Appendix A: Supplemental Material

Here, We provide several figures and details about our experiment that did not fit within the constraints of the submission format. We first detail the qualitative free-response feedback we received from participants. We then show means and confidence intervals of the data in our analysis from the body of the paper. Finally, the networks and drawings which appear in our study, along with some examples of the study webpage, are provided.

Qualitative feedback

We collected comments and feedback from participants after they completed the survey. They were encouraged to respond with free text to the following prompts:

- Please describe the strategy you used to answer the questions.
- Did you have any problems taking this study?
- Please leave any other comments or observations below.

Strategy

We asked questions regarding the participants' strategy in order to understand how they are making use of given interactions to answer the questions. Most participants reported that the **Hover** interaction followed by **Pan** interaction were the most helpful for solving the tasks provided to them. One participant reported,

> *I rely heavily on the hovering tool where the nodes and the edges are highlighted when I hover my mouse over the nodes. I use this to find linked nodes when a small region has a lot of nodes together. I also use it to find the neighbors of the highlighted node and move my cursor back and forth between the target node and its neighbors to count edges. I also use the double-click feature often center the target node so I can easily check neighbors and edges.*

A few participants also mentioned the zoom and recenter interactions in their responses. Notably, no participant mentioned the reset visualization as a part of their strategy which is consistent with our data; see Fig. 9 (b). The type of tasks participants were asked to complete influenced their strategy. An instance of a comment left by a participant placed in the task group with **T3** and **T5** is,

> *Find the point, then use the hover to determine neighbors. For the shortest path found the most direct path. For the neighbors, just hovered to find the neighbors then went through each neighbor, hovered and counted the degree.*

The feedback left by participants reconfirms our results regarding the use of interactions with different visualizations.

Problems

By understanding what problems participants faced while taking our study, we can highlight the limitations and challenges of the study. One of the main problems highlighted by different participants was that the question node did not change color on being hovered and if it was the neighbor of a hovered node. One user mentioned,

> *Already highlighted nodes (orange) don't change color when they are neighbors of a hover node, making it difficult to see if they are connected to it or not.*

This was an intentional design decision to always have question nodes be visually consistent, but proved frustrating to several participants. Another limitation we encountered through participants' comments was node-edge or edge-edge overlap. A few comments mentioned it was difficult for the participants to identify if there are connections between nodes because of overlapping and made it difficult for them to solve the tasks. One participant left a comment,

> *Some nodes were positioned on top of edges so it was sometimes difficult to see if two nodes were connected or if the edge went through to a different node.*

While the hover and zoom interactions were designed to counter this issue, it could not fully solve overlap for the more dense graphs. Another common problem faced by participants was the zoom and pan in the **H** and **S** conditions. Several users reported it was "unintuitive" or that it "felt weird" to operate. A user reported,

> *The click-and-drag for elliptic surfaces felt a little off for how it moved the graph at times, when dragging near the edges of the circle.*

This suggests that more training might be needed to allow participants to become comfortable with the typical interactions required for the non-standard network visualization conditions.

General Comments

The comments for the last question acted to solicit any other opinions or issues the participants faced that they felt was not apt to mention for the other two questions. Several participants mentioned their opinions on what they liked and what they preferred while some expressed their dissatisfaction with one of the conditions. The **H** condition was especially polarizing with some describing it as "interesting" or "visually fun" and others detailing their frustration. One participant wrote

> *I love the aesthetics of the (hyperbolic style).*

while another said

> *I hated hyperbolic. The globe and flat styles were comparable, but I would never want to use hyperbolic*

Several participants also noted they were only asked two types of questions throughout the experiment,

> *Asking the same question again and again did not make the experience pleasant.*

Participants answered the same two questions 54 times; while some might have found this repetitious, it was a necessary consequence of a within-participant experience. The randomization of the presentation order of the stimuli would have mitigated against any fatigue effect.

