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Assessment of Differences in Human Depth Understanding Between Stereo and Motion Parallax Cues in Light-Field Displays

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About Me

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- **Research Interests**
  - 3D Imaging
  - Virtual/Augmented Reality
  - Light Field Displays

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Agenda

- Background
- Research Aim
- The Experiment
- The Tools Used in This Study
- Results
- Conclusion
- References

■ Background

How We See in Three Dimensions

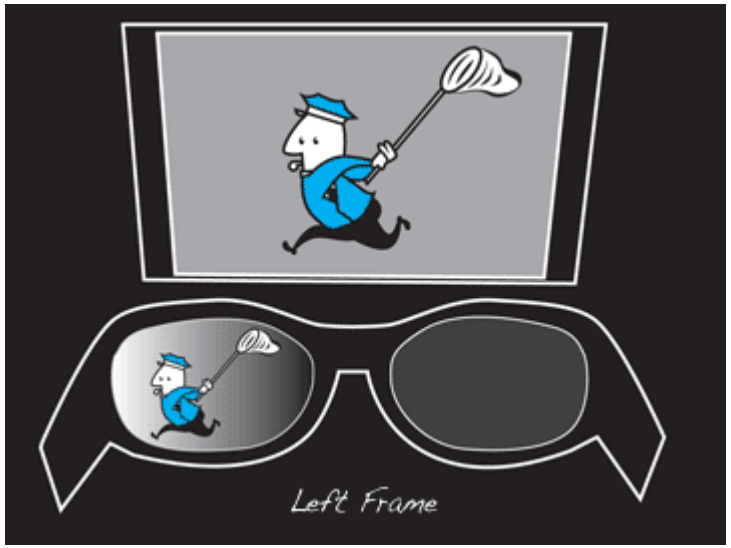
There are multiple techniques that allow humans to see the world around them in three dimensions.
Two of these are motion parallax and stereoscopy.[1]

Motion Parallax

Objects closer to the viewer move faster than those further away from the viewer.

Stereoscopy

Each eye sees a slightly different angle of the same scene. The brain puts this together to create a 3D image.



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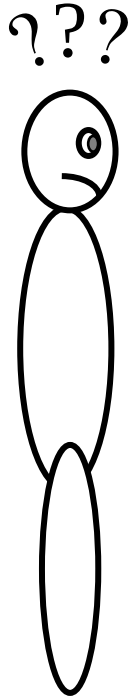
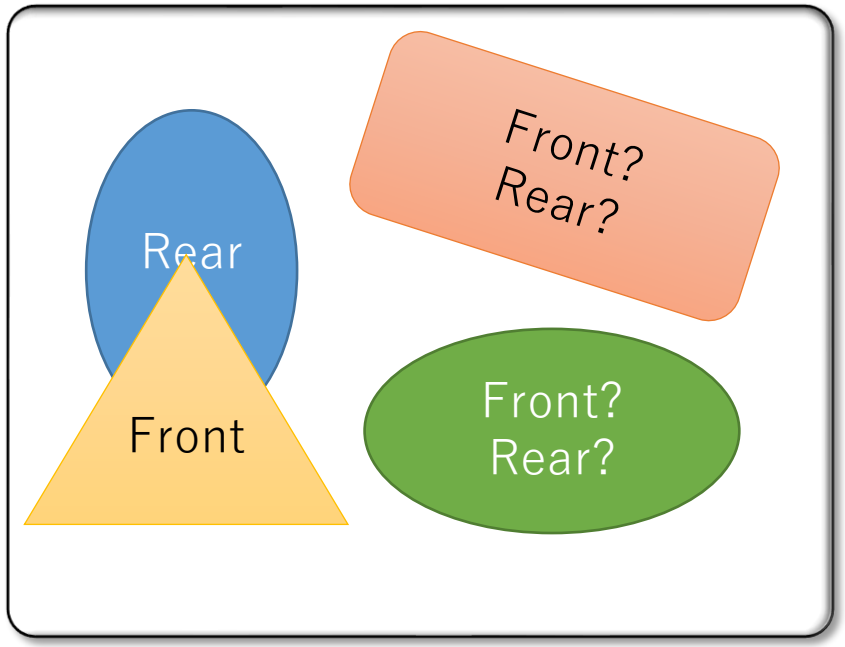
■ Background

Issues with 2-Dimensional Screen

- A 2-Dimensional (2D) screen does not show actual depth. [2]
- It can be hard to understand where objects are within the scene.
- A 2D screen can show motion parallax, but it cannot show stereoscopy on its own.





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Background

Light Field Display (LFD)

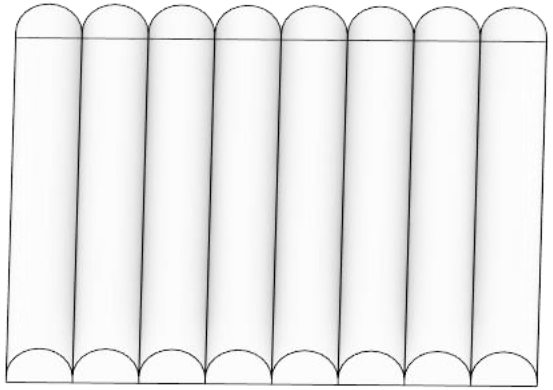
- Trackers
  - VR and AR use trackers to create 3D environments
  - Requires setup and space
- Special lenses
  - Makes multiple views of a scene
  - Creates stereoscopy
  - No extra space required

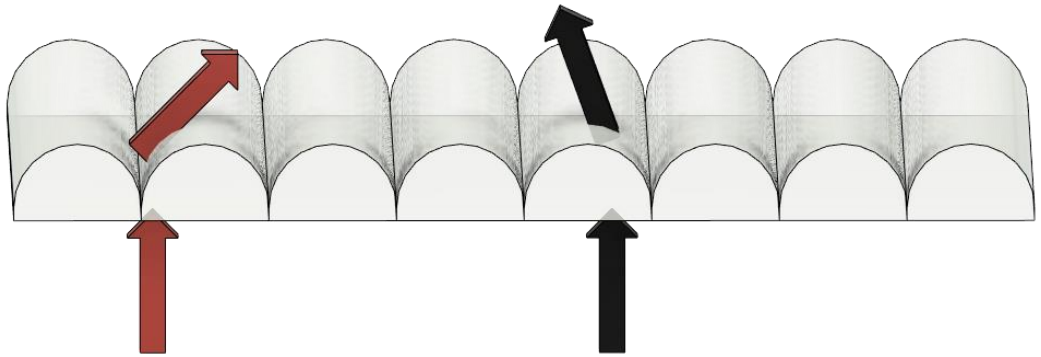
Looking Glass by Looking Glass Factory[3]

Background

Lenticular Lenses

- Curved lenses
- Bends the light of the images displayed behind the lenses.
- Allows for multiple images to be placed behind the lenses
  - Each eye sees a different image
- Stereoscopy is achieved.



