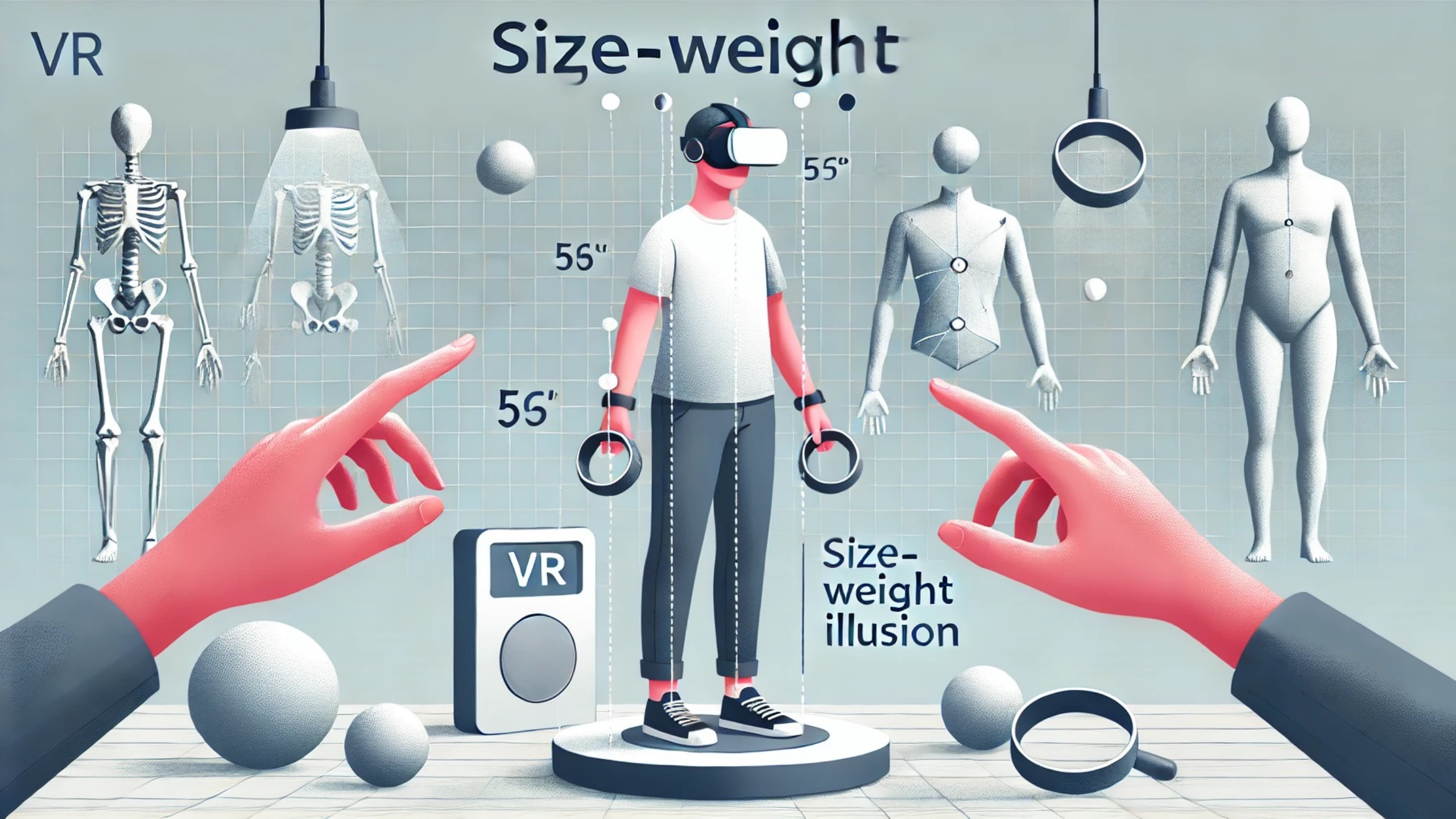

VR
Size-weight
55"
55"
55"
VR
Size-
weight
illusion

Weight perception in VR

Presented by Shengyi Gong

Size-weight illusion (SWI)

Figure 1: Three-dimensional space (RW)

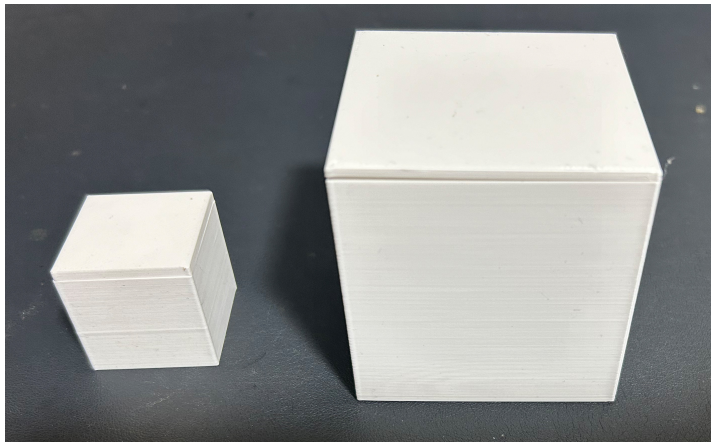
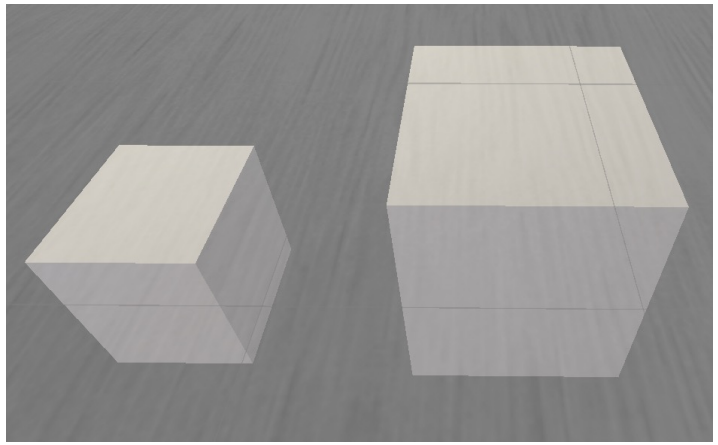


Figure 2: Four-dimensional space (VE)