Additional results visualizations

During our analyis, we created several types of plots to understand our collected data. In particular, we thought the below interval plots

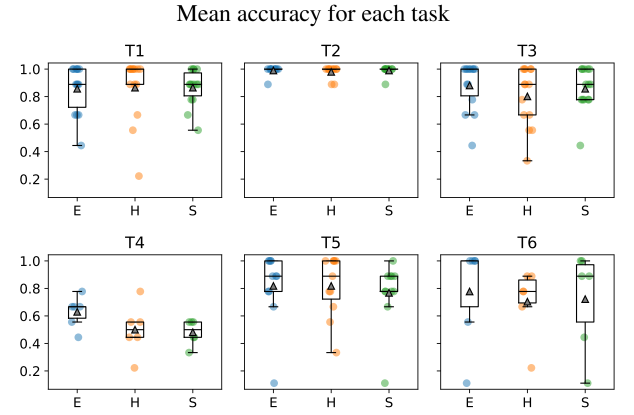


Figure 10: *Box plots in the style of Fig. 5 for accuracy results by task.*

(Figure 11, Figure 12) were insightful in seeing the distribution of time, accuracy, and interactions. However, we ultimately decided to exclude them from the main body of the paper in the interest of space.

Color scheme

We use colorblind-safe options for the nodes: light blue (#648FFF) for visualizing nodes by default, yellow (#FFB000) for hovered nodes hovered, magenta (#DC267F) for neighbors of hovered nodes, and orange (#FE6100) for "highlighted" nodes related to the question.

Subjective feedback analysis

We include the full analysis charts for the subjective feedback data in Fig. 14. Surprisingly, there is little difference in areas where we expected. For instance, we expected the participants would find **H** and**S** more aesthetically pleasing, but this did not seeom to be the case.

Appendix B: Drawings

Table 4 and Table 5 contain all of the static drawings in each condition present in our experiment. The columns indicate the condition **E, H, S** while the rows are titled with the network name.

