Enhancing Spatial Reasoning Capability Using VR Immersive Experience

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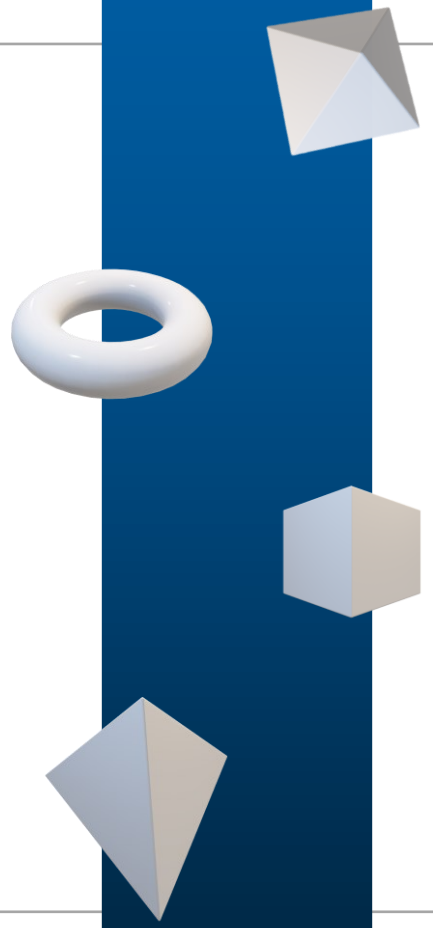
Introduction



"A cognitive skill that enables individuals to **mentally perceive** and **manipulate objects**." (Carroll, 1993; Salzman et al., 1999)

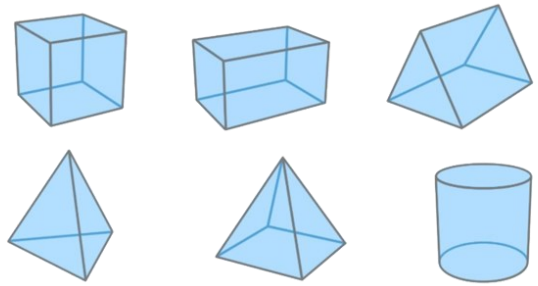
"The ability to **generate, retain, retrieve**, and **transform** well-structured visual images", allows people to understand and reason about the relations among objects in three or two dimensions, interpret their surrounding 3D world, and affect their spatial task performances in large-scale environments"

Carroll, J. B. (1993). Human cognitive abilities: A survey of factor-analytic studies (No. 1). Cambridge University Press.

Salzman, M. C., Dede, C., Loftin, R. B., & Chen, J. (1999). A model for understanding how virtual reality aids complex conceptual learning. Presence Teleoperators and Virtual Environments, 8, 293– 316.

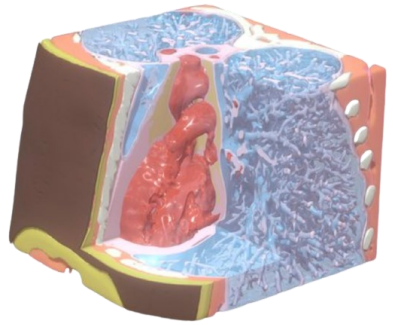
Related Fields

Mathematics

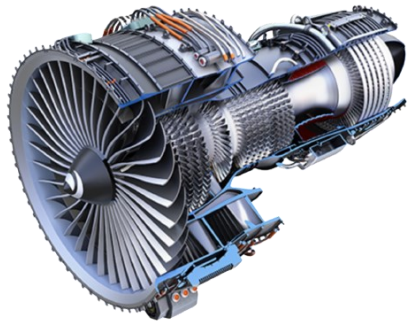


Art & design

Science



Technology



Research Problems

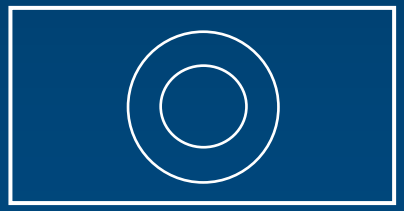
- The insufficient emphasis in the educational system.
- The lack of research to determine the most effective teaching method.
- The difficulties in 3D visualization.

Research Problems

Top views are similar

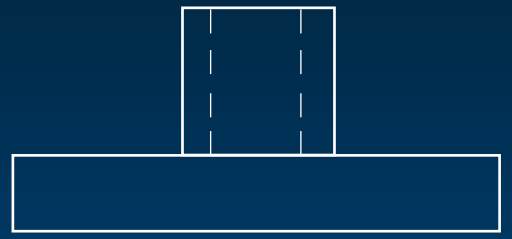
(1)

(2)

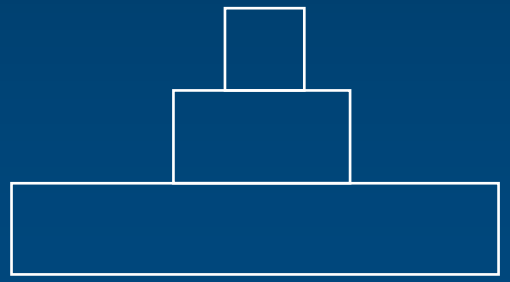


But side views are different

(1)



(2)



Research Assumptions

Learning in a virtual environment may **contribute to improve** performance on spatial reasoning tasks, and **higher levels of immersion** may be associated with stronger gains. (Parong et al., 2020).

Parong, J., Pollard, K. A., Files, B. T., Oiknine, A. H., Sinatra, A. M., Moss, J. D., ... & Khooshabeh, P. (2020). The mediating role of presence differs across types of spatial learning in immersive technologies. Computers in Human Behavior, 107, 106290.

Research Motivations

- Learning spatial reasoning in multi-discipline fields.
- A novel application to learn spatial concepts.

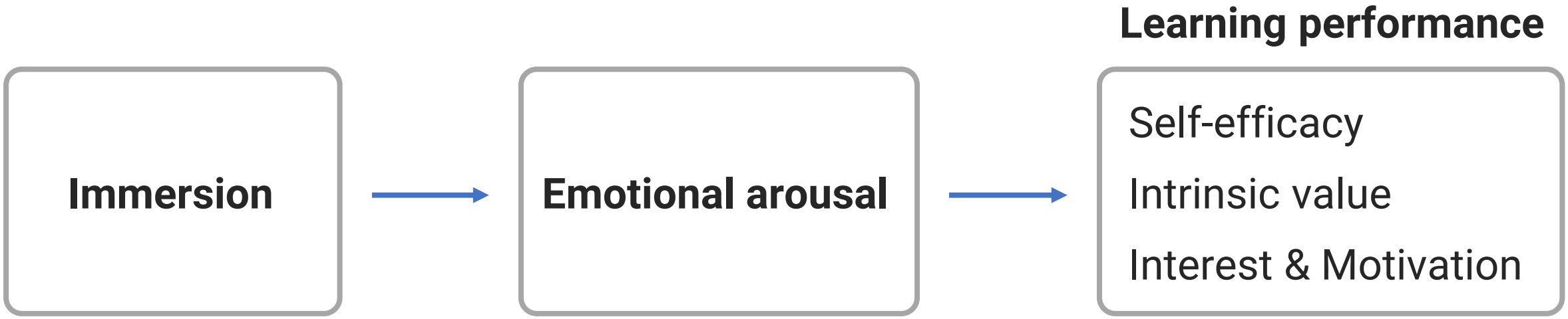
Research Contributions

- Learners' feedbacks in multi-dimensions - > VR – learners' immersion – emotional arousal - learning performance.

Research Objectives

- The effectiveness of VR in enhancing spatial reasoning skills.
- Factors affecting learning performance of spatial reasoning through VR.

Research Hypothesis



Hypothesis:

VR can help improve spatial reasoning's learning performance.

Learning performance: the achievement of a learning activity. It includes two aspects: the result and the process. Moccozet,L (2012)

Moccozet, L. (2012, July). Introducing learning performance in personal learning environments. In 2012 IEEE 12th International Conference on Advanced Learning Technologies (pp. 702-703). IEEE.

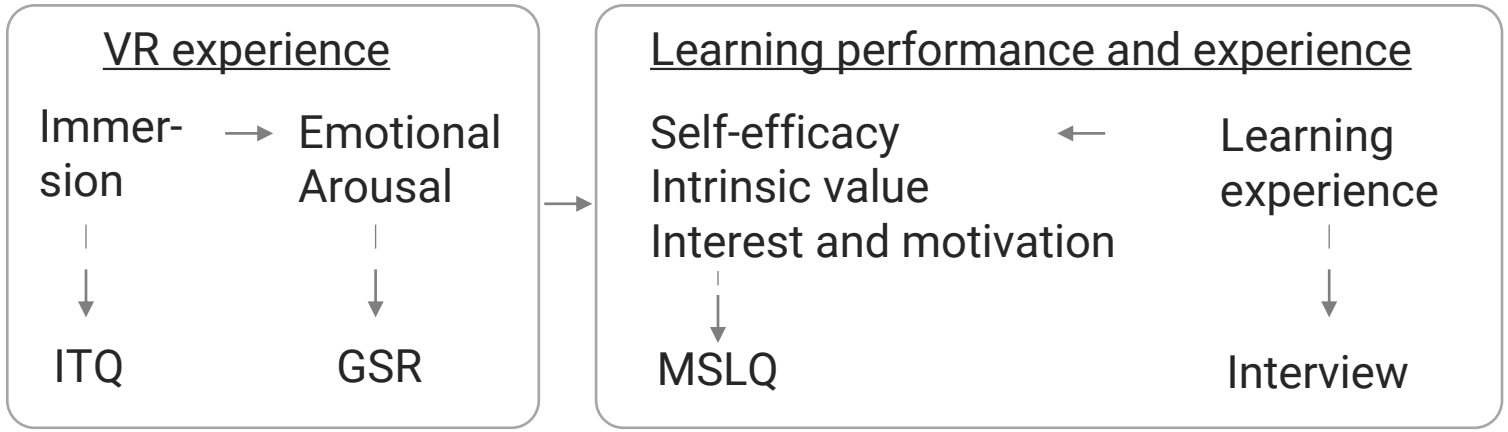
Research Framework

Phase A: Background Research

- Research background
- Set up goals and motivations
- Establish research hypothesis
- Literature Review
- Coming up methodology

- VR in learning spatial reasoning
- Emotional arousal in VR
- Immersion in VR
- Emotional arousal and learning performance

Phase B: Pilot Study



Phase C: Evaluation and Conclusion

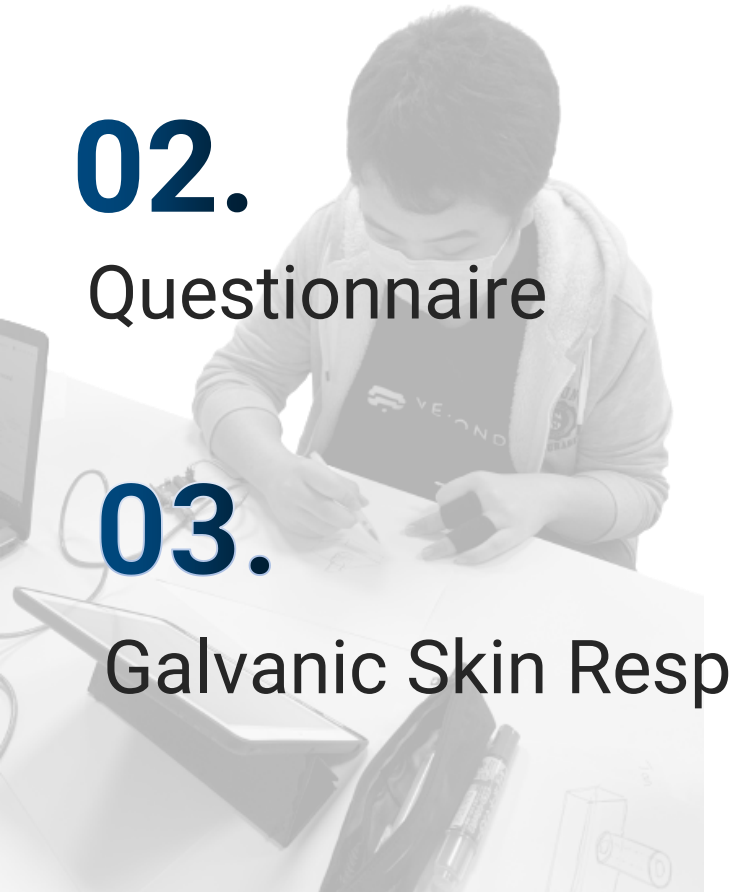
- Analyze results
- Future Work
- Conclusion

Research Methodology

01.

