UNIVERSITÀ DEGLI STUDI
DI GENOVA

Design and implementation of an open source visuo-haptic simulator for surgical training

Candidate: Chiara Saporetti

Supervisors: Professor Maura Casadio, Dr. Serena Ricci

Robotics Engineering Course – Master Thesis

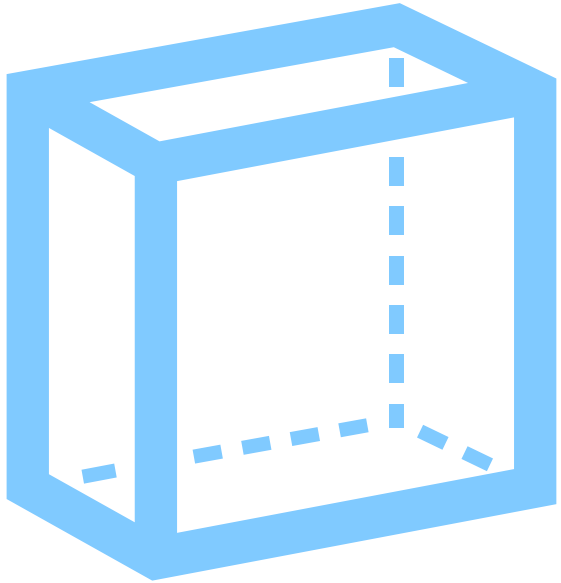
Context and motivation

- **Surgical training**: involves the use of tactile sense. Various teaching options have been tested: ethical/practical problems.
- Increasing interest in Robotic Minimally Invasive Surgery: still lacks **haptic feedback**.
- Visuo-haptic simulation advantages provides multi-sensory feedback, shows different real-case scenarios, allows repeatability.

Context and motivation

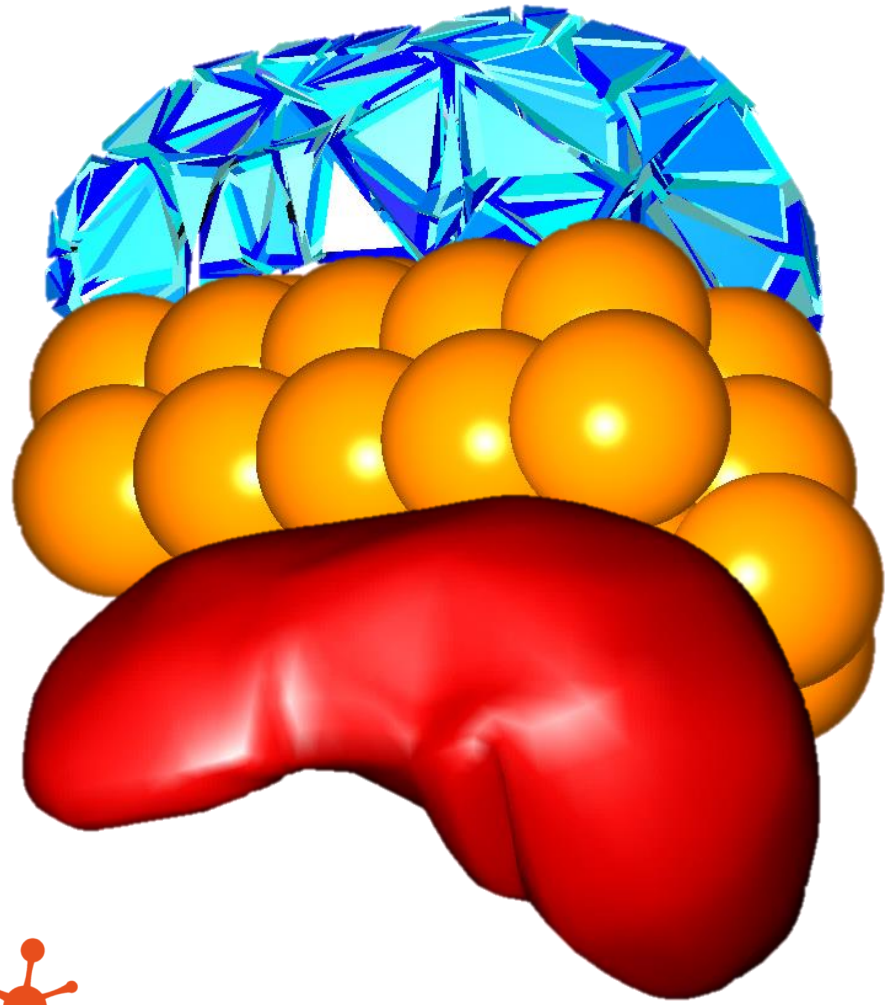
- **Open-source** software, accessible to everyone on GitHub: SOFA Framework.

- My contribution: visuo-haptic simulations of:
  - a dexterity task
  - an incision task
  - a single-device suture task
  - a double-device suture task



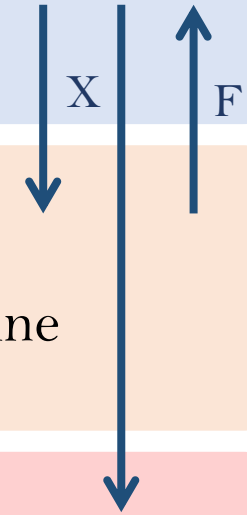
Virtual Environment Models

Software: SOFA Framework



SOFA

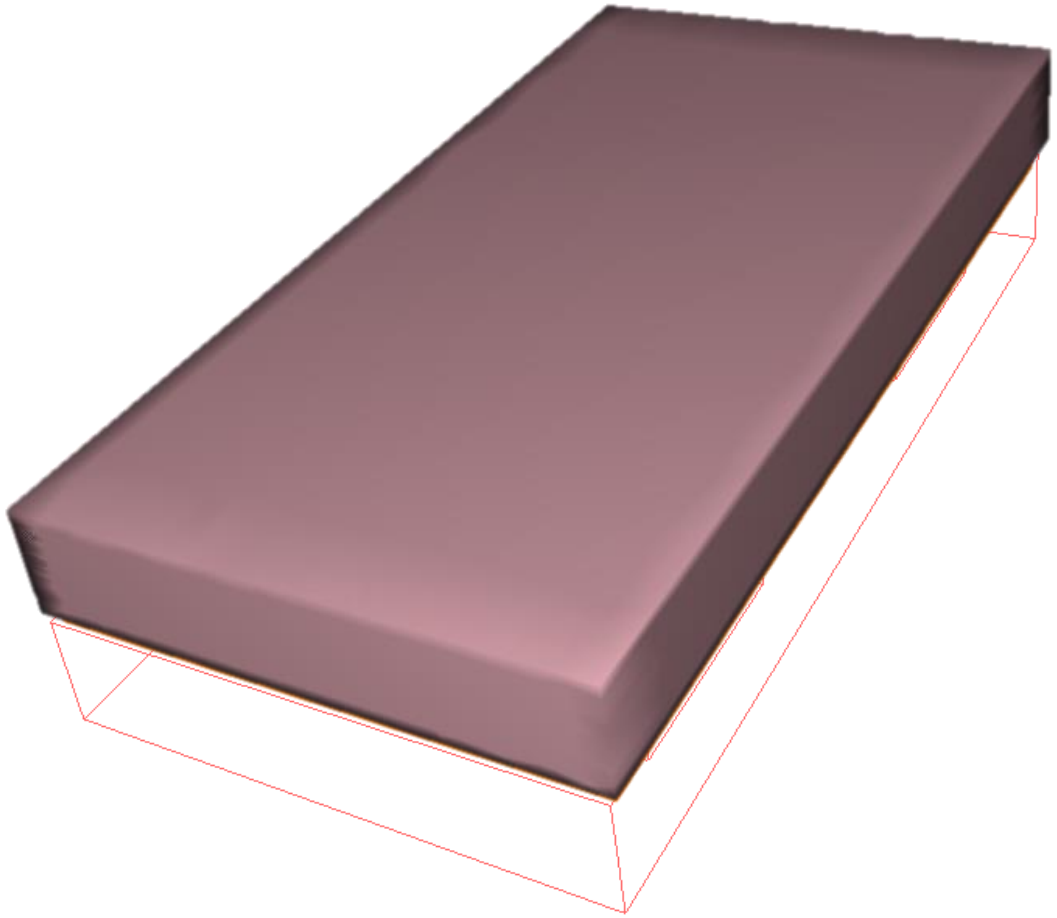
Behavior model:
F = ma



Collision model:
Three phases pipeline

Visual model:
Graphical rendering

Skin virtual model



Tetrahedra to triangles

Behavior model:

- Tetrahedral meshes
- Box to keep it fixed
- Other boxes to compute indices

Identity mapping

Collision model:

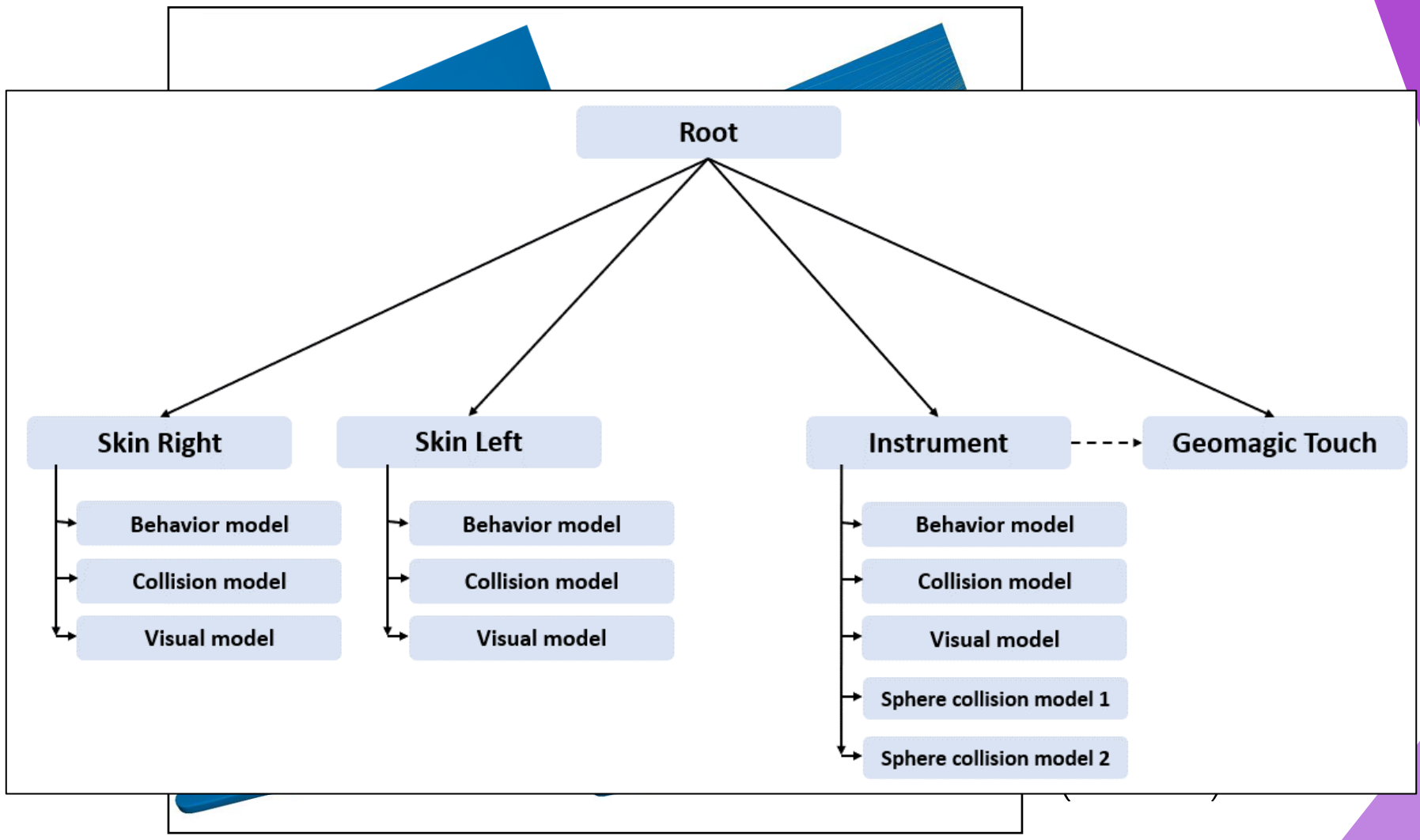
- Triangular meshes

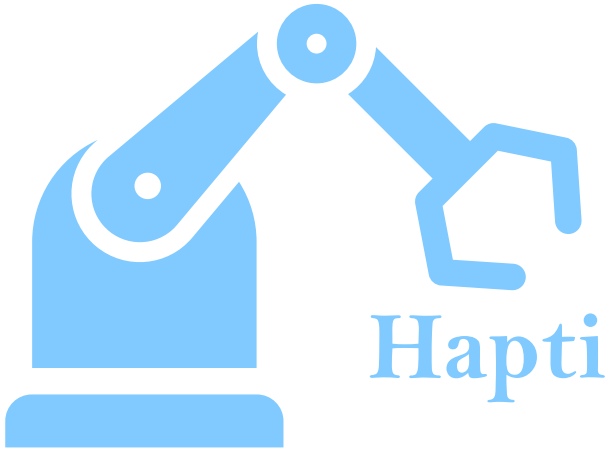
Visual model:

- Triangular meshes

Instrument virtual models

- Four different interaction objects.
- Model: downloaded and modified on Blender.
- Physics: defined with SOFA scripts.
- Positioned in the simulation structure.

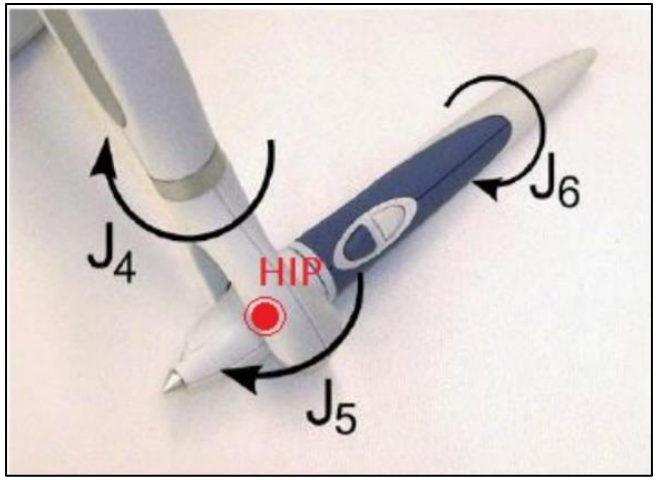




Haptic Device

Hardware: Geomagic Touch

ACTUATED JOINTS – position of the HIP



PASSIVE JOINTS – orientation of the stylus

Instruments models

Dexterity

Incision

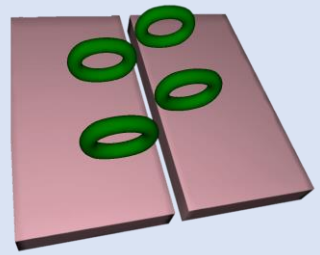
Suture

Haptic interaction scheme

HUMAN USER

HAPTIC DEVICE

SOFA VIRTUAL ENVIRONMENT



$x = f(q)$
$\dot{x} = J(q)\dot{q}$

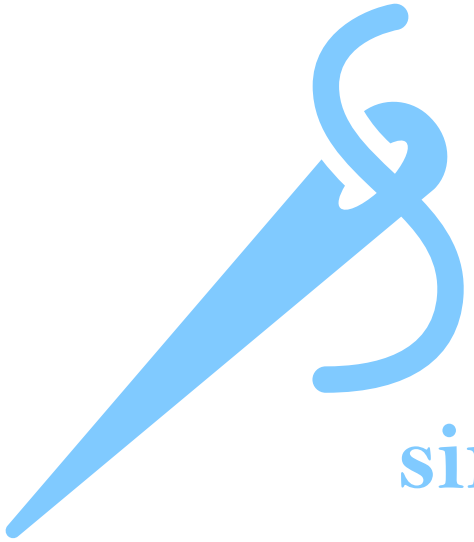
q

Manipulation → Sensing → Joint sensors → Forward Kinematic Equations → Haptic control → Geomagic plugin