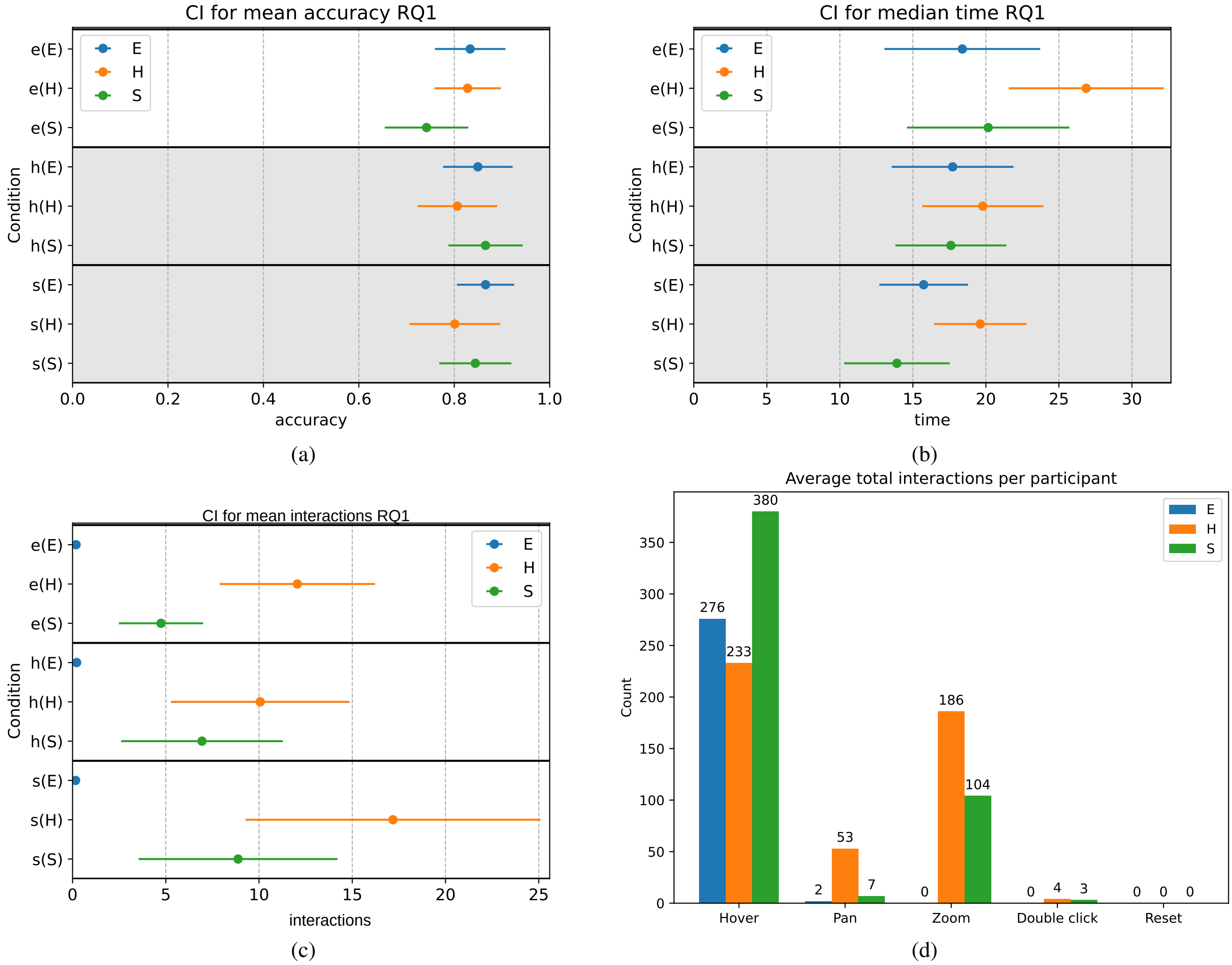


Figure 11: *Mean values for (a) accuracy, (b) time, and (c) interaction means including 95% Confidence Intervals (CI) for **RQ1**. Grey cells indicate no significant differences were found between the three conditions, while white cells indicate at least one difference. Average number of interactions (d) show that while hover was used in all geometries, pan and zoom were utilized more in the **H** and **S** conditions.*

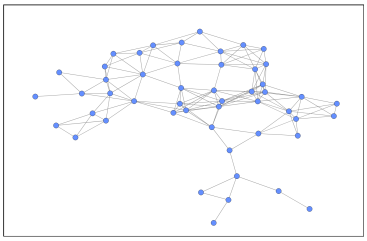