User Interview

- Learners’ subjective feelings.
- Pain-points with the two drawing methods.



02.

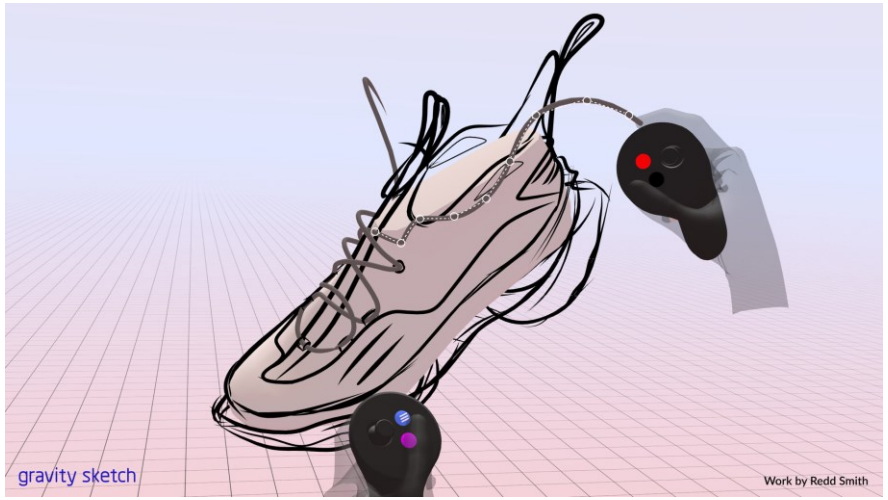
Questionnaire

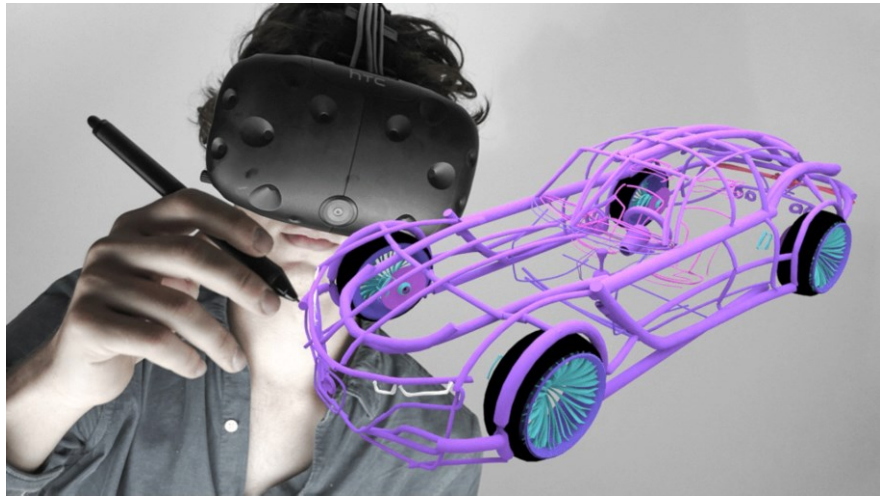
- Immersive assessment scale.
- Learning performance scale.

03.

Galvanic Skin Response

- Learners’ emotional arousal.
- Supporting the impact of immersion on learning performance.





Tool Support

Gravity Sketch is the application offering users a platform to be creative in VR environment.

Experimental Process

Phase 1

Traditional Drawing
(GSR sensor)

↓

VR Drawing
(GSR sensor)

↓

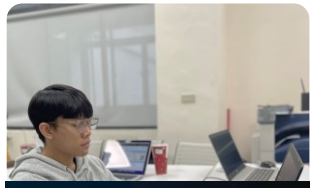
Questionnaire
(Immersion &
Learning performance in VR)

Phase 2

Traditional Drawing
(GSR sensor)

