Data Vis Project Fall 2019

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Project info: `https://matthewberger.github.io/teaching/vis/fall2019/project`
Github for project: `https://github.com/criselsuarez/Data_Vis_Project_2019`
Raw Data `https://vanderbilt.app.box.com/folder/90883476978`

1 Proposal

Due Nov. 1

1.1 Basic info

- **Project title:** Spatial Navigation using Virtual Reality (VR) in 3D space
- **Team members:** Haley Adams, Nick Liu, Crisel Suarez
- **Link to project repository:** `https://github.com/criselsuarez/Data_Vis_Project_2019`

1.2 Background and Motivation

Virtual reality (VR) is a common conduit for examining how humans perceive and reason about space, because it provides a controlled, 3D environment for study. A subset of this area of research has evaluated how people reason about 3D space by looking at spatial orientation (or reorientation) where orientation is evaluated through a variety of a blindfolded pointing tasks [1, 2].

Surprisingly, prior VR studies that evaluate spatial memory through orientation only evaluate angular error on a single axis. Worse yet, error is typically displayed in a simple bar graph or line chart over aggregate data. As such, the underlying user behavior is unclear without an in-depth analysis of a given paper's statistics.

Furthermore, target objects in these studies are typically placed at similar heights. For example, Williams et al. [1] evaluated target objects placed on the ground. And even when slope is encoded, orientation is evaluated from an allocentric–as opposed to an egocentric–perspective [3]. It is unknown how

Figure 1: Virtual stairwell with target objects near eye height

Figure 2: Virtual stairwell with target objects at variable heights

individuals encode height from an egocentric perspective in spatial memory tasks.

1.3 Objectives

We want to enhance our understanding about how people encode the positions of objects in 3D space through visualization. More specifically, we want to better understand how people encode the vertical component of space (height) when they locate target objects. We hope to achieve this through plotting raw orientation data to identify outliers and trends. Then, we intend to further analyze user behavior by comparing measures of error between experimental conditions that require height encoding and those that do not. We predict that participants are encoding height. In theory if people encode height–they should perform better in the condition where target objects vary height.

In addition, it may be beneficial to evaluate other factors. For example, eighteen distinct objects (e.g., teddy bear, lamp, sock) are used for the experiment. It is possible that some object types may be easier to remember. However, this is a secondary goal.

1.4 Data

Preliminary data was collected from eight participants total. All participants were tested in two environmental conditions: one in which nine target objects were placed near eye-height (Figure 1) and one in which nine target objects were placed at varying heights (Figure 2). The stairwells shared the same dimensions and features, excluding target objects. The order in which the two environments were displayed was counterbalanced across subjects.

An HTC Vive Pro (Figure 3 head-mounted display with a wireless adaptor was used to render the virtual environment and to track a user's position in

Figure 3: An image of the HTC Vive Pro with the wireless adapter (Credit: Road to VR))

space. For each condition, participants were allowed to freely explore the environment and they were told which objects in the stairwell were relevant for the experiment. After three minutes, participants were asked to stand at a predetermined vantage point on the stairwell from which all items were visible. The experimenter read aloud the testing protocol and removed visual feedback from the participant when they were ready to continue. During the experiment, the only visual feedback the participant received was a circle beneath their feet and a target placed at the center of the stairwell for resetting orientation between trials. Otherwise, the participant could only see a dark blue/gray hue. The two reset points were necessary to prevent drifting position and orientation during the experiment.

All participants conducted 27 total trials per condition. For each trial, participants were asked to turn to face a target object. And then they were asked to turn to face a target object. There were nine target objects total and participants were asked to turn to face each target three times.

For each trial, data was recorded at the start of the turn (when the participant faced the reset point) and data was recorded at the end of a turn (when the participant faced the target object). At these start and end points, information was extracted from the participant's gaze. Specifically, we recorded the user's direction vector and orientation. From these values a measure of angular error was recorded for the x and y axes. The time elapsed during a trial was also recorded.

1.5 Data Processing:

For exploratory analysis of raw data, we will include information from all 27 trials and we will need to plot using a polar coordinate system to accurately encode orientation. However, performance on spatial orientation tasks is highly variable for a given subject. Therefore, for a more accurate representation of human performance we will observe median errors, which will result in 9 trials per condition for each participant. Most data processing has already been performed during collection (e.g,, angular error calculations). However, we will have to carefully consider how to convert from our data domain to our visualization's visual range after finalizing design decisions.

