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The Effect of Stimulus Concurrence on Memorizing Constellations in VR

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Abstract: In an exploratory study, we tested the effects of two kinds of VR presentations of constellation drawings and labels on memorization. We asked participants to memorize two sets of 14 constellations each: one set presented all at once, and another presented one by one. We evaluated their memorization skills by immediately conducting a test after each memorization set, removing half of the labels and half of the drawings for participants to name or draw, respectively. The results of this within-subjects pilot study point towards the concurrent (show-all) presentation of stimuli having higher scores than the individual (one-by-one) condition. However, the selection of the constellations may have influenced the preliminary results, hence, further modification of the evaluation procedure is required for future work.

Keywords: Virtual Reality, Spatial Memorization, Cognitive Load

1. Introduction and Background

Virtual reality (VR) has been used in various educational contexts. The affordances of VR point towards learning visualizations and interactions that may not have been possible when experienced only in the real world. Expert knowledge transfer becomes on-demand, ubiquitous, and portable when staged in VR-based scenarios, and the level of immersion is emphasized when the specialist knowledge or learning material concerns natural phenomena.

The initial curiosity for this study originated from the traditional presentation of constellation maps in astronomy or general science books, where the learner may experience cognitive overload when parsing through multiple constellation drawings and names simultaneously. When these constellations are rendered onto a sphere in VR, extraneous visual factors like light pollution and structures on Earth can be eliminated, and what remains are the positions of the stars as humans see them from Earth, from a hemisphere. Additionally, we want to explore the different factors that affect the view customization of constellations about cognitive load: how dense or scarce they are presented (density), how often they can be viewed (temporality), and in combination, are they presented all together at once or one by one (concurrence).

This study also hinges on prior explorations of VR as a tool for expert annotation (Caluya and Santos, 2019), learning astronomy in AR/VR (Kim et al., 2023), and spatial memorization (Caluya, et al., 2023). In an ongoing investigation, we observe the effects of the different presentation and learning techniques unique to VR on task performance. Annotations can come in 3D drawings or text-based labels that could carry semantic and spatial information. Further, recent studies of virtual memory palaces (Krokos, et al., 2019, Caluya, et al. 2023) also demonstrate the educational potential of VR by providing an alternate yet immersive 3D environment for learners to customize the space and perform the memory of loci technique.

The main research questions of this work in progress are as follows: (1) If the constellations are regarded as information to be memorized, what are the best ways they can be presented? (2) Since VR can control the amount of information displayed at a specific instance, what level of concurrence is more effective for a spatial memorization task? This paper presents the preparations that we have made to create the VR constellation application, with a within-subjects pilot study regarding the effects of stimulus concurrence.

2. Methodology

2.1. Application Development: Seiza VR

We present Seiza VR, a prototype VR application running on Unity 2018. The development of the environment involved the integration of ready-made systems. The VR user interface (UI) came from another study about learning cloud types from 360-degree images (Caluya and Santos, 2019, see Figure 1a). Constellation positional data and visualizations used in our application came from a GitHub repository complete with a video tutorial[1]. The positions of the stars are normalized so that each star point is projected onto a spherical surface (see Figure 1b), thus, making it more convenient to stylize the drawings of the stars and the line segments that make up the constellation. Finally, we want to create a test scenario where learners can use the annotation UI, "stick" labels onto the 3D space, and draw freehand 3D annotations (see Figure 1c).

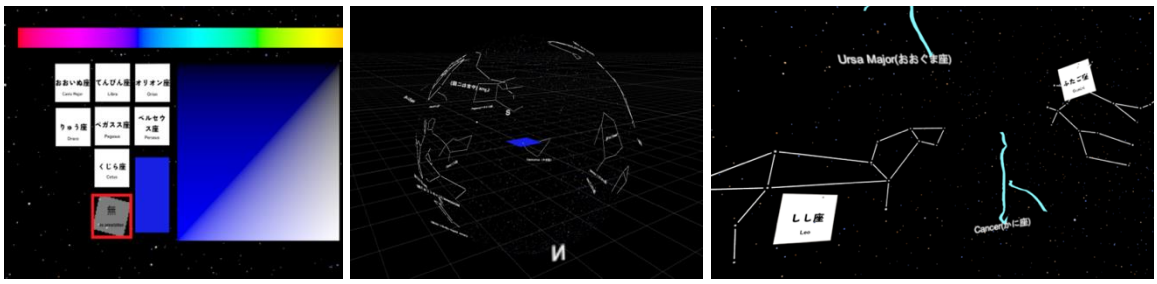

Figure 1. Seiza VR views: annotation selection menu UI (a), exocentric view of the sphere (b, game engine only), and egocentric view (c, in-game only).

2.2. Experimental Procedure

While iterating through versions of the application, we also performed a pilot study to explore how it can be improved as both a learning aid and an evaluation tool for spatial memorization of constellations. Each constellation we selected is presented with a drawing (pre-defined line segments) and a label containing an English and a Japanese name.

After answering a pre-experiment survey about their prior knowledge of constellations and VR technology, we subjected them to two consecutive sessions of **memorization** and **recall**. We prepared two sets of 7 constellations (one set for summer, one set for winter), assigned each set to the condition/independent variable that we wanted to observe (concurrence, i.e., concurrent vs. individual presentation), and counterbalanced the assignments to reduce order effects (i.e., 4 unique combinations of set-concurrence pairs). Participants consistently saw all the stars rendered in 3D space and the letters that indicate the cardinal directions (N, E, W, S). They were also given time to familiarize themselves with the HTC Vive Pro 2 headset and controllers. **During a memorization session**, the VR scene starts with the initial view of the stars and direction labels. Then the experimenter will show the constellation drawings with corresponding labels according to the concurrence condition. In the *concurrent* condition, all 7 constellations are presented for 3 minutes, then immediately hidden for the participant to draw some annotations for 3 minutes. After this, the process repeats for 3 and 2 minutes, respectively. In the *individual* condition, the constellations are shown individually, and participants can opt to proceed to the next constellation upon request. The total time for showing individually and making the annotations is only set to a maximum of 11 minutes for consistency with the other condition. **The recall session** consists of the same initial setup, however, either the drawing or the label is hidden for each constellation (7 hidden labels, 7 hidden drawings). We then ask participants to pin the appropriate labels to the shown constellations and draw the constellations next to the shown labels. To evaluate, we considered an answer correct if the labels matched the existing constellations, or if the drawings resemble the original rendering presented during the memorization session. In one

[1] https://github.com/Firnox/StarrySky

test, a participant can earn as high as 7 points for correct labels, and 7 points for correct drawings. Our main hypothesis is that showing constellations individually may yield higher recall test scores, as the isolation of a shape and a name can create a direct semantic relationship, the sparse environment minimizes distraction, and the cognitive load at any given time is manageable.

3. Preliminary Results and Future Work

We conducted a pilot study with 16 participants who were all university students (aged: 19-24 years old). Most participants (10) are not confident at all with their knowledge of constellations or stars, and most participants (10) have already tried head-mounted displays (whether VR or AR). The results are shown below (Figure 2), which does not support our initial hypothesis. The drawing and labeling score averages are higher in the concurrent condition. However, these scores are not statistically significant, and upon further analysis, scores are imbalanced when the set is considered. Our future work then is focused on selecting the constellations that will be shown as stimuli, and a deeper investigation of the interaction effects between the summer constellation set and the concurrent presentation.

Figure 2. Results of the recall test scores, grouped according to set-concurrence pairs (top) and general scores according to concurrence condition (bottom)

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