Research on the Whole Station's Interior Orientation Cues Oriented to Navigation Enhancement

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Abstract. The large and complex interior space of multi-cabin space station makes the astronauts easily happened to navigational disorder during the travel. With the need to enhance the navigation ability of the astronauts, based on a method study on space station intra-vehicular navigation simulation including both VR visual simulation and physiological HDBR simulation, multiple different sets of sample scenes are designed for the orientation cues numbers reflected by the whole visual orientation cues that has similar form, and the specific form of the whole visual orientation cues that reflects same orientation numbers. Through the experimental data analysis, the influence law of the whole station's interior orientation cues on the navigation task performance and associated physiological effects in the cabin are obtained.

1. Introduction
The multi-cabin space station has a complex three-dimensional axial space structure, and the astronauts are prone to navigation problems in the cabins. The astronauts mainly use visual cues to conduct space navigation[1], one of the visual environmental factors affecting intra-vehicular navigation is the whole station's interior orientation cues.

In this article, the whole station's interior orientation cues refers to the orientation information which is provided by the various elements in the environment, especially the elements that are composed and implied in the space station interior, one of which is the whole station's interior orientation cues. In 2005, Aoki et al. conducted a comparative test on three sets of color schemes of the space station interior bulkhead, the experimental results showed the visual information were effective for improving the target object orientation ability and spatial memory ability of the virtual weightless environment[2]. The research results of Aoki et al. have provided some reference for the design of visual orientation cues in multi-cabin space stations, but there is no further research on whether there are other effective methods for enhancing navigation capability.

Therefore, based on a simulation system of the space station intra-vehicular navigation including both VR visual simulation and physiological HDBR simulation, this paper studies the influence law of the orientation cues numbers reflected by the whole visual orientation cues which have similar form on the intra-vehicular navigation task performance and associated physiological effects, and the influence law of the specific form of the whole visual orientation cues which reflect same orientation cues numbers on the intra-vehicular navigation task performance and associated physiological effects, thus to provide an effective reference for enhancing the intra-vehicular navigation capability of astronauts.

2. The space station intra-vehicular navigation simulation system
In related studies, the VR simulation method is used to simulate the astronauts' visual navigation in multi-cabin space station's interior by Aoki et al[2-5], and the physiological HDBR simulation is a mature method for simulating physiological effects of weightlessness[6,7], therefore, the VR visual simulation and physiological HDBR simulation are combined as the space station intra-vehicular navigation simulation system, as shown in figure 1. The simulation system is composed of the graphics workstation computer 1, the wide-field head-mounted display 2, the three-dimensional mouse 3, and the angle adjustable experimental bed 4. The simulation system's scenario of the virtual space station refers to the structure of the international space station and is slightly modified, as shown in figure 2. The virtual space station consists of two cubic node cabins (Node1, Node2) which are 2×2×2 m³ in size and seven rectangular non-node cabins which are 2×2×6 m³ in size. The interior surface of the cabin is mapped with pictures of the international space station interior, each cabin is distinguished by different visual signs and given unique name.

3. The experiment

3.1. The experimental subjects
A total of 110 (18-28 years old) subjects participated, all without visual or auditory impairment. The subjects were asked to participate in the mental rotation test and visual rotation ability test before the experiment. All the subjects were divided into 11 groups, with 10 people in each group. The distribution of gender and test scores in each group of subjects was balanced.

3.2. The experimental process

3.2.1. The preparation stage of experiment. The subjects were placed on a supine position with the -6 ° head-down posture and wore a wide-view helmet-mounted display, kept this pose for a period of time; then, the simulation program of the virtual multi-cabin space station scene in the graphics workstation was started. The subjects operated the three-dimensional mouse to realize the roaming in the multi-cabin space station and to check the equipment availability.

3.2.2. The navigation training stage of experiment. In the training part, the subjects firstly followed the simulated astronauts walking along nine preset path in the space station, they went through three rectangular cabins and two node cabins that required the observation orientation of the subjects be consistent with the simulated astronaut. The subjects secondly passed through each cabin of the virtual space station, they must used the keyboard or handle to switch the orientation to complete the corresponding task. The subjects were asked to select one of all the paths on the screen and to go to the cabin on their own under the guidance of the simulated astronaut. After reaching the destination, the subjects needed to return to the starting point, if it was wrong, they were asked to try it again. The
subjects visited each cabin three times (except for the American laboratory in the middle of the space station—all paths past through it).