Background & Introduction

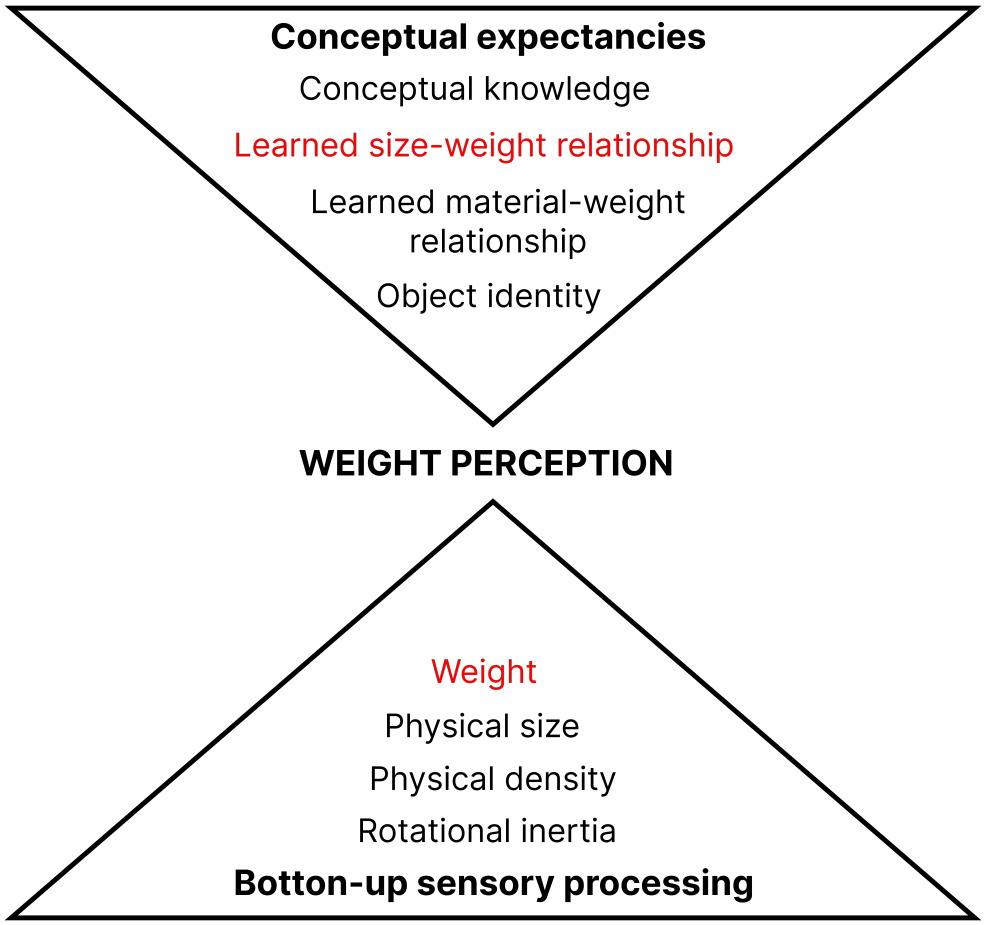
· The size-weight illusion usually causes people to perceive the actual weight of an object, resulting in a weight illusion.

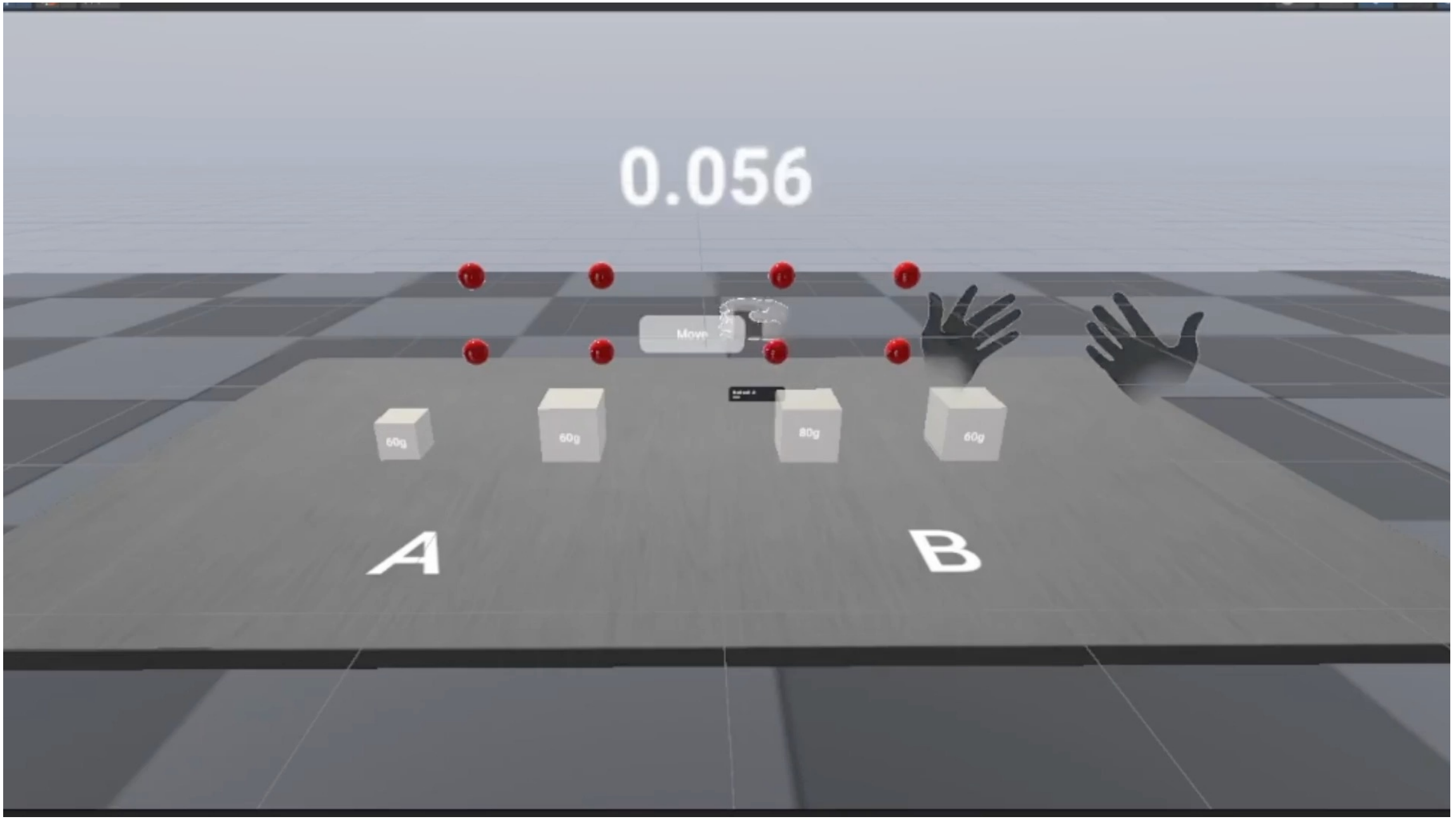
· This phenomenon is common in both real life and VR.

· This study proposes a bottom-up approach to explain the weight illusion.

· In the field of theory and science, I used EMG bioelectric signals to predict weight perception in VR for the first time, and it can be applied in fields such as VR games and art, and it has certain potential.

A meta – analysis of the size-weight illusion




0.056
Move
60g
60g
80g
60g
A
B

Research Question

Is it possible to accurately predict weight perception in VR by analysing muscle-generated activity through EMG bioelectrical signals, and to further validate the consistency of physiological and psychological judgments on weight perception of objects in the VR environment?

Two experiments ---------- four hypotheses

Experiment 1 (Condition 1 - Same size, different EMG thresholds):

· Hypothesis 1: In Experiment B, participants can successfully use EMG physiological signals to predict the weight of the virtual grasped object after grasping two cubes of the same size but different weights

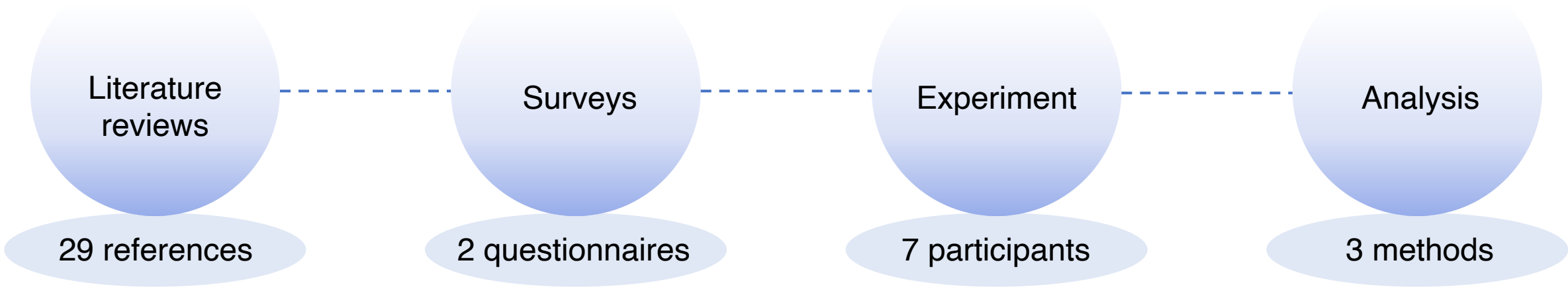
· Hypothesis 2: In Experiment B, participants cannot successfully use EMG physiological signals to predict the weight of the virtual grasped object after grasping two cubes of the same size but different weights

Experiment 2 (Condition 2 - Different size, same EMG threshold):

· Hypothesis 1: In Experiment A, participants' psychological perception of weight is consistent with the weight reflected by physiological signals after grasping two cubes of different sizes but the same weight.

