The digital environment is sent from the computer to the screen in the
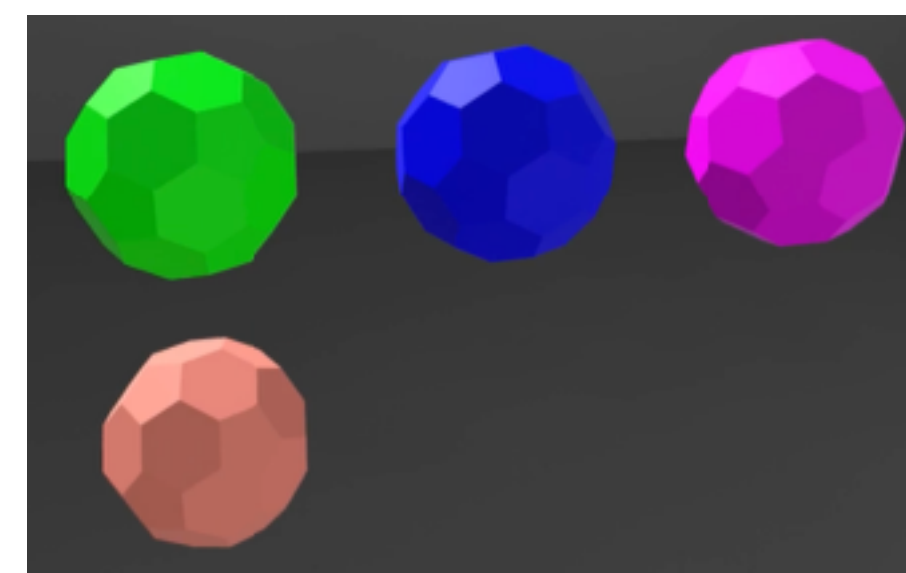