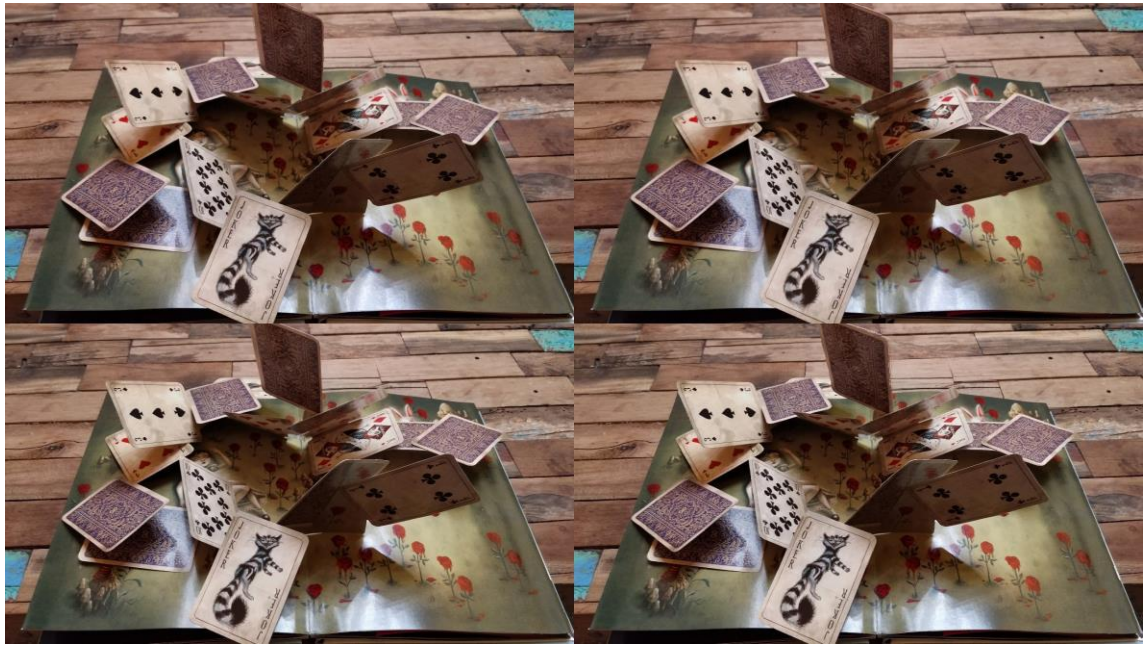


■ Background

Lume Pad by Leia Inc.

- LFD Tablet
- Four images

- Displays images for lenticular lenses
- Can be turned on and off



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■ Research Aim

My aim is to analyze the difference in human understanding between motion parallax and stereoscopy using an LFD.

- The Lume Pad is both an LFD and a standard tablet.
- It can show both motion parallax and stereoscopy.