· Hypothesis 2: In Experiment A, participants' psychological perception of weight is inconsistent with the weight reflected by physiological signals after grasping two cubes of different sizes but the same weights.

Methodology

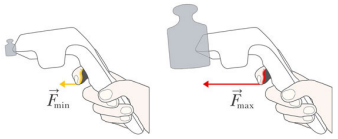


Literature reviews

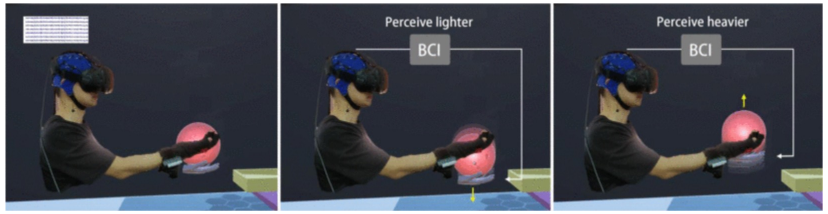
· Weight illusion in VR

(SWI)

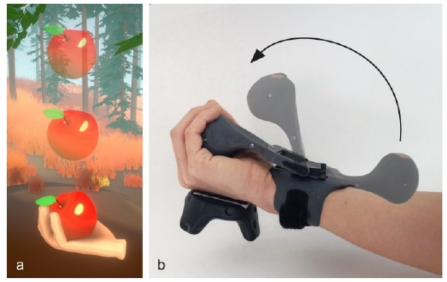
- Trigger muscle



- EEG

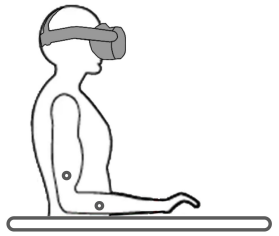


- Pivot

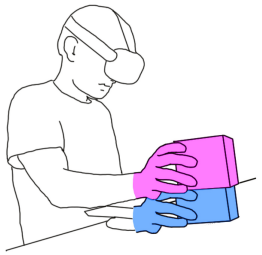


· The impact of muscle bioelectrical signals on weight perception

- Seated grip method



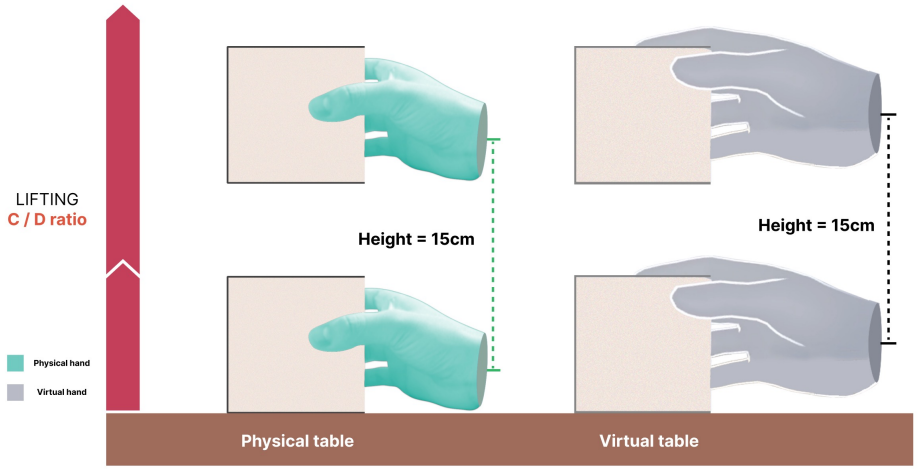
- Muscle contraction activity
- Transient and steady-state



Literature reviews

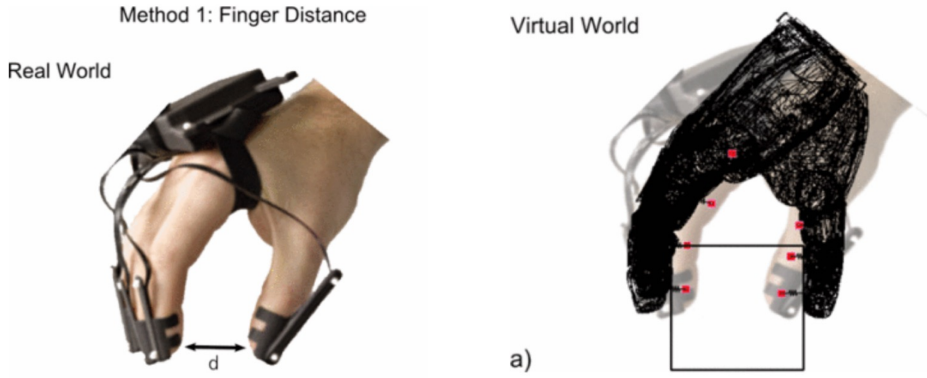
· The mapping between the user's physical input and the virtual response can influence the perception of weight

C / D Ratio = 1



Control (C): The physical movement or action performed by the user

Display (D): The resulting movement or response displayed in the virtual environment



· The connection between Weber fraction and pseudo-tactile feedback

Weber Fraction: Evaluate and quantify the sensitivity of perceptual systems

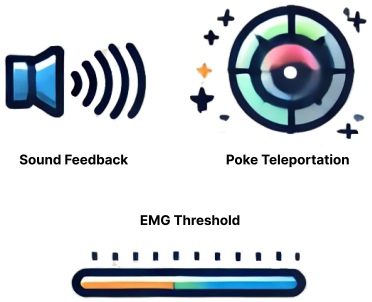
Weight Feedback: Vertical force simulation

Experimental plan

Focus Lifespan

· Attention

Feedback Indicator



· Real-time feedback

Accurate Tracking

· Consistent hand gesture

· Focus Lifespan ------ Overall system time control

1.Participant fatigue level

· Attention

· Arm fatigue level

· Matching two system time series and virtual object spatial positions

2.User guidance factors

· UI Indication Content

· Hand movement indication animation

· Shorten interaction time

3.Friction and finger grip strength

· Finger ring device

· Nano gel

· Eliminate all physical factors

· Feedback Indicator ------ Reduce errors due to unnecessary interactions

1.Sound feedback

· Extensor digitorum relaxed –
virtual hand in place
– sound triggered

· Extensor digitorum contraction –
virtual hand at 15cm height
– sound triggered

2.Threshold visualization

· Extensor digitorum relaxed –
virtual hand in place
– Threshold: (0.000 - 0.030)

· Extensor digitorum contraction –
virtual hand at 15cm height
– Threshold: (0.030 - 0.120)