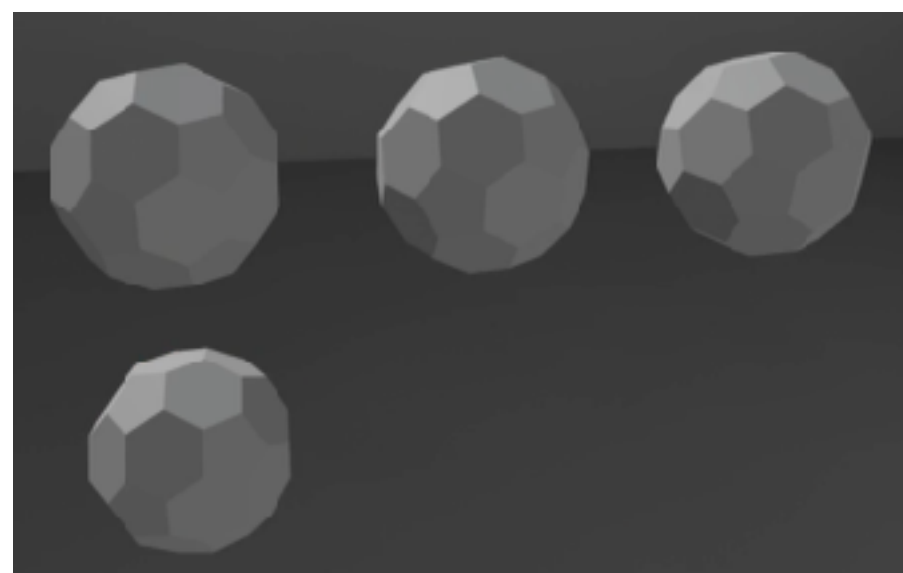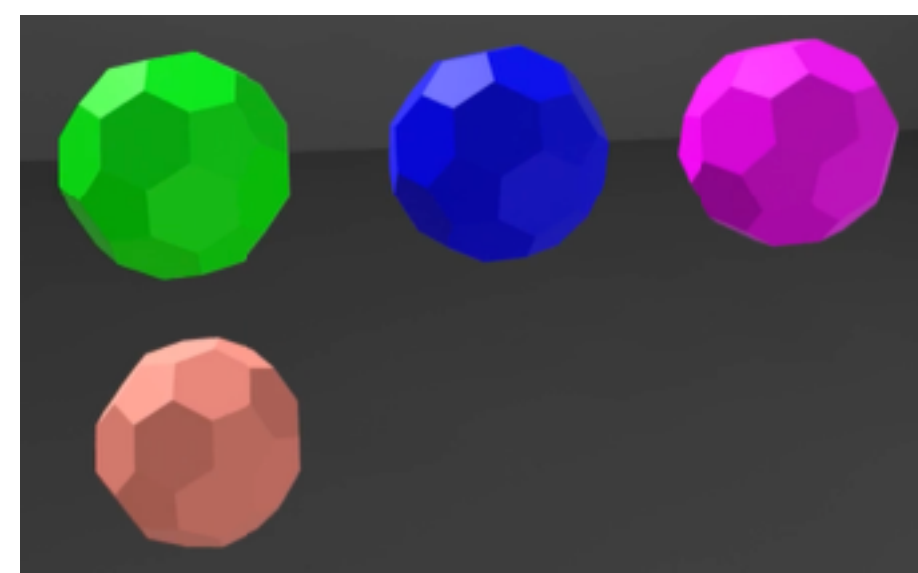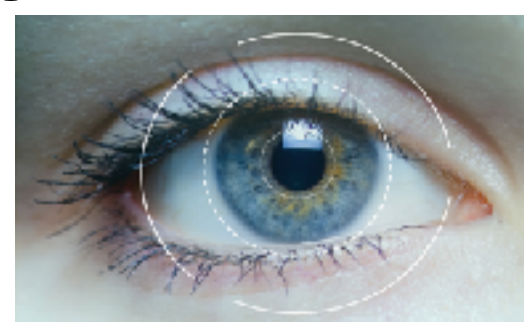