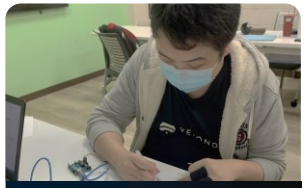
↓

Interview



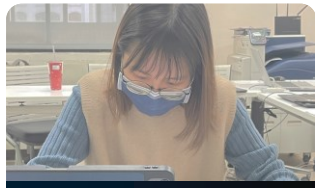
Text Analysis

- Word Cloud
- Co-occurrence networks



GSR Sensor

- Data visualization
- Wilcoxon Signed Rank Test

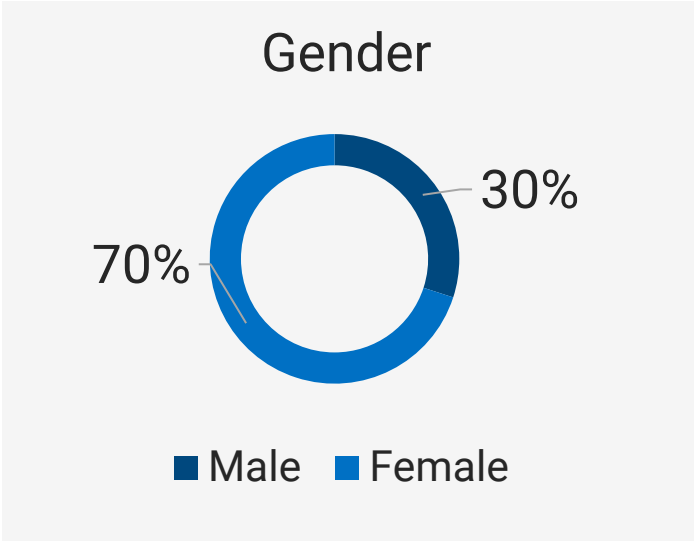


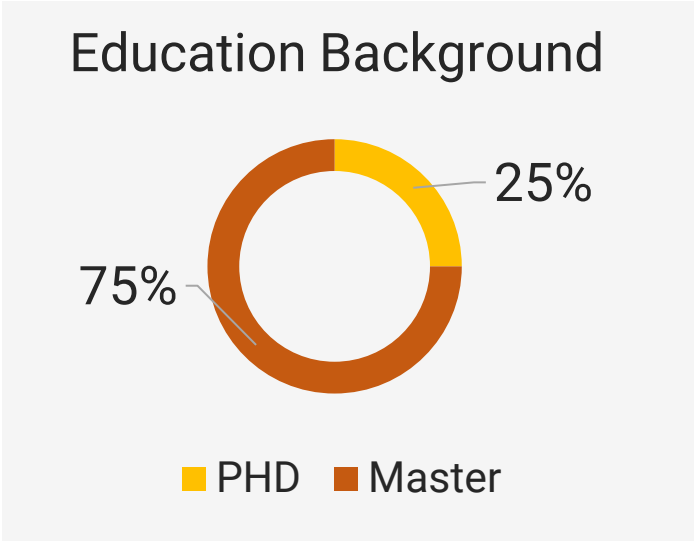
Questionnaire

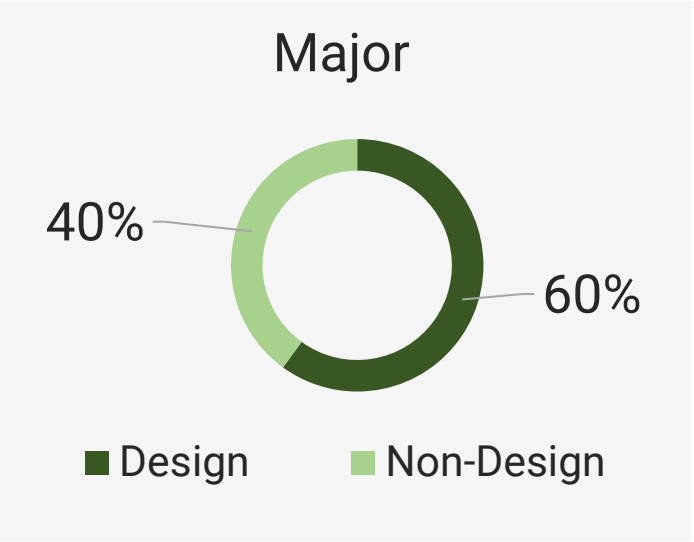
- Descriptive statistics

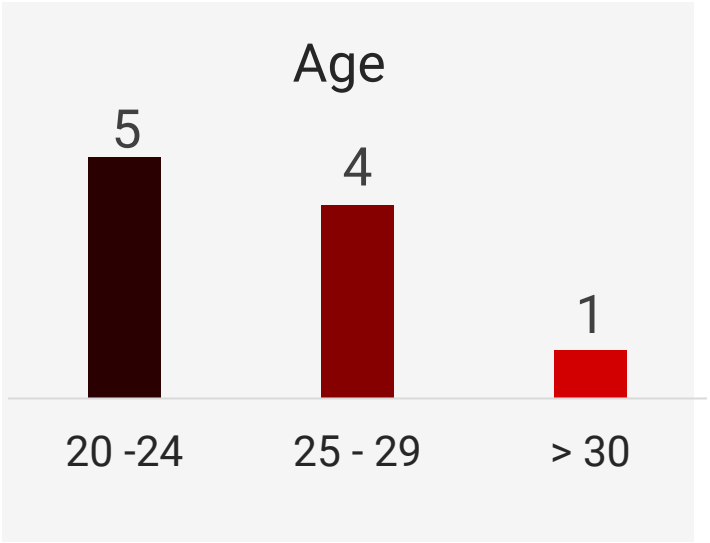
Experimental Process

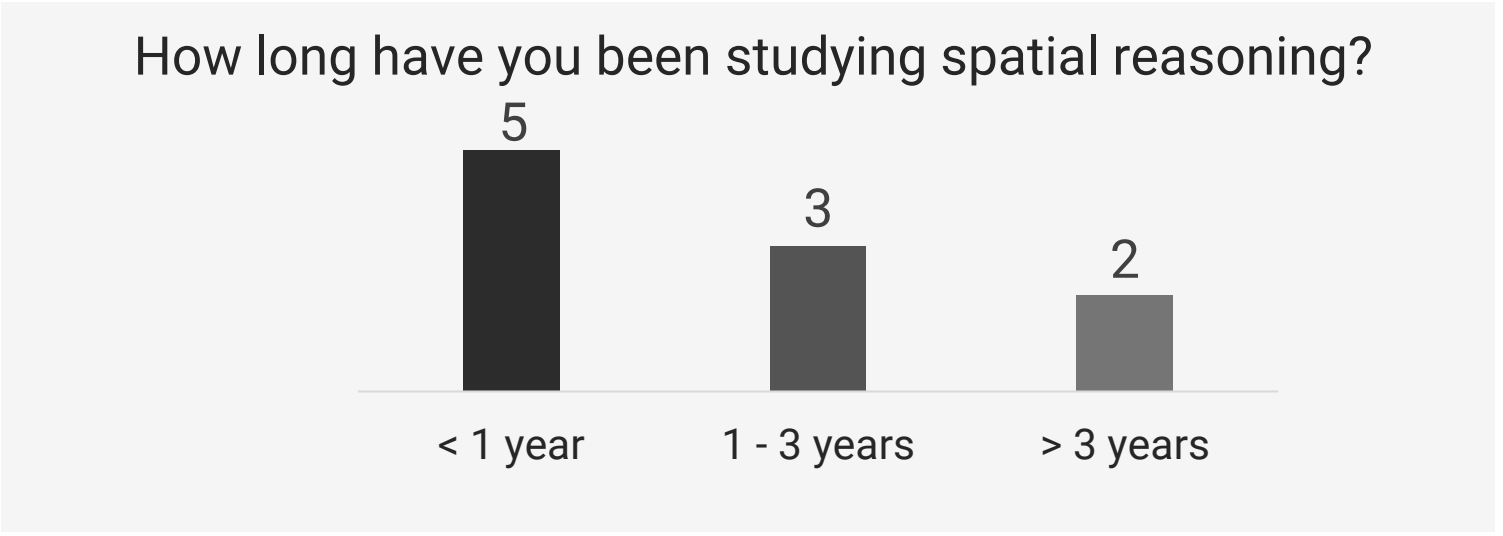
Participants Demographics





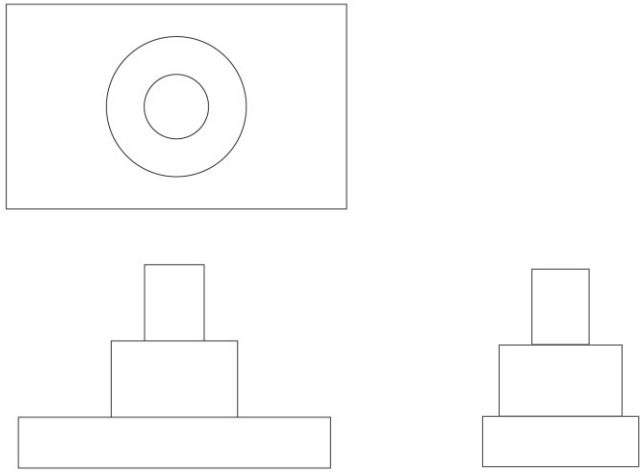




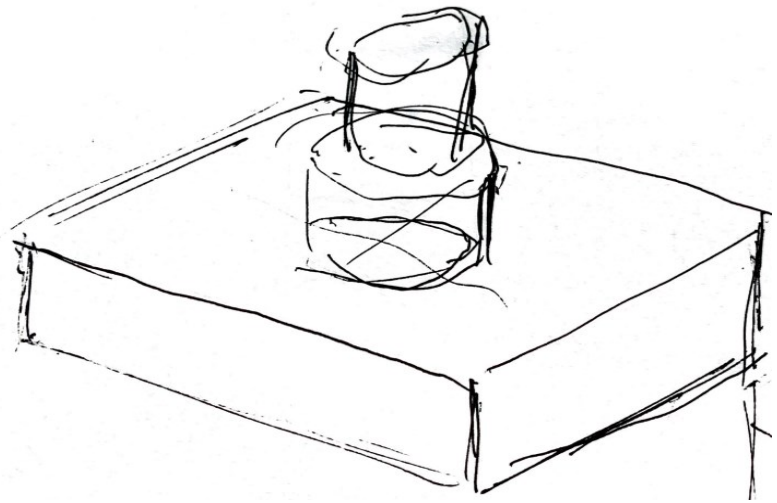


Phase I Experiment

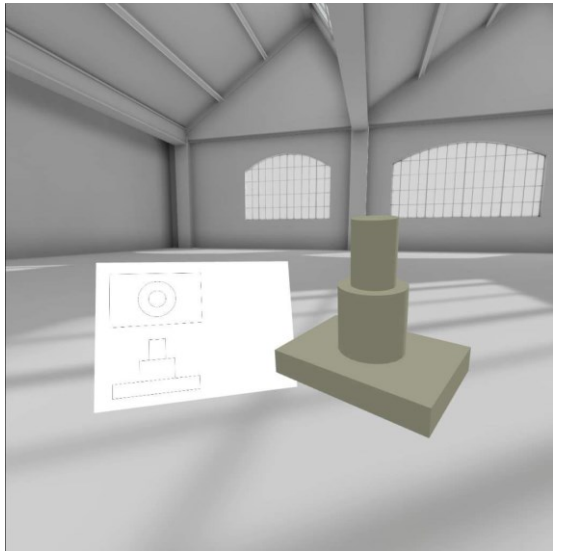
Given models



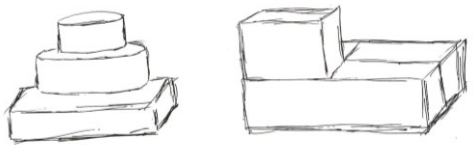
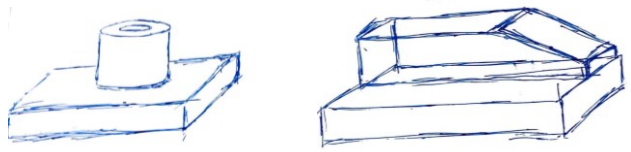
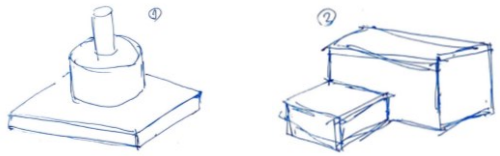
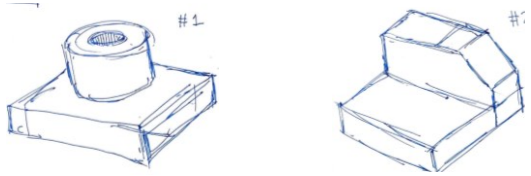
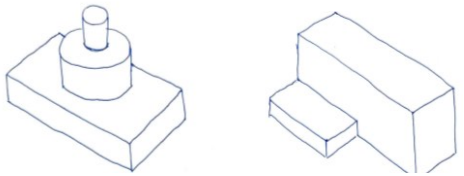
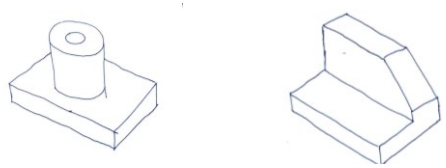
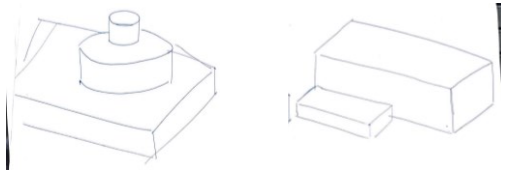
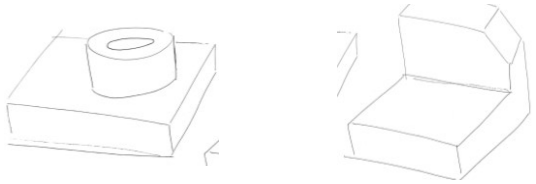
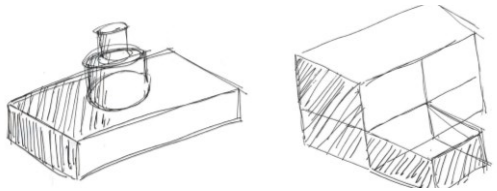
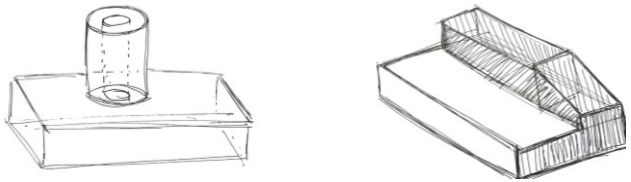
Traditional Drawing



VR Drawing



Traditional Drawing Before and After VR Immersion

Learner	Traditional Drawing (Phase 1)	Traditional Drawing (Phase 2)
1		
2		
3		
4		
5		

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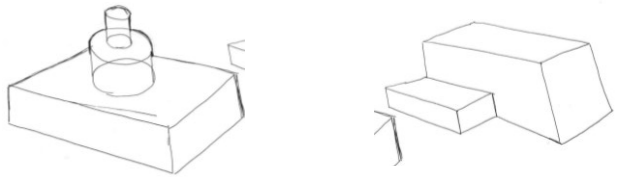
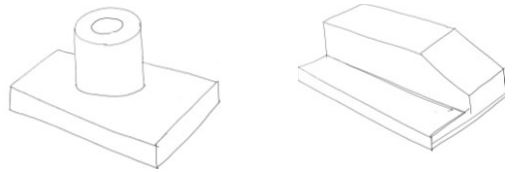
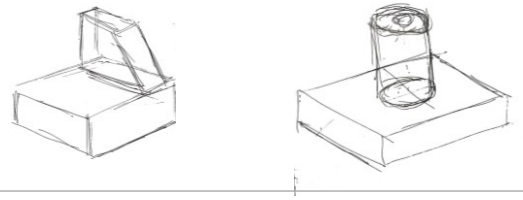
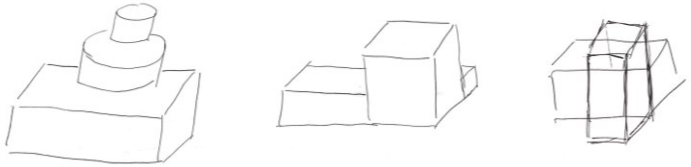
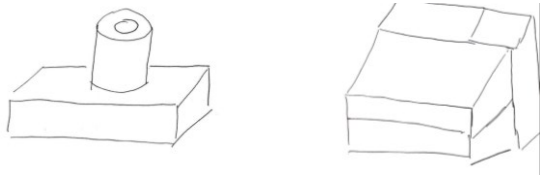
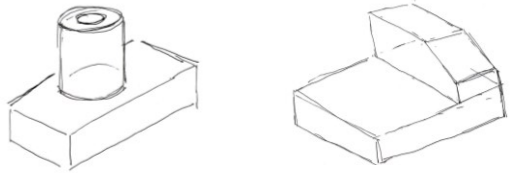
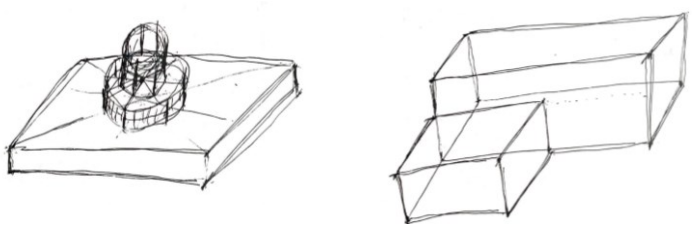
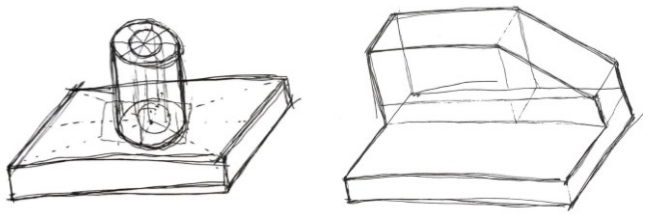
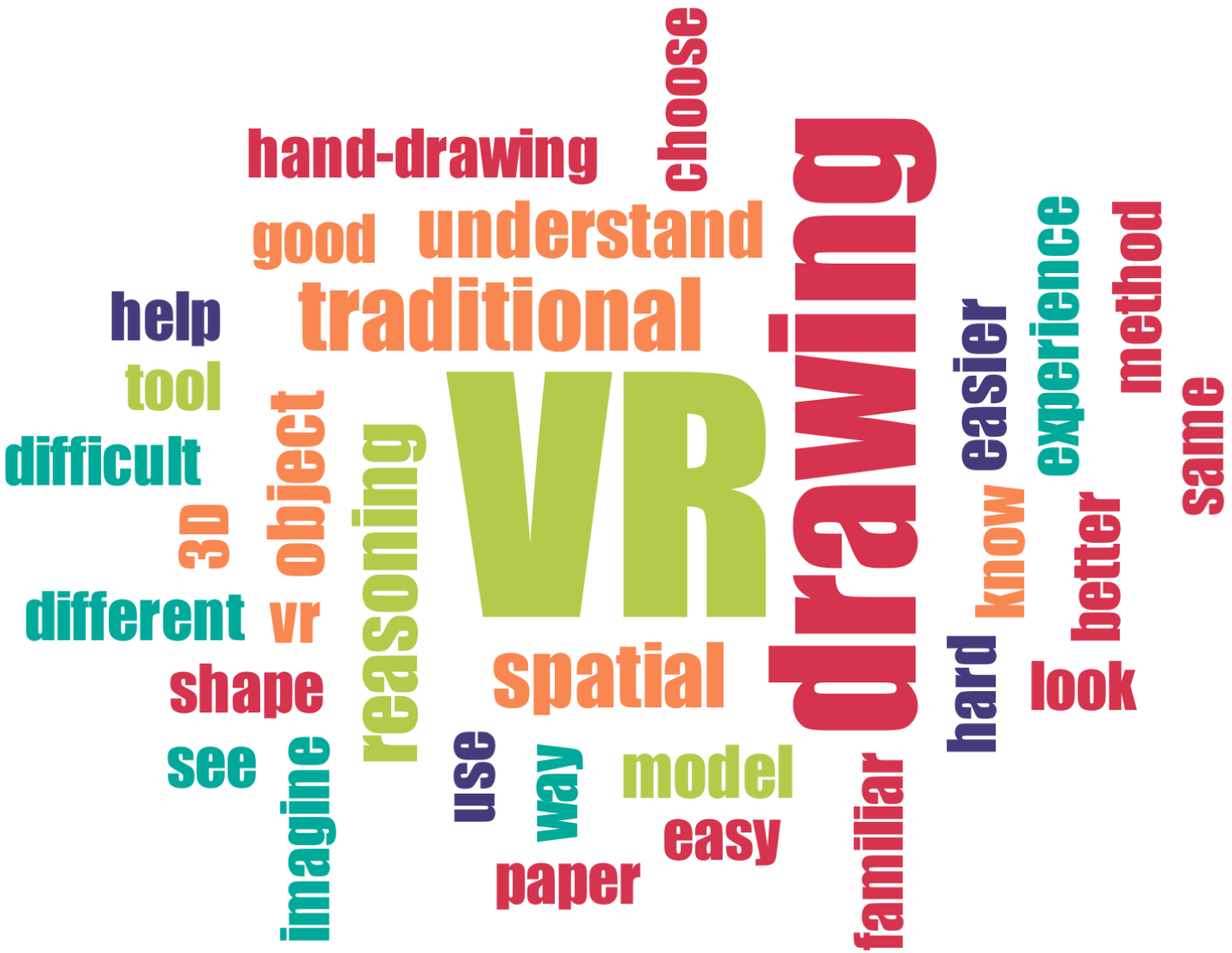
6		
7		
8		
9		
10		

