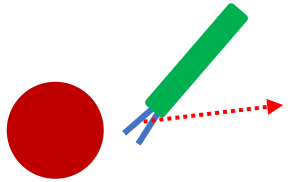
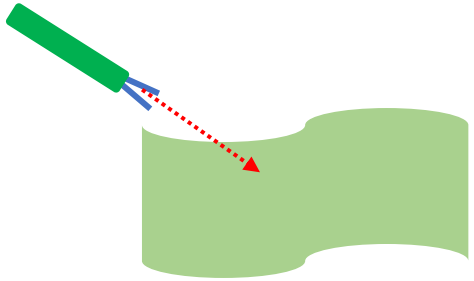
Virtual Fixtures

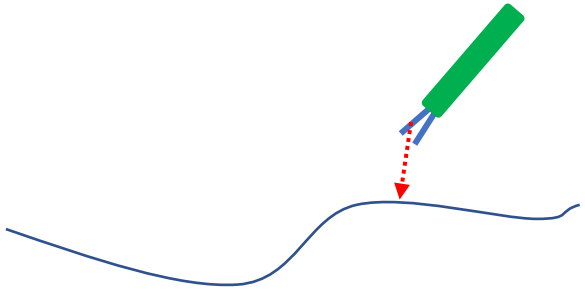
- *Obstacle Avoidance*



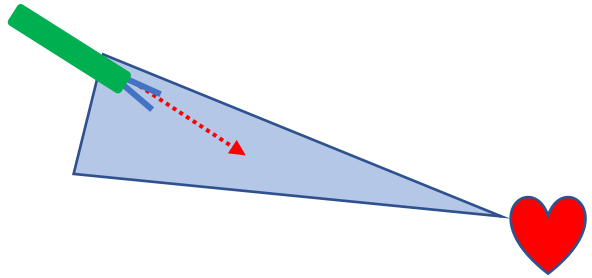