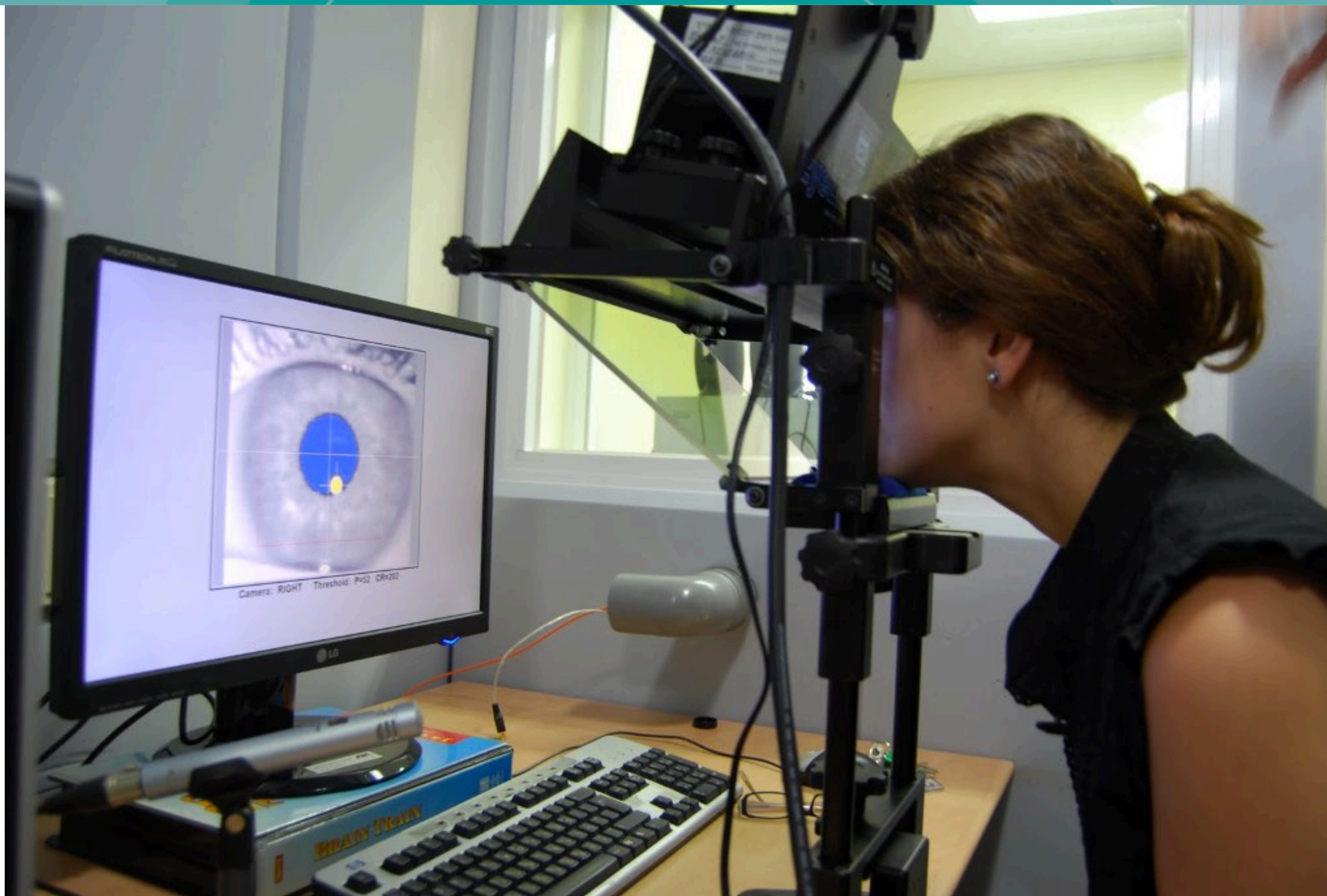
Follow-Up Phase 1
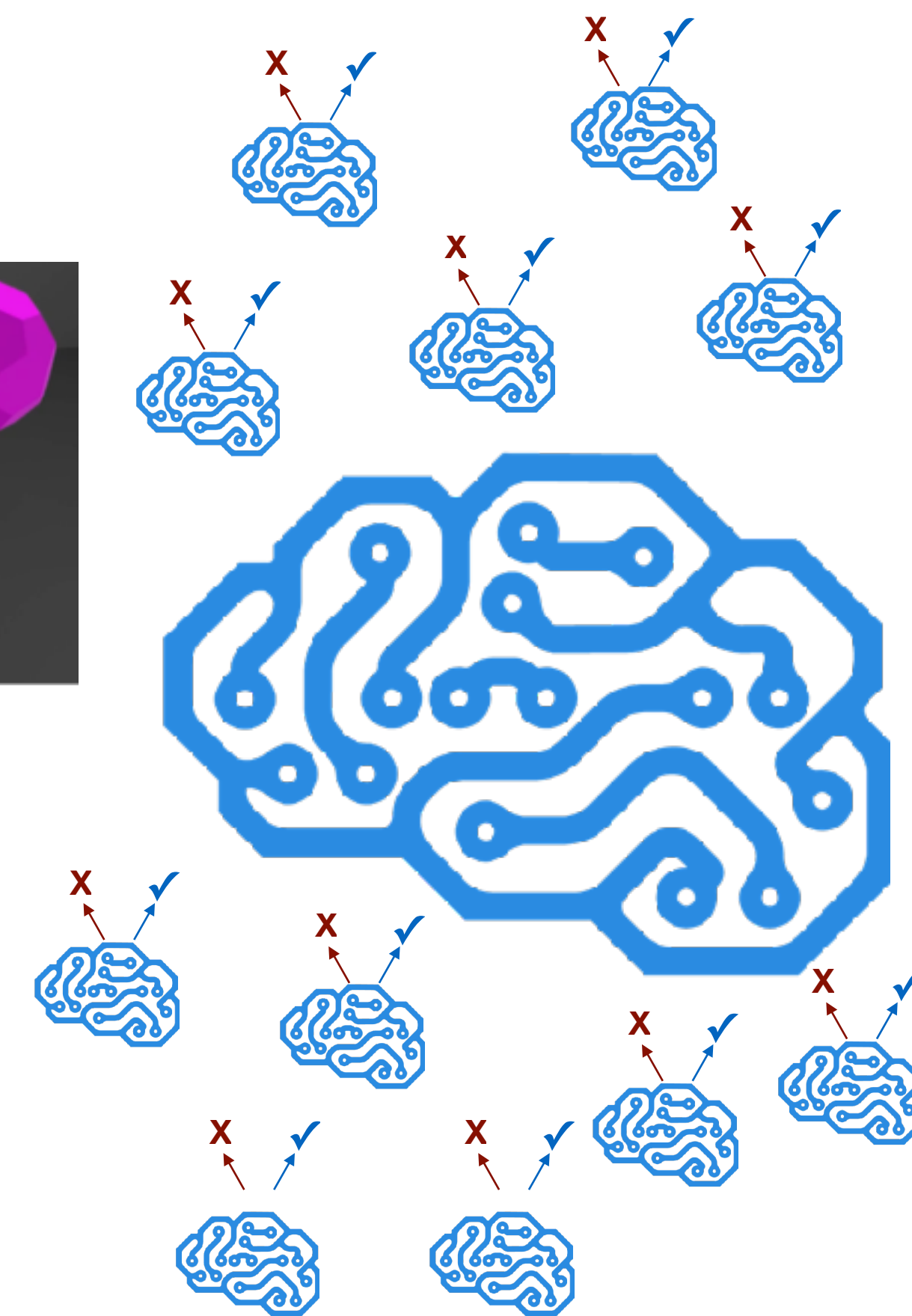