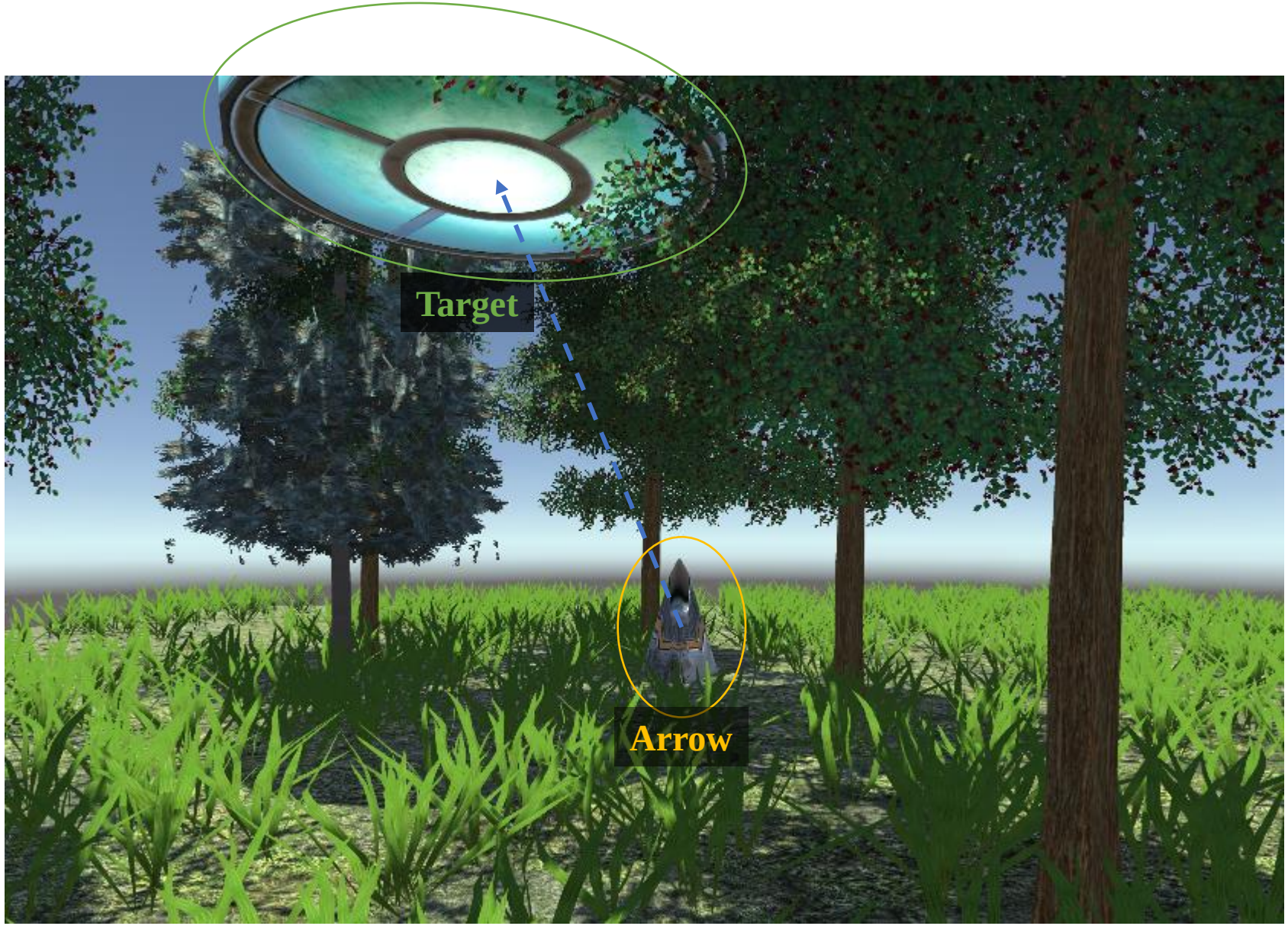
The Experiment

Concept

Subjects were asked to aim an arrow at a target.

Trees and other obstacles are added to the scene to block sight lines.

To perform the task, the subject needs to move the camera, see the motion parallax effect, and understand where the objects are.



■ The Experiment

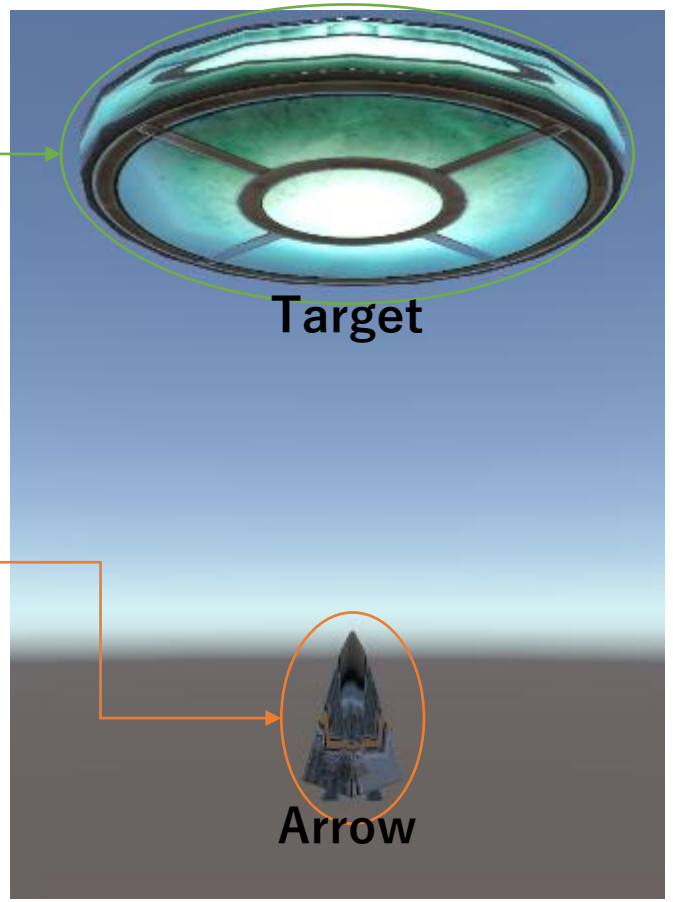
Key Objects

➢ **Target**

- The target has a diameter of 10 m
- The target is five meters above the ground
- It is at a different x and z position for each attempt

➢ **Arrow**

- The subject controls this with the Dual Sense controller.
- It starts in the center of the scene on each attempt.



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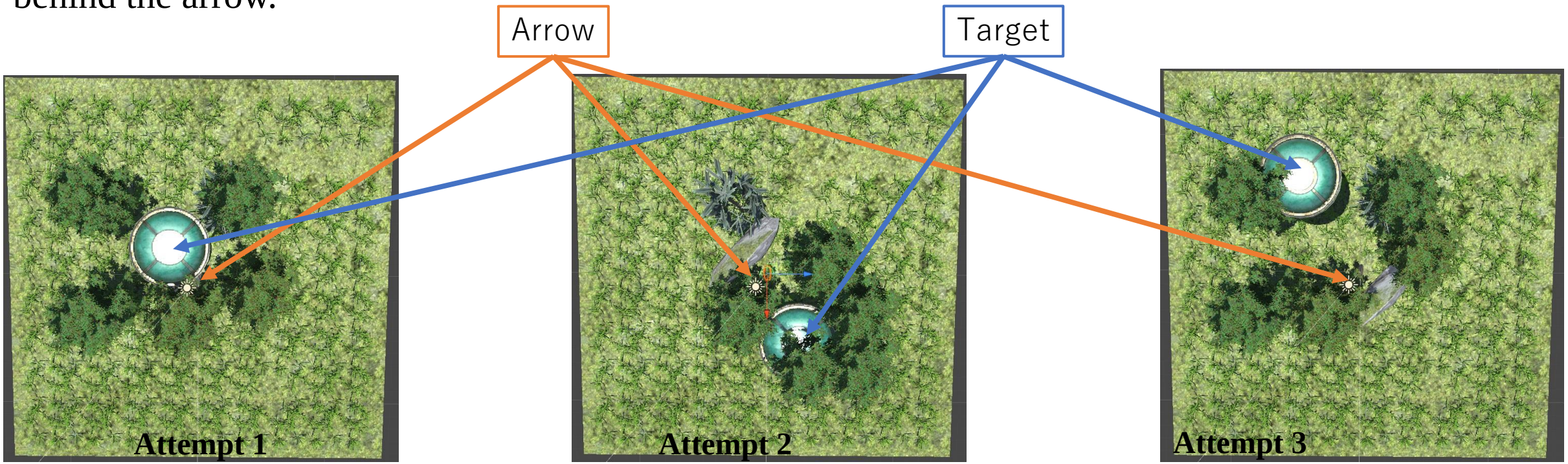
■ The Experiment

Scenes

There are no random elements.