- *Surface Guidance*

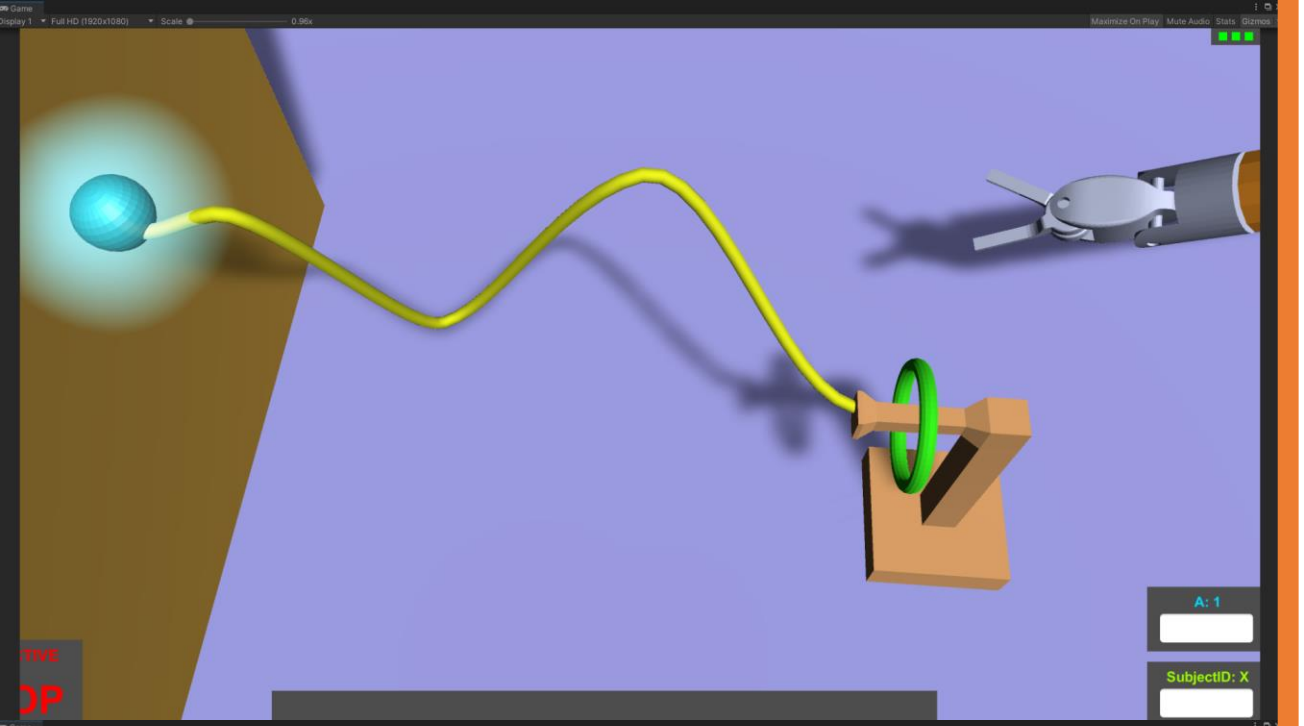


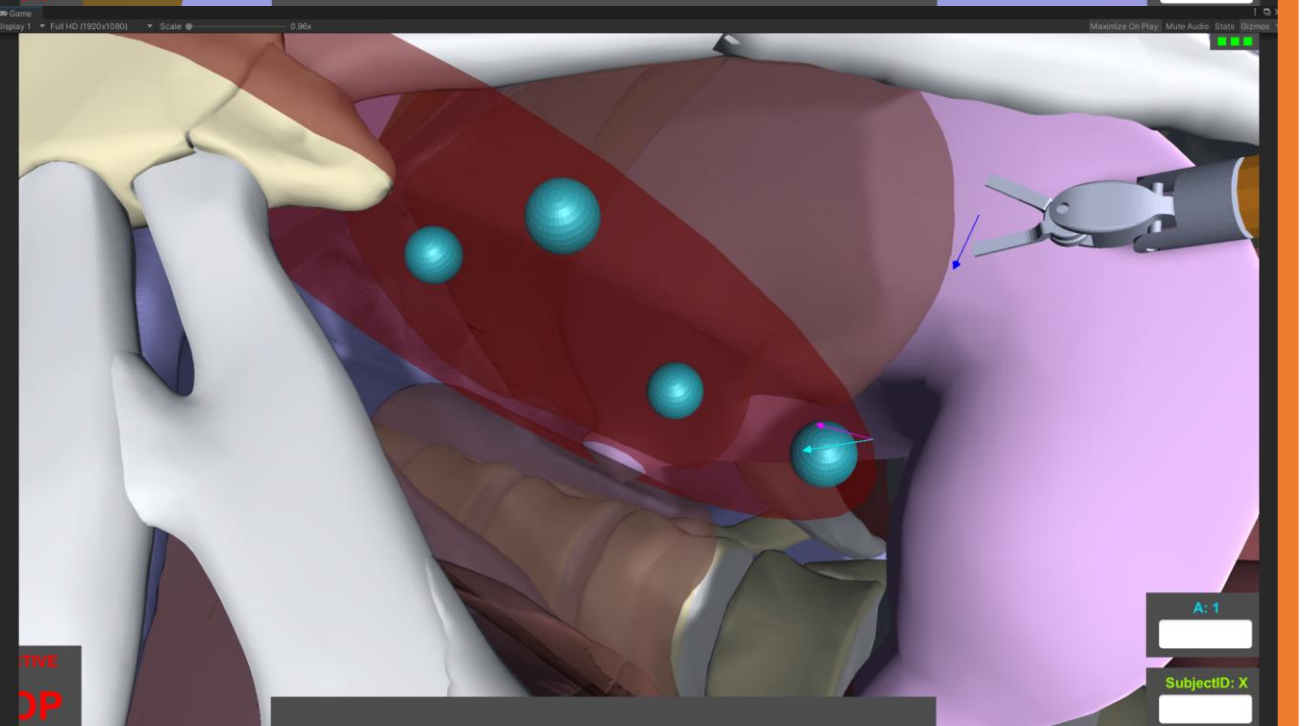
- *Trajectory Guidance*



- *Insertion Guidance*







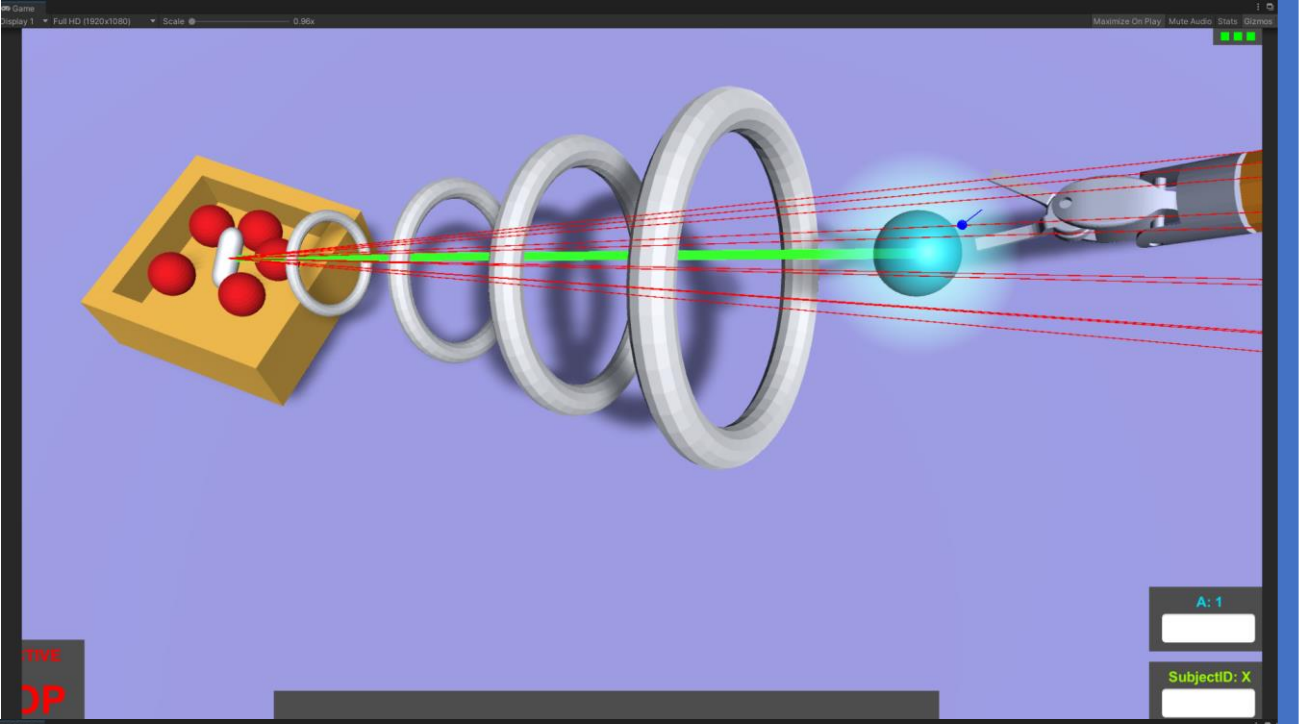
Wrist articulation