3.Poke teleportation

· Click UI button with left hand

· Teleport to the next test point

· Accurate Tracking ------ Reduce experimental errors

1. Ensure C/D Ratio = 1

· Ensure that weight perception is not affected by visual cues

2. Consistent hand movement trajectory

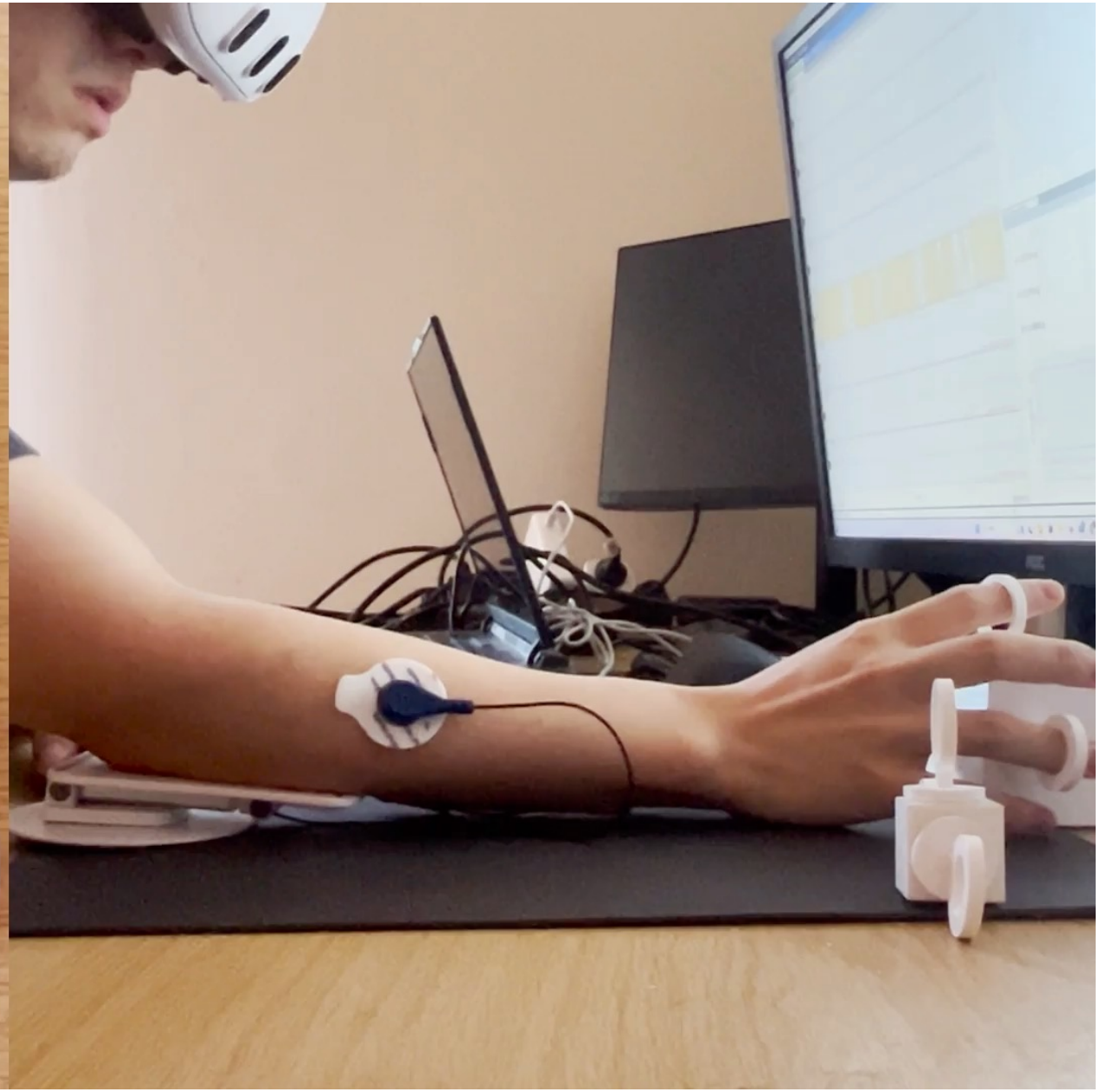
· Ensure that the movement trajectories of the real hand and the virtual hand are consistent

3. Consistent hand gestures

· Ensure that the grasping gesture is fixed

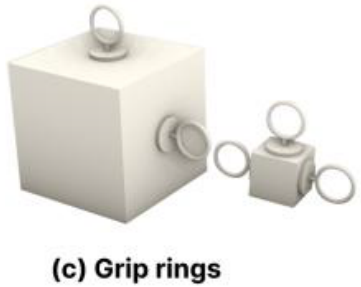
How to perceive the weight of three-dimensional space in four-dimensional space?