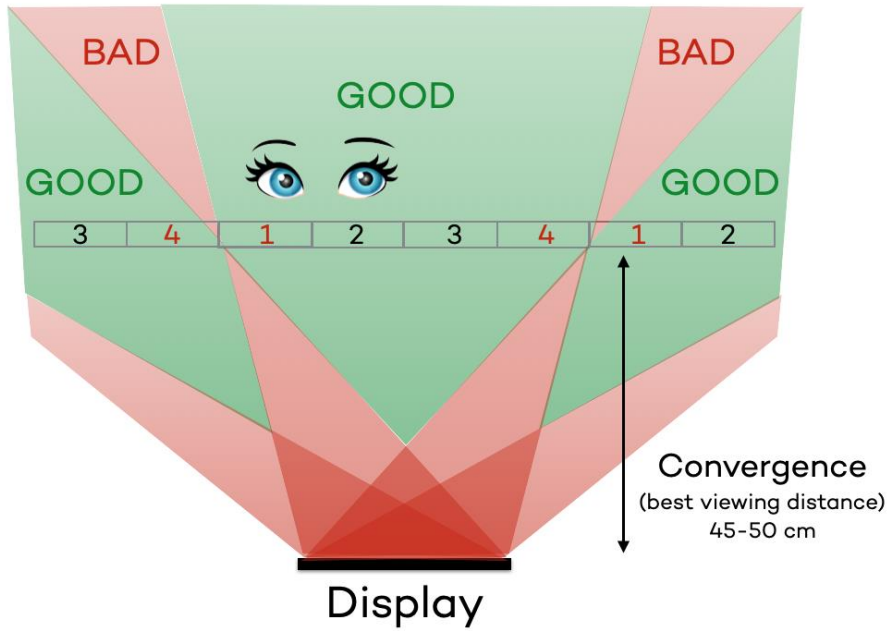
A rock is placed directly behind the arrow so that the subject cannot simply align the camera behind the arrow.

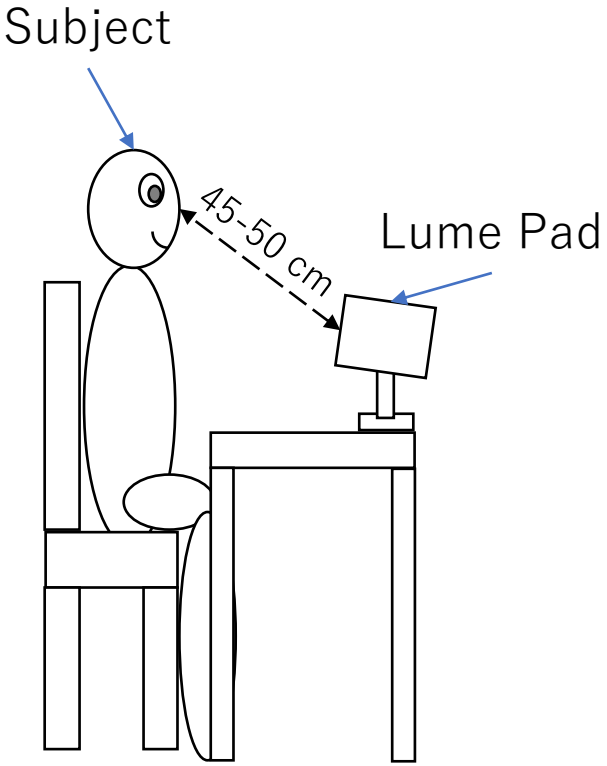


■ The Experiment Concept

The Experiment Environment

- **Position**
  - Subjects sat at table
  - 45-50 cm from the tablet
  - Tablet was oriented towards their face
  - Subjects can move to see LFD effect





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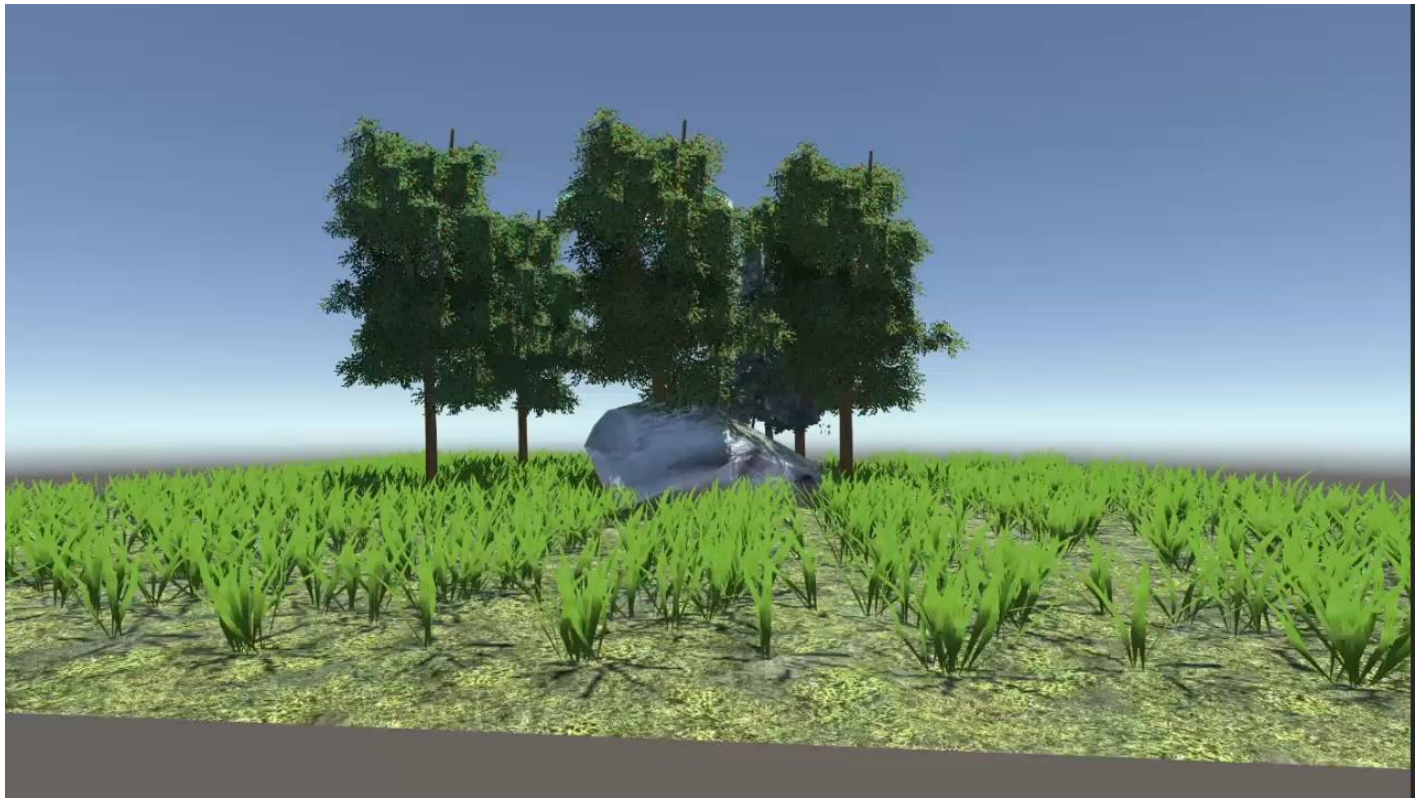
The Experiment