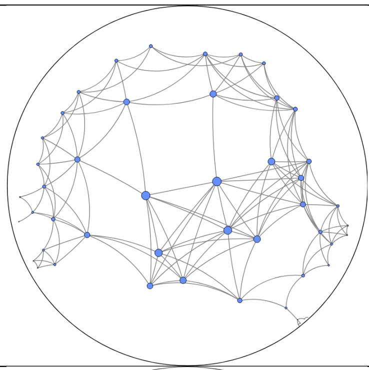
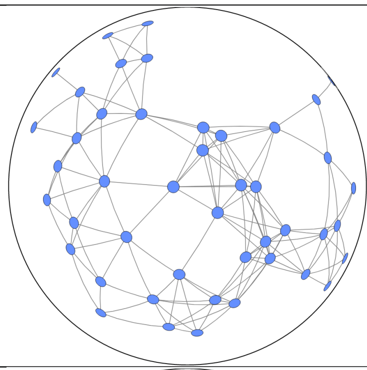
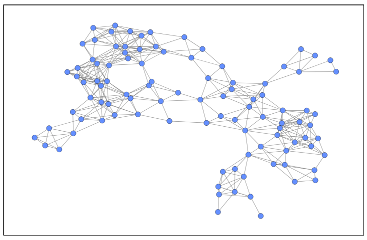
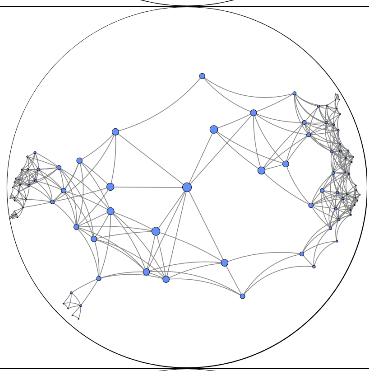
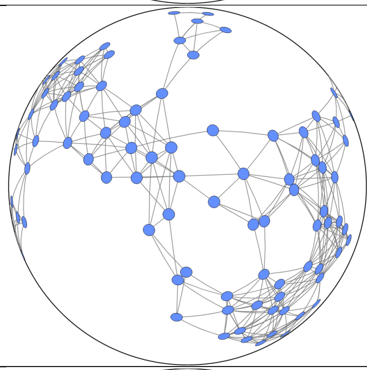
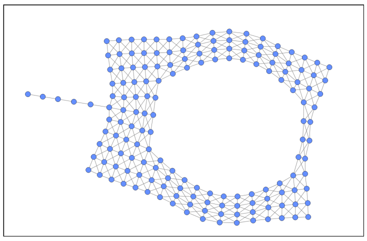
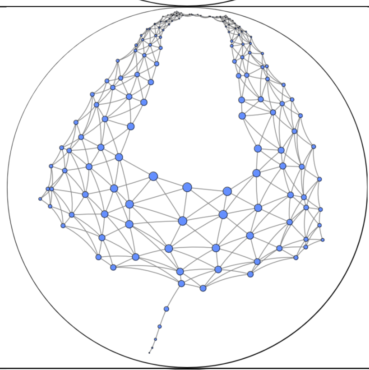
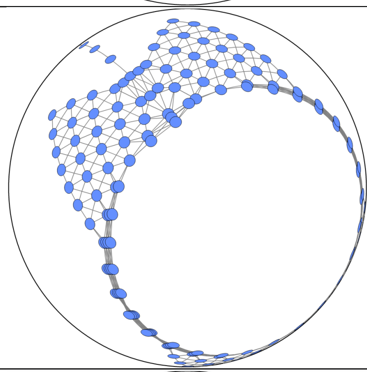
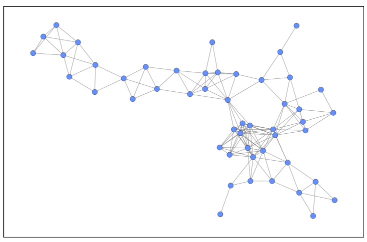
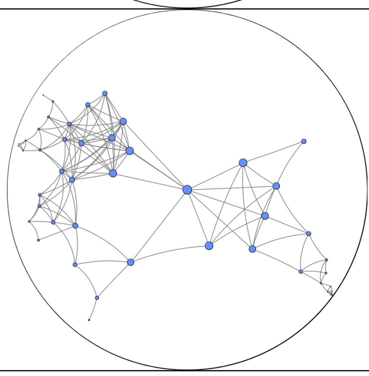
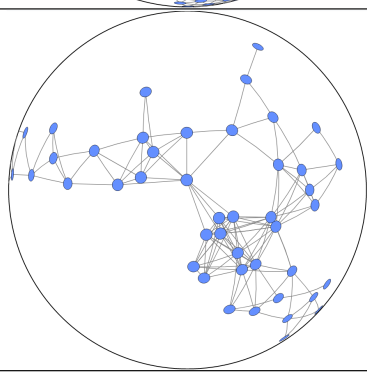
Name	**E**	**H**	**S**
E_rand_small			
E_rand_large			
dwt_162			
H_rand_small			