Follow-Up Phase 2
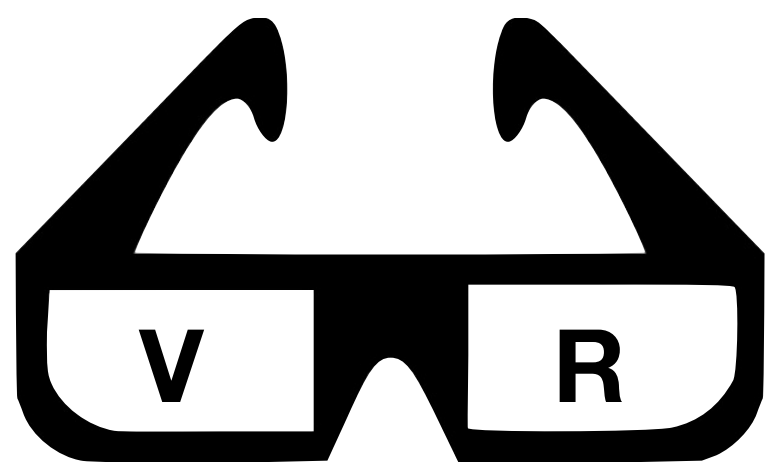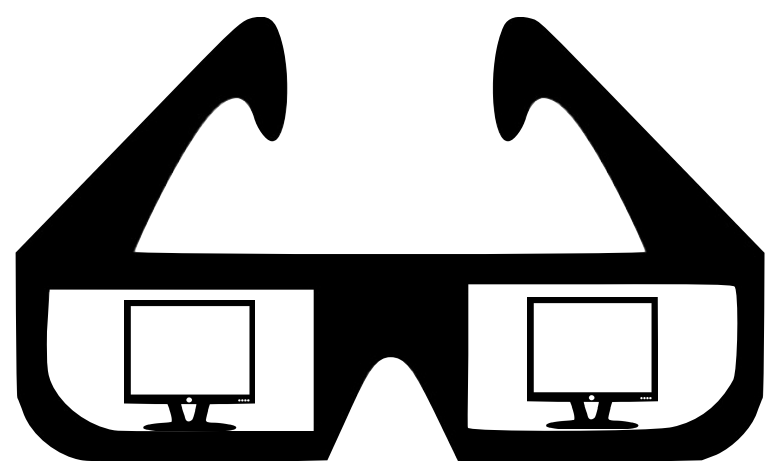