Word Cloud Analysis on Interview Results

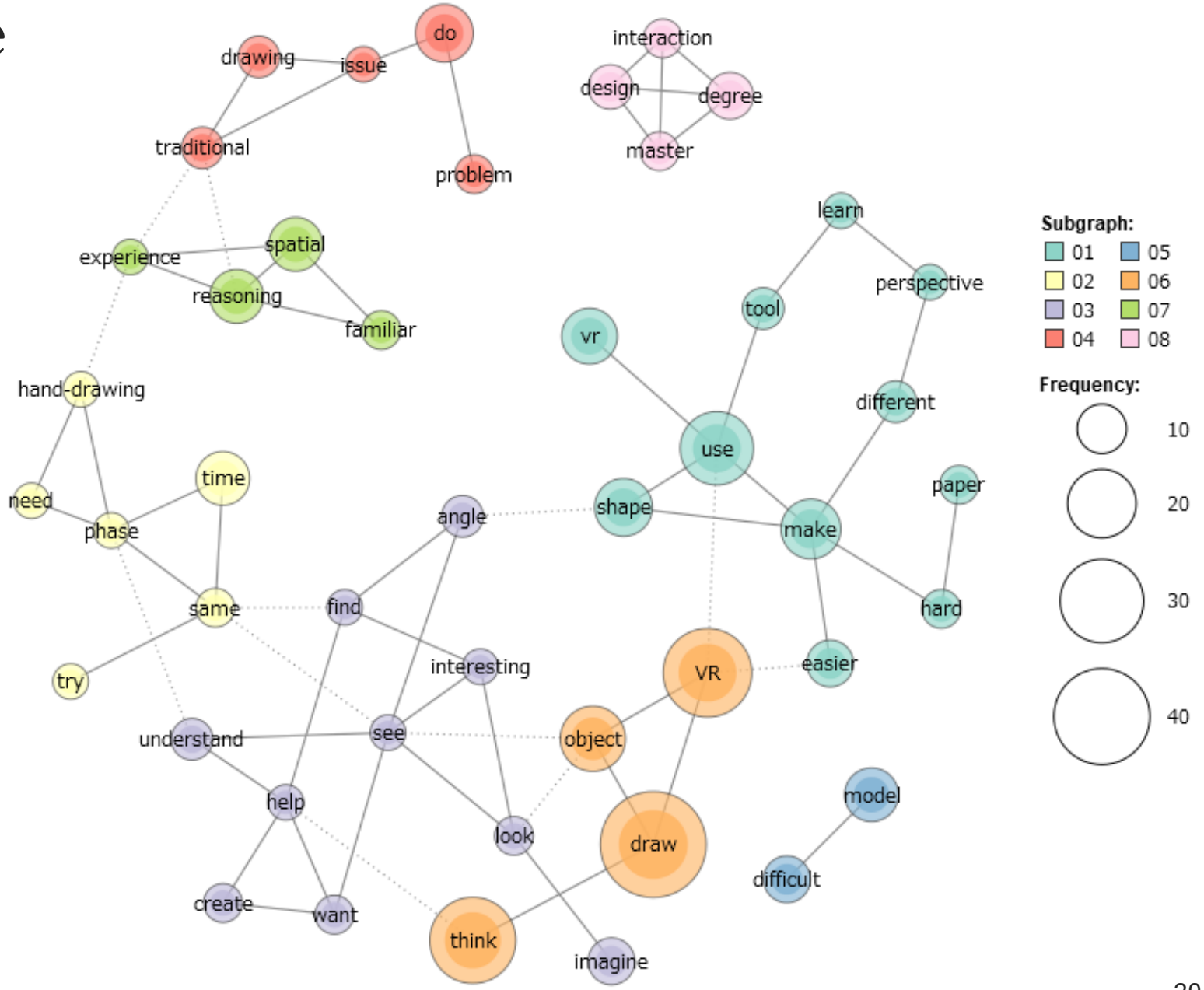
- Minimum frequency : 8

- Eliminated words :
- VR/Traditional drawing
- Preposition pronoun
- Transition
- Definite article



Text Co-occurrence Networks Analysis

- **“Make”, “shape”, “different”** connect with VR via **"easier”.**
- **“Tool”, “learn”, “perspective”** connect with VR via **"use”.**



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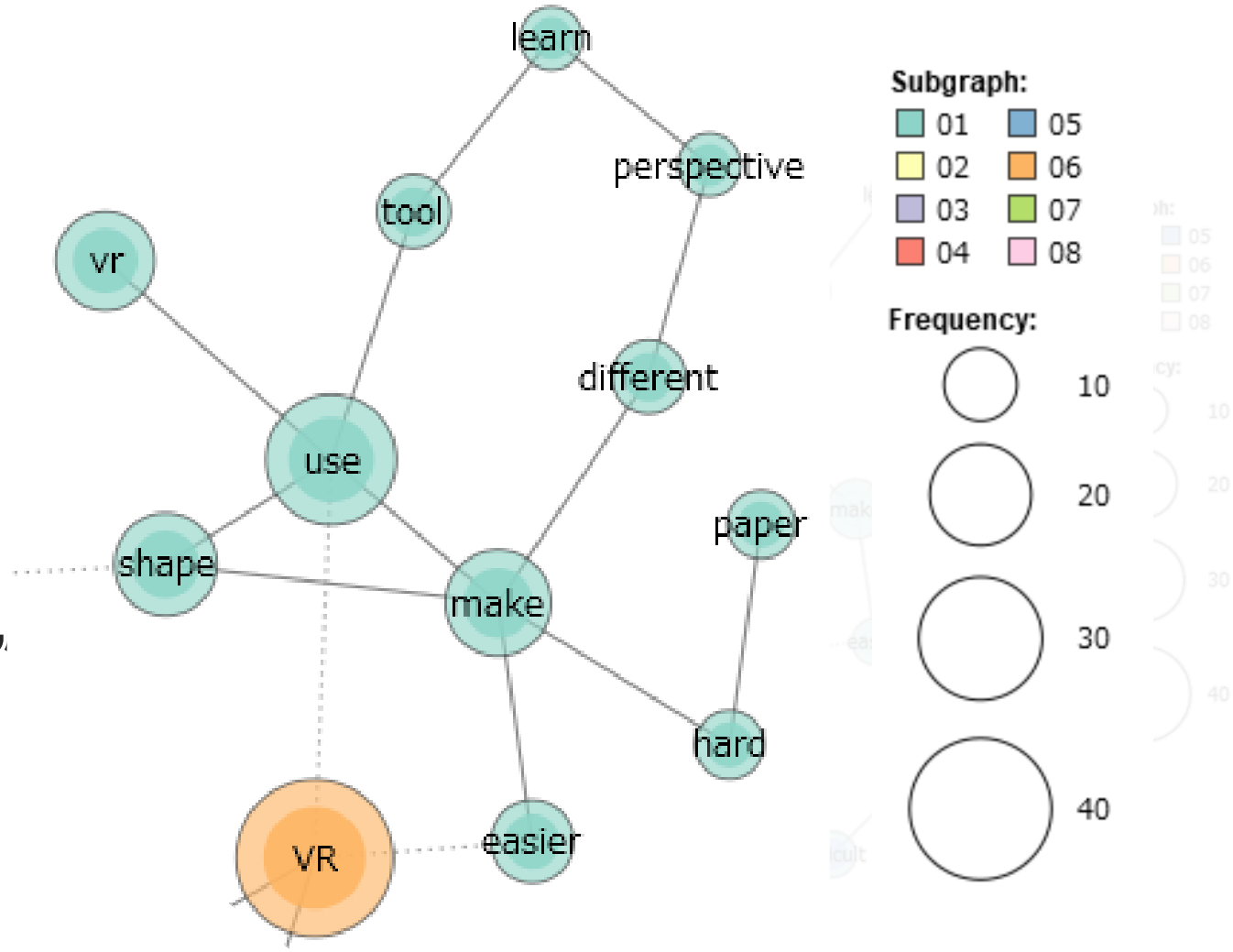
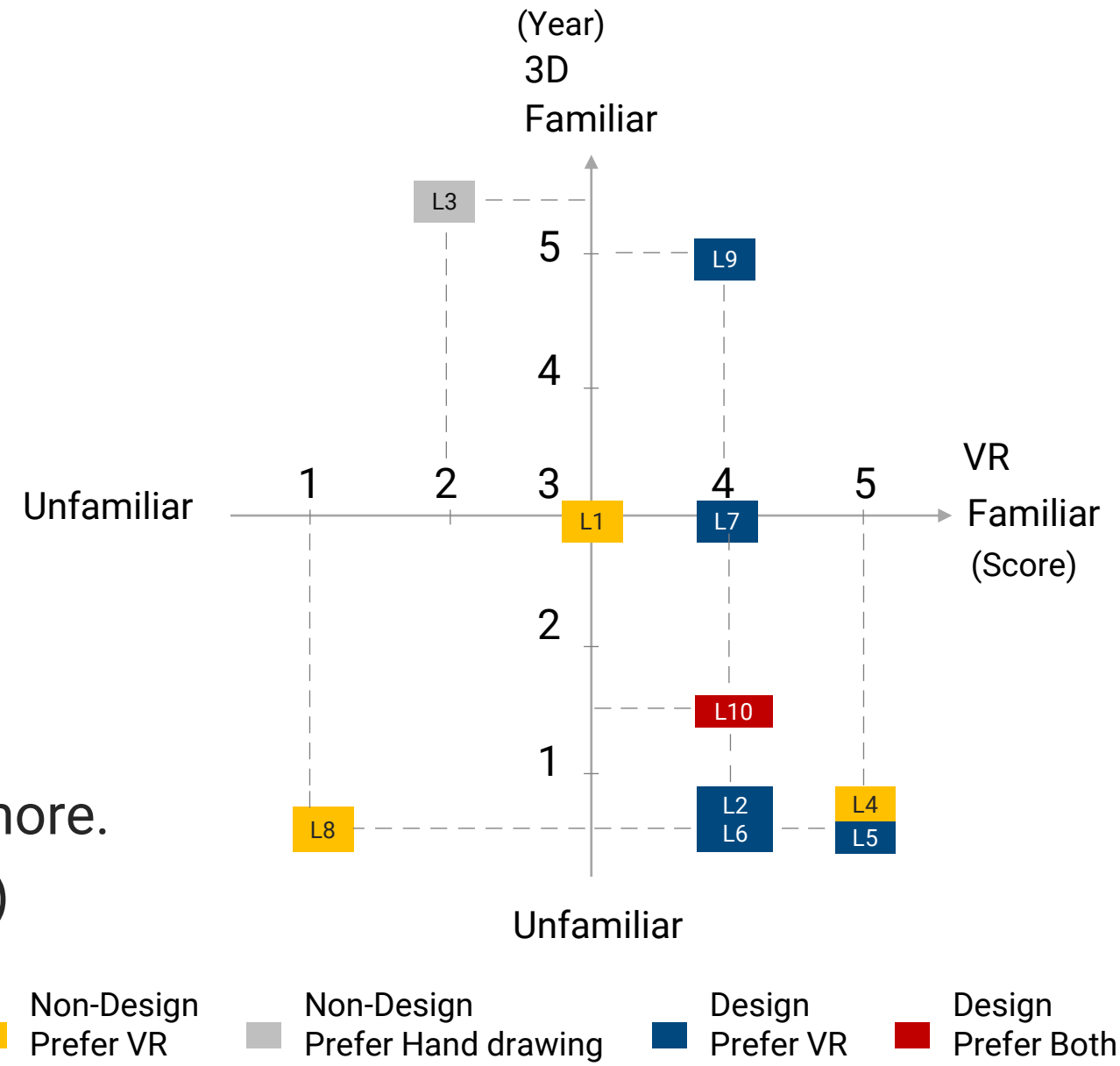