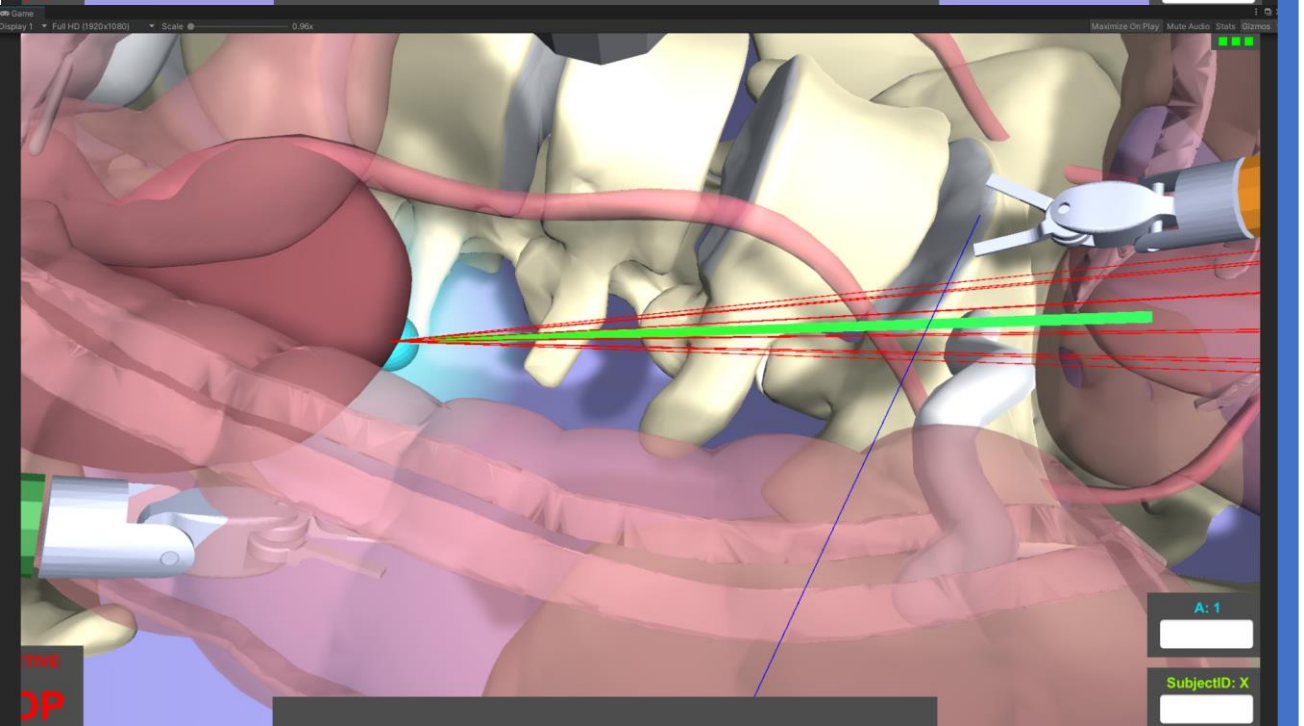
Virtual fixture

- Trajectory GUIDANCE
- Surface GUIDANCE

Evaluation metrics

- Distance and angle to reference trajectory/surface
- *Time of execution*
- *Clutch time*