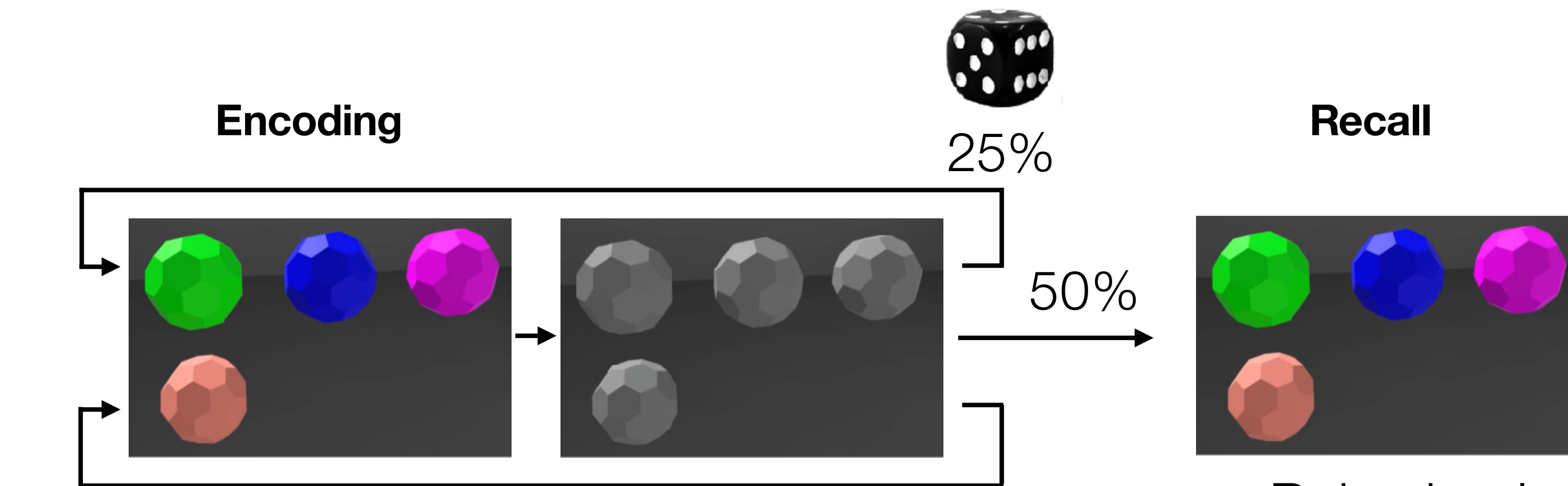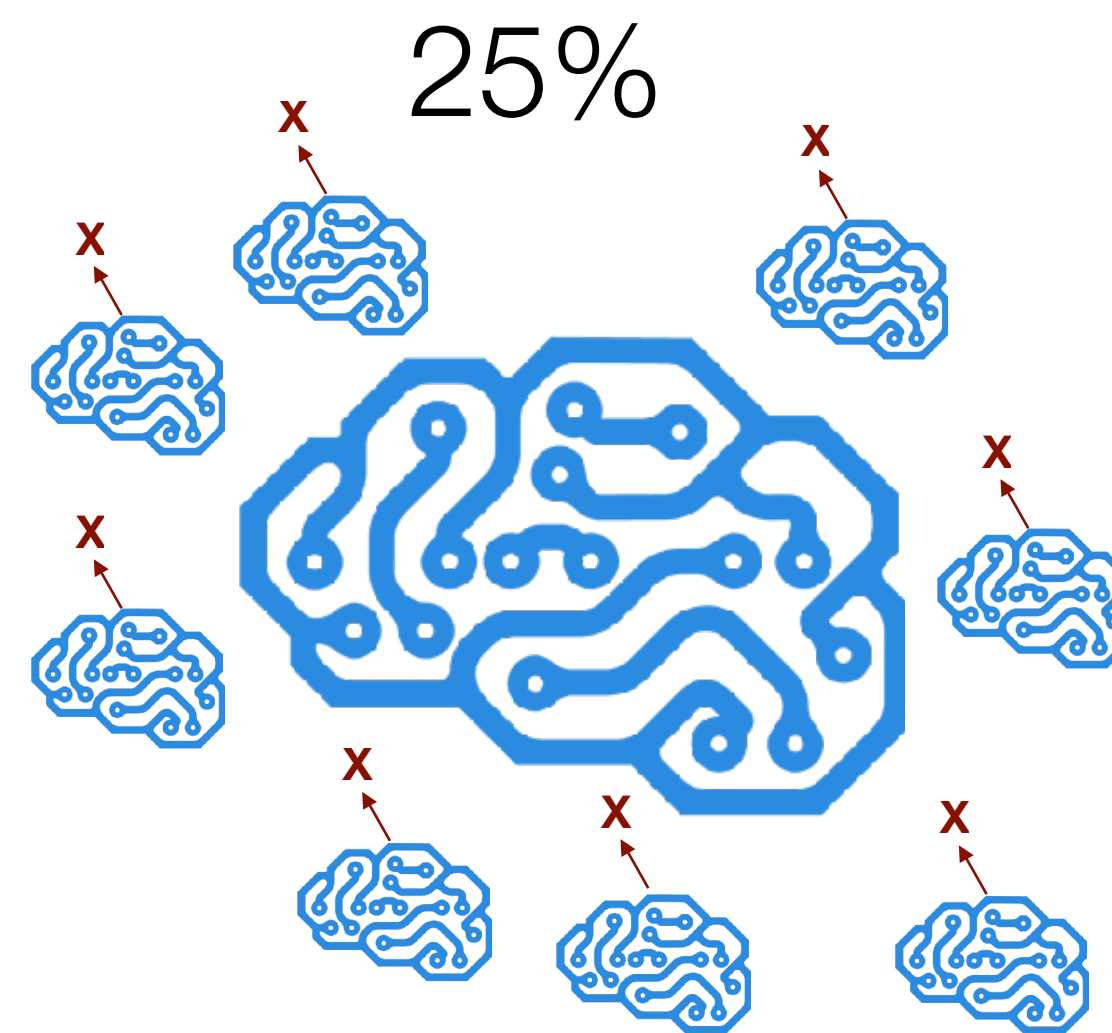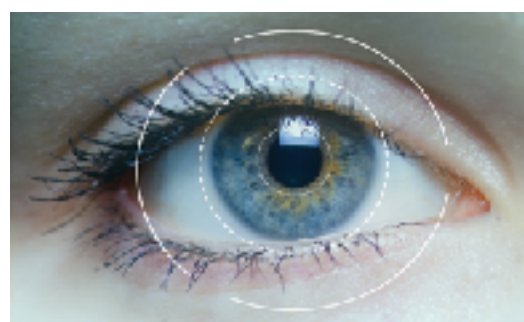