Participants' Interview Analysis I

- Design background -> Prefer VR
- Non-Design background ->
  Not familiar with VR -> Prefer VR
- Only one person who is non-design background prefers hand drawing more. (Age > 30 yrs old, experience > 5yrs)

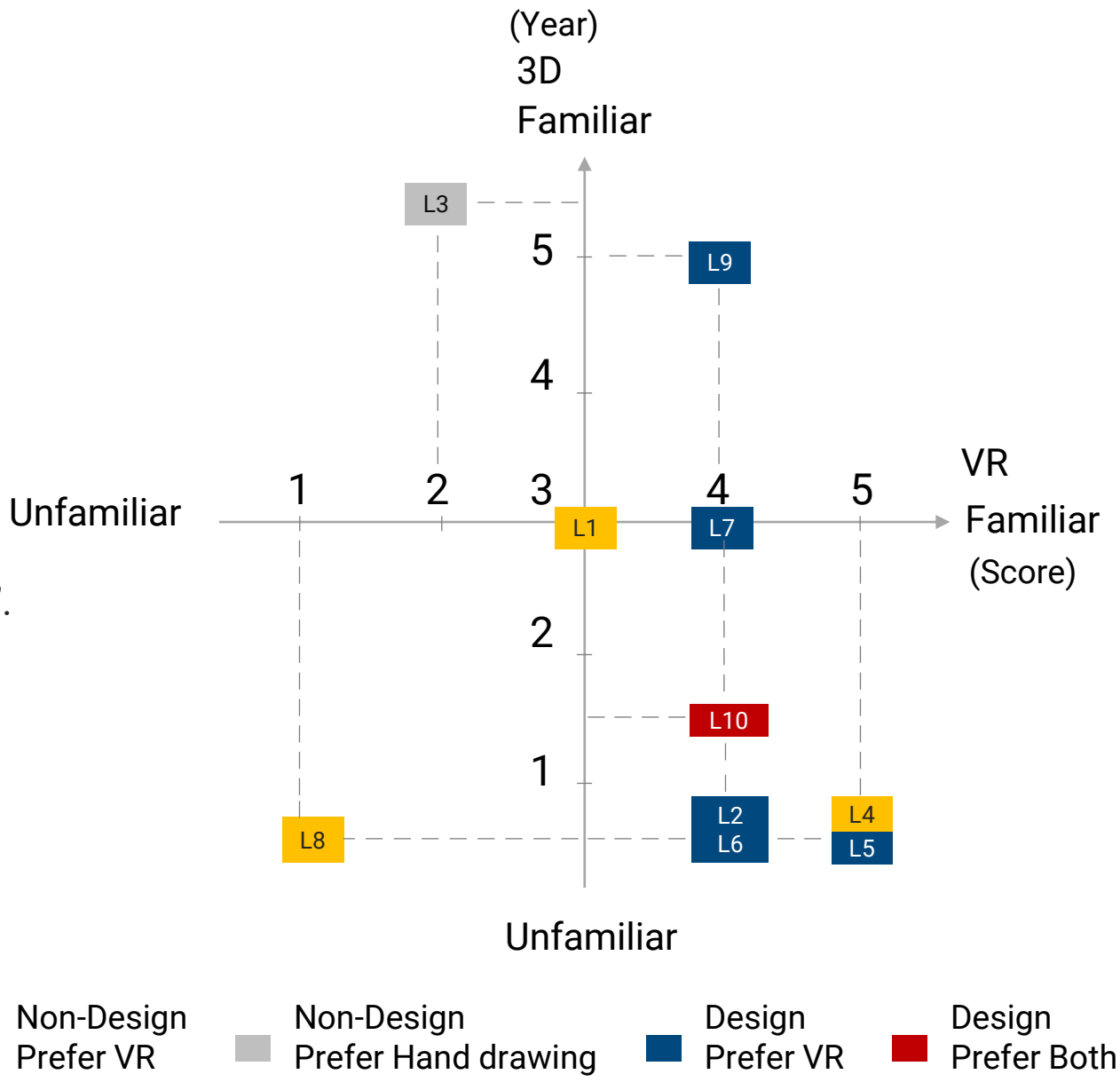


Participants' Interview Analysis II

Learner 3:
"I think in VR, it is hard to control the tool.
I'm not used to that tool. I use the traditional way"

Learner 4:
"In VR, I can look around the object & drawing.
Since it is 3D object, I can check its angles and height".

Learner 5:
"For now, traditional drawing is easier to understand.
However, if I had more skill in VR, and get used to in
VR, I will change my mind ".



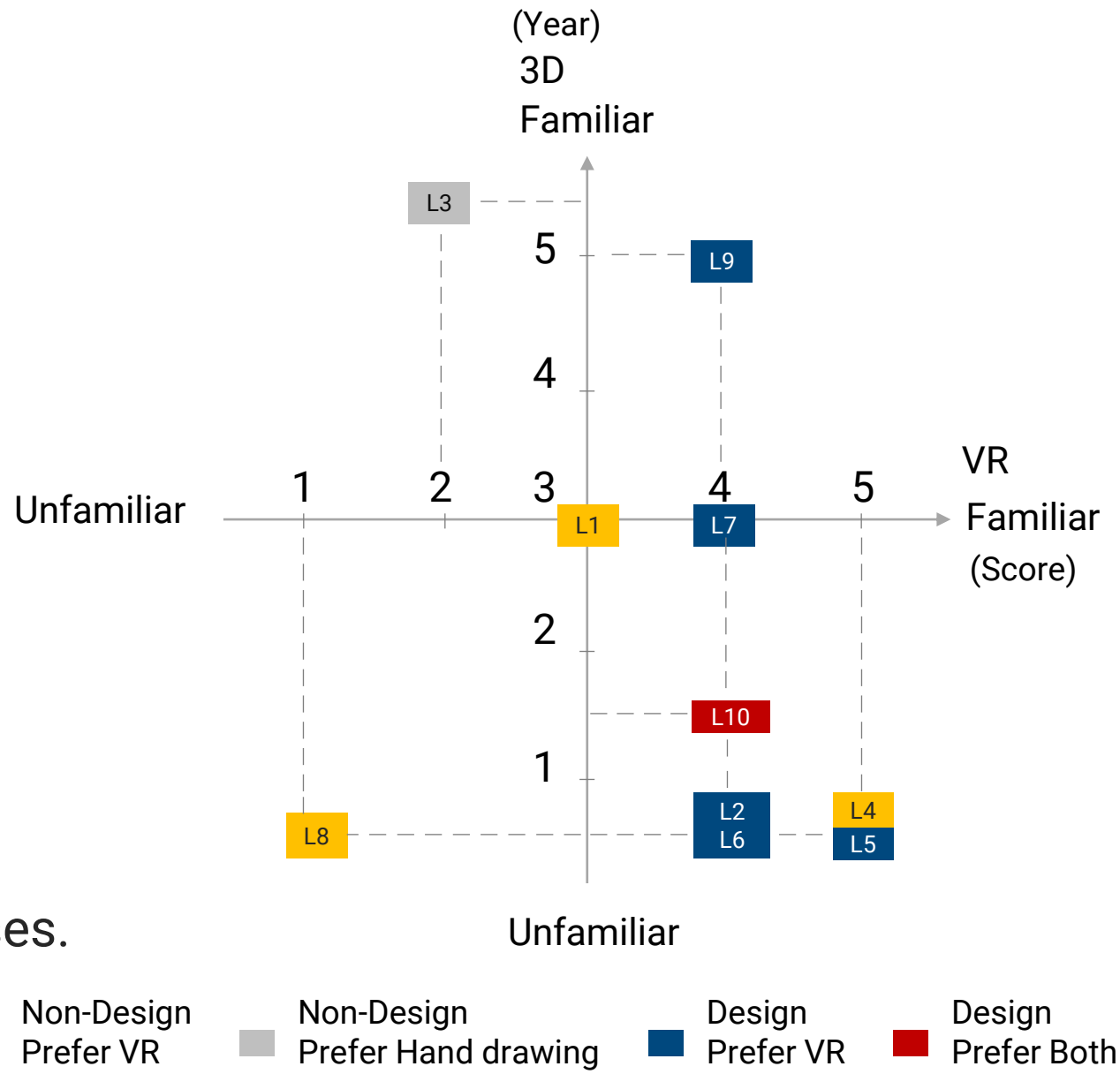
Participants' Interview Analysis III

Positive feedback

- See different perspectives.
- Can rotate actively.