The Procedure

- Each subject did not have previous knowledge of the test
- One practice attempt to learn controls
- Split into 2 groups

Group 1
- Practice attempt in Motion Parallax
- First 3 attempts in Motion Parallax
- Second 3 attempts in Stereoscopic

Group 2
- Practice attempt in Stereoscopic
- First 3 attempts in Stereoscopic
- Second 3 attempts in Motion Parallax



■ Tools used in This Study

Hardware

➢Lume Pad

- ➢ Screen Size: 10.1-inch
- ➢ Standard Mode
  - ➢ Number of views: 1
  - ➢ Resolution: 2560 × 1600 pixels
- ➢ Light Field Mode
  - ➢ Number of views: 4
  - ➢ Resolution: 640 X 400 pixels

➢Dual Sense Wireless Controller

- ➢ Uses Bluetooth to connect to Lume Pad

Lume Pad

Dual Sense

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■ Tools used in This Study

Control Scheme

Left Stick: Controls the arrow rotation.

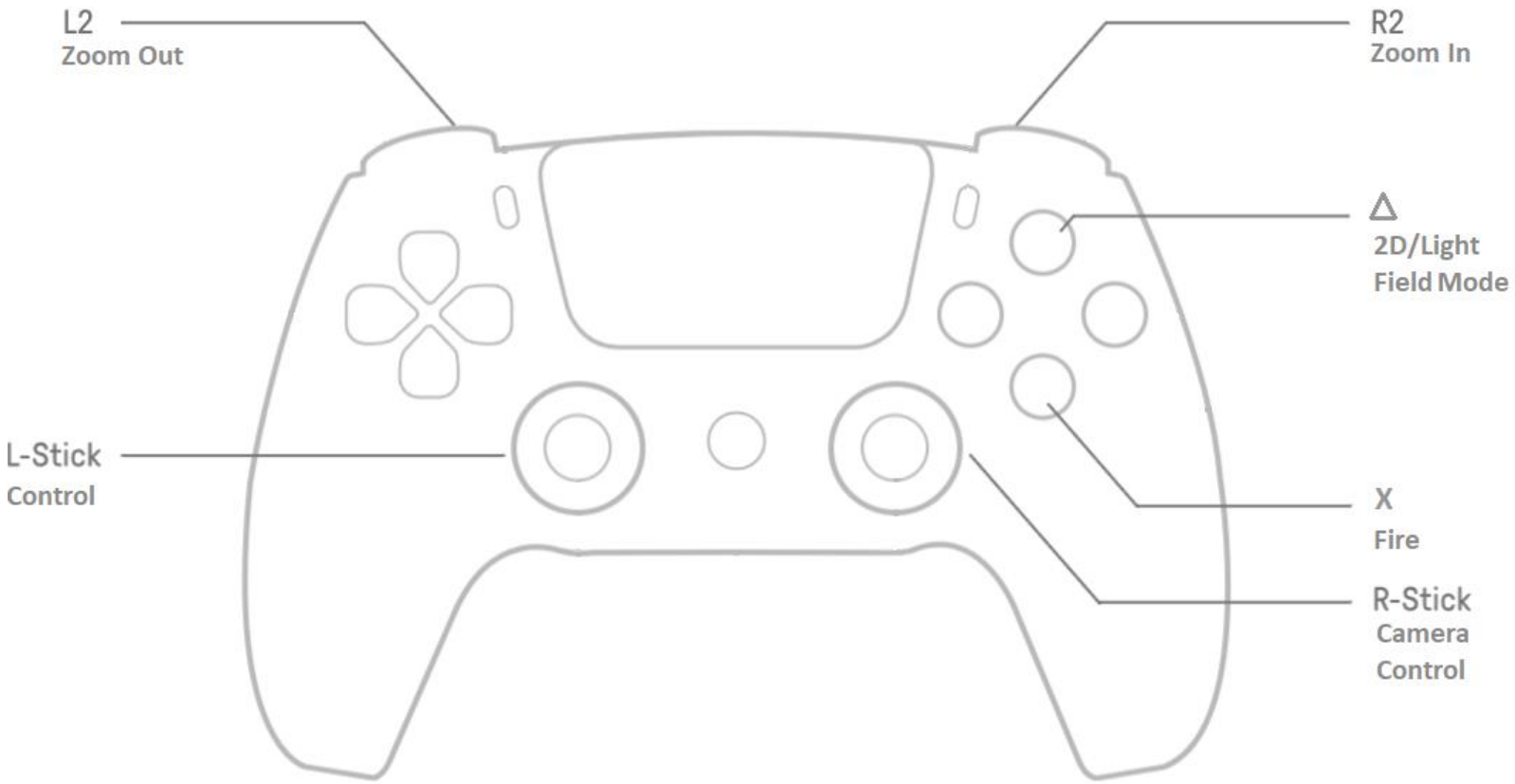
X Button: Fires the arrow