The Future

Trickshot
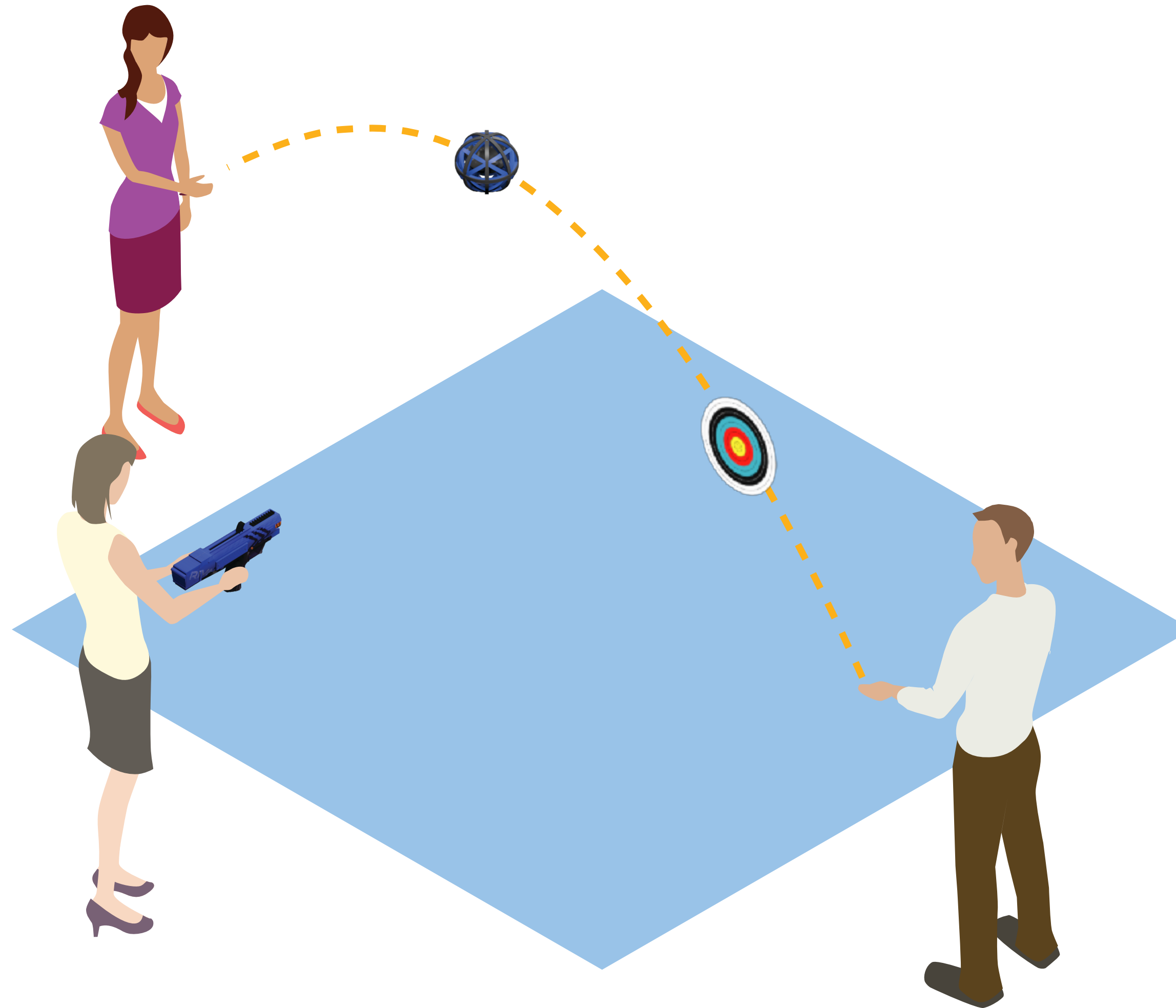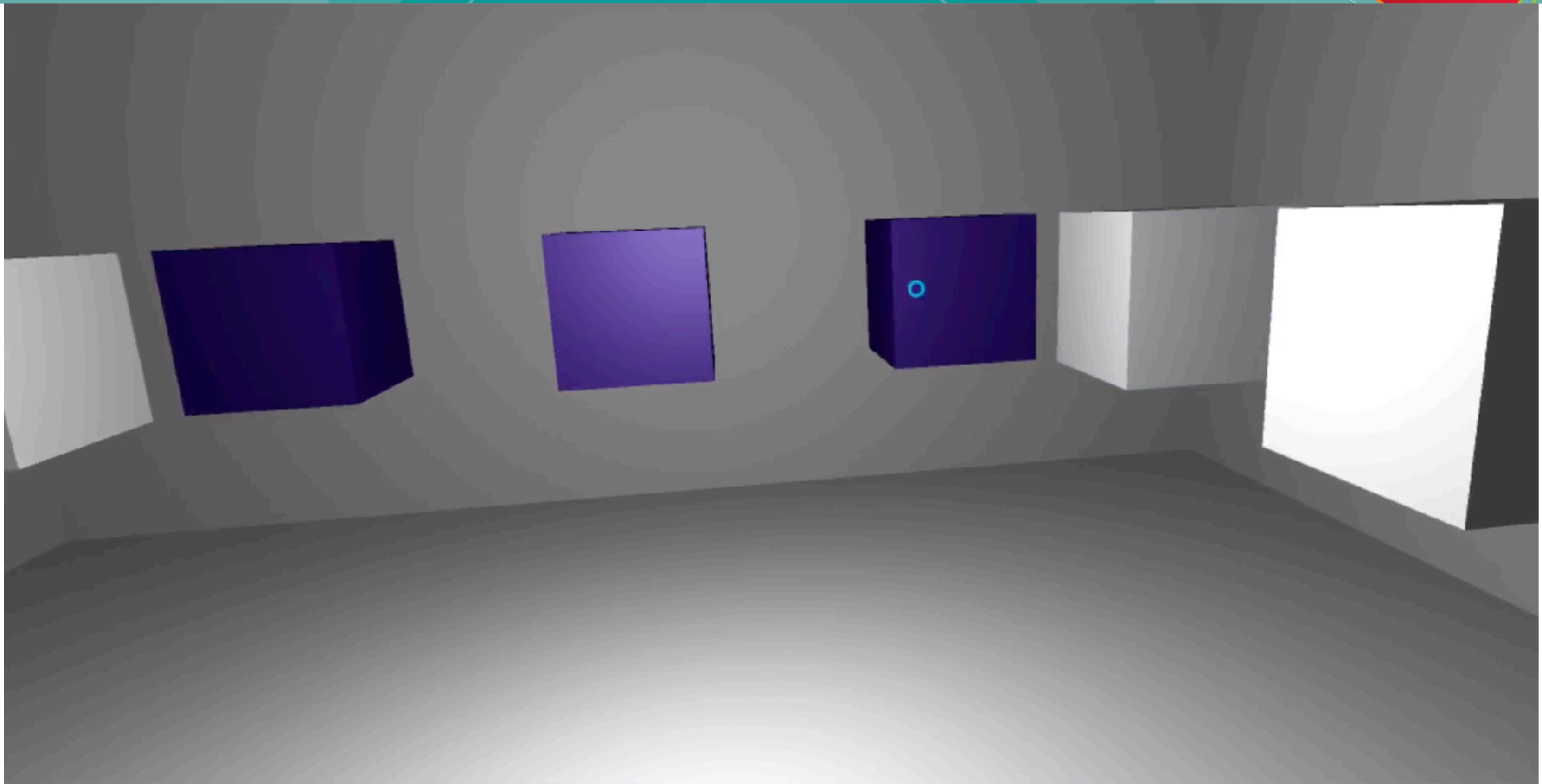