Negative feedback

- Not familiar with the tool.
- Dizziness.
- Not comfortable when wearing glasses.



GSR Sensor Data Analysis II

Unfamiliar with 3D, same background

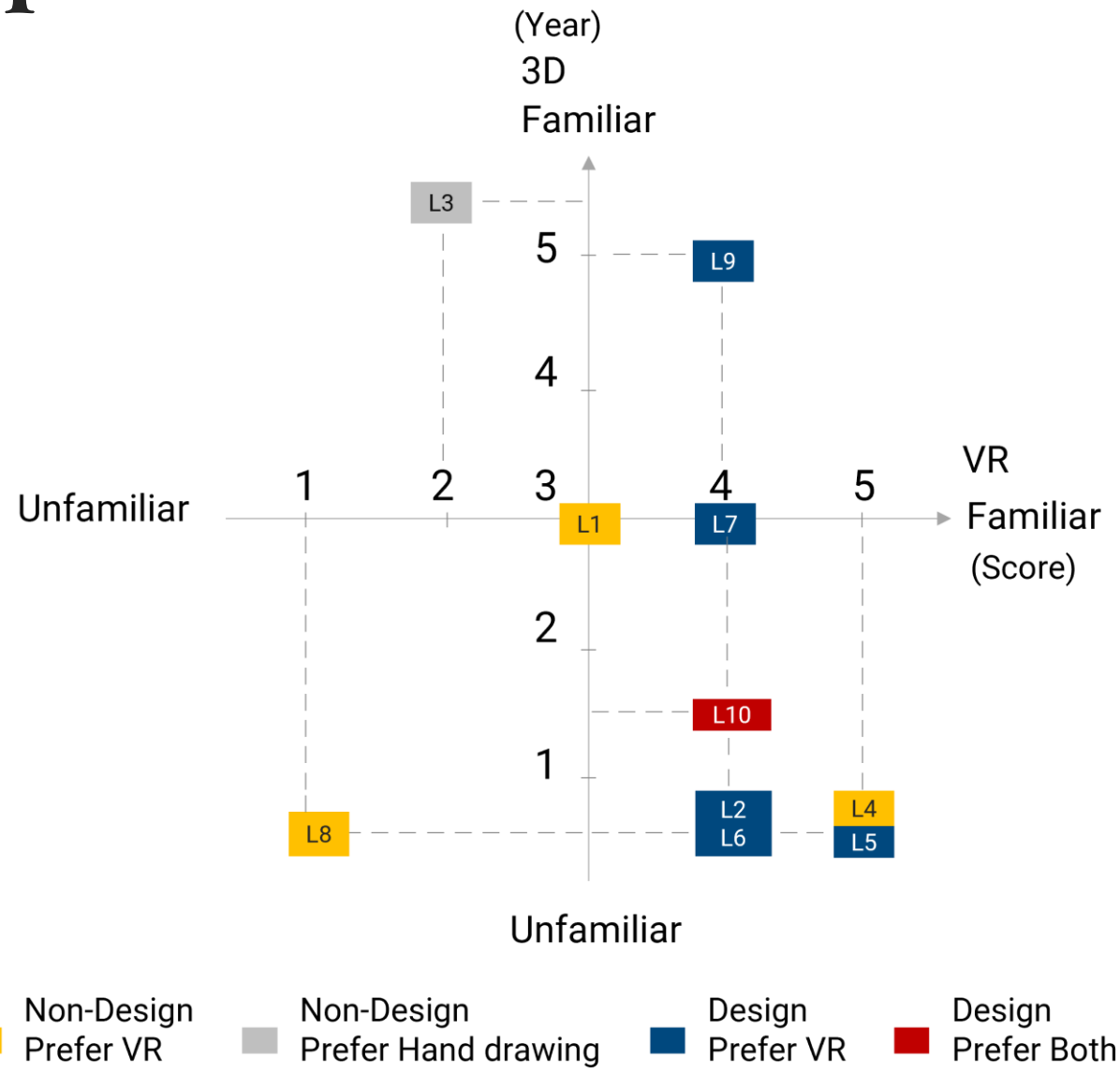
Learner 4 & Learner 8

Unfamiliar with 3D, different background

Learner 8 & Learner 6

Familiar with 3D, different background

Learner 3 & Learner 7

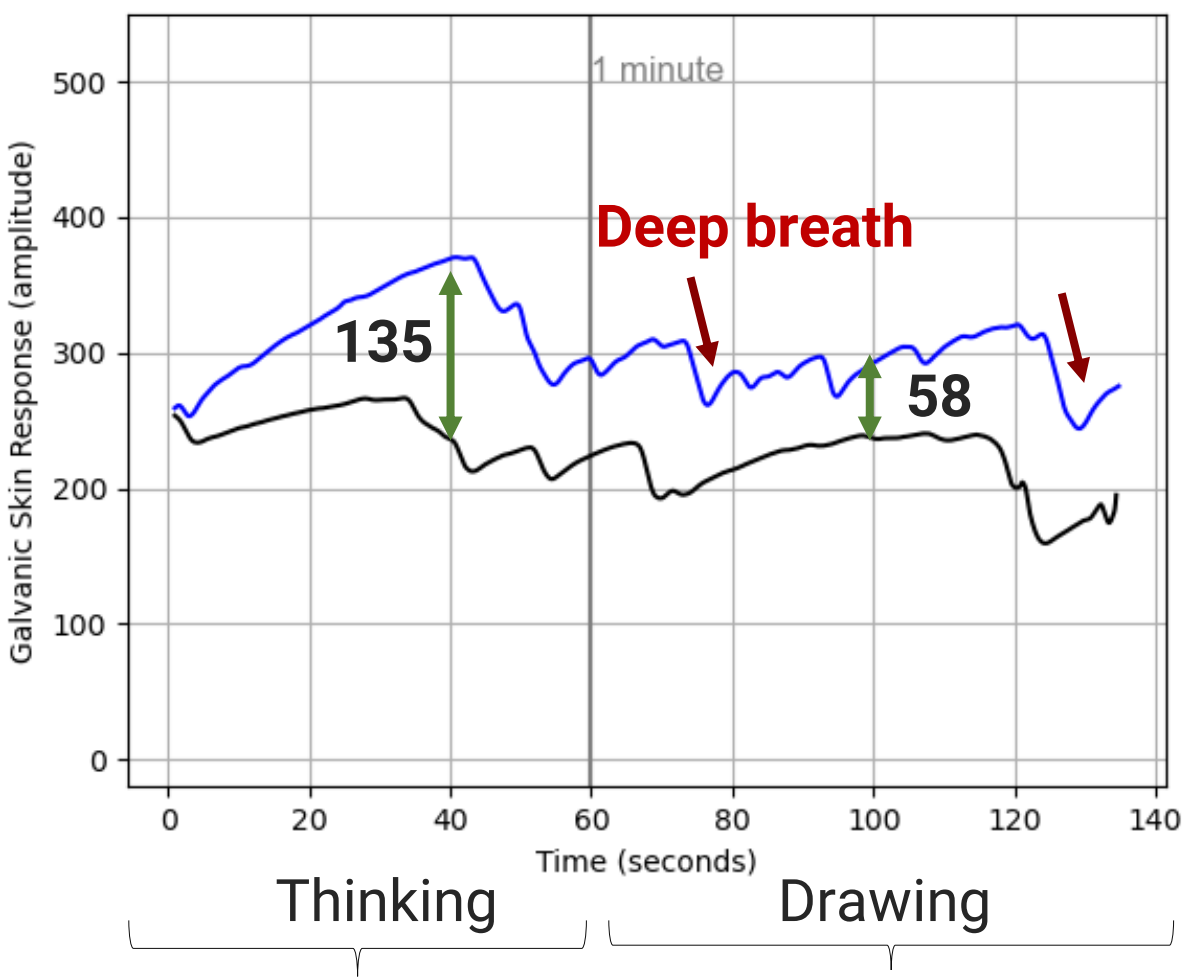


GSR Sensor Data Analysis I

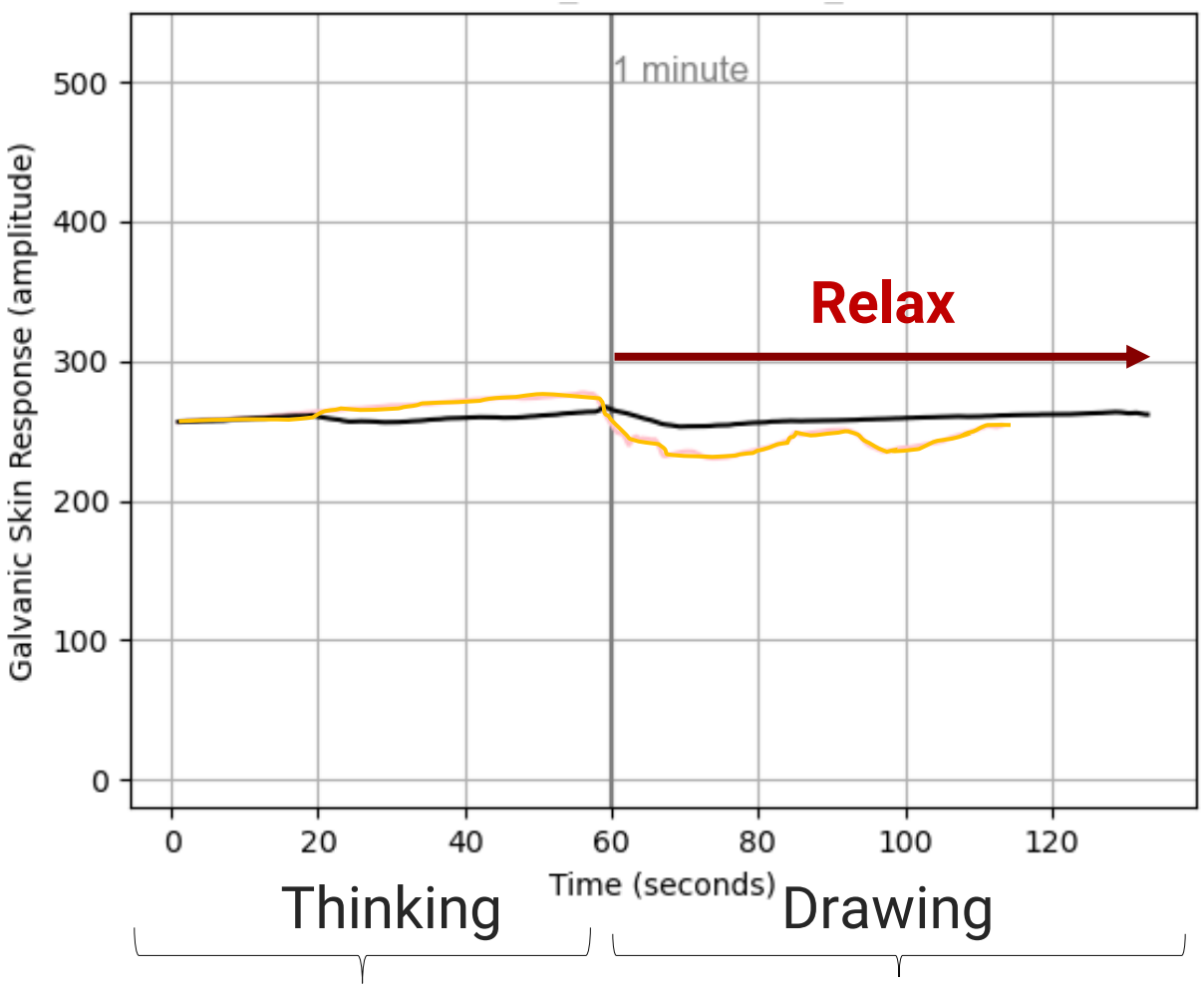
Traditional drawing before using VR

Traditional drawing after using VR

Learner 2: Design, Familiar with VR



Learner 3: Non-Design, Unfamiliar with VR



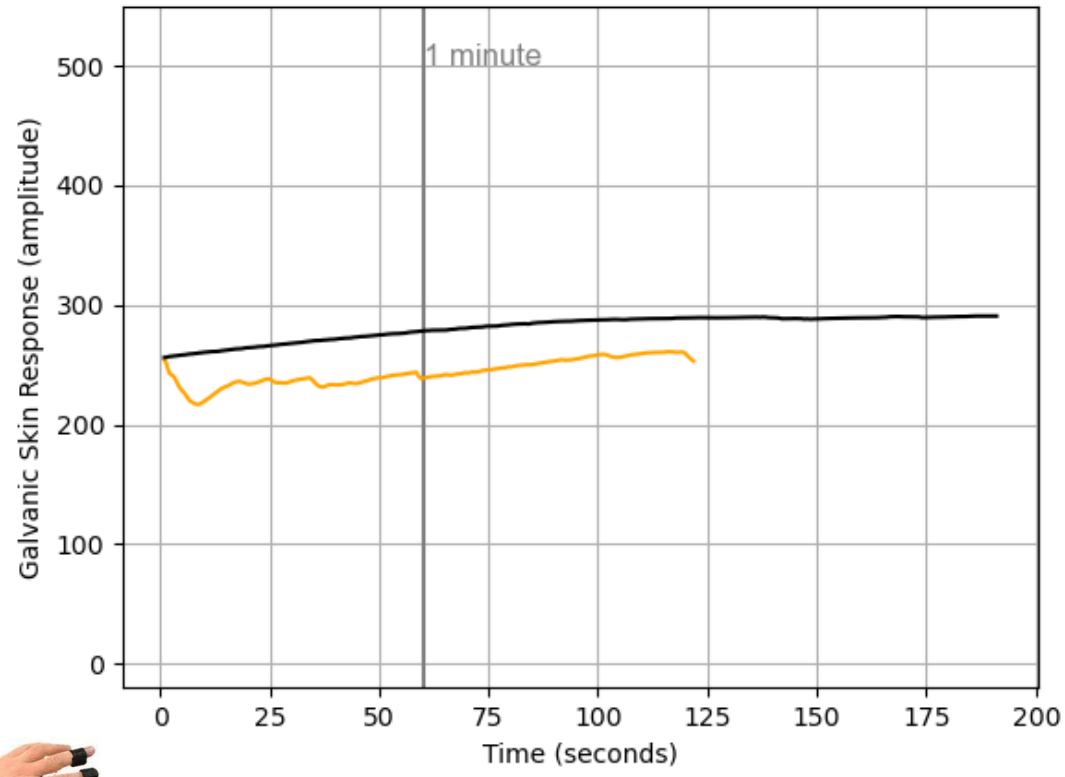
GSR Sensor Data Analysis III

Unfamiliar with 3D, same background

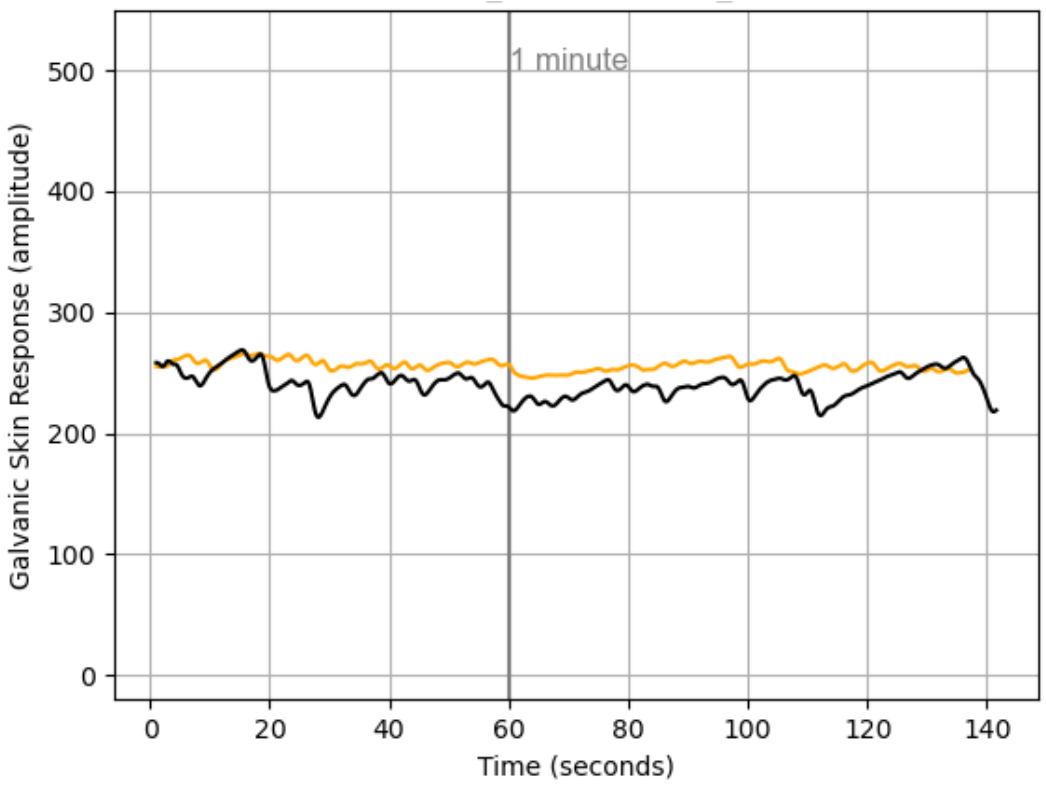
Traditional drawing before using VR

Traditional drawing after using VR

Learner 4: Non-Design, Familiar with VR



Learner 8: Non-Design, Unfamiliar with VR



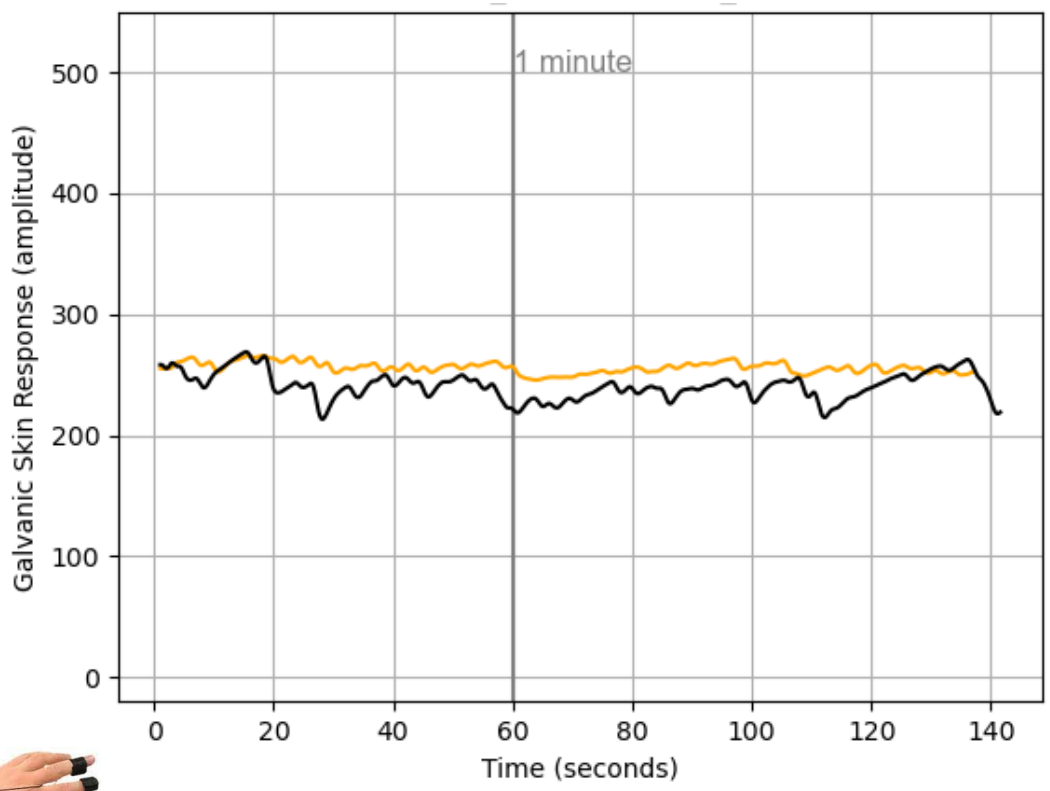
GSR Sensor Data Analysis IV

Unfamiliar with 3D, different background

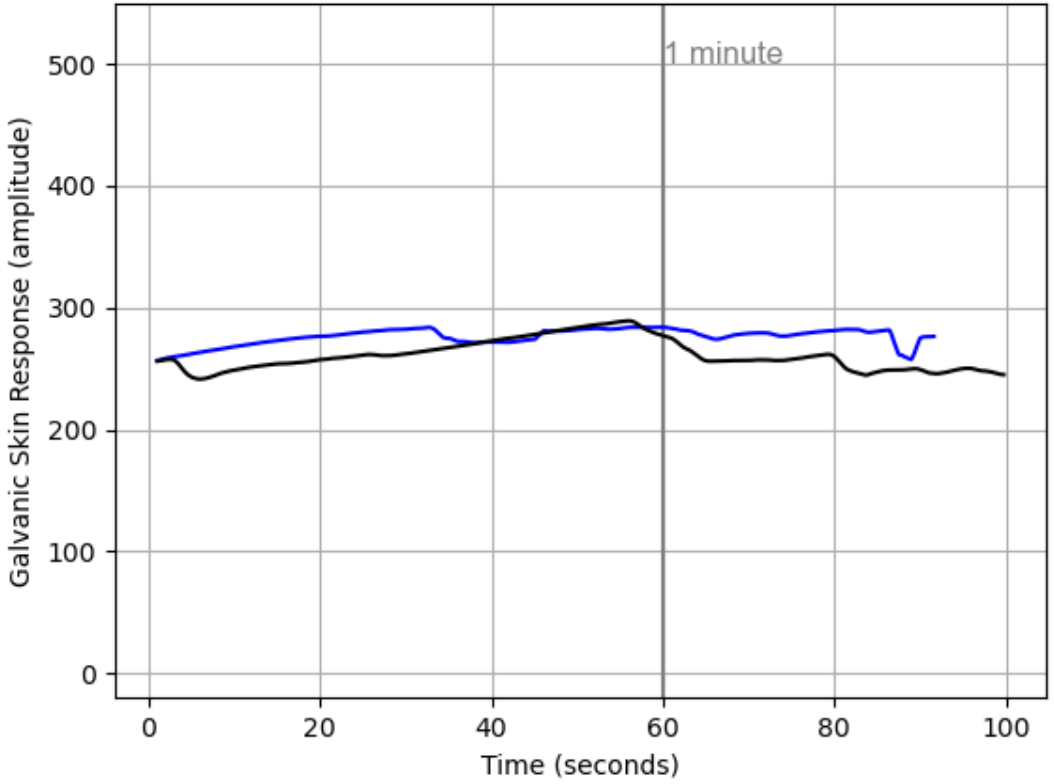
Traditional drawing before using VR

Traditional drawing after using VR

Learner 8 : Non-Design, Unfamiliar with VR



Learner 6: Design, Familiar with VR



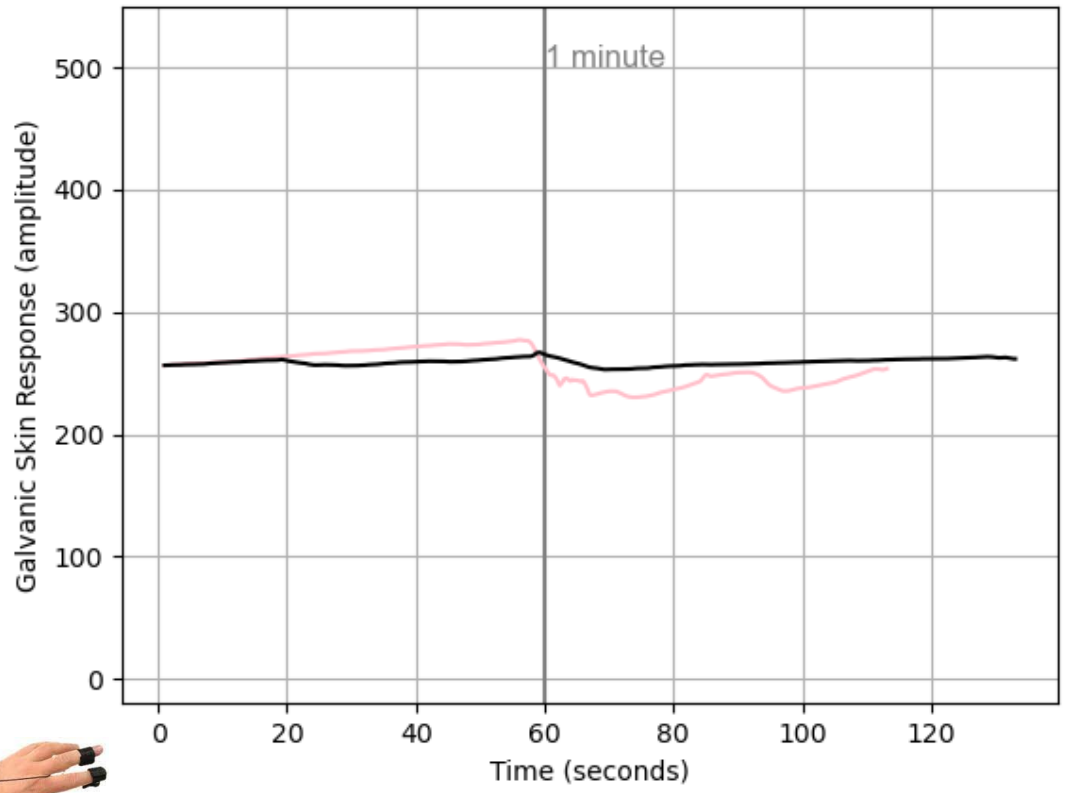
GSR Sensor Data Analysis V

Familiar with 3D, different background

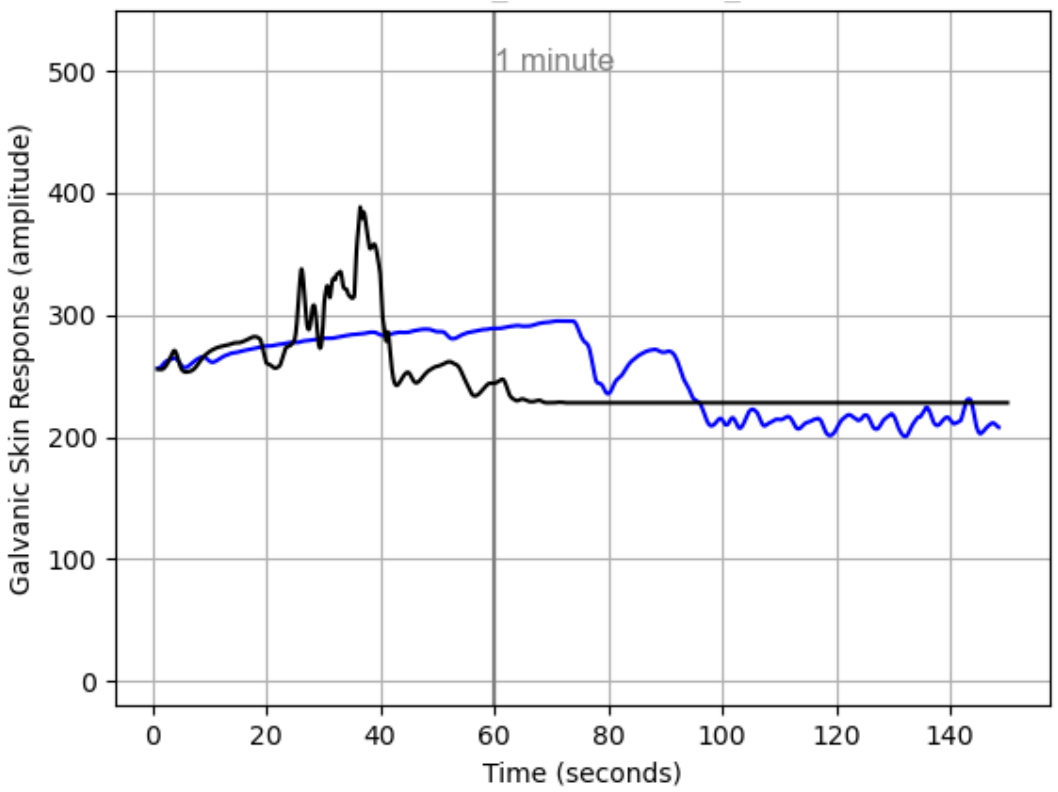
Traditional drawing before using VR

Traditional drawing after using VR

Learner 3 : Non-Design, Unfamiliar with VR



Learner 7: Design, Familiar with VR



Research Results and Discussion I

GSR Data

Test Statistics[a]

	Traditional2_Total - Traditional1_Total
Z	-11.110[b]
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Significant difference in the emotional arousal level.

The Immersive Tendency Questionnaire (ITQ)

Item Statistics

	Mean	Std. Deviation	N
I1. I felt stimulated by the virtual environment.	7.70	1.636	10
I2. I become so involved in the virtual environment that I was not aware of things happening around me.	7.60	2.171	10
I3. I identified to the character I played in the virtual environment.	7.40	1.265	10
I4. I become so involved in the virtual environment that it is if I was inside the game rather than manipulating a gamepad and watching a screen.	7.70	2.263	10
I5. I felt physically fit in the virtual environment.	6.80	2.044	10
I6. I got scared by something happening in the virtual environment.	4.70	3.302	10