10000
UNIT



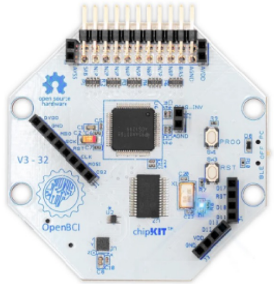
Technical Implementation

Physical Devices



· Fixed gesture

Communication

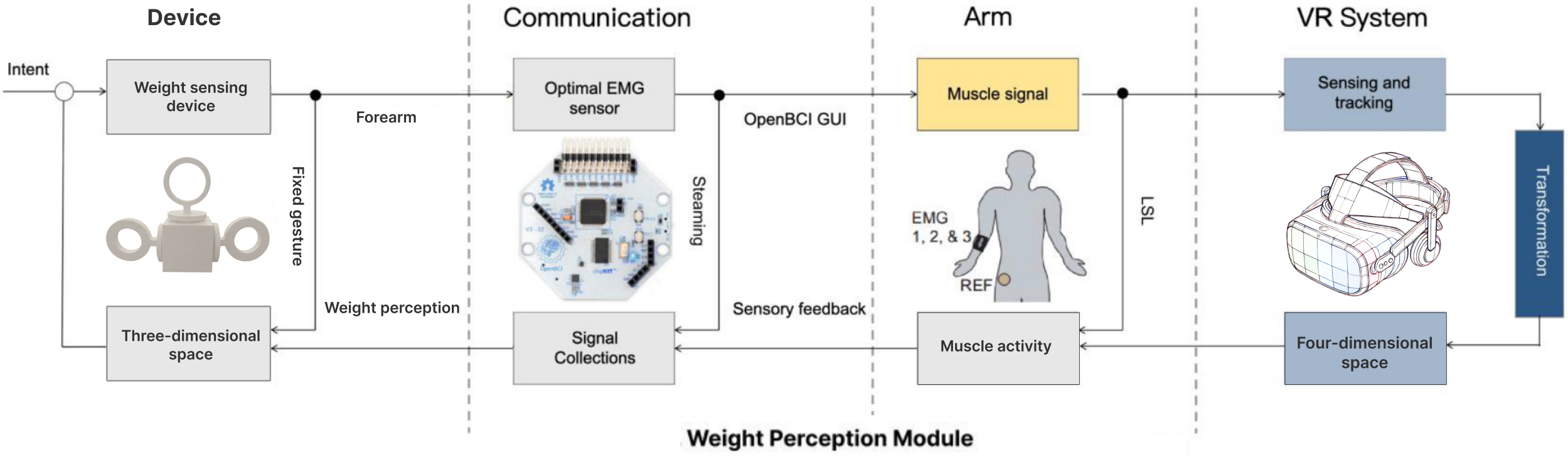


· Muscle electrical signal communication

Program

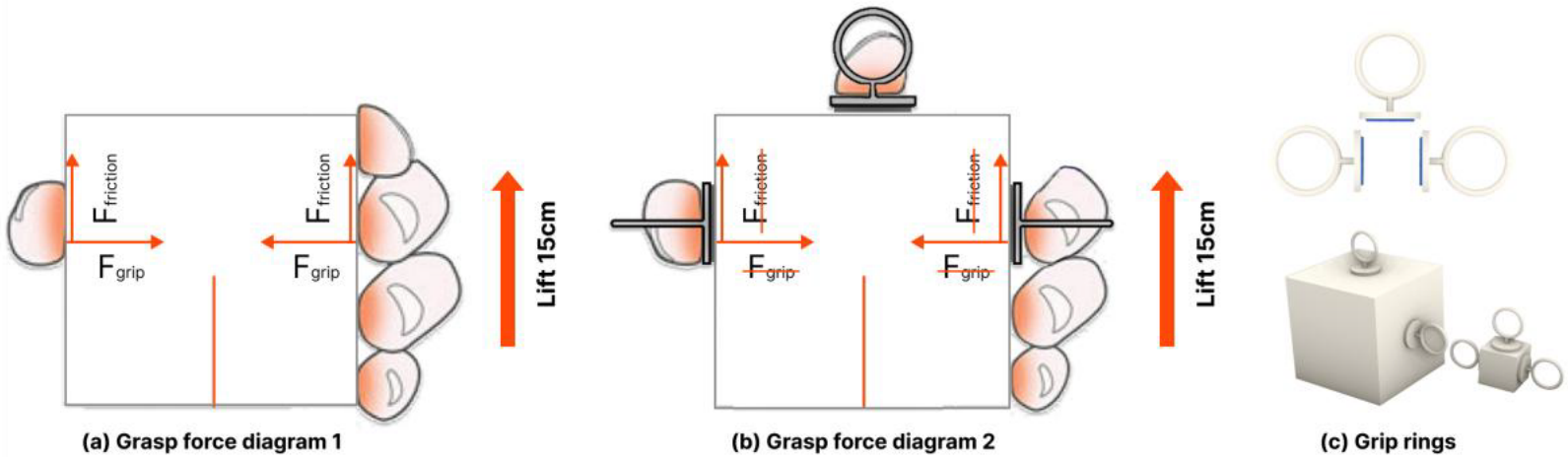
· Program system design

EMG system communication process



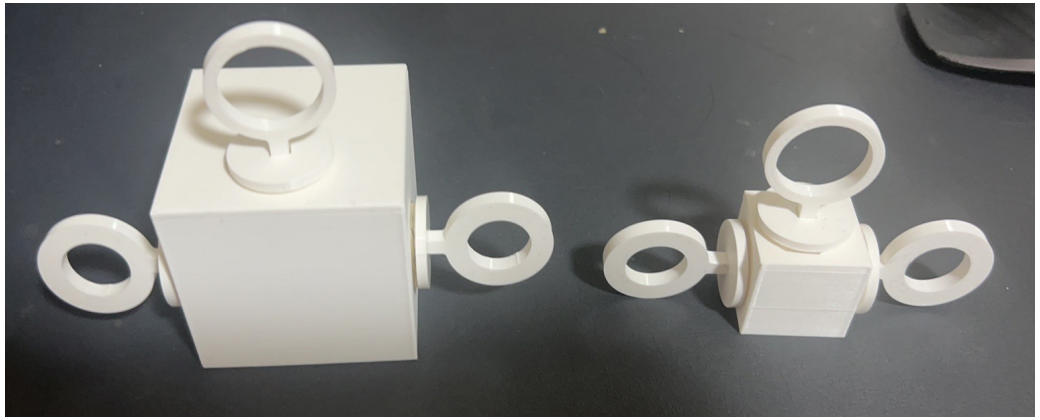
Weight sensing device

Figure 3. Force visualization during the lifting process of an object



(a) Grasp force diagram 1 (b) Grasp force diagram 2 (c) Grip rings

(a) The hand is subjected to external forces from objects (b) The hand is not subjected to external forces from objects (c) Hand grip device



Communication

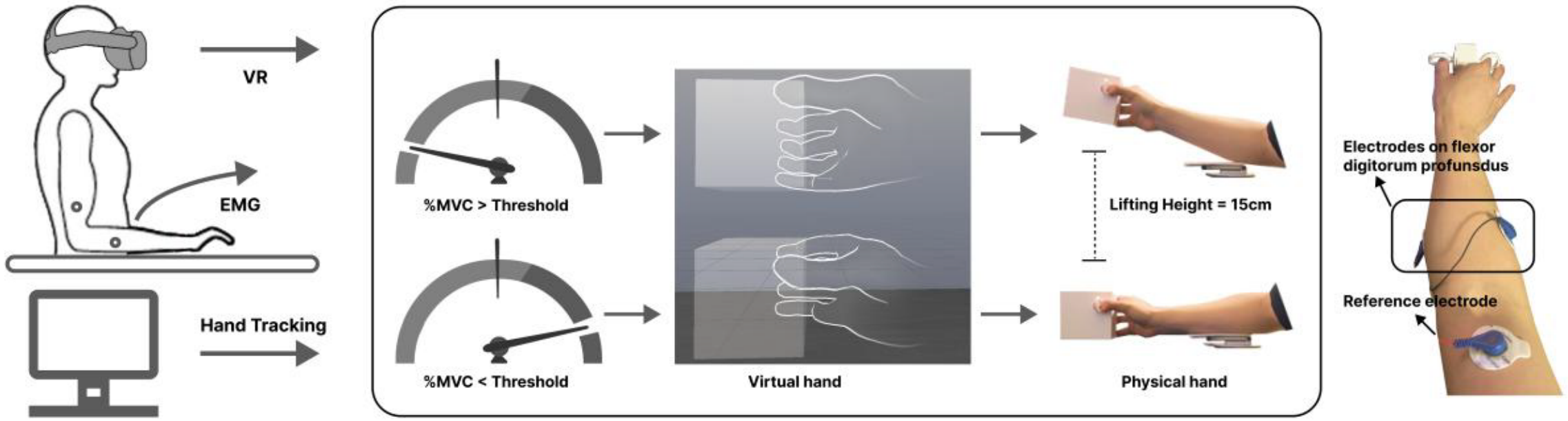


Figure 12. Overall structure of the proposed method in this study: (a) structure, (b) EMG electrodes attached to the extensor digitorum

Program

stage	Unity running status	Physical Object	Virtual Object	Time (sec)	Muscle activity	Physical Cube state	Virtual Cube state
1	Not Running	60g large box	————	0	relaxation	Stay still on desktop	————
2	Running	60g large box	————	0 - 10	relaxation - contraction - relaxation	Stay still on desktop	Stay still on desktop
3	Running	60g large box	Experimental Group B Cube 1	10 - 20	relaxation - contraction - relaxation	be lifted	be lifted
4	Running	80g large box	Experimental Group B Cube 2	25 - 35	relaxation - contraction - relaxation	be lifted	be lifted
5	Running	60g large box	Experimental Group A Cube 1	40 - 45	relaxation - contraction - relaxation	be lifted	be lifted
6	Running	60g small box	Experimental Group A Cube 2	50 - 60	relaxation - contraction - relaxation	be lifted	be lifted
7	Not Running	60g small box	————	60 - Nah	relaxation	Stay still on desktop	————

Figure 10. Muscle activity and Unity program time recording chart

Game Demo

Experimental results analysis

1.Compare the smoothed EMG value with the threshold set in VR

· Prediction of weight perception accuracy in VR

2.Compare the EMG threshold with subjective perceived weight value in the questionnaire

· Analysis of physiologically perceived weight and consistency of physiologically perceived weight

Questionnaire analysis

· The aim is to help all participants understand the SWI concept in advance.