$\tau = J^T F$

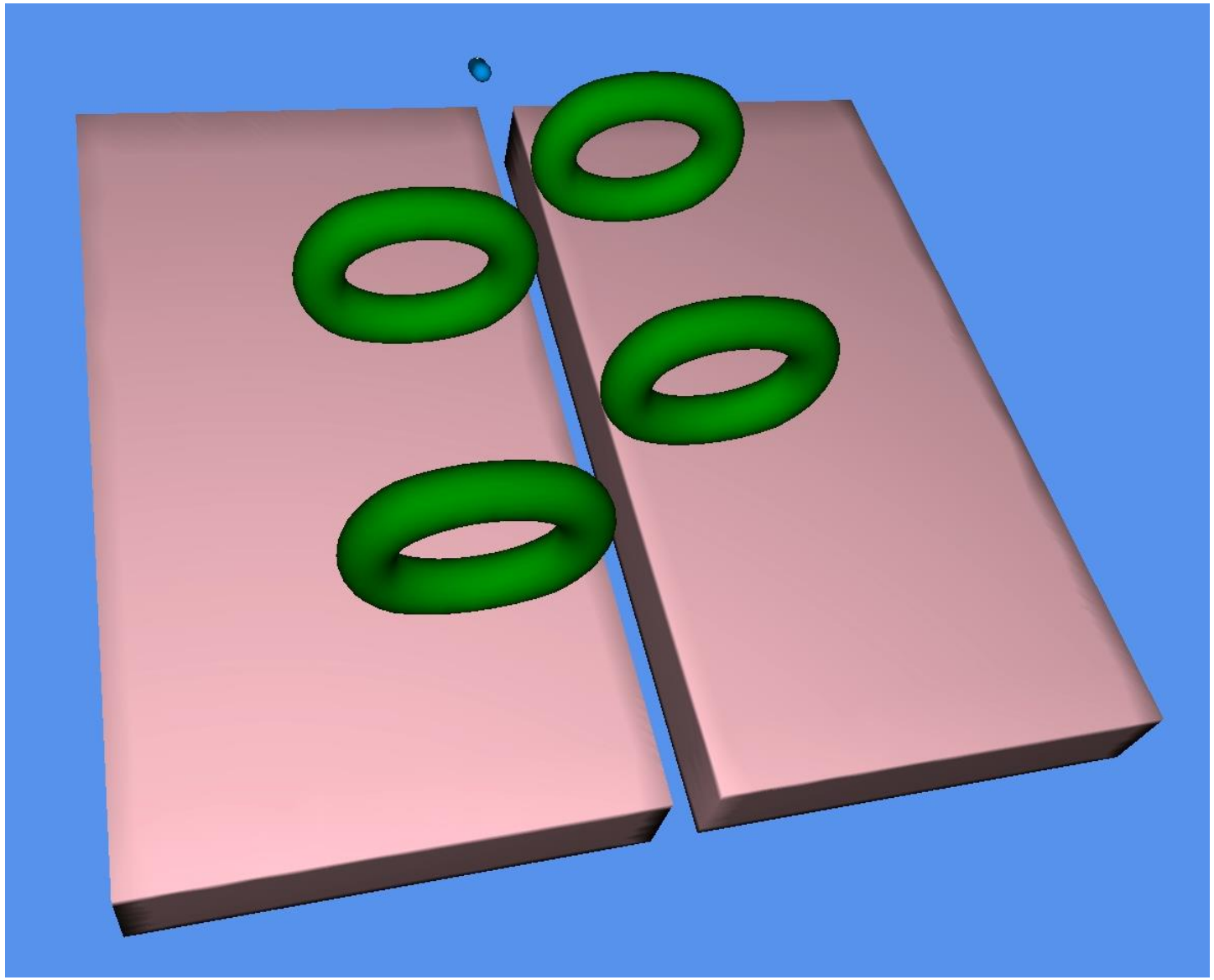
F

Perception ← Actuation ← Actuators ← Torque calculation ← Haptic feedback

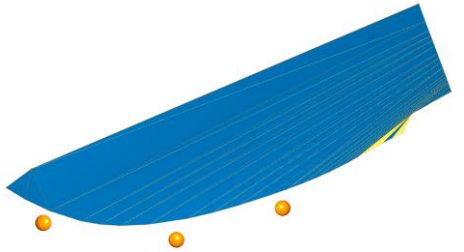


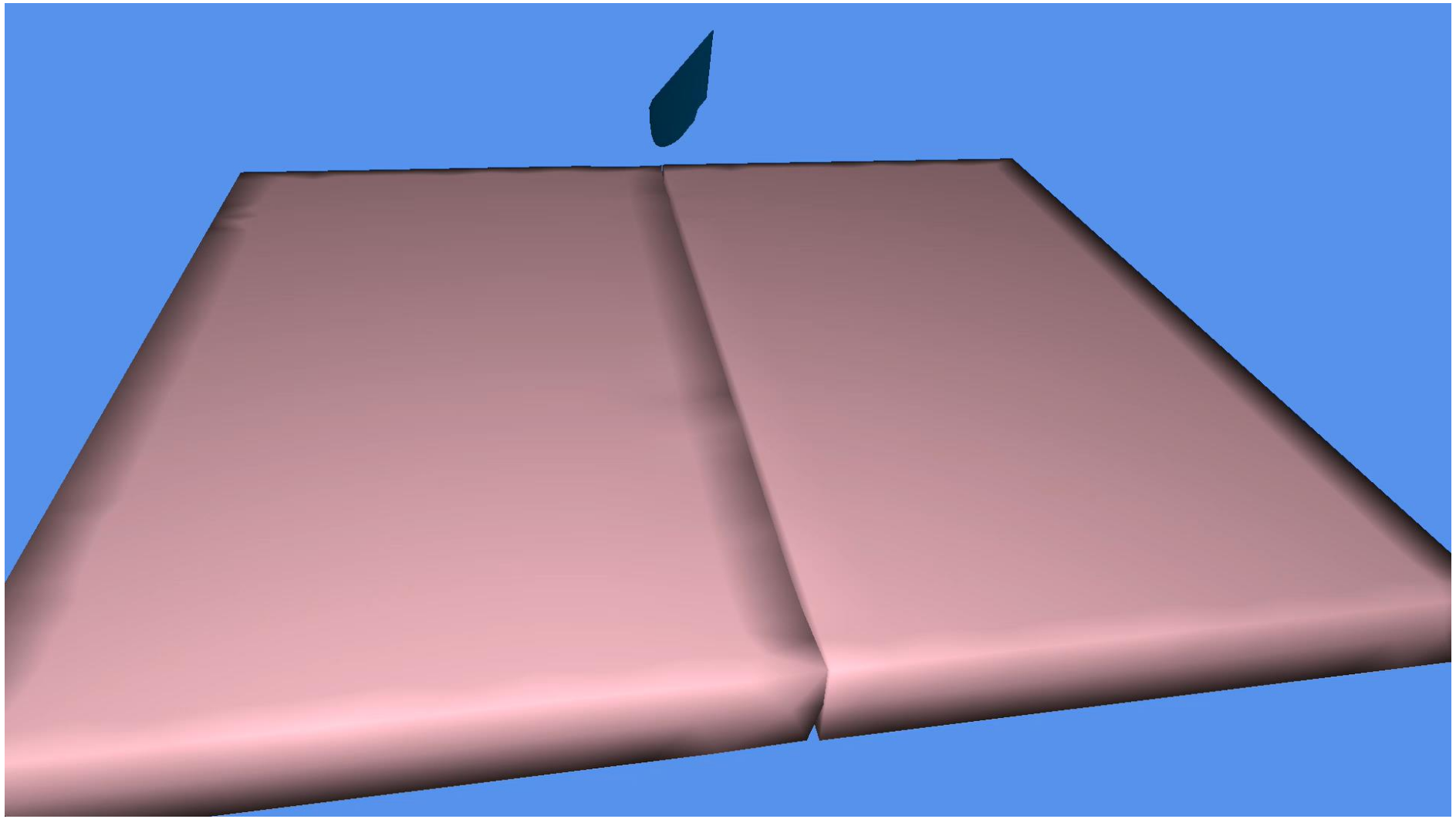
Medical task simulations: implementation