I7. I become so involved in the virtual environment that I lose all track of time.	6.80	2.098	10

Research Results and Discussion II

GSR Data

Test Statistics[a]

	Traditional2_Total - Traditional1_Total
Z	-11.110[b]
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Significant difference in the emotional arousal level.

The Immersive Tendency Questionnaire (ITQ)

Item Statistics

	Mean	Std. Deviation	N
I1. I felt stimulated by the virtual environment.	7.70	1.636	10
I2. I become so involved in the virtual environment that I was not aware of things happening around me.	7.60	2.171	10
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I4. I become so involved in the virtual environment that it is if I was inside the game rather than manipulating a gamepad and watching a screen.	7.70	2.263	10
I5. I felt physically fit in the virtual environment.	6.80	2.044	10
I6. I got scared by something happening in the virtual environment.	4.70	3.302	10
I7. I become so involved in the virtual environment that I lose all track of time.	6.80	2.098	10

"I feel stimulated by the virtual environment" (7.7, SD = 1.636)

"I identified the character I played in the virtual environment" (7.4, SD = 1.265)

MSLQ – Questionnaire Analysis I

Motivated Strategies for Learning Questionnaire

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.788	.800	3

Item Statistics

	Mean	Std. Deviation	N
Self_Efficacy_VR	6.2333	1.29624	10
Intrinsic_Value_VR	6.7500	.88976	10
Interest_and_Motivation_VR	6.9500	1.03950	10

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	6.644	6.233	6.950	.717	1.115	.137	3

MSLQ – Questionnaire Analysis II

Motivated Strategies for Learning Questionnaire

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.788	.800	3

The reliability is acceptable (0.788).

MSLQ – Questionnaire Analysis III

Motivated Strategies for Learning Questionnaire

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.788	.800	3

VR can improve interest and motivation in learning spatial reasoning (6.95, SD = 1.03950).

Item Statistics

	Mean	Std. Deviation	N
Self_Efficacy_VR	6.2333	1.29624	10
Intrinsic_Value_VR	6.7500	.88976	10
Interest_and_Motivation_VR	6.9500	1.03950	10

The average value of this survey is 6.644, which is relatively good.

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	6.644	6.233	6.950	.717	1.115	.137	3

MSLQ – Questionnaire Analysis IV

Motivated Strategies for Learning Questionnaire

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.788	.800	3

Item Statistics

	Mean	Std. Deviation	N