△Button: Changes the display type

Right Stick: Rotates the camera

Left Trigger: Pulls the camera away from the center of the scene

Right Trigger: Pushes the camera towards the center of the scene



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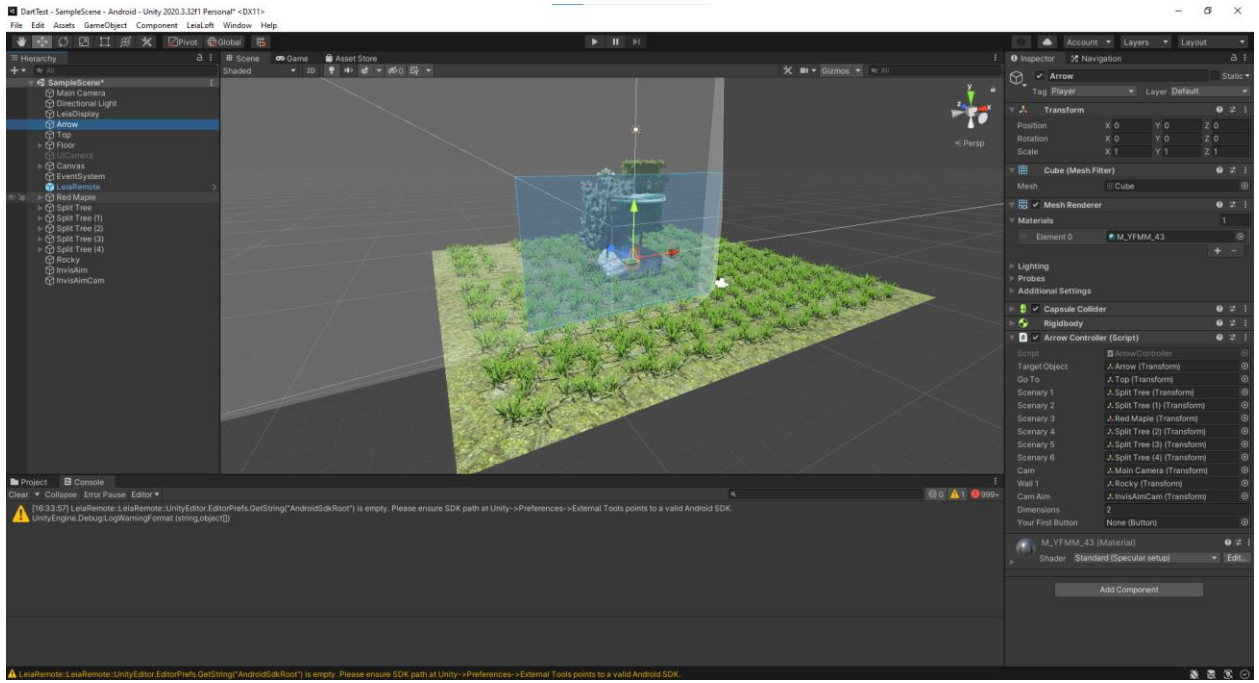
■ The Tools used in This Study

Software

- **Unity**
  - Allows for straight forward set up of scenes.
  - Units used in this experiment are meters (m).



- **Lume Pad SDK [5]**
  - Built in Lume Camera handles LFD effect.
  - LFD effect can be switched on and off with push of a button.

Results

2 groups of 6 subjects

- MP: Motion Parallax
- ST: Stereoscopy

Error = $\sqrt{(x_1 - x_2)^2 + (z_1 - z_2)^2}$

x_1 and z_1 correspond to the target while x_2 and z_2 correspond to the arrow.

A lower number is desired

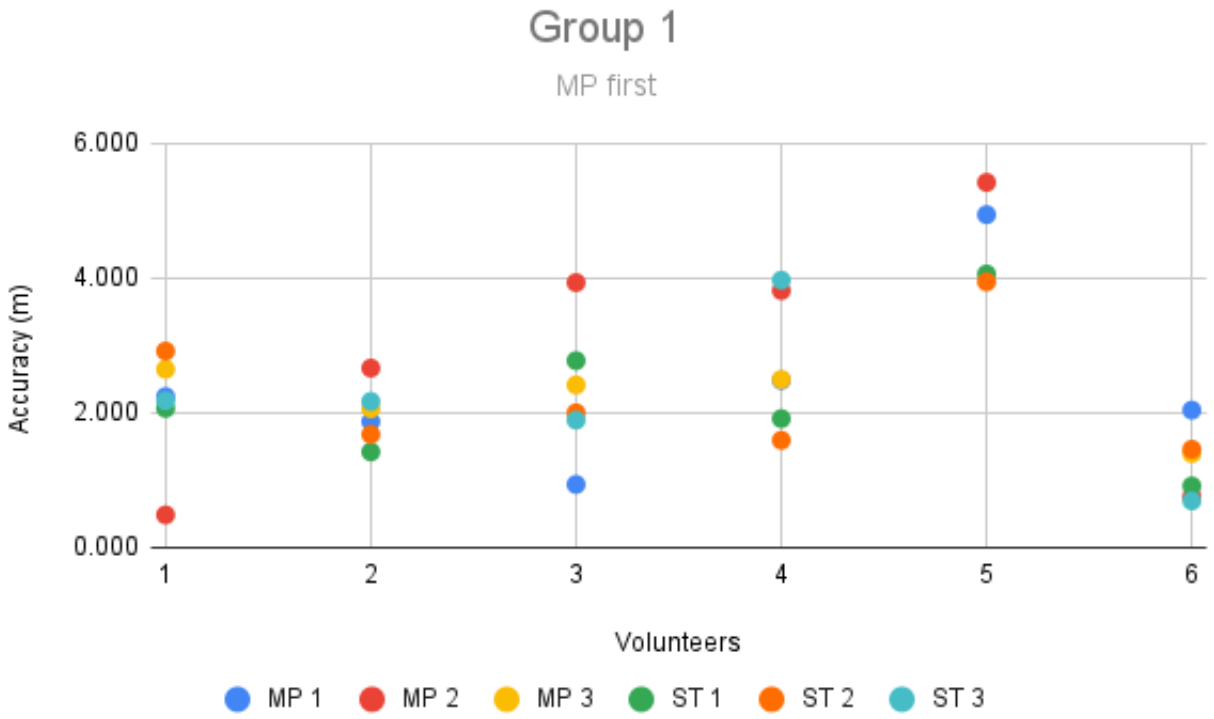
A number over 2.5 does not hit the target.