Table 4: *The first set of graphs and their embeddings in our experiment.*

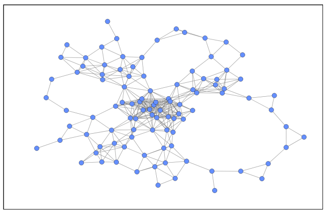
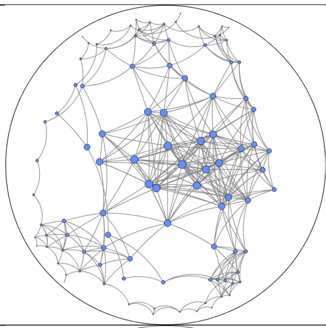
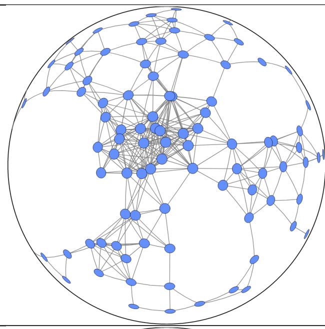
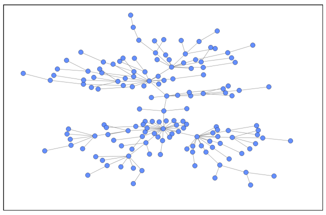
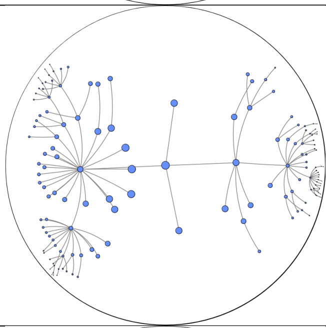
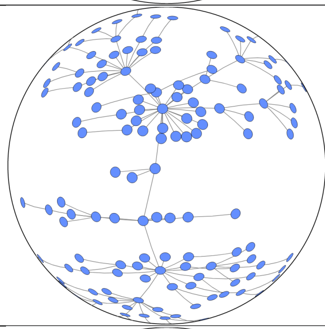
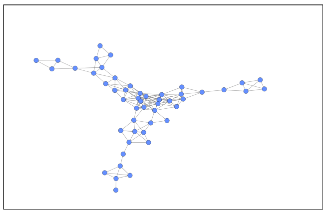
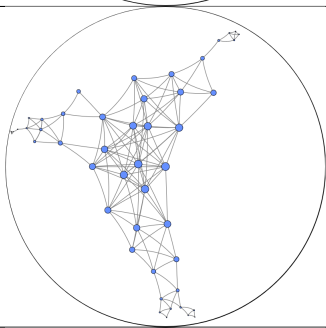
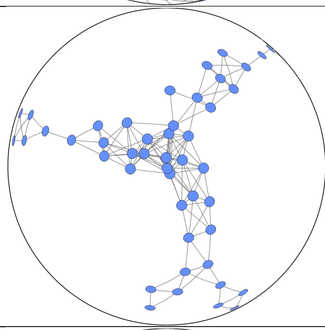
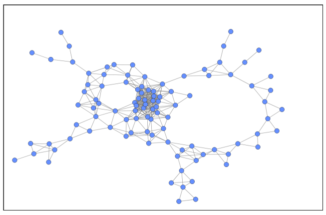
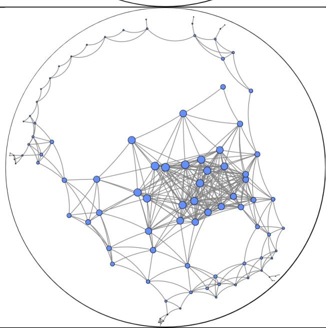
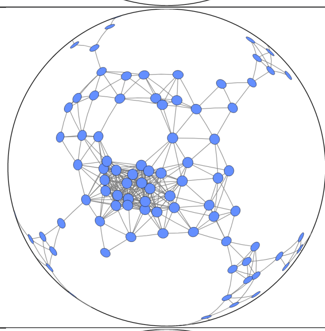
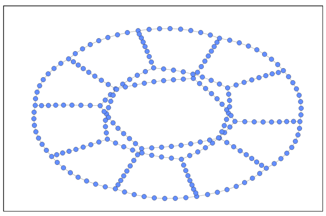
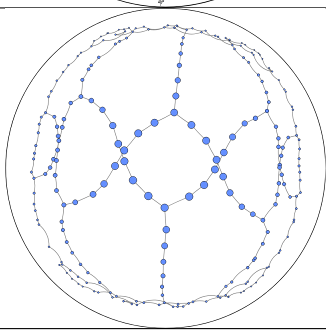
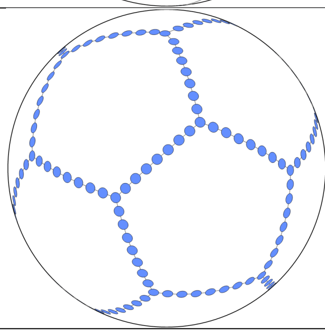
Name	E	H	S
H_rand_large			
tree_150			
S_rand_small			
S_rand_large			
dodecahedron_3			