VR SWI Pre-Questionnaire

During the entire experiment, the tester needs to grasp the object with a precise grasping posture, otherwise the results will be invalid.

1. What is your ID?

输入你的答案

2. What is the weight change?

输入你的答案

3. Was the object on the left heavier than the object on the right?

- ◯ much lighter
- ◯ lighter
- ◯ the same
- ◯ heavier
- ◯ much heavier

4. How confident are you in your decision?

输入你的答案

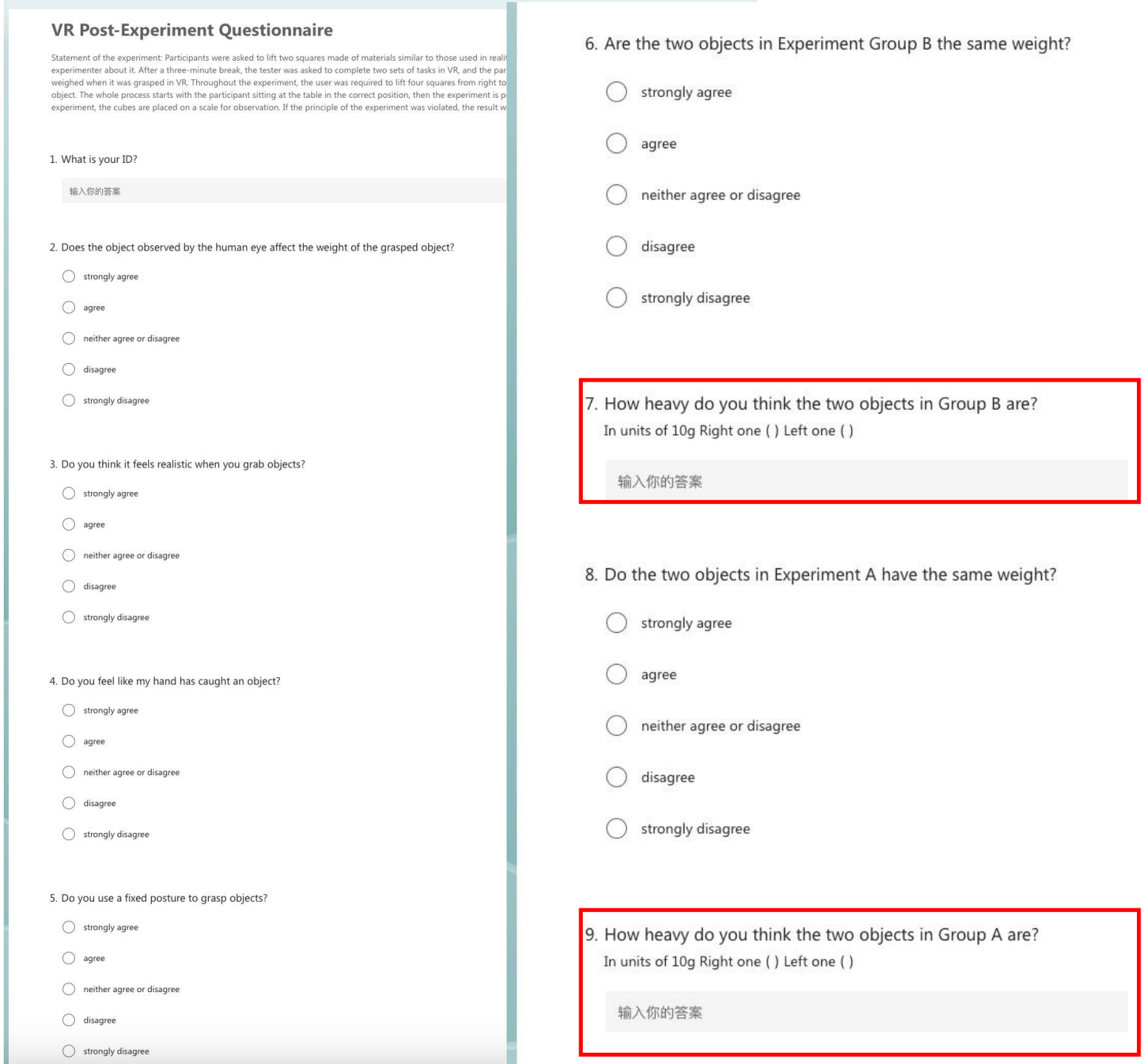
5. The weight of a large object is several times that of a small object 2 times / 3times

输入你的答案

Questionnaire analysis

· The second questionnaire mainly assessed whether visual cues in SWI would change the subjective perception of weight and the effectiveness of pseudo-tactile sensations.

· The aim is to quantify participants' perception of weight change.



VR Post-Experiment Questionnaire

Statement of the experiment: Participants were asked to lift two squares made of materials similar to those used in reali
experimenter about it. After a three-minute break, the tester was asked to complete two sets of tasks in VR, and the par
weighed when it was grasped in VR. Throughout the experiment, the user was required to lift four squares from right to
object. The whole process starts with the participant sitting at the table in the correct position, then the experiment is p
experiment, the cubes are placed on a scale for observation. If the principle of the experiment was violated, the result w

1. What is your ID?

输入你的答案

2. Does the object observed by the human eye affect the weight of the grasped object?

- strongly agree
- agree
- neither agree or disagree
- disagree
- strongly disagree

3. Do you think it feels realistic when you grab objects?

- strongly agree
- agree
- neither agree or disagree
- disagree
- strongly disagree

4. Do you feel like my hand has caught an object?

- strongly agree
- agree
- neither agree or disagree
- disagree
- strongly disagree

5. Do you use a fixed posture to grasp objects?

- strongly agree
- agree
- neither agree or disagree
- disagree
- strongly disagree

6. Are the two objects in Experiment Group B the same weight?

- strongly agree
- agree
- neither agree or disagree
- disagree
- strongly disagree

7. How heavy do you think the two objects in Group B are?
In units of 10g Right one ( ) Left one ( )

输入你的答案

8. Do the two objects in Experiment A have the same weight?

- strongly agree
- agree
- neither agree or disagree
- disagree
- strongly disagree