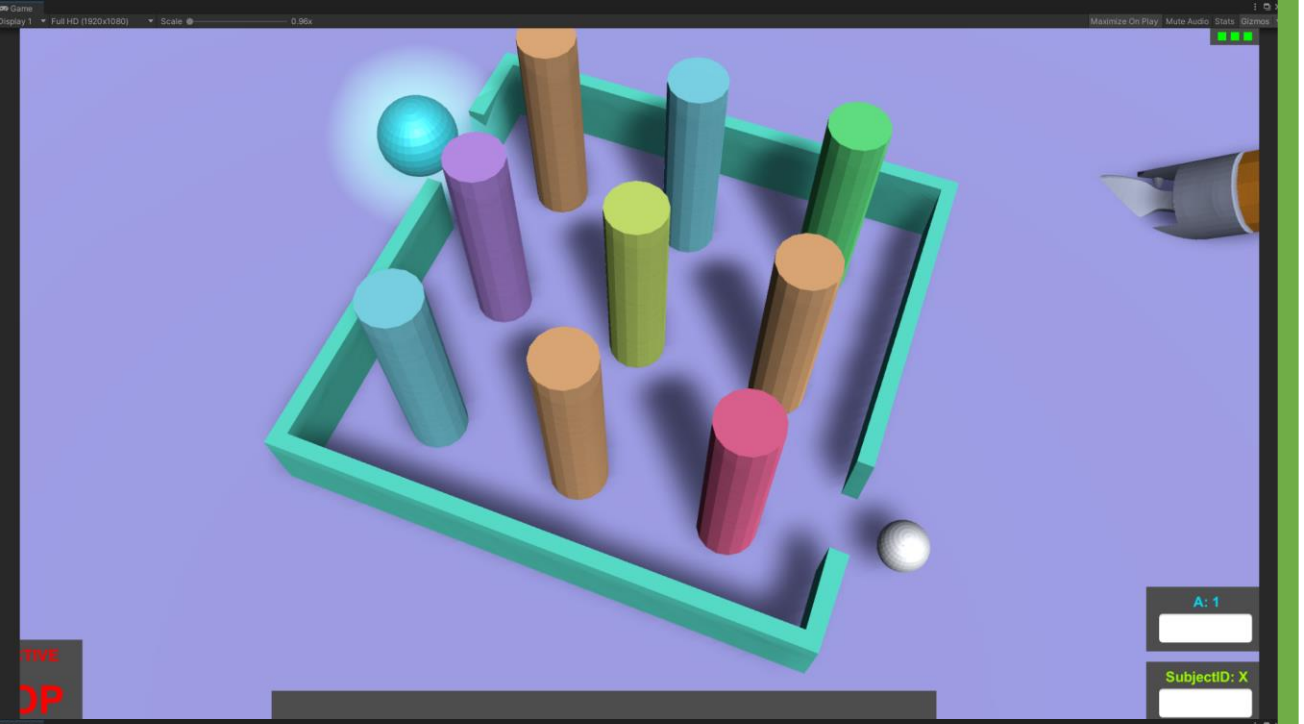
Depth perception

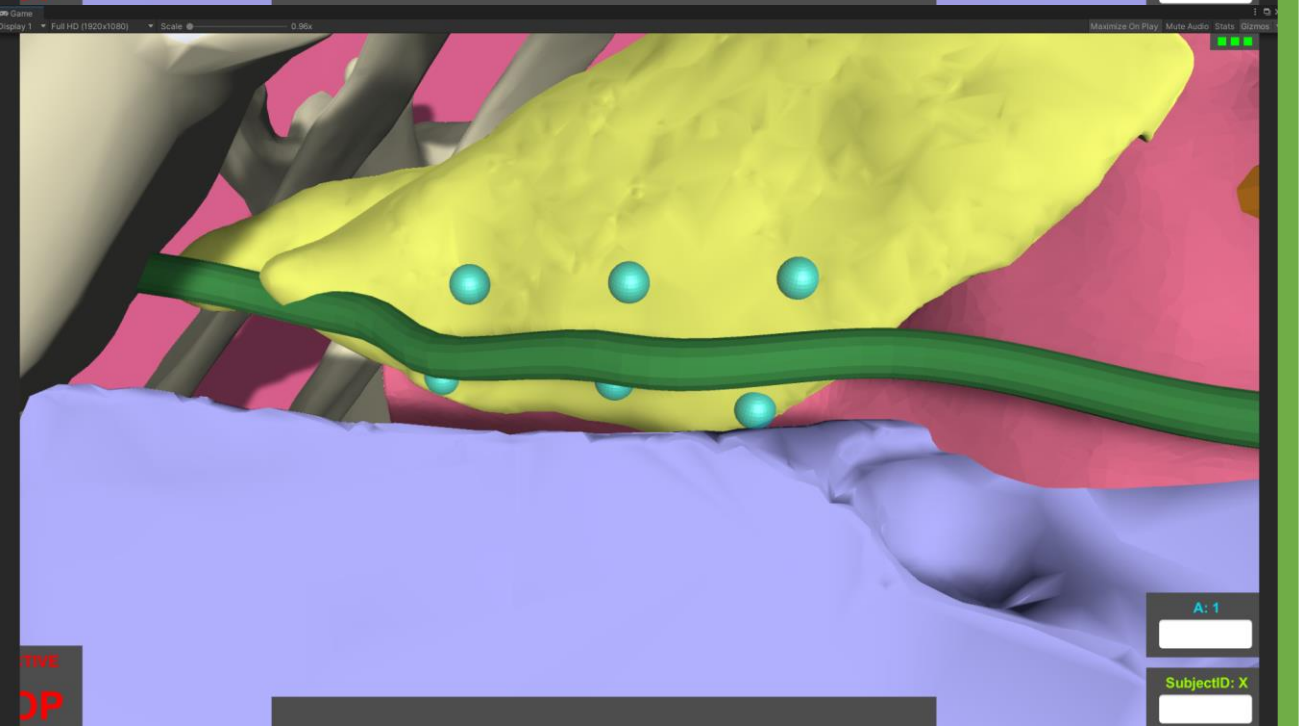
Virtual Fixture:

- Insertion GUIDANCE

Evaluation metrics

- Distance error from trajectory
- Distance from camera
- *Time of execution*
- *Clutch time*