1.6 Must-have features

The bar chart visualizations will uncover the relationship between specific objects and their angular error and the relationship between the each subject and their angular error. For the interactions for the bar charts, we will have a toggle button that will toggle the x-axis to either "Subject" or "Object". This will be complimented with transitions.

The polar coordinate visualizations will display the angle data corresponding to each subject.

1.7 Optional features

We will allow the user to hover over the bar chart with a horizontal line that will align to the y-axis to accurately access the value.

We will also allow the user to hover over the polar coordinate visualization which will show the angle of the hover with respect to the center.

1.8 Project Schedule

Week 11 : 10/28-11/1	**Meeting: Fri. Nov. 1** **Time: ???**
Project Proposal Due (11/1)	Work on project proposal. -CNH Worked on project description and submitted to Brightspace. -C Schedule, Basic info, Background/Motivation -H: Data & Data Processing, Background/Motivation -N: Major have and optional features -ALL: Visualization Design

Week 12 : 11/2- 11/8	**Meeting: Thur. Nov. 7** **Time: 2:30**
Project Update Due (11/8)	CH - Start cleaning data. CHN - Do initial plot designs for boxplot and polar coordinate plot.

Week 13: 11/11- 11/15	**Meeting: Wed. Nov. 13** **Time: After class**
Due: Nothing	All- Have data cleaned. Start initial analysis, and visualizations for boxplot and pilar coordinate plot.

Week 14: 11/18- 11/22	**Meeting: Mon. Nov. 18** **Time: After class** **Meeting: Nov. 21** **Time: 2:30**
Project Prototype (11/18)	All- Evaluate visualizations and have half of user interactivity working. All- Finish all plots.

Week 15: 11/25-11/29	THANKSGIVING!!! All- Start working on the presentation.

Week 16	Meeting: TBD Time: TBD
Presentation (12/2 or 12/4)	All -Present and live demonstration of visualization. All- Review Final Project and Process Book

Week 17	Meeting: TBD Time: TBD
Final Project Submission (12/9)	All- Finalize final project, process book. All - submit everything on to Github.

1.9 Visualization Design

1.9.1 Initial designs

In the idealization phase, we created numerous rough sketches for showcasing raw angle information for each object and angular error for each object and each person. Figure 4 showcases a collection of four alternative designs. The top two images employ unique strategies for displaying angular information using a polar coordinate system. The bottom left image attempts to transform this information into euclidean space to enhance legibility. Finally, the bottom right image wrestles with how to display error data in a meaningful way with interactions. Moving forward, we will have to carefully consider how to represent object types and individual data since there are 9 objects and 8 participants, respectively. We have discussed using indicative glyphs to indicate specific objects in scatter-plots. However, we may need to revisit this choice if the charts become cluttered.

1.9.2 Realization Design

For our final design, we plan on having 4 visualizations: a bar graph for the X-angular errors Vs. Objects/Subjects, a bar graph for the Y-angular errors Vs. Objects/Subjects, a polar coordinate visualization for the start and end of the X-angles, and a polar coordinate visualization for the start and end of the Y-angles. For the polar coordinates, we hope to see clusters of data, from which we can draw conclusion about the memory perception of each specific object. We chose to use color to encode the different kind of objects. For the bar graph, we hope to better understand the accuracy of perceiving different