9. How heavy do you think the two objects in Group A are?
In units of 10g Right one ( ) Left one ( )

输入你的答案

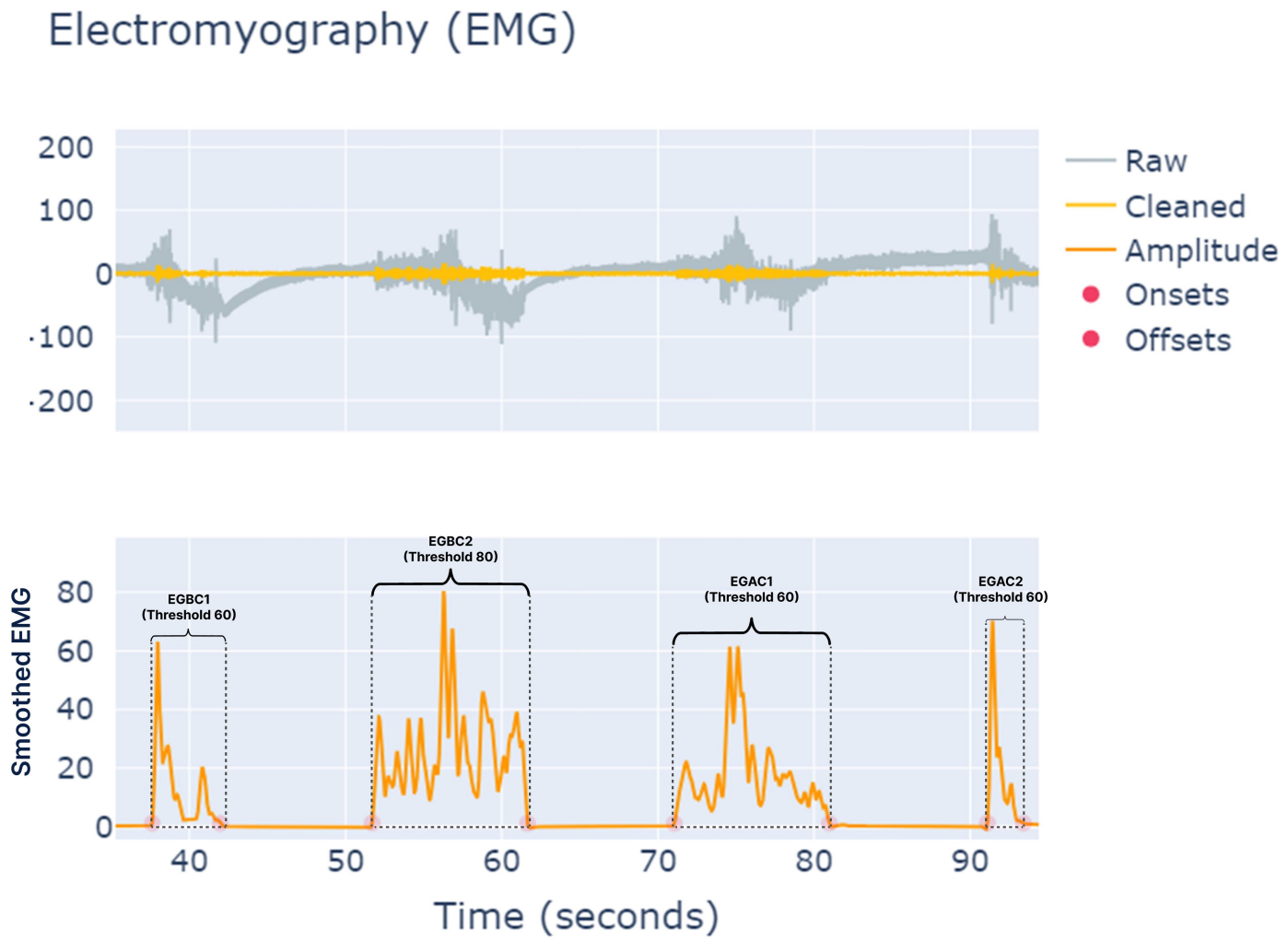
Questionnaire analysis (T – score)

Question	Mean	SD	P - value
Does the object observed by the human eye affect the weight of the grasped object?	0.58	0.6	0.152
Do you think it feels realistic when you grab objects?	0.43	0.79	0.2
Do you feel like your hand has caught an object?	1	0.58	0.004
Do the two objects in Experiment A have the same weight?	-0.43	1.4	0.448
Are the two objects in Experiment Group B the same weight?	-0.86	0.9	0.045

EMG results by object strength (Quantitative analysis)

Raw and processed data

Smoothed EMG data

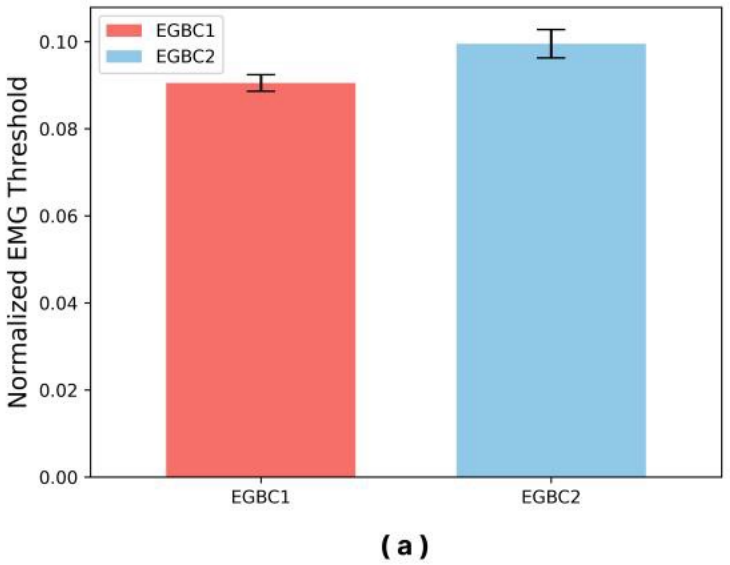


Results of EMG amplitude as participants lifted each object: graph of EMG amplitude fluctuations as four objects were lifted.

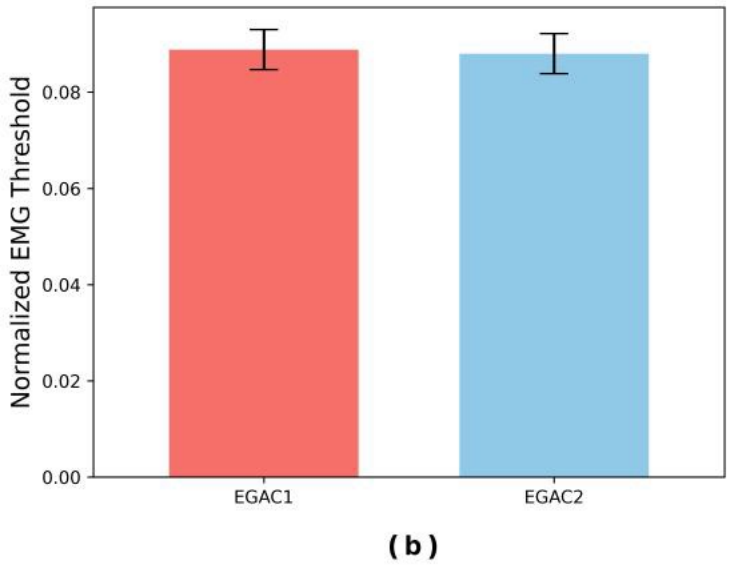
Data analysis (Quantitative analysis)

EMG thresholds set in Unity and t-test results for two groups of agents

p = 0.055



p = 0.90



Smoothed EMG plots between starting and stopping when participants lifted each object.

Its results almost support Hypothesis 1 in Experiment 1.

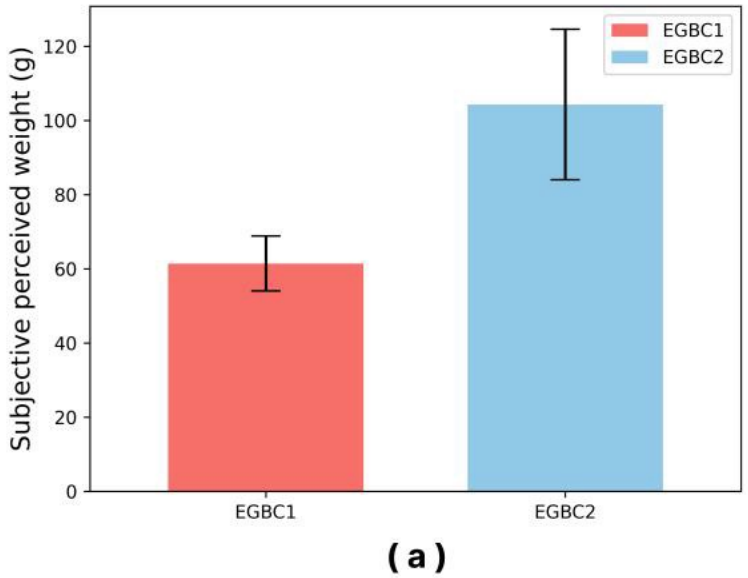
· Vertical axis: Normalized EMG Threshold in Unity