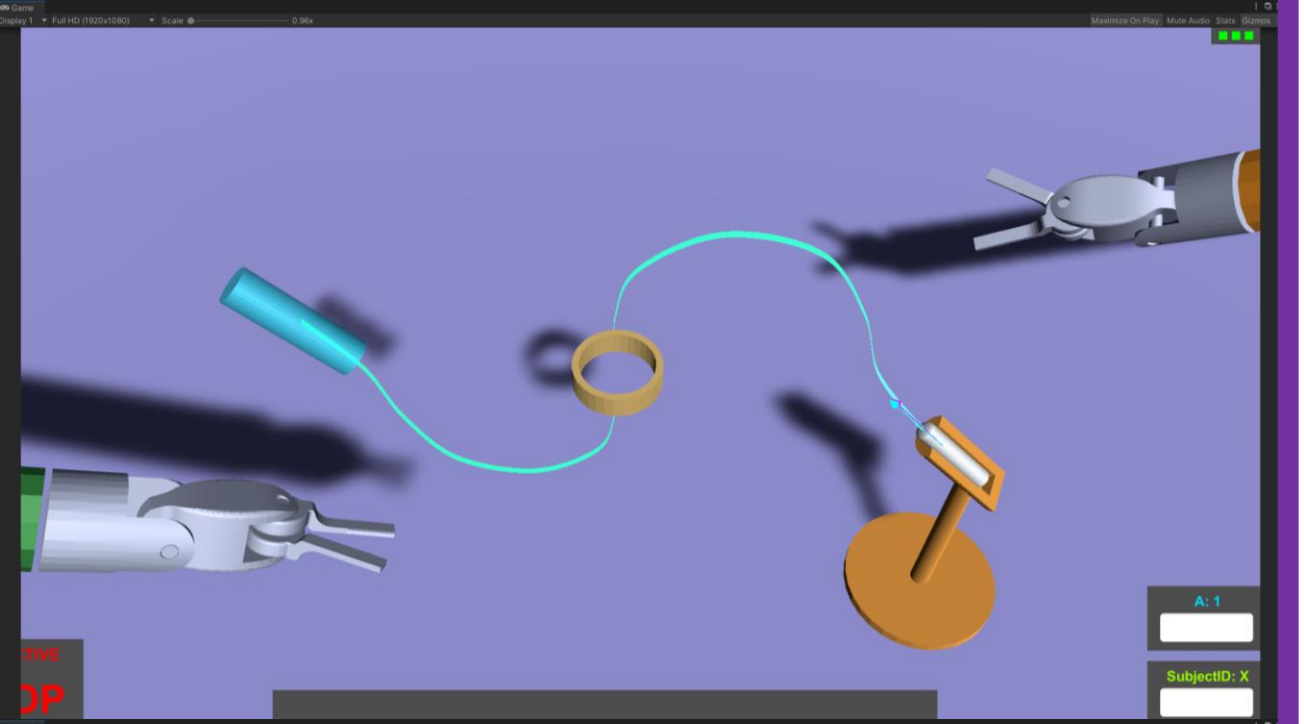
Visual Interpolation

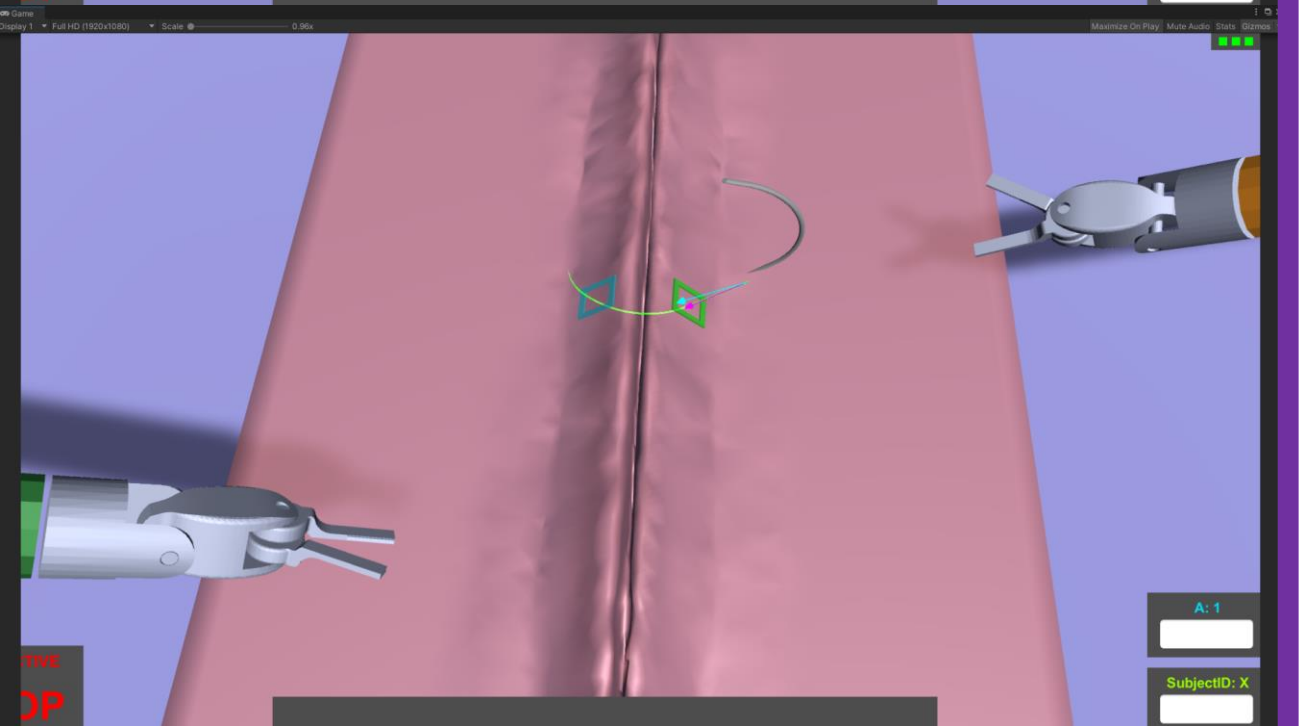
Virtual Fixture

- Obstacle avoidance

Evaluation metrics

- Distance from obstacles
- *Time of execution*
- *Clutch time*





Hand-to-Hand

Virtual Fixture:

- Trajectory guidance

Evaluation metrics

- Distance and angle to reference trajectory
- Number of drops
- *Time of execution*
- *Clutch time*

Experimental Phase

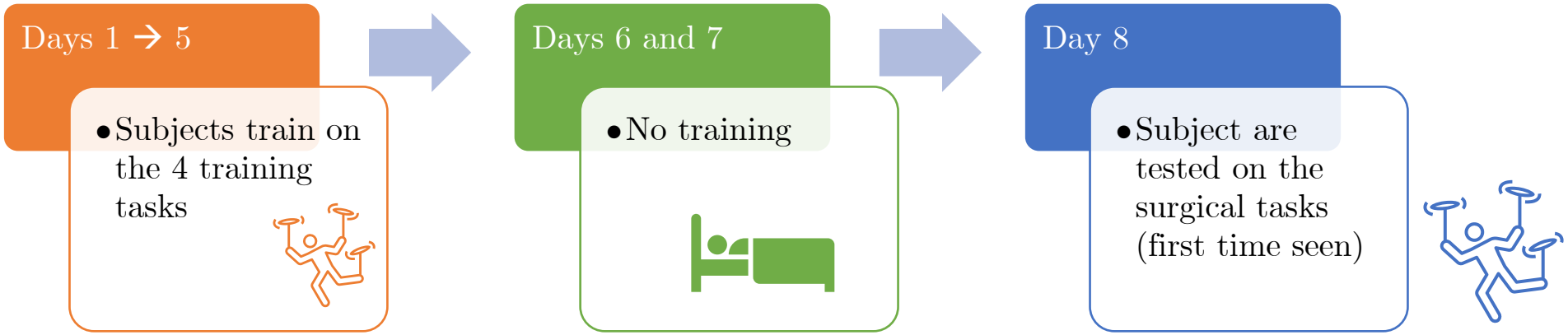
- One control group **C**
- One assisted group **A**

1. Both **A** and **C** performs a few repetitions unassisted, to assess that they belong to the same population
2. Group **A** goes on with an adaptive assistance-as-needed paradigm, **C** goes on unassisted

3. Statistical hypothesis to be verified: **Increase in performance**
   - Multi day trial?
   - How to set baseline performances? Record surgeon's performance?

Experimental Phase: Goals

4 surgical training tasks, 4 tasks simulating real procedures



To demonstrate:

- **Better overall performance**
- **Skill retention** after 2 days break
- **Skill transfer** from training to surgical skills