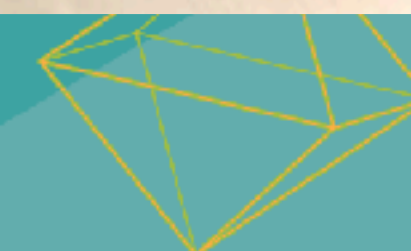
Final Thoughts
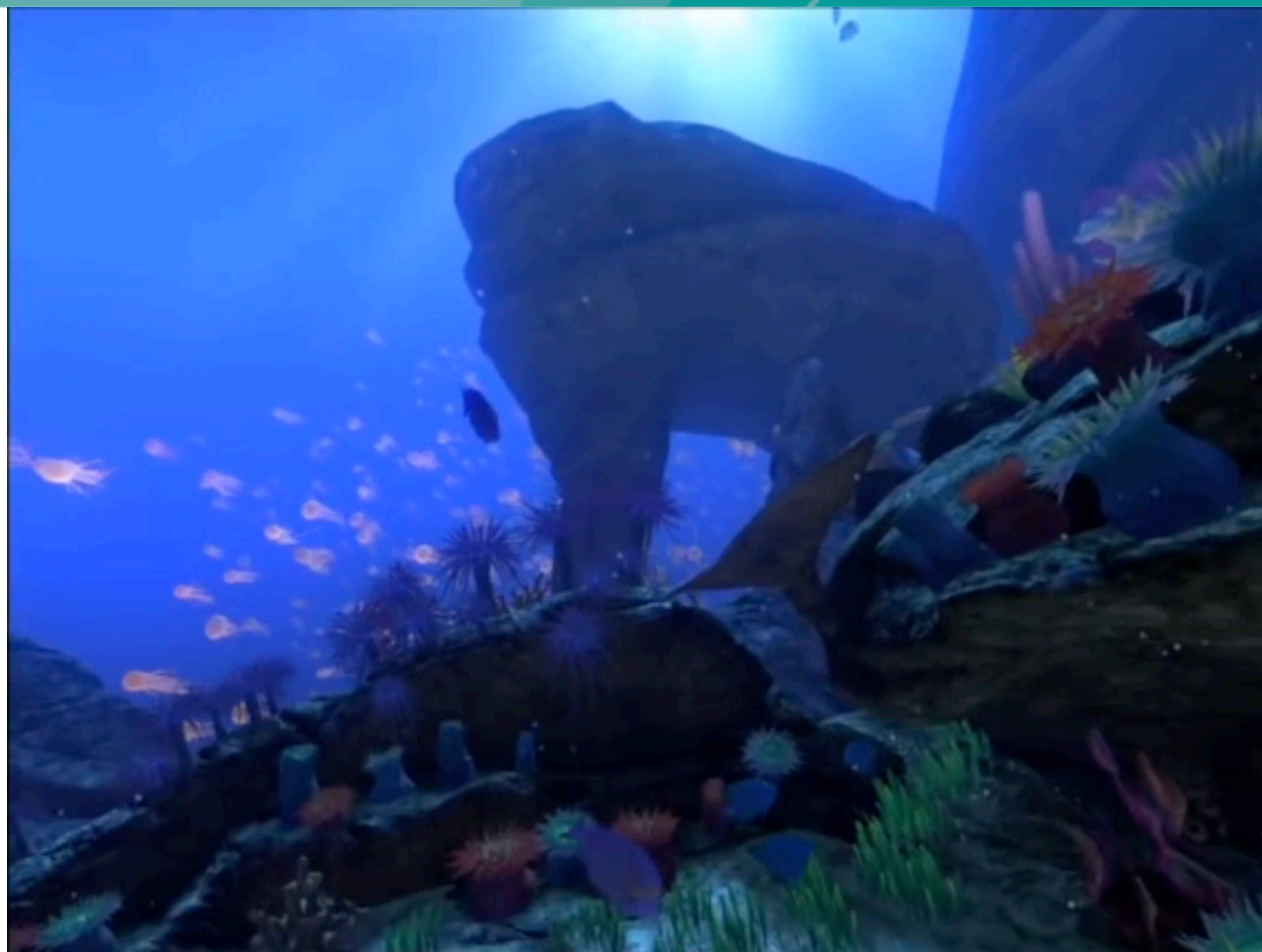