Table 5: *The rest of the graphs and their embeddings in our experiment.*

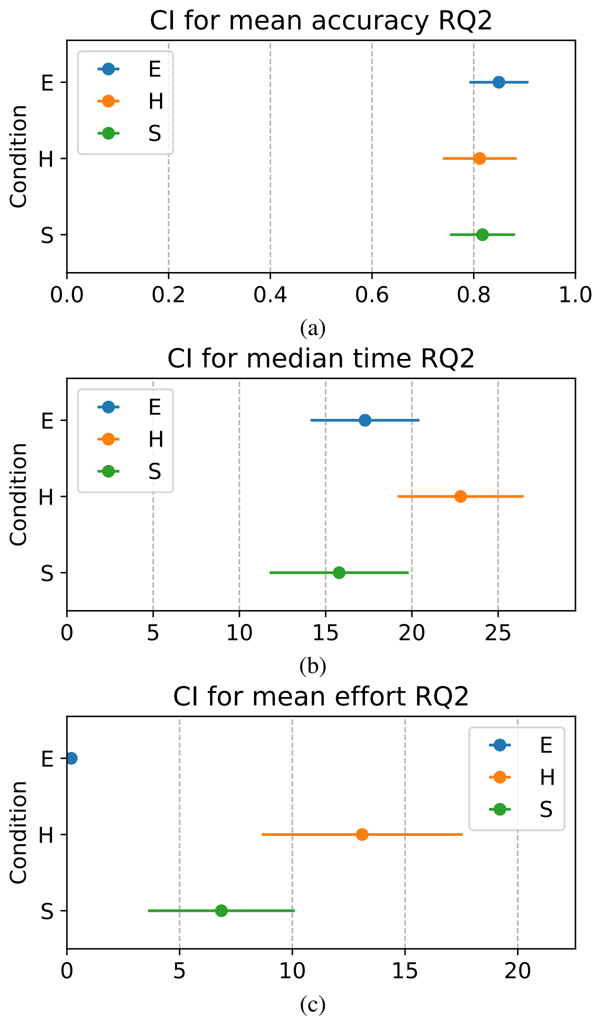


Figure 12: *Mean values for (a) accuracy, (b) time, and (c) interaction means including 95% Confidence Intervals (CI) for **RQ2**.*

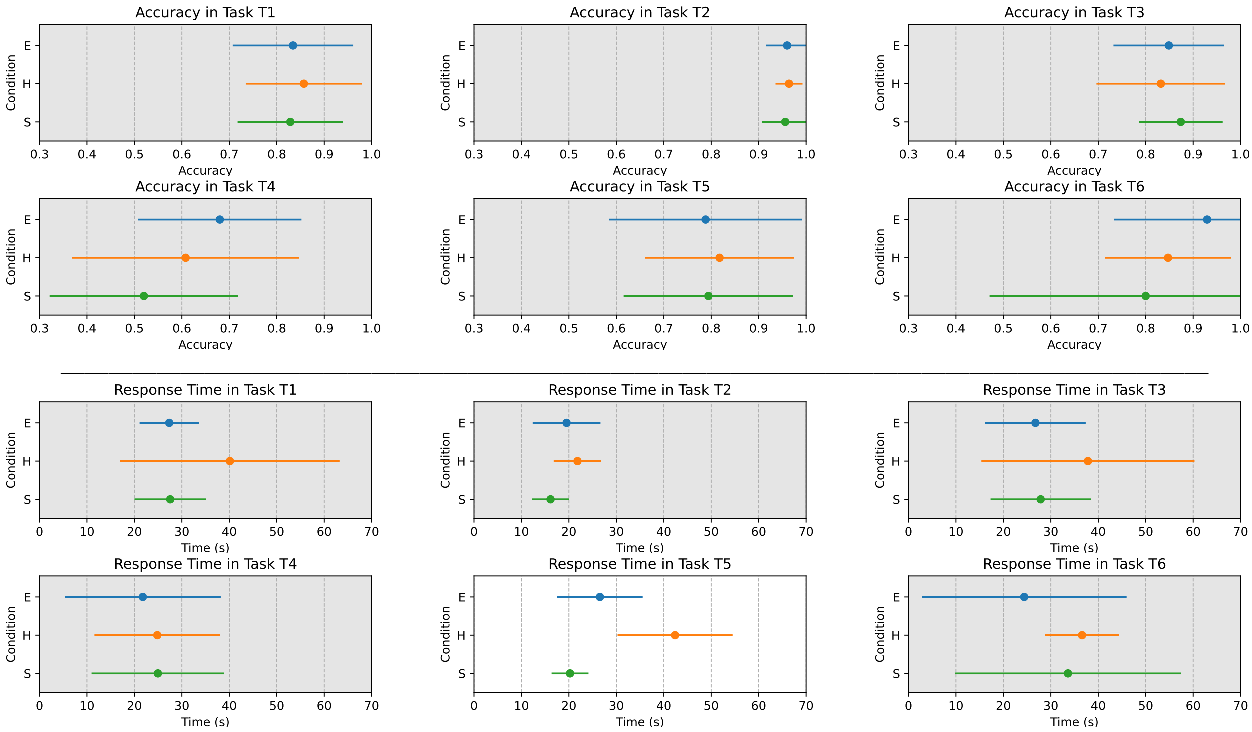


Figure 13: *Means and 95% CI by task for each visualization condition in (top two rows) accuracy and (bottom two rows) time. Grey cells indicate no statistical significance where white cells indicate at least one pairwise significance.*