Self_Efficacy_VR	6.2333	1.29624	10
Intrinsic_Value_VR	6.7500	.88976	10
Interest_and_Motivation_VR	6.9500	1.03950	10

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	6.644	6.233	6.950	.717	1.115	.137	3

"I think I would choose VR to learn. It is really hard to picture what really happens in your mind. But with the help of VR, I think it is more helpful for us. We know the simulation of what is going to happen." - Learner 1

MSLQ – Questionnaire Analysis V

Motivated Strategies for Learning Questionnaire

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.788	.800	3

Item Statistics

	Mean	Std. Deviation	N
Self_Efficacy_VR	6.2333	1.29624	10
Intrinsic_Value_VR	6.7500	.88976	10
Interest_and_Motivation_VR	6.9500	1.03950	10

Self-efficacy average score is the lowest, especially about the idea of replacing traditional drawing by this virtual drawing, most of the participants are unsure and some responses are relatively low.

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	6.644	6.233	6.950	.717	1.115	.137	3

MSLQ – Questionnaire Analysis VI

Motivated Strategies for Learning Questionnaire

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.788	.800	3

Item Statistics

	Mean	Std. Deviation	N
Self_Efficacy_VR	6.2333	1.29624	10
Intrinsic_Value_VR	6.7500	.88976	10
Interest_and_Motivation_VR	6.9500	1.03950	10

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	6.644	6.233	6.950	.717	1.115	.137	3

“I got dizzy”, “I cannot draw for a long time, because it is heavy.” – Learner 3

“ I think I may be it is expensive to draw in the VR.” - Learner 6

Research Results and Discussions

01. GSR

Fluctuations in learners' emotional intensity.

02. Interview

7 out of 10 participants choose VR to learn spatial reasoning.

Most of participants state that VR can help them understand spatial reasoning easier.

03. Questionnaire

Improved learning performance, especially in terms of intrinsic value, learners' interest and motivation.

VR can help improve spatial reasoning learning performance.

Research Discussion & Limitation

01.

Pilot Studies Results

02.

Sample Number

03.

Tools Familiarity

04.

Task Results Comparison

Future Works

01.

Improve Experiment Agenda and Plan

02.

Demographics Sampling

03.

Data Analysis with Behavior Observation

04.

Persona and Grouping Analysis

Thank You for Your Attention!

Q&A

Enhancing Spatial Reasoning Capability Using VR Immersive Experience

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