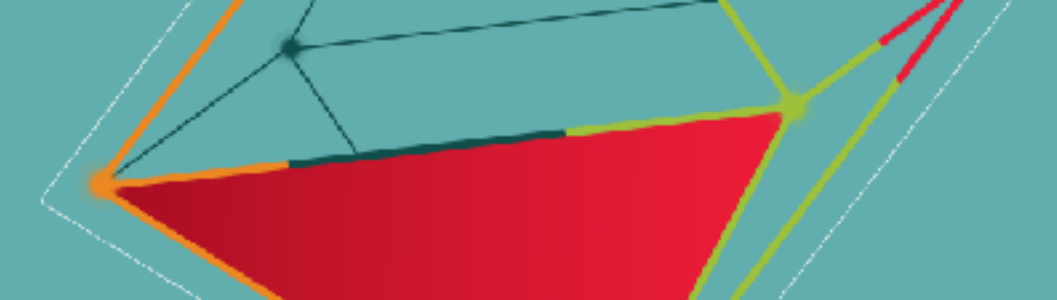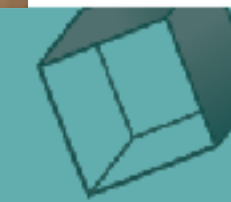
"Good design is good business"

Thomas J. Watson