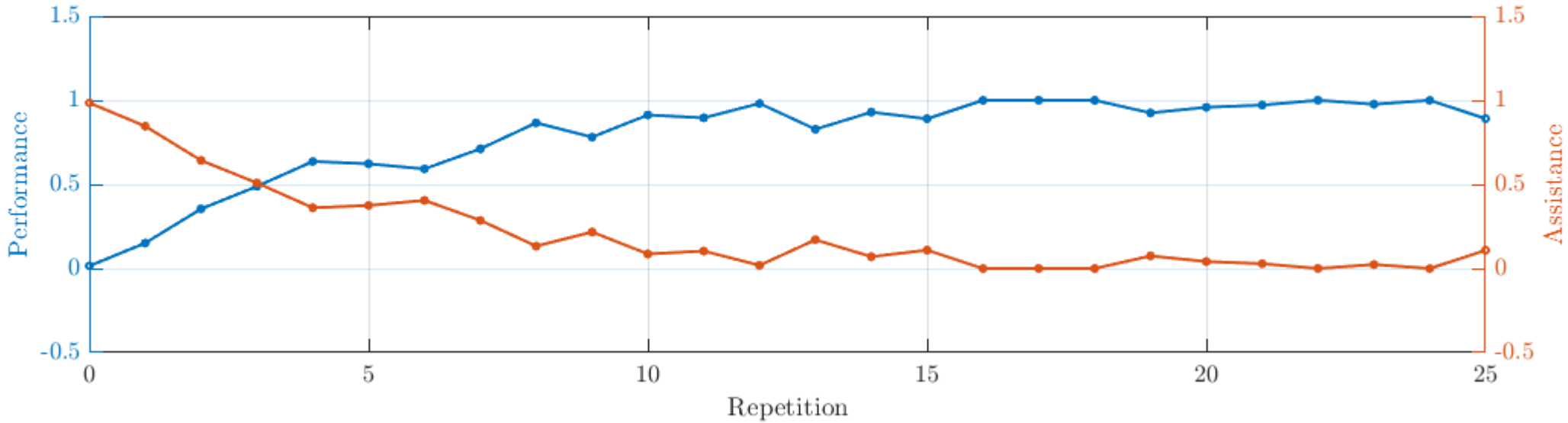
Adaptive Assistance protocol

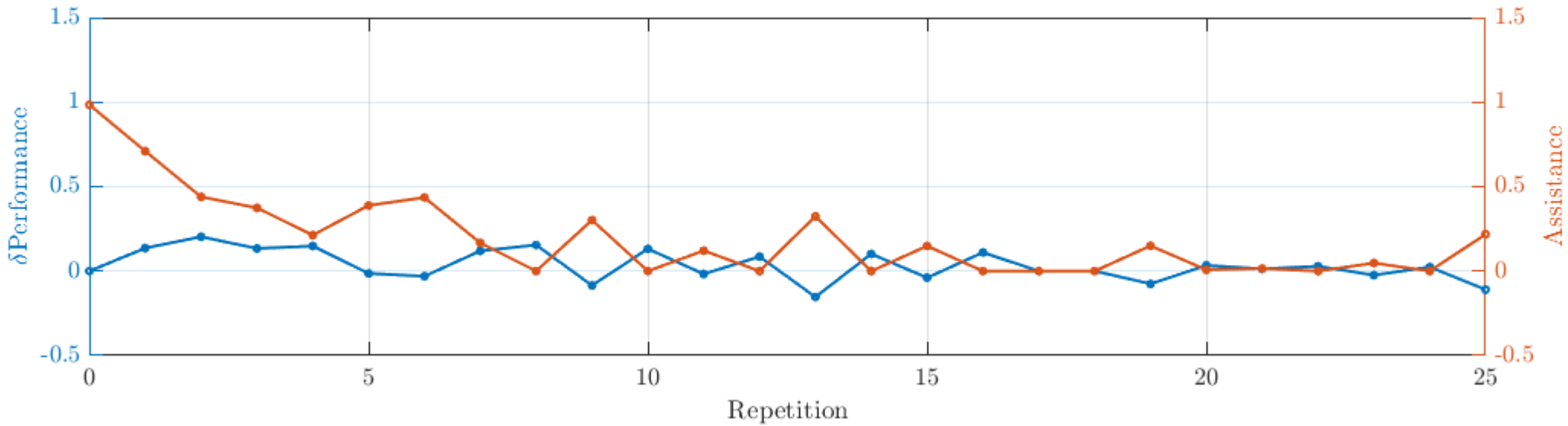
The amount of assistance provided to the user:

- Should be low if the user performance is good (and viceversa)
- Should be lower if the user performance is improving (and viceversa)

$$\boldsymbol{Assistance} = (1 - P^{\alpha}) - \beta \cdot \Delta P$$

- $(1 - P^{\alpha})$: Contribution of the current performance
- $-\beta \cdot \Delta P$: Contribution of the performance improvement
- $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ set to tune the contributions


Performance
Assistance
Repetition
1.5
1
0.5
0
-0.5
0
5
10
15
20
25


δPerformance
Assistance
Repetition
1.5
1
0.5
0
-0.5
0
5
10
15
20
25