Dexterity task

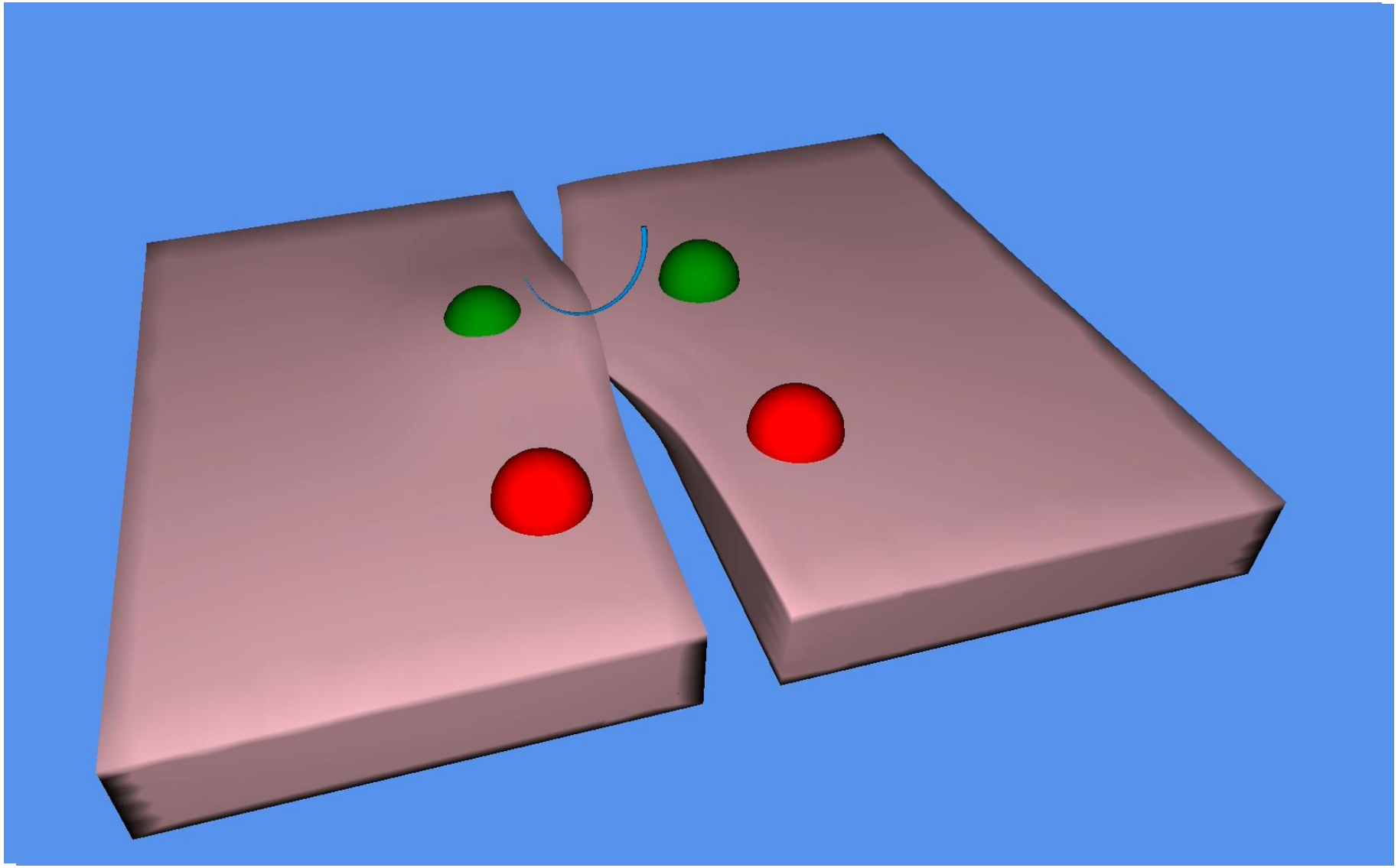


Incision task

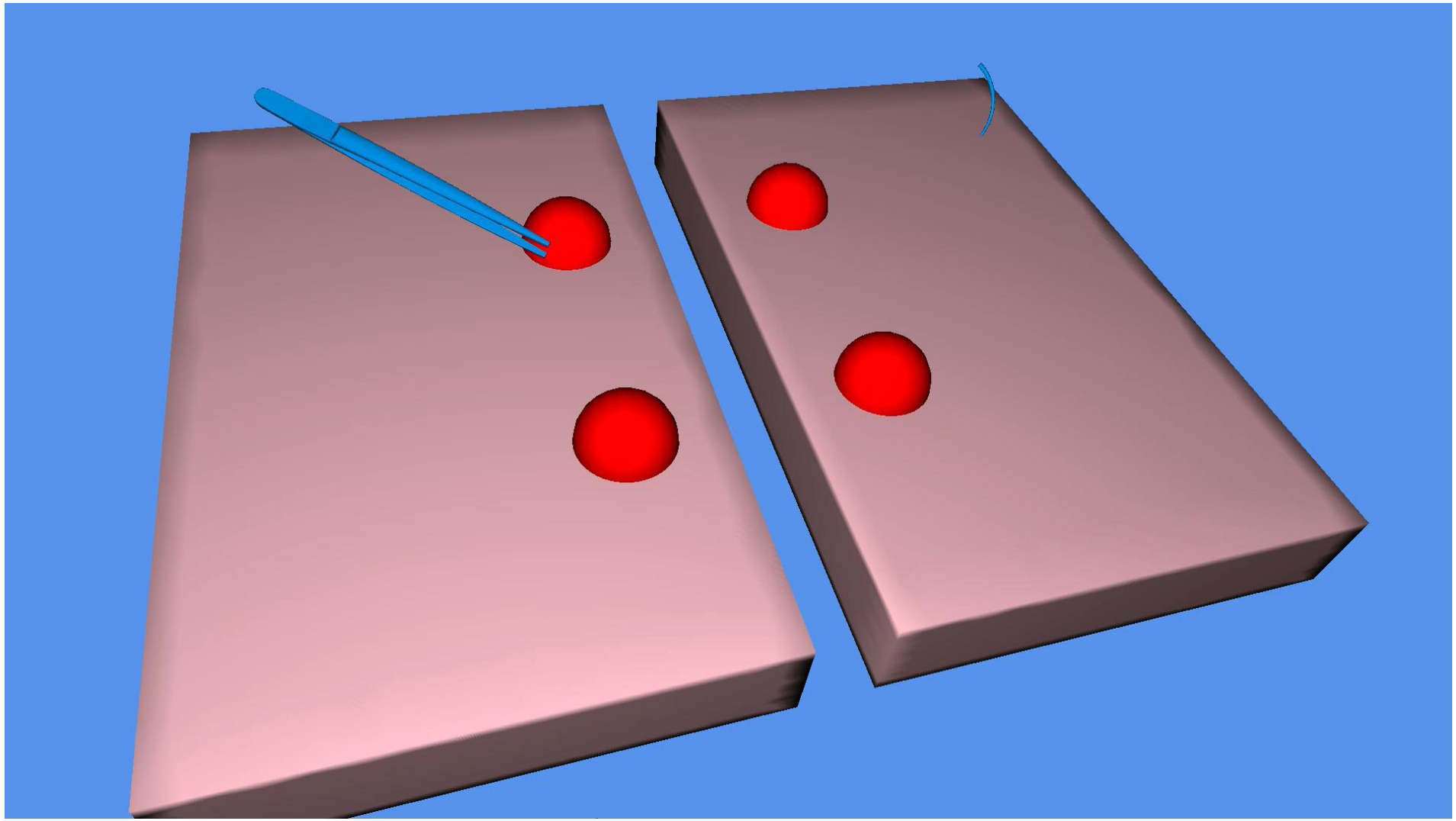


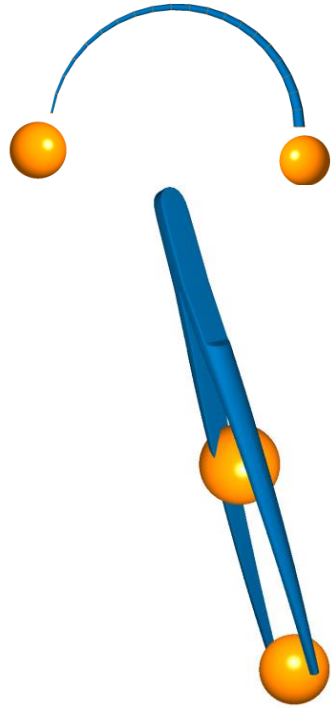


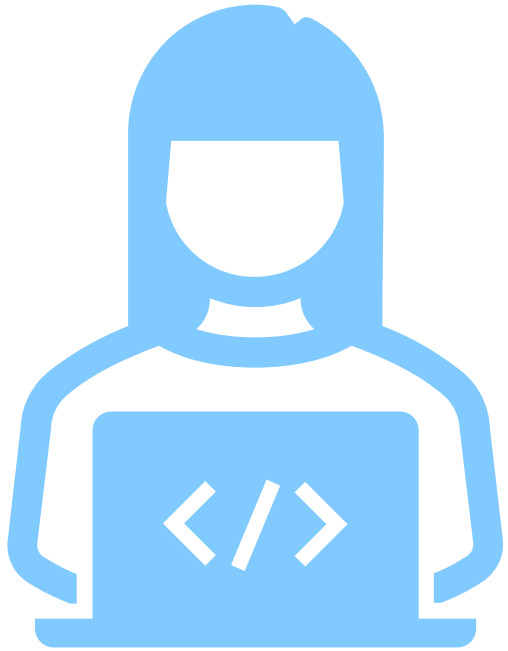
Suture task: single-device



Suture task: double-device

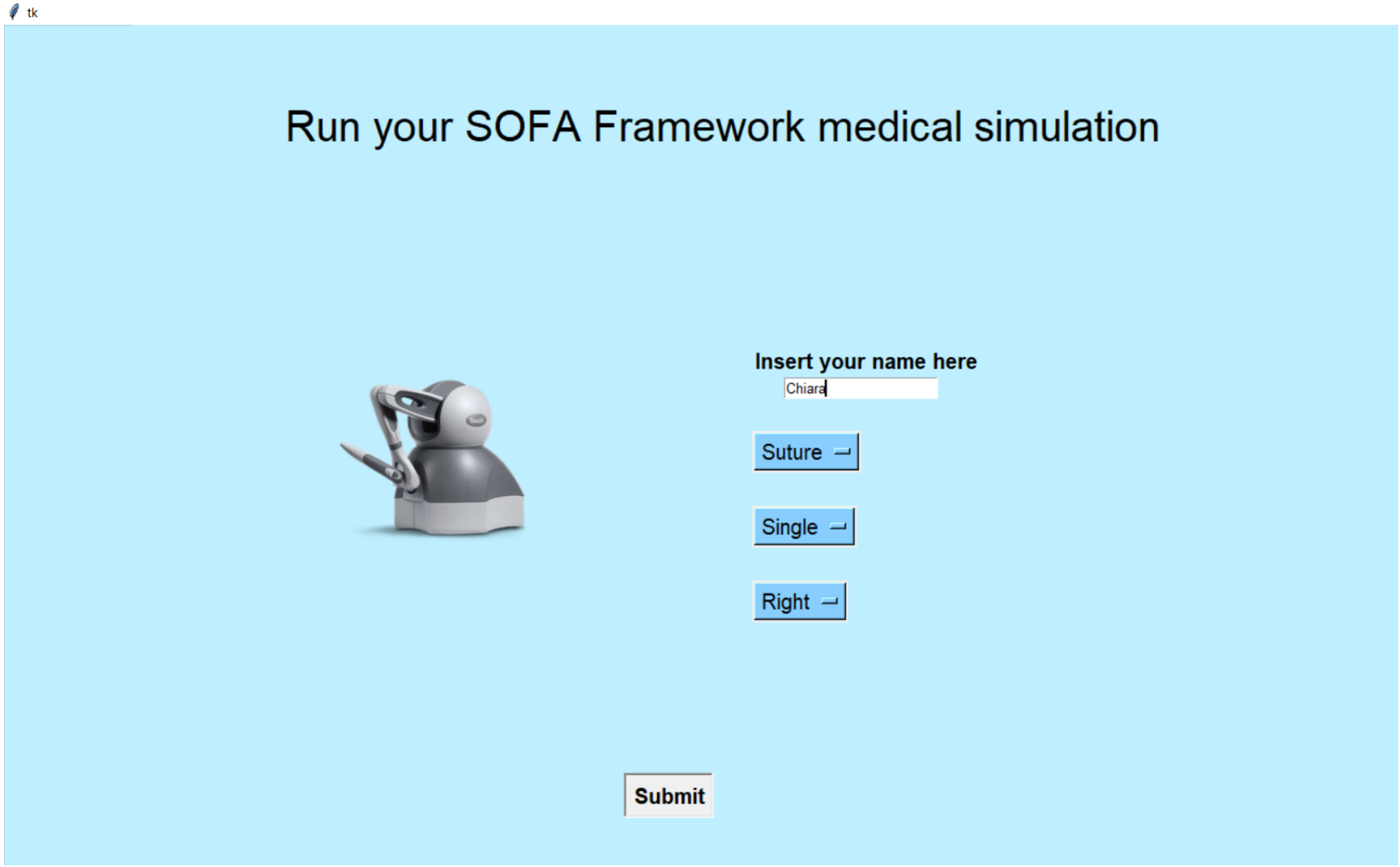






Graphical User Interfaces

Graphical User Interface

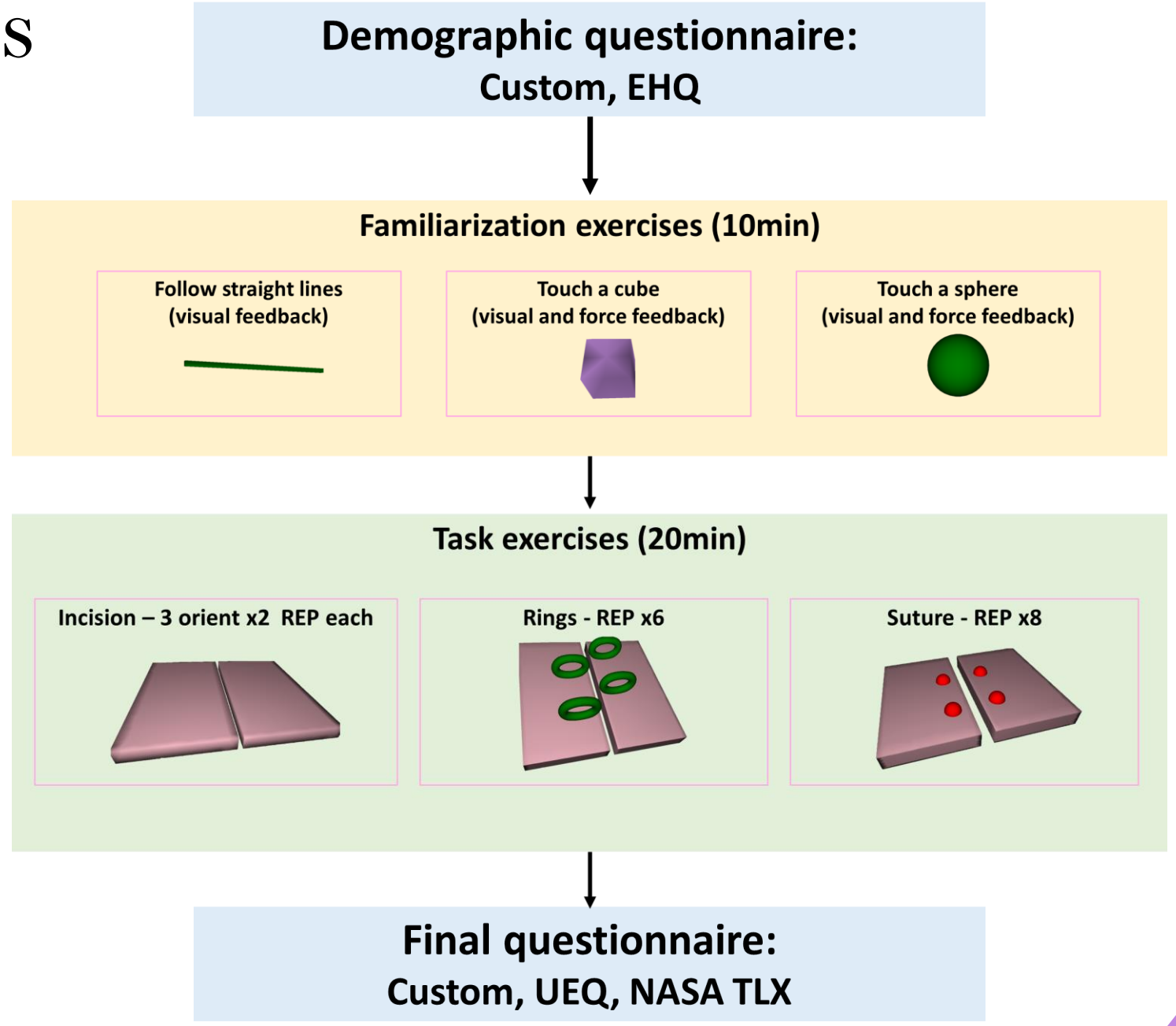


Testing phase

Experiments