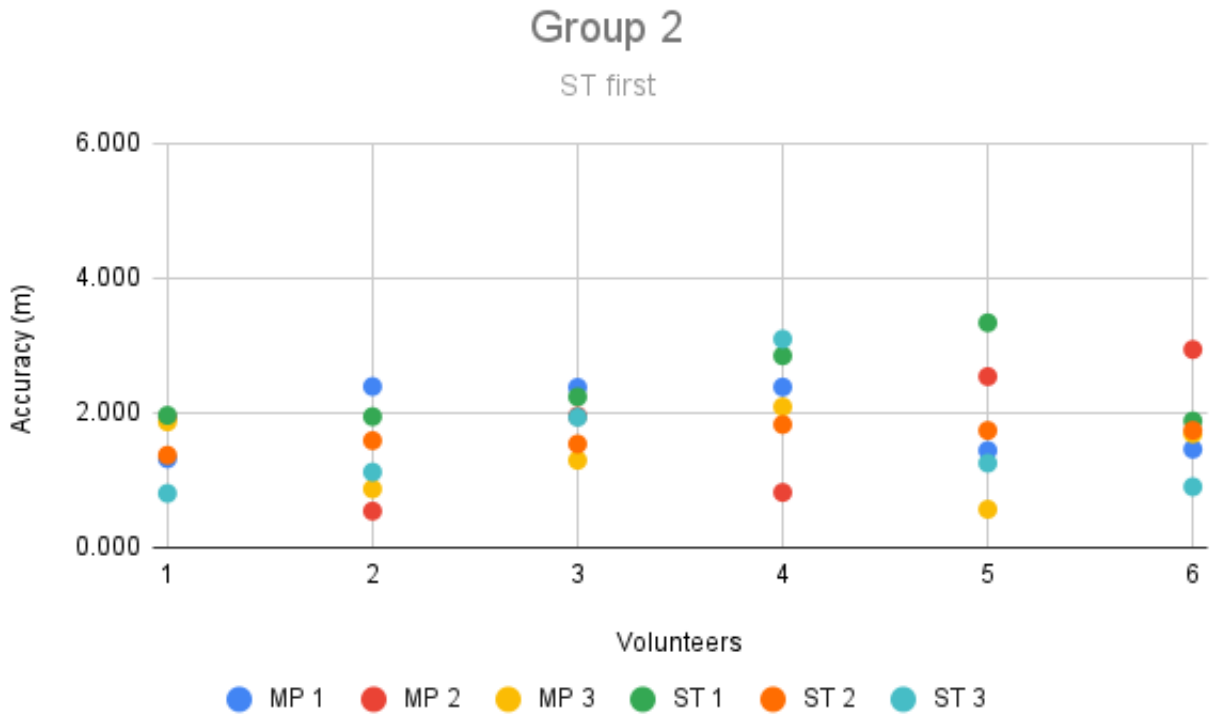
Subject	MP Attempt 1	MP Attempt 2	MP Attempt 3	ST Attempt 1	ST Attempt 2	ST Attempt 3
Group 1						
1	2.234	0.475	2.642	2.060	2.912	2.175
2	1.864	2.659	2.054	1.413	1.673	2.163
3	0.928	3.932	2.408	2.770	1.993	1.885
4	2.477	3.813	2.490	1.907	1.585	3.967
5	4.942	5.422	12.061	4.058	3.942	12.597
6	2.033	0.749	1.387	0.905	1.451	0.684
Group 2						
1	1.956	1.363	0.795	1.310	1.923	1.859
2	1.937	1.580	1.112	2.385	0.532	0.861
3	2.231	1.530	1.927	2.372	1.946	1.287
4	2.842	1.820	3.091	2.377	0.809	2.083
5	3.333	1.731	1.245	1.433	2.533	0.558
6	1.873	1.733	0.893	1.453	2.936	1.681

First Attempts

Second Attempts

■ Results





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■ Results

Comparison of Results

Subject 5 from Group 1 was excluded from these calculations.

Group 2 was more accurate on average and were more tightly grouped.

