Enhancing Spatial Reasoning Capability Using VR Immersive Experience

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RESEARCH OUTLINE

- Methodology
- Evaluation
- Discussion & Future work
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”

Related Fields

Mathematics

Science

Art & design

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)
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).

Research Motivations

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

Research Contributions


Research Objectives

• The effectiveness of VR in enhancing spatial reasoning skills.
• Factors affecting learning performance of spatial reasoning through VR.
Learning performance: the achievement of a learning activity. It includes two aspects: the result and the process. Moccozet, L (2012)

Hypothesis:
VR can help improve spatial reasoning’s learning performance.

Learning performance

Immersion

Emotional arousal

Self-efficacy
Intrinsic value
Interest & Motivation
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**

- **VR experience**
  - Immersion
  - Emotional Arousal
  - ITQ
  - GSR

- **Learning performance and experience**
  - Self-efficacy
  - Intrinsic value
  - Interest and motivation
  - MSLQ
  - Interview

**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

Gender
- Male: 70%
- Female: 30%

Education Background
- PHD: 75%
- Master: 25%

Major
- Design: 40%
- Non-Design: 60%

Age
- 20-24: 5
- 25-29: 4
- > 30: 1

How long have you been studying spatial reasoning?
- < 1 year: 5
- 1 - 3 years: 3
- > 3 years: 2
Phase I Experiment

Given models

Traditional Drawing

VR Drawing
Traditional Drawing Before and After VR Immersion

<table>
<thead>
<tr>
<th>Learner</th>
<th>Traditional Drawing (Phase 1)</th>
<th>Traditional Drawing (Phase 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>2</td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td>3</td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
<tr>
<td>4</td>
<td><img src="image7.png" alt="Image" /></td>
<td><img src="image8.png" alt="Image" /></td>
</tr>
<tr>
<td>5</td>
<td><img src="image9.png" alt="Image" /></td>
<td><img src="image10.png" alt="Image" /></td>
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Traditional Drawing Before and After VR Immersion

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<tr>
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<td>7</td>
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<td></td>
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<tr>
<td>10</td>
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</table>
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".
Text Co-occurrence Networks Analysis

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

![Diagram showing participant preferences and familiarity with VR and 3D.](image-url)
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 II

Learner 3: Non-Design Prefer VR
Learner 4: Non-Design Prefer Both
Learner 5: Design Prefer Both
Learner 6: Non-Design Prefer Hand drawing
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

Learner 2: **Design, Familiar with VR**

Learner 3: **Non-Design, Unfamiliar with VR**

![Graph showing GSR sensor data for Learner 2 and Learner 3](image)

- **Learner 2**:
  - **Design**, Familiar with VR
  - 135 Galvanic Skin Response (amplitude) at 40 seconds
  - 58 Galvanic Skin Response (amplitude) at 100 seconds
  - Deep breath

- **Learner 3**:
  - Non-Design, Unfamiliar with VR
  - Relax

![Graph showing GSR sensor data for Learner 2 and Learner 3](image)
GSR Sensor Data Analysis III

**Unfamiliar with 3D, same background**

**Learner 4**: Non-Design, **Familiar** with VR

- Traditional drawing before using VR
- Traditional drawing after using VR

**Learner 8**: Non-Design, **Unfamiliar** with VR
GSR Sensor Data Analysis IV

Unfamiliar with 3D, different background

Learner 8: Non-Design, Unfamiliar with VR

Learner 6: Design, Familiar with VR

- Traditional drawing before using VR
- Traditional drawing after using VR
GSR Sensor Data Analysis V

**Familiar with 3D, different background**

**Learner 3:** Non-Design, Unfamiliar with VR

**Learner 7:** Design, Familiar with VR

- Traditional drawing before using VR
- Traditional drawing after using VR
Research Results and Discussion

GSR Data

The Immersive Tendency Questionnaire (ITQ)

<table>
<thead>
<tr>
<th>Test Statistics(^a)</th>
<th>Traditional2_Total - Traditional1_Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>-11.110(^b)</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>.000</td>
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a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

Significant difference in the emotional arousal level.

<table>
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<th>Mean</th>
<th>Std. Deviation</th>
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<td>11. I felt stimulated by the virtual environment.</td>
<td>7.70</td>
<td>1.636</td>
<td>10</td>
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<td>12. I become so involved in the virtual environment that I was not aware of things happening around me.</td>
<td>7.60</td>
<td>2.171</td>
<td>10</td>
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<td>13. I identified to the character I played in the virtual environment.</td>
<td>7.40</td>
<td>1.265</td>
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<tr>
<td>14. I become so involved in the virtual environment that it is as if I was inside the game rather than manipulating a gamepad and watching a screen.</td>
<td>7.70</td>
<td>2.263</td>
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<tr>
<td>15. I felt physically fit in the virtual environment.</td>
<td>6.80</td>
<td>2.044</td>
<td>10</td>
</tr>
<tr>
<td>16. I got scared by something happening in the virtual environment.</td>
<td>4.70</td>
<td>3.302</td>
<td>10</td>
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<td>17. I become so involved in the virtual environment that I lose all track of time.</td>
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Research Results and Discussion II

GSR Data

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Significant difference in the emotional arousal level.

“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

<table>
<thead>
<tr>
<th>Cronbach’s Alpha Based on Standardized Items</th>
<th>N of Items</th>
</tr>
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<tbody>
<tr>
<td>.788</td>
<td>.800</td>
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## Item Statistics

<table>
<thead>
<tr>
<th>Question</th>
<th>Mean</th>
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<tbody>
<tr>
<td>Self_Efficacy_VR</td>
<td>6.2333</td>
<td>1.29624</td>
<td>10</td>
</tr>
<tr>
<td>Intrinsic_Value_VR</td>
<td>6.7500</td>
<td>.88976</td>
<td>10</td>
</tr>
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<td>Interest_and_Motivation_VR</td>
<td>6.9500</td>
<td>1.03950</td>
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## Summary Item Statistics

<table>
<thead>
<tr>
<th>Item Means</th>
<th>Mean</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Range</th>
<th>Maximum / Minimum</th>
<th>Variance</th>
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</tr>
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<tbody>
<tr>
<td>Item Means</td>
<td>6.644</td>
<td>6.233</td>
<td>6.950</td>
<td>.717</td>
<td>1.115</td>
<td>.137</td>
<td>3</td>
</tr>
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The reliability is acceptable (0.788).
The average value of this survey is 6.644, which is relatively good.

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

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“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
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.
### MSLQ – Questionnaire Analysis VI

**Motivated Strategies for Learning Questionnaire**

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- “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

Contact

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National Taipei University of Technology