Eight surgeons
Average age: 46±16.2
4 Female, 4 Male
Average years of experience: 22.4±19.1
All right-handed

Eight age-matched non experts
Average age: 44.1 ±18.3
4 Female, 4 Male
Two left-handed



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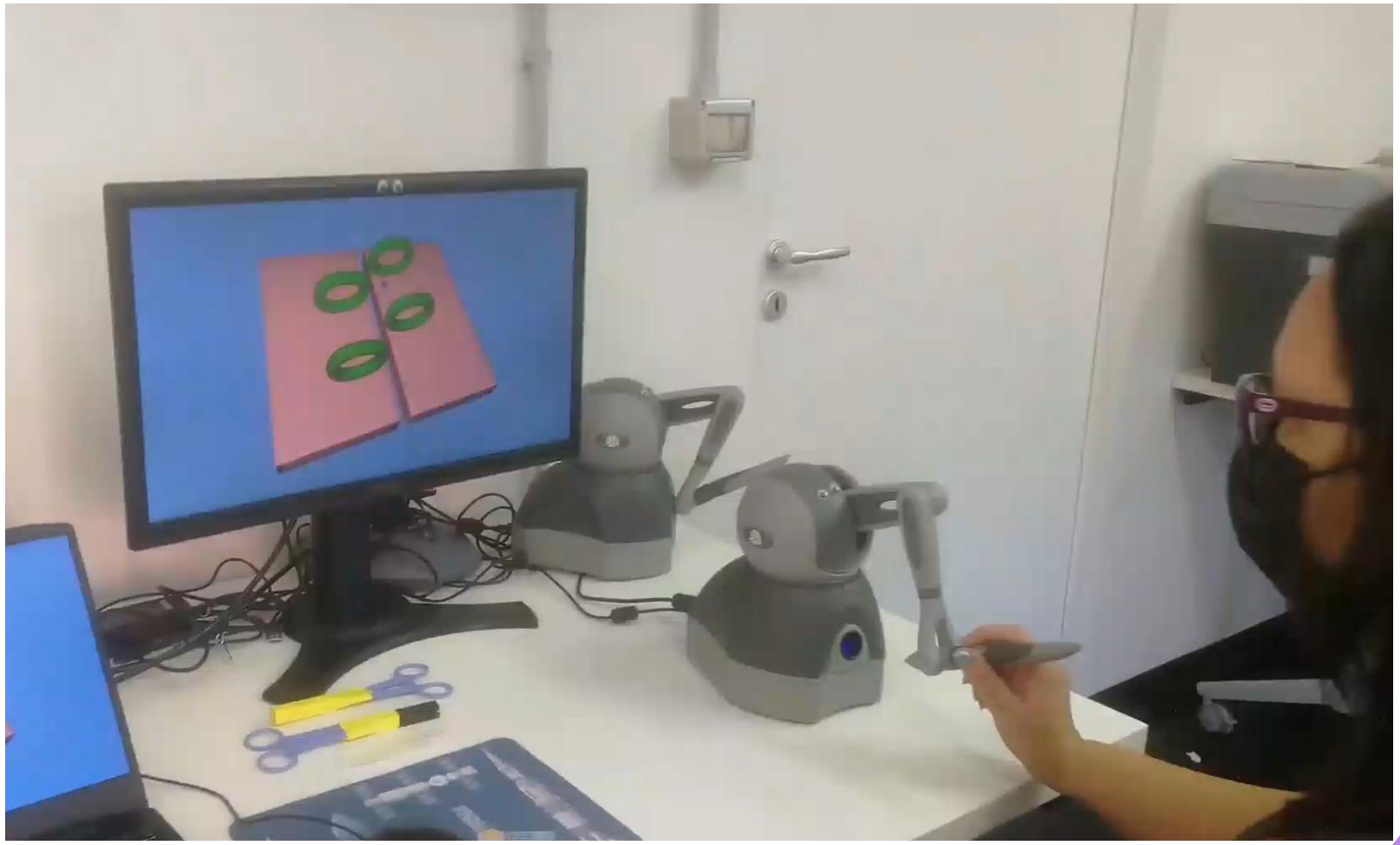
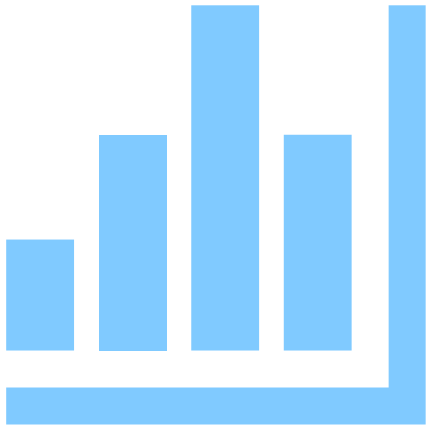
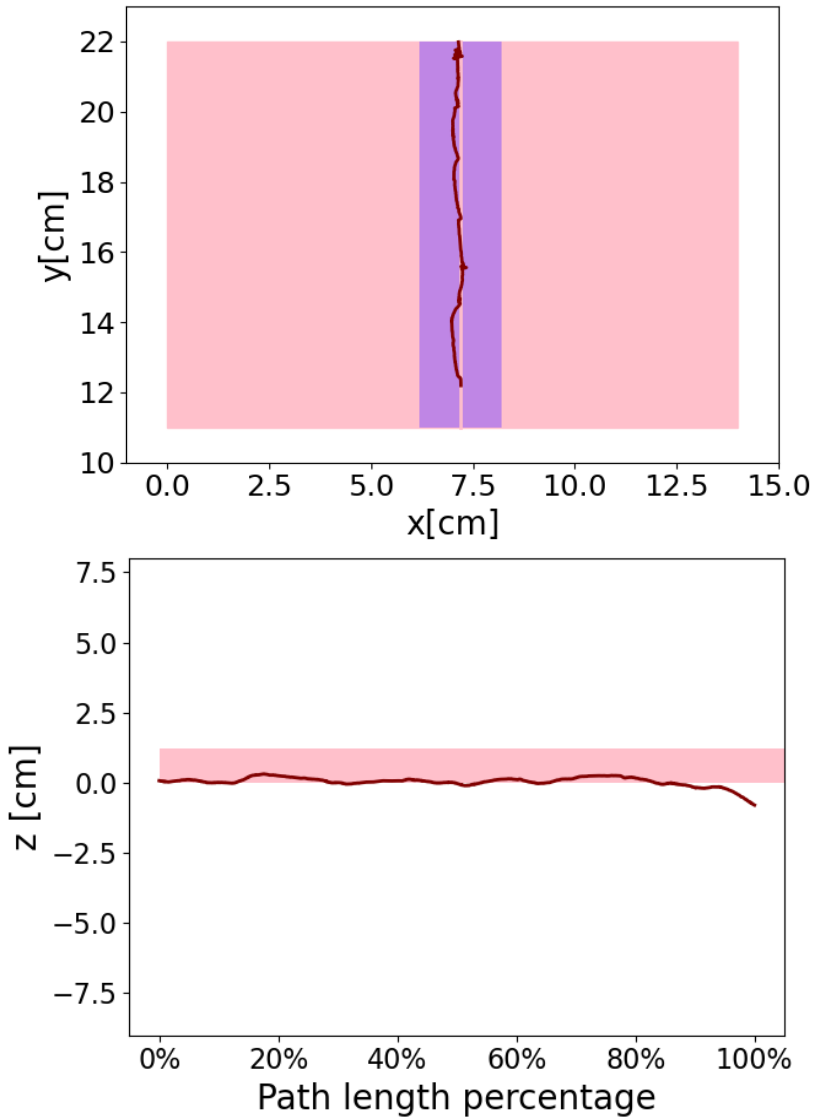




Results

Incision: Behavioral data



Plot color legend:

- Pink: skin, violet: incision area

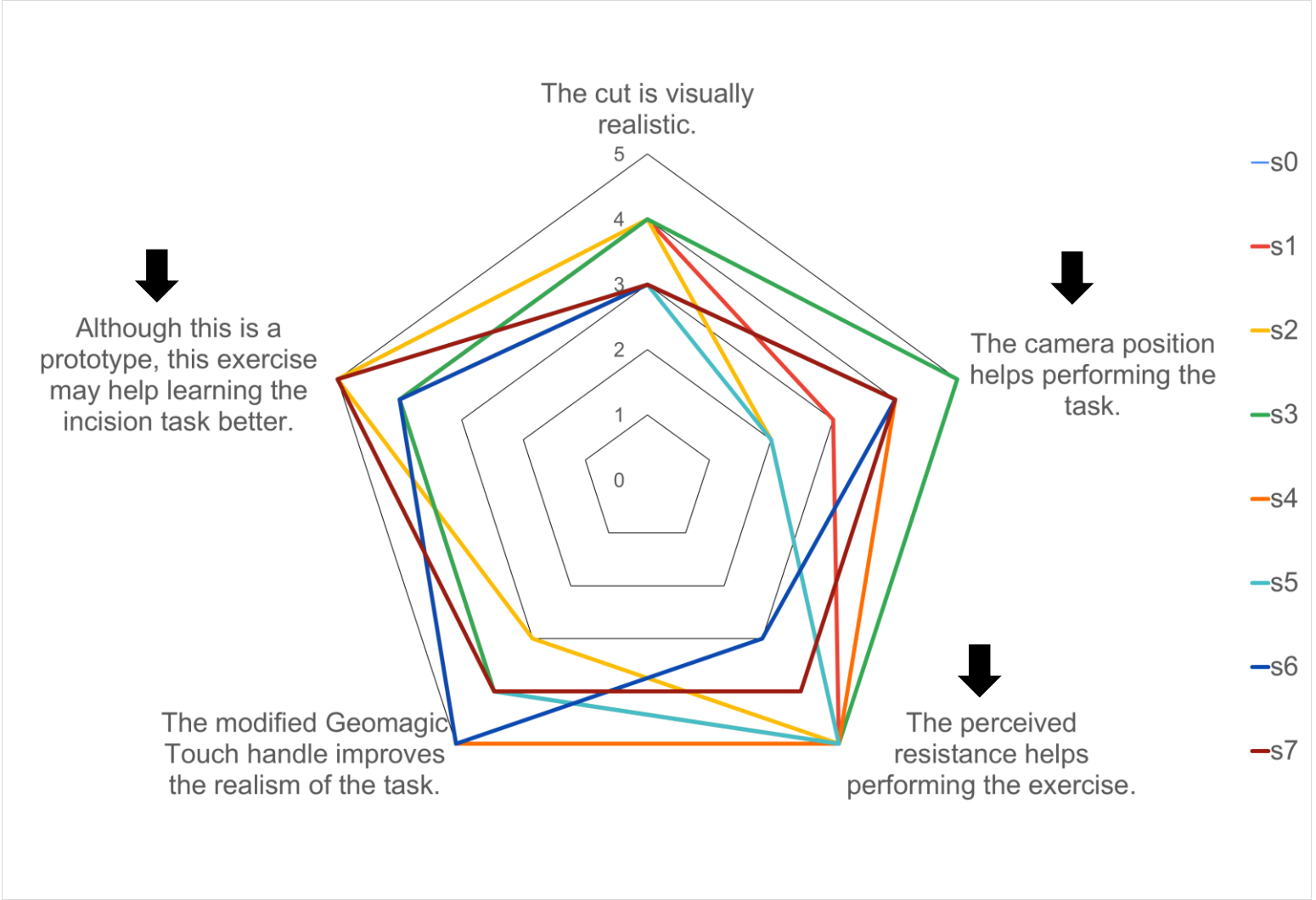
Metrics…

- Incision: maximum deviation from cutting line along x and z

…compared to:

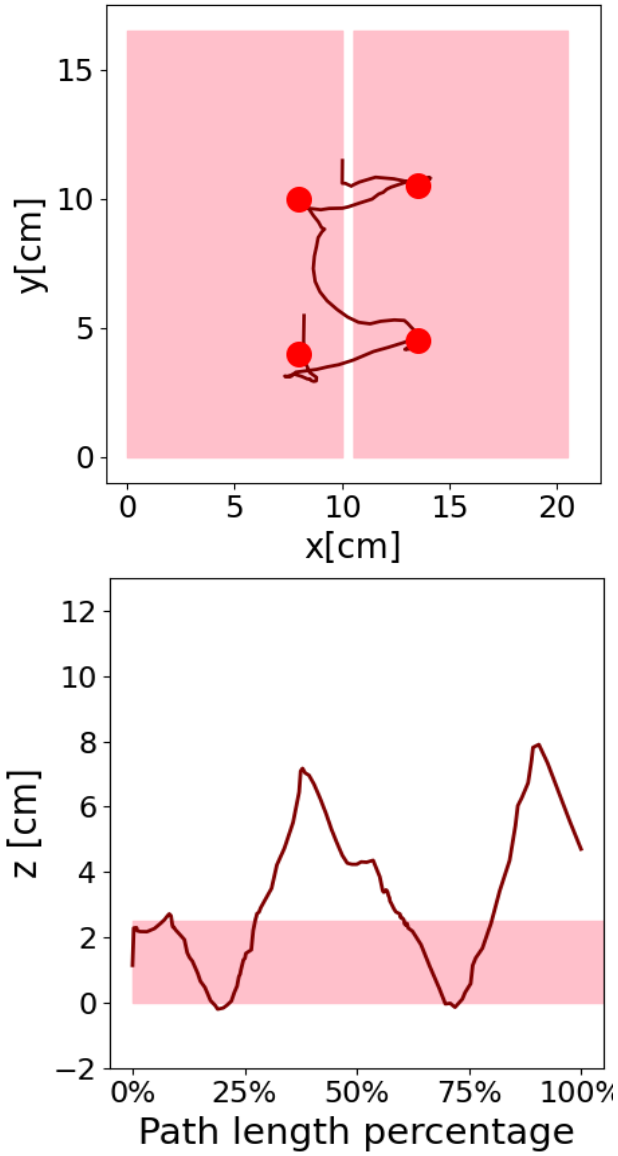
- Group
- Age

Incision: Survey data



Range: 1 (I totally do not agree) to 5 (I totally agree)

Suture: Behavioral data



Plot color legend:

- Pink: skin, red: spheres

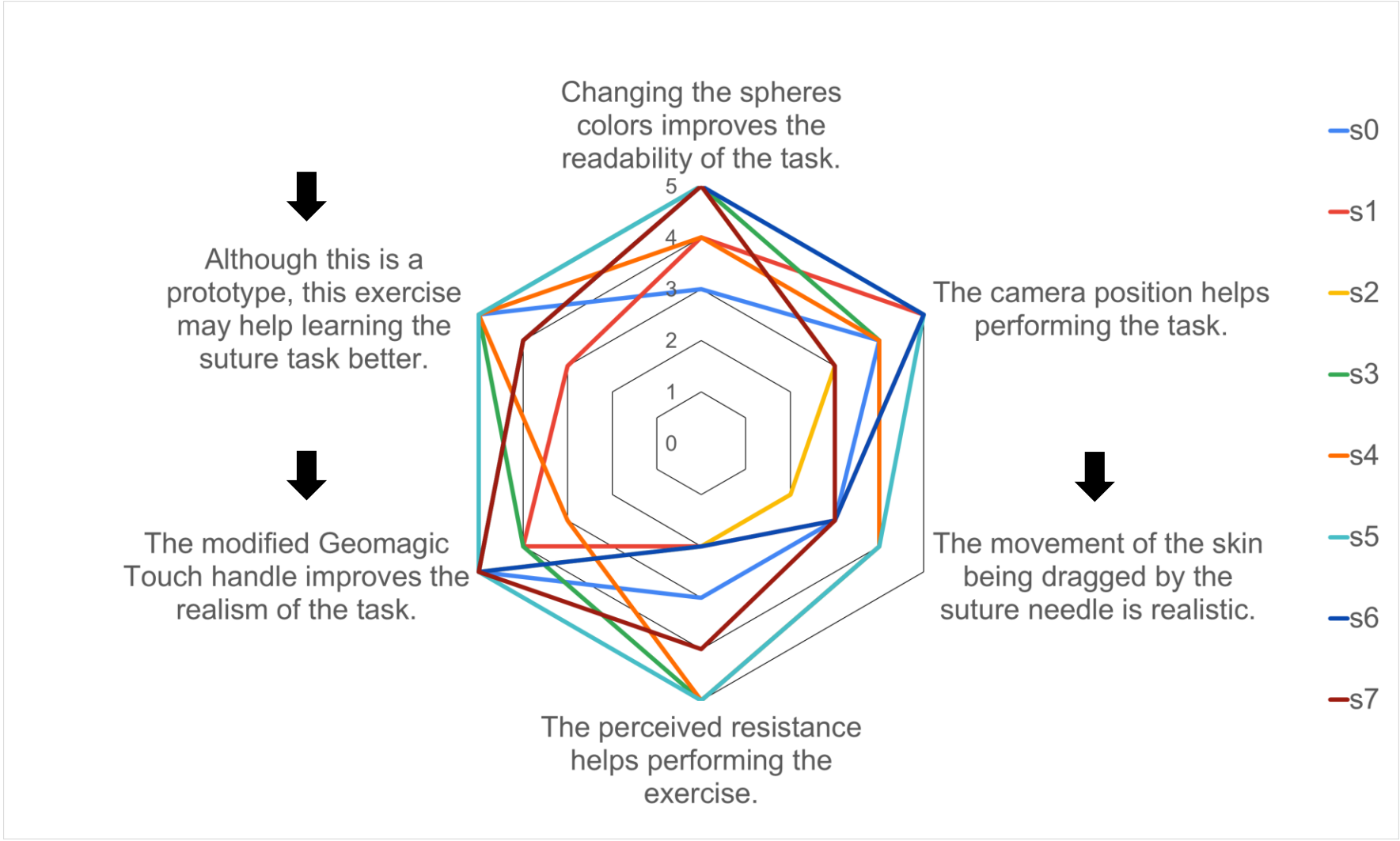
Metrics…

- Suture: 3D path length

…compared to:

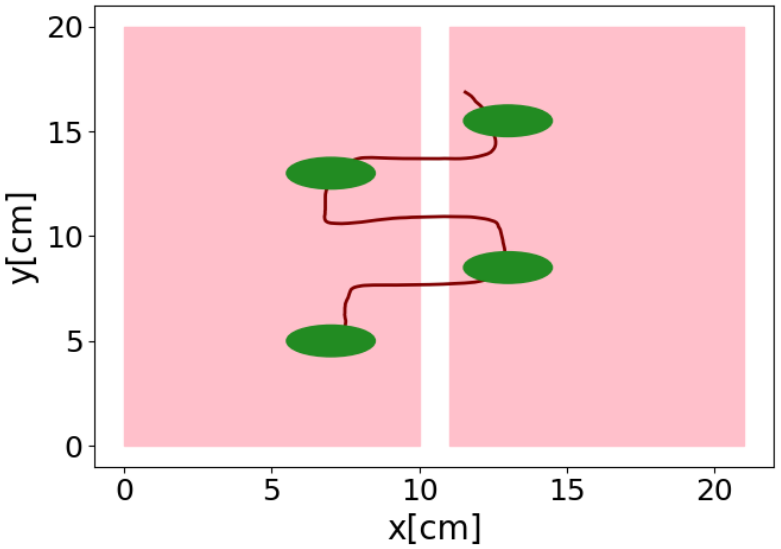
- Group
- Age

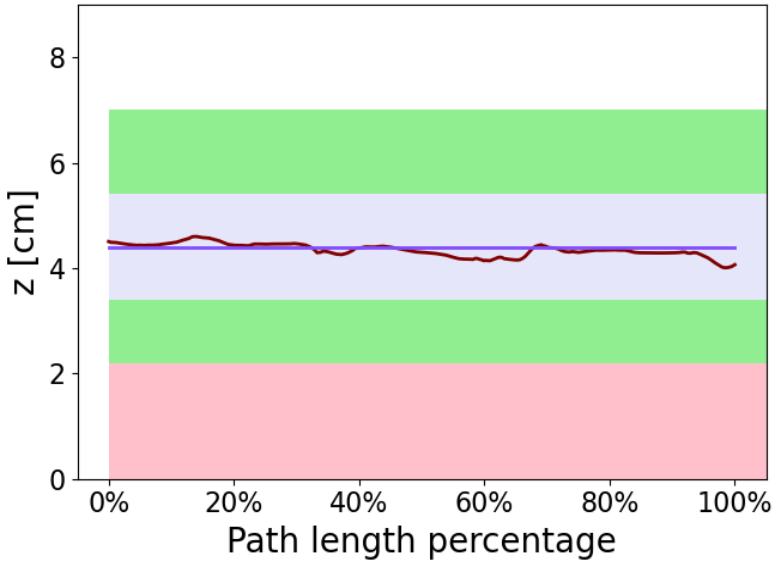
Suture: Survey data



Range: 1 (I totally do not agree) to 5 (I totally agree)

Dexterity: behavioral data





Plot color legend:

- Pink: skin, green: rings, violet: rings holes

Metrics…

- Dexterity: 2D and 3D path length

…compared to:

- Group
- Age

MODEL

DEVICE

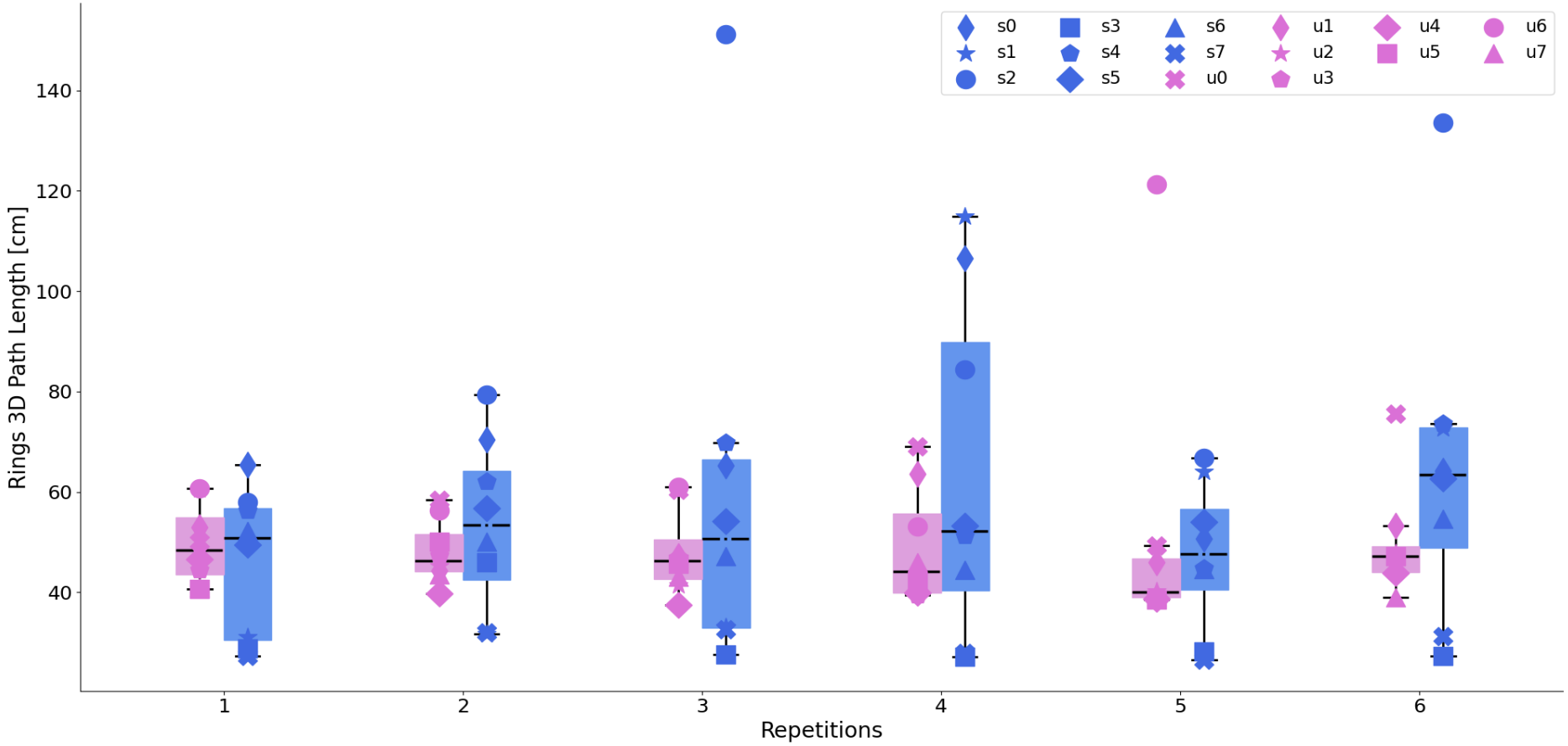
TASKS

GUI

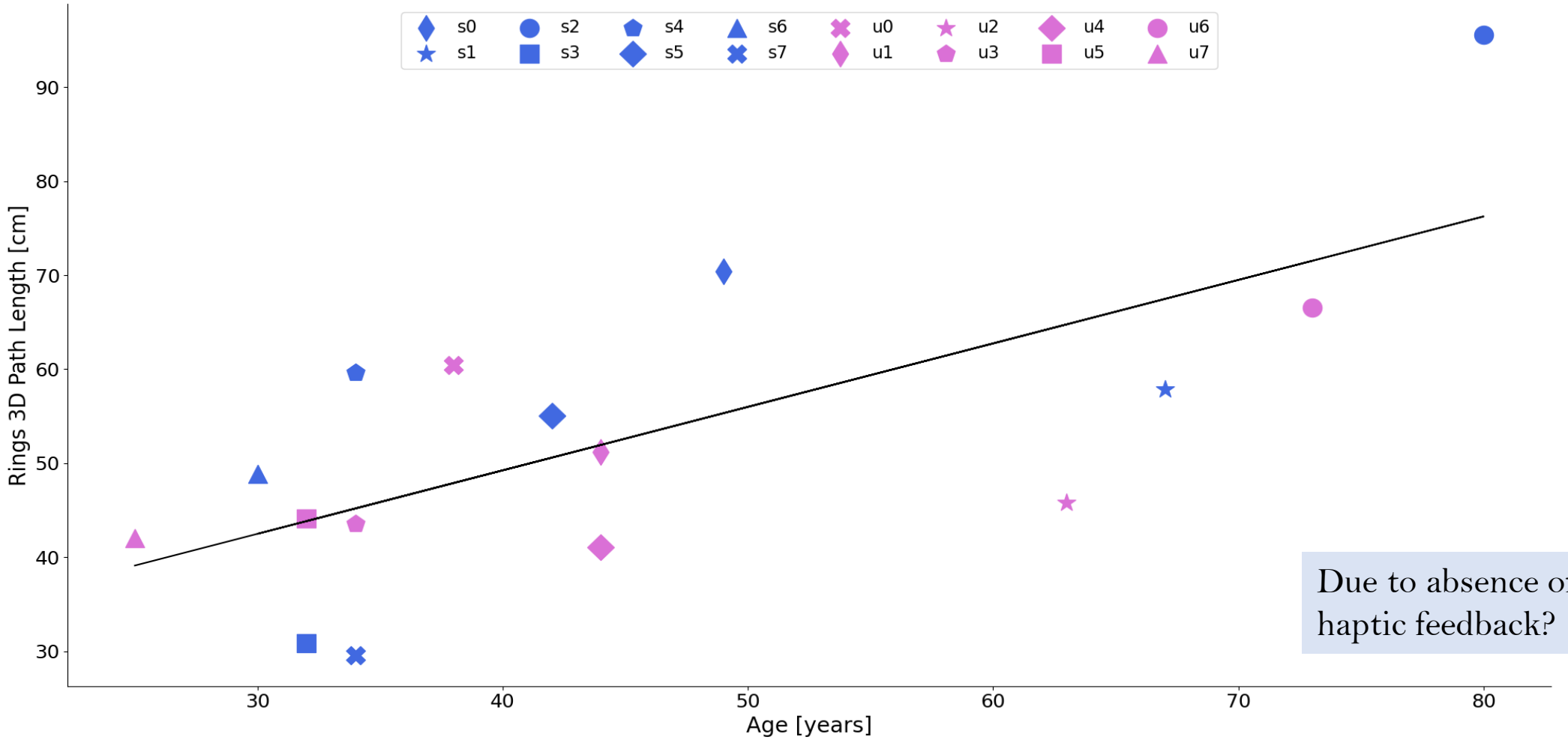
TESTS

RESULTS

Capsule trajectory Path Length



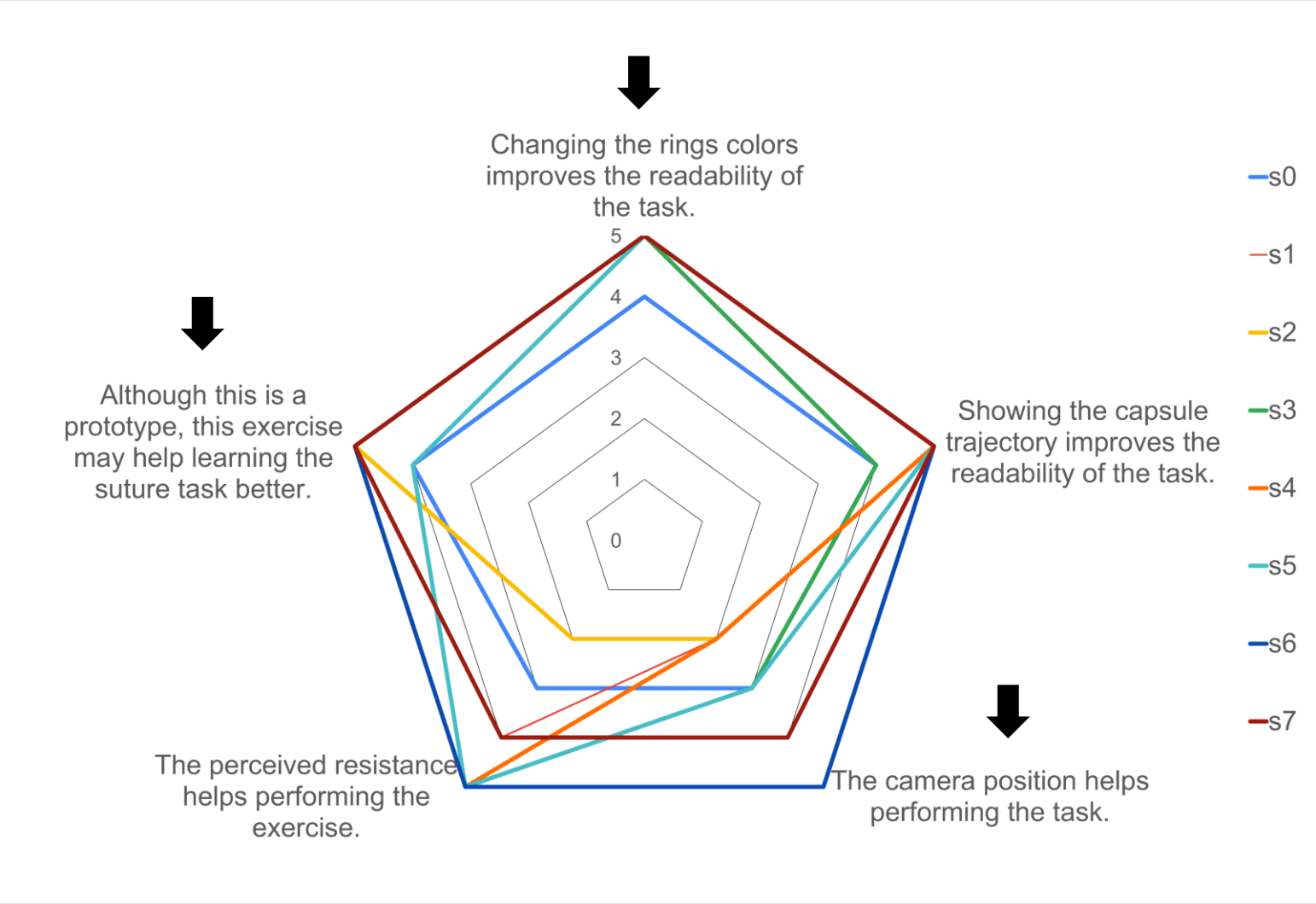
Capsule trajectory Path Length



Due to absence of haptic feedback?

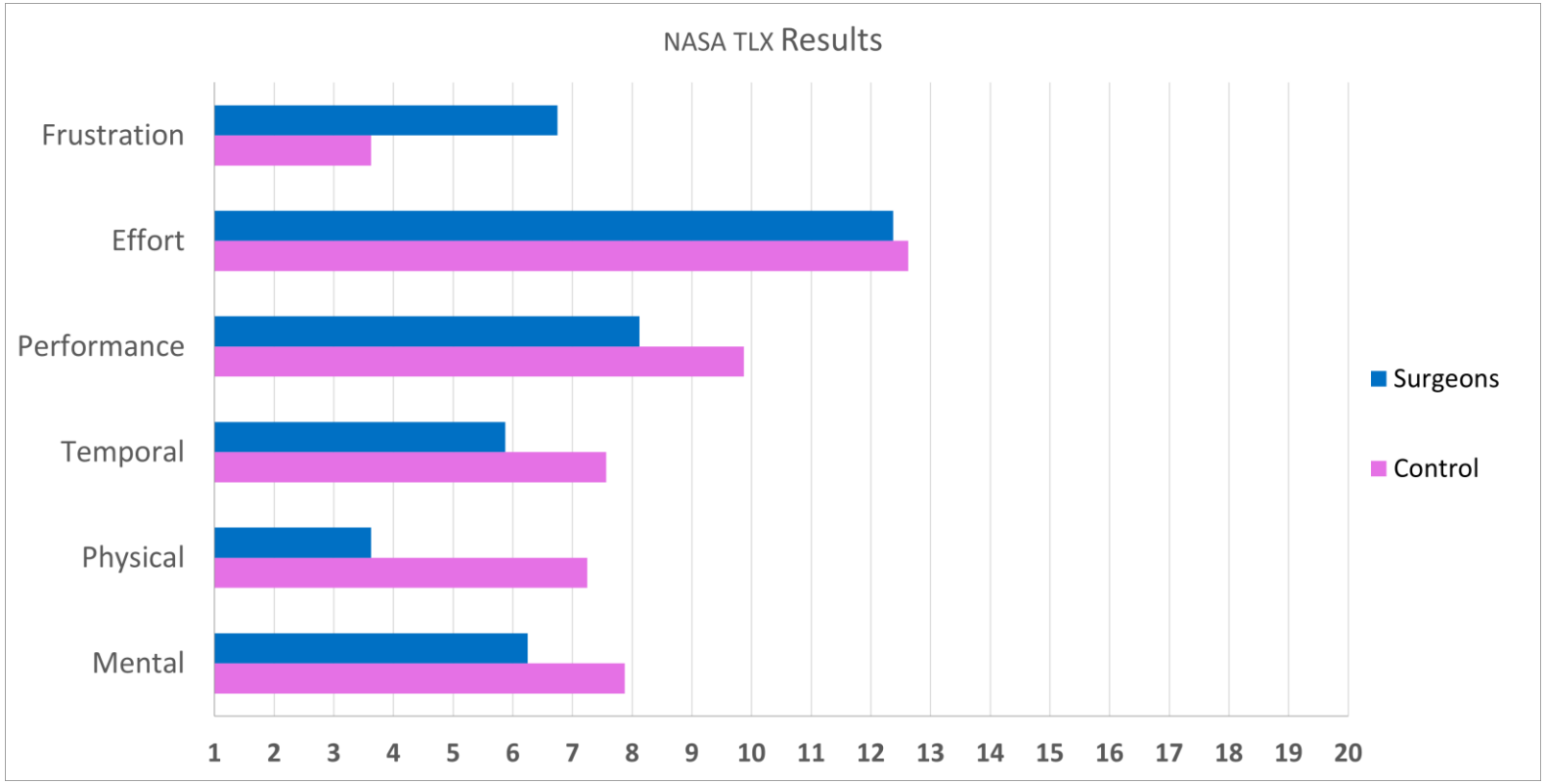
Spearman correlation value: R=0.66, p=0.006

Dexterity: survey data



Range: 1 (I totally do not agree) to 5 (I totally agree)

NASA TLX Questionnaire data



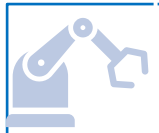
Range: 1 (Very low workload) to 20 (Very high workload)

Conclusions

Conclusions

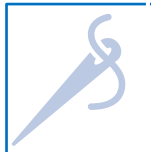
Virtual models:

Skin, Scalpel blade, Suture needle, Forceps, Capsule



Haptic device handles:

Scalpel, Needle holder



Tasks algorithms:

Dexterity, Incision, Single-device suture, Double-device suture

Graphical User Interface:

Installation, Task execution

Experiment:

Setup, Task definition, Surveys

Behavioral data analysis:

Visual inspection, Definition of metrics → correlation with age!

Questionnaire data analysis:

Further improvements, potentialities

Future Works

Improve skin model graphics:
color, texture

Improve skin model haptics:
tune parameters

Add more visual feedback:
suggestions, comments, reminders

Add a results GUI:
did the student learn in time?

The simulator now

Festival della Scienza, Genova

IMSH* Abstract:

A haptic skin model to train surgical residents and analyze the neural correlates of surgical learning

S. Ricci, D. Torrigino, C. Saporetti, M. Chirico, G. Borgonovo, M. Minuto, M. Casadio

**International Meeting on Simulation in Healthcare (IMSH): a scientific conference that explores the latest innovations and best practices in healthcare simulation.*