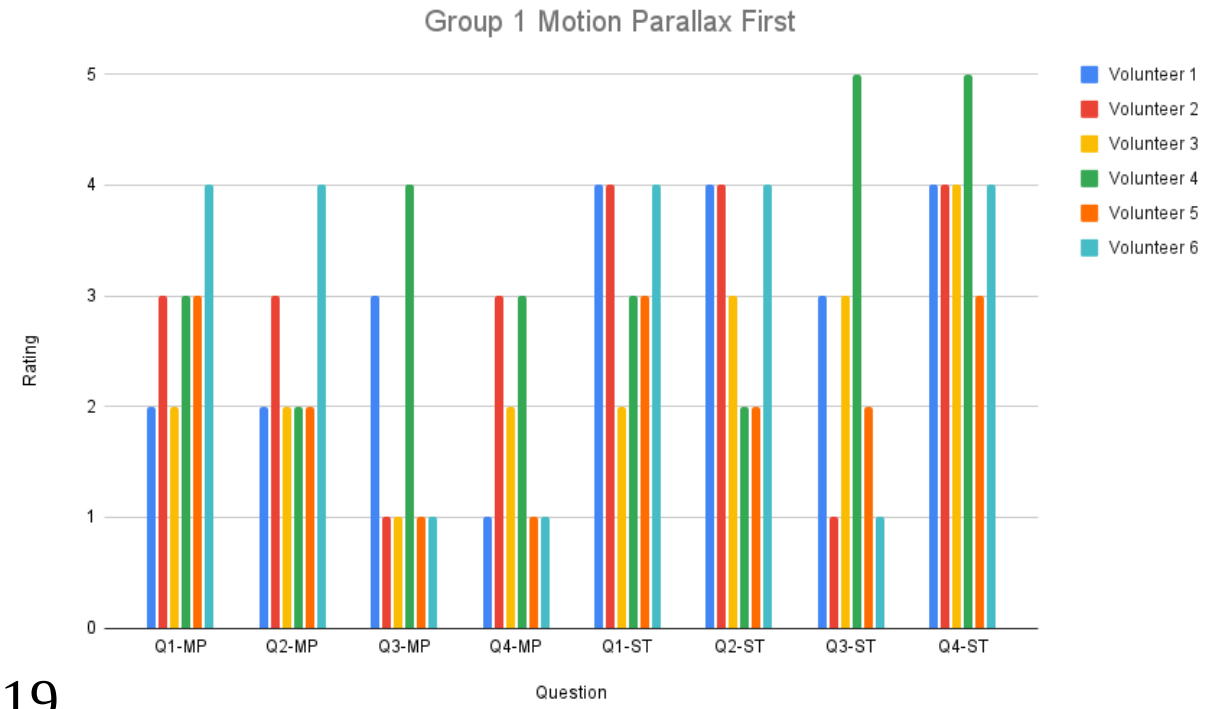
Both groups were more accurate and had smaller standard deviations with stereoscopic over motion parallax.

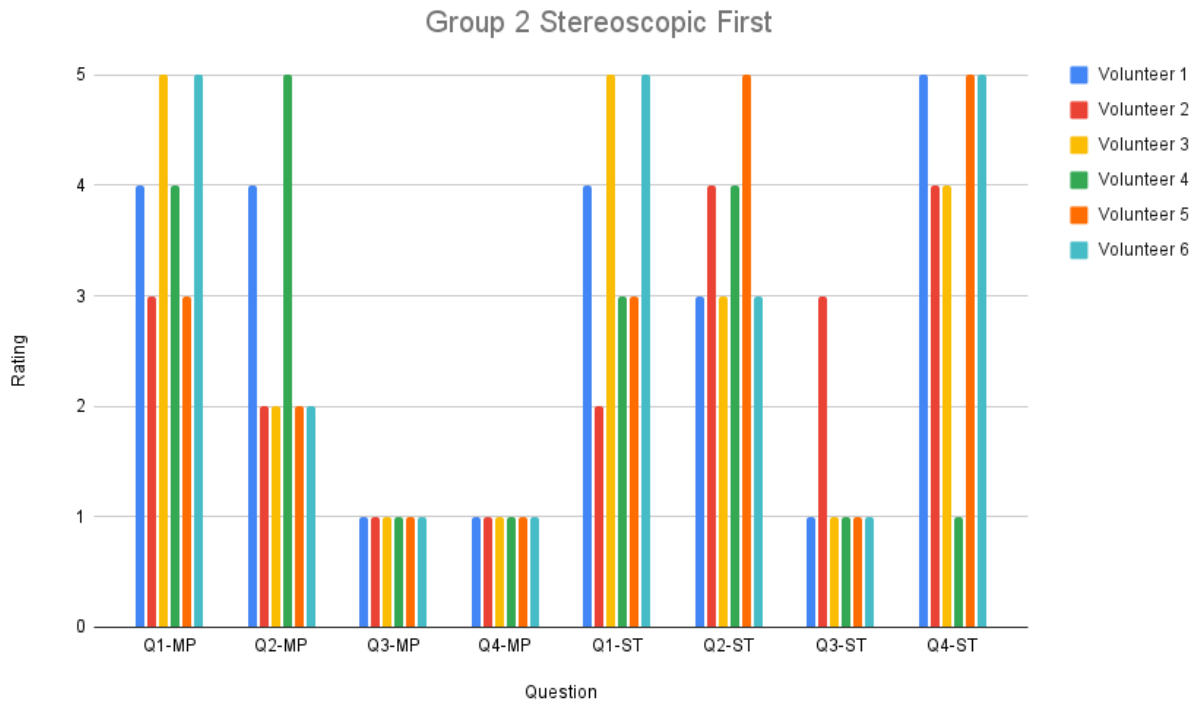
Test	Mean	Standard Dev	Min
Group 1 MP	2.143	0.989	0.475
Group 2 MP	1.833	0.361	0.684
Group 1 ST	1.970	0.812	0.795
Group 2 ST	1.685	0.201	0.532

Results

Questionnaire

1. How well do you feel that you understood the scene? Did you know where everything was?
2. How confident were you in your aim? Did you think you would be close to the target?
3. How much discomfort did you feel? Did your eyes hurt? Did you feel sick?
4. Could you see the 3D effect? Do you feel a 3D sensation?





■ Conclusion

Achievement

• Showed that the human mind can understand a scene in Stereoscopy better than with Motion Parallax on an LFD.

Future work

• Add eye tracking

• Simplify the test

  •At least one subject struggled with the controls

References

[1] Faubert, J. (2001, February). Motion parallax, stereoscopy, and the perception of depth: Practical and theoretical issues. In *Three Dimensional Video and Display: Devices and Systems: A Critical Review* (Vol. 10298, p. 1029809). International Society for Optics and Photonics.

[2] K. Kato and O. D. A. Prima, “3D Gaze Characteristics in Mixed-Reality Environment,” eTELEMED 2021 : The Thirteenth International Conference on EHealth, Telemedicine, and Social Medicine, IARIA, pp.11-15, 2021.

[3] Looking Glass Factory: The Hologram Company, https://lookingglassfactory.com/ [Retrieved at June 2022]

[4] 3D Lightfield Experience Platform, https://www.leiainc.com/ [Retrieved at May 2022]

[5] SDK and Developer Resources, www.leiainc.com/sdk. [Retrieved at 10 June 2022]

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