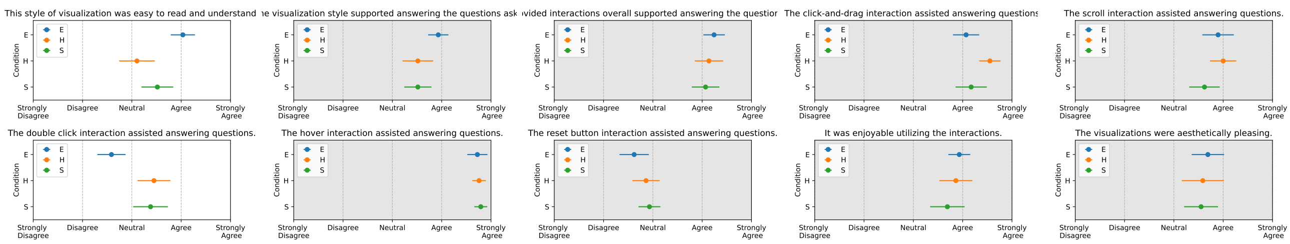
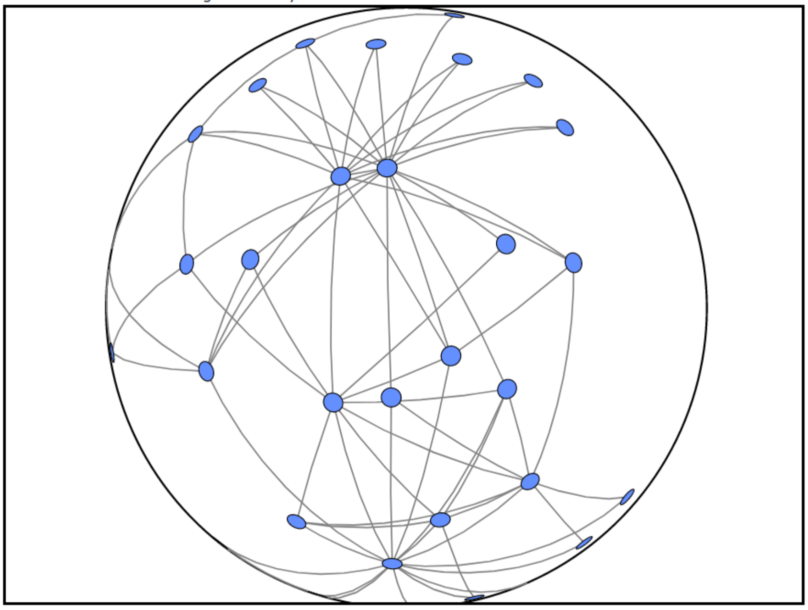


Figure 14: *CI charts for the subjective feedback analysis. Of the 10 questions, only two (shown with white background) had significant difference in their means.*

Example visualization

In this part of the test, you will see graph visualizations in the style below. Try spending some time familiarizing yourself with the visualization style. You can click and drag to move the visualization, hover over nodes to highlight neighbors, and double click to automatically pan to a location. The exact interactions are listed below. These descriptions will also be available during the survey.



Based on different visualizations, you will be answering some questions which can invlove counting, path following and estimation. You can use different interactions to make your tasks easier:

- **Click and drag:** You can click and drag to move the graph around the space.
- **Scrool (wheel):** Scrolling within the visualization will bring the graph closer or further away.
- **Hover:** By hovering over nodes, you will be able to see the hovered node highlighted (yellow) and the neighbors highlighted (red) along with them.
- **Double click:** Double clicking anywhere on any location in the drawing will recenter the point you clicked to the center of your screen.
- **Recenter:** Clicking the recenter button (top right of screen) will take the visualization back to it's original placement.

Figure 15: *The introduction page in our experiment.*

How many neighbors of the highlighted node have degree 2?
○ 1
○ 2
○ 3
○ 4

(a)

How many neighbors do the two highlighted nodes have in common?
○ 2
○ 3
○ 4
○ 5

(b)

What is the length of the shortest path between the two highlighted nodes?
○ 3
○ 4
○ 5
○ 6

(c)

Please ***estimate*** how many ***nodes*** are in the graph?
○ 0-100
○ 100-200
○ 300-400
○ 400-500

(d)

What is the most frequent degree of the highlighted nodes?
○ 2
○ 4
○ 6
○ 7

(e)

How many nodes are reachable in 3 steps from the highlighted node?
○ 8
○ 9
○ 11
○ 12

(f)

Figure 16: *All tasks displayed to participants (a) T1 (b) T2 (c) T3 (d) T4 (e) T5 (f) T6*