· Horizontal axis: Proxy object in the VR environment during the experiment

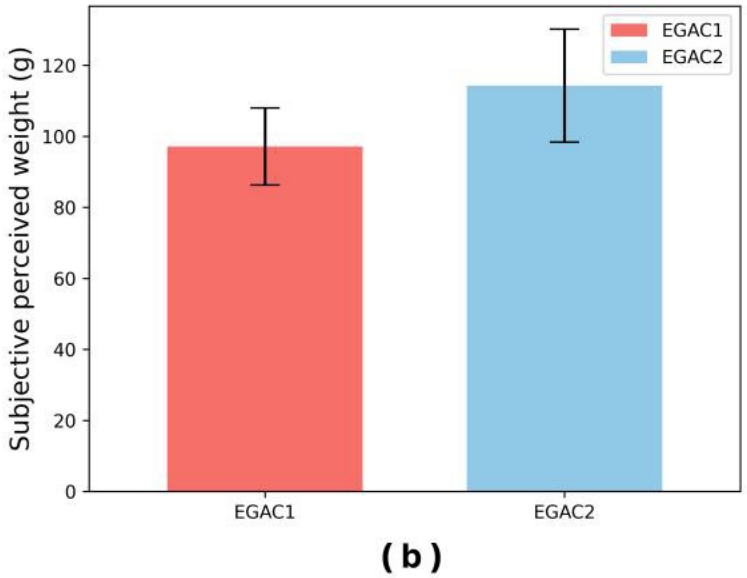
Data analysis (Quantitative analysis)

t-test results between subjective weight perception results and EMG thresholds

p = 0.064



p = 0.428



These results show that the subjects in experimental group B had greater differences in perceived weight when grasping a cube, while the subjects in experimental group A had less differences in perceived weight when grasping a cube.

· Vertical axis: Subjective perceived weight (g)

· Horizontal axis: The EMG threshold set in Unity at which the proxy object is raised

Expected Conclusion

If EMG threshold significantly affects weight perception, participants may report different weight perceptions even if objects are of the same size.

This indicates that the size of the EMG signal is a key factor in weight perception.

Comprehensive comparison

· Hypothesis 1 in this experiment1 was verified to be valid, and the potential of using EMG bioelectrical signals to simulate weight perception in a VR environment seems promising.

However, due to the small sample size, the accuracy and reliability of the research results are not very high, but this is an area worthy of further research.

· Hypothesis 2 in Experiment 2 is likely to be successfully verified, but there are some factors that need further verification.

All control variables affecting the experiment

1) Friction between hand and object

2) Grip force generated directly by the hand and the object

3) User fatigue during the system process

4) Keep the virtual and real gesture and movement trajectory consistent

5) Keep the physical and virtual fixed gesture visualisation movement trajectory consistent

6) Keep the virtual and real object size consistent

7) Keep the virtual and real objects gravity consistent

8) Keep the time series of data in Openbci GUI and Unity consistent

Limitation & Future

1) Increase the participant population to obtain a larger sample size

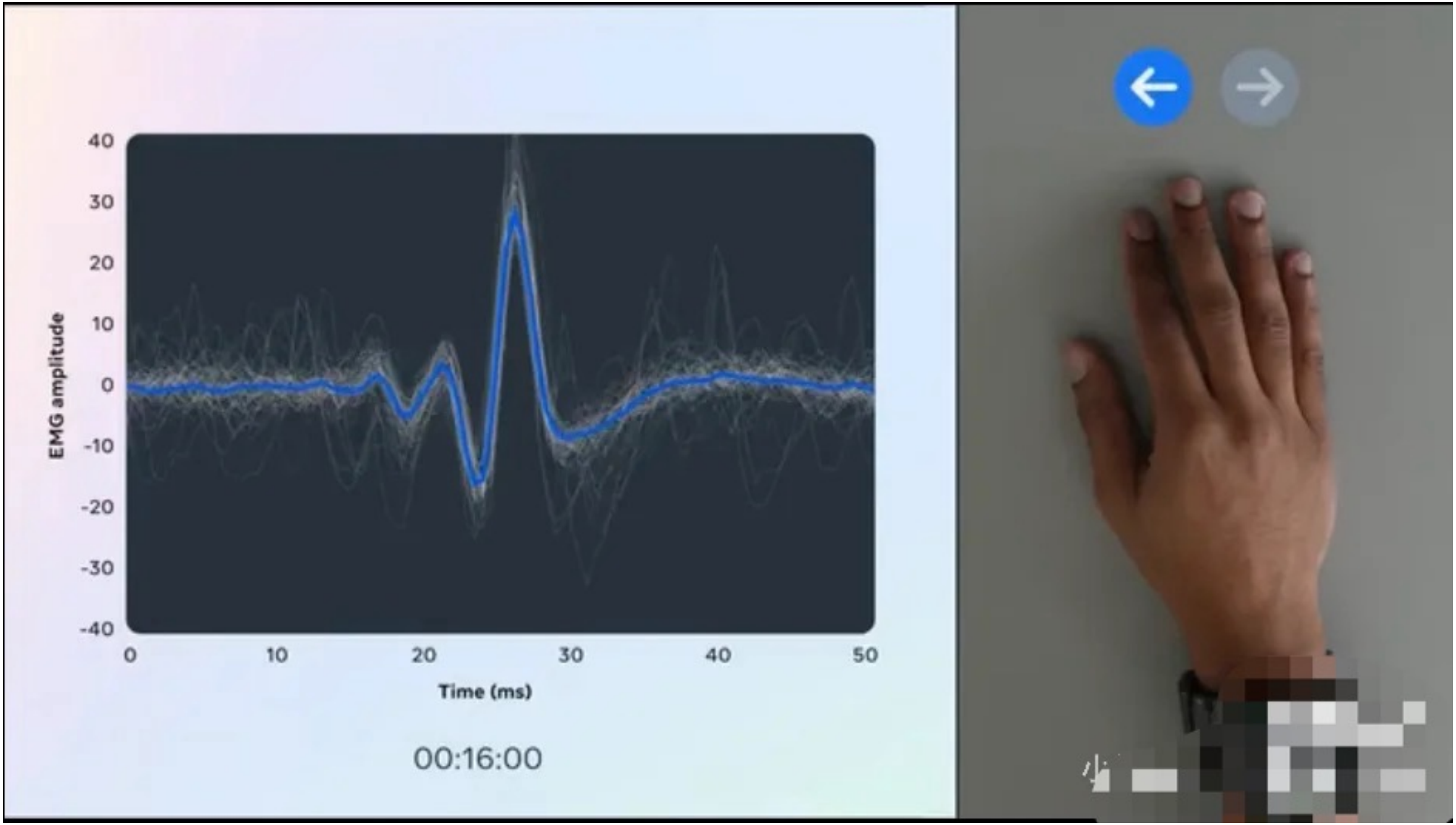
2) Verify Weber Fractions for weight perception in the VR environment

3) Add a more interactive auditory system

4) Add system availability scale (System Usability Scale, SUS)

5) Add Visual Analogue Fatigue Scale (VAS-F)


RESEARCH PROTOTYPE
RESEARCH PROTOTYPE


40
30
20
10
0
-10
-20
-30
-40
EMG amplitude
0
10
20
30
40
50
Time (ms)
00:16:00

Thanks!