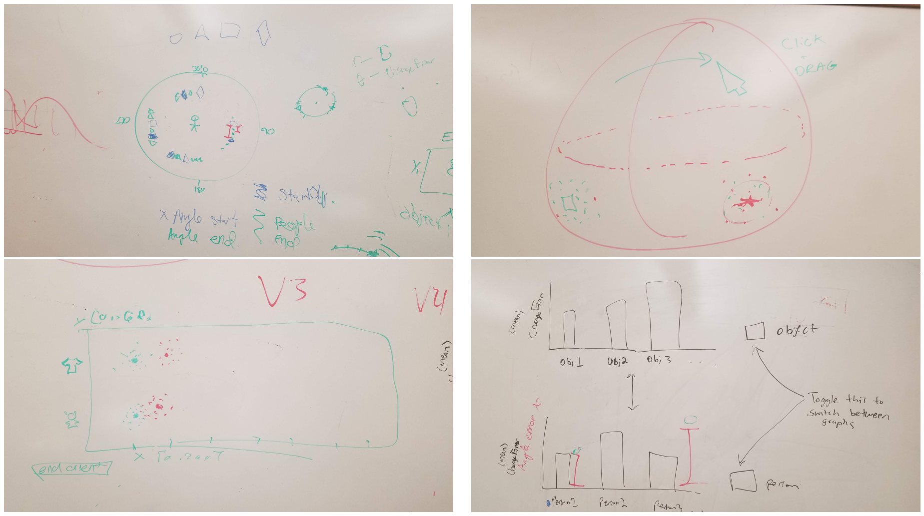
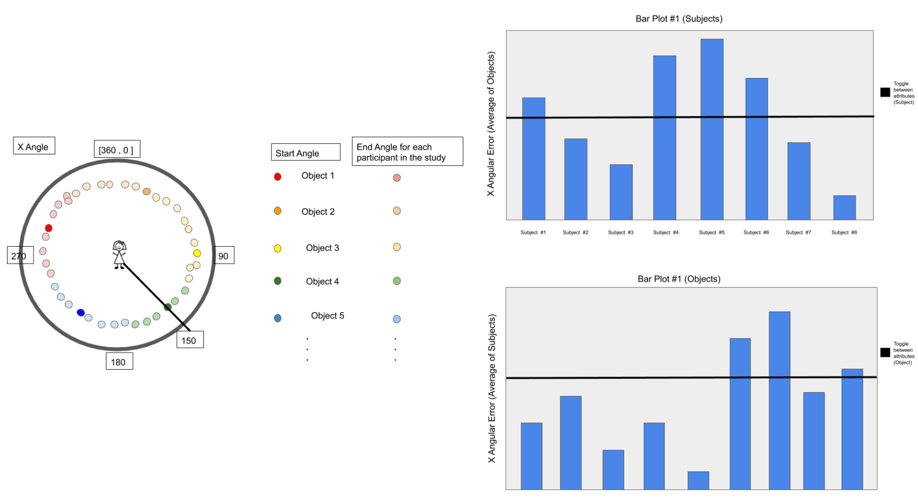


Figure 4: Four alternative designs for visualization

types of objects.



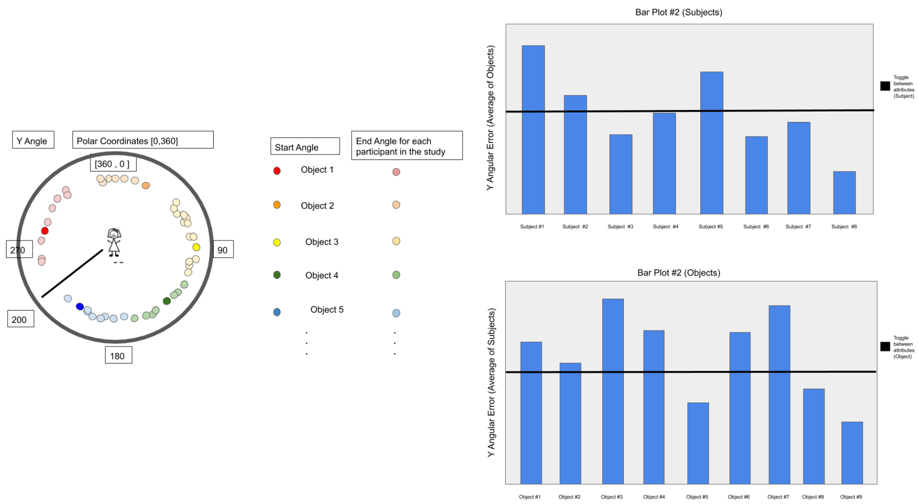


Figure 5: Realization Designs for visualization

References

[1] Williams, B., Narasimham, G., Westerman, C., Rieser, J., and Bodenheimer, B., "Functional similarities in spatial representations between real and virtual environments," *ACM Trans. Appl. Percept.* **4** (July 2007).

[2] Kelly, J. W., McNamara, T. P., Bodenheimer, B., Carr, T. H., and Rieser, J. J., "The shape of human navigation: How environmental geometry is used in maintenance of spatial orientation," *Cognition* **109**(2), 281 – 286 (2008).

[3] Kelly, J., "Head for the hills: The influence of environmental slant on spatial memory organization," *Psychonomic Bulletin & Review* **18**, 774–780 (2011). 10.3758/s13423-011-0100-2.