3.2.3. The navigation testing stage of experiment. In the testing part, the subjects were asked to perform orientational and path-finding task, they were asked to indicate the orientation of their destination firstly, then to move as fast as possible to complete the path-finding task, and then to indicate the location of the starting point. There were two parts in this testing part, and each part had 9 tests. In each test, the wrong type r indicating the orientation, the response time indicating the destination and the operation time of completing the evacuation task were recorded. In the orientational task, if the orientational was correct, r=r0, or else r=r1.

In addition, the subjects were asked to dictate oral the space station cabin layout after the completion of all tasks, the staff drew a virtual space station layout map according to the description of the subject and confirmed with the subjects whether it matched the description, the error type e in this layout was recorded. When it was exactly true, e=e0; if the cabin sequence (structure) described by the subjects was correct, but the cabin interior orientation was wrong, e=e1; if the cabin sequence (structure) was wrong, e=e2.

In the process of simulated navigation and autonomous navigation, the head of the subjects received EEG continuous real-time monitoring on the head. Before and after the experiment and related nodes, they also received the head resting FMRI scan to obtain the objective information of the physiological state of the brain. Finally, the staff also asked and recorded the symptoms of motion sickness such as dizziness during the experiment.

3.3. The design of experimental sample scenes

3.3.1. Sample scenes design based on different numbers of the whole orientation cues. Six sets of sample scenes were designed, as shown in figure 3. It showed different orientation numbers of the whole orientation cues (n), where A1 scheme n=0, A2 scheme n=2, A3 scheme n=4, A4 n=6, A5 scheme n=6, A6 scheme n=6. The subjects were informed of the meaning of the orientation each color represented before the experiment began.

![Figure 3](image)

**Figure 3.** A sample scheme showing the numbers of whole orientation cues.

3.3.2. Sample scenes design based on different visual form of the whole orientation cues. Five sets of sample scenes were designed, as shown in figure 4. It reflected different visual form of the whole orientation cues. The B1 scheme reflected different color contrasts, the B2 scheme reflected the color brightness gradient, the B3 scheme reflected the graph arrangement, the B4 scheme reflected the text marking mode, and the B5 scheme reflected the graphic marking mode. Before the experiment began, the subjects were informed of the meaning of the orientation represented by each visual form.

![Figure 4](image)

**Figure 4.** A sample scheme showing the visual form of the whole orientation cues.
3.4. The experimental results and analysis

3.4.1. The experimental results of the sample scenes which reflect the orientation numbers of the whole orientation cues. Through the statistics of the obtained experimental data, we can obtain the comparison chart of the accuracy rate of orientational task, the average time of the path-finding task, the accuracy rate of psychological map task and the proportion distribution of symptoms of motion sickness for different sample scenes which reflect different orientation numbers of the whole orientation cues.

![Figure 5. Comparison of the accuracy rate of orientational task for different samples.](image)

In figure 5, the accuracy rate of orientational task corresponding to A1(n=0) was significantly lower than others (P<0.05); the accuracy rate of the orientational task corresponding to A2(n=2) and A3(n=4) were significantly higher than A4(n=6), A5(n=6) and A6(n=6) (P<0.05).

![Figure 6. Comparison of the average time of path-finding task for different samples.](image)

In figure 6, the average time of path-finding task corresponding to A1(n=0) was significantly higher than others (P<0.05); the average time of path-finding task corresponding to A2(n=2) and A3(n=4) were significantly lower than A4(n=6), A5(n=6) and A6(n=6) (P<0.05).

![Figure 7. Comparison of the accuracy rate of psychological map task for different samples.](image)

In figure 7, the accuracy rate of psychological map task corresponding to A1(n=0) was significantly lower than others (P<0.05); the accuracy rate of psychological map task corresponding to A2(n=2) and A3(n=4) were significantly higher than A4(n=6), A5(n=6) and A6(n=6) (P<0.05).

![Figure 8. Comparison of the proportion distribution of symptoms of motion sickness for different samples.](image)

In figure 8, there was no significant difference in the proportion of mild, moderate and severe motion sickness symptoms in all samples (P>0.05).

Conclusion and analysis: Compared with the situation without the whole orientation cues, the setting of the whole orientation cues can improve the navigation task performance to some extent, but the symptoms of motion diseases such as dizziness have not been significantly improved. As the orientation number n (0≤n≤6) of the whole orientation cues increases, the navigation task performance does not appear to improve continuously; when the orientation number of the whole orientation cues is n=2 or n=4, the navigation task performance is relatively high.

3.4.2. The experimental results of the sample scenes which reflect visual forms of the whole orientation cues. Through the statistics of the obtained experimental data, we can obtain the
comparison chart of the accuracy rate of orientational task, the average time of the path-finding task, the accuracy rate of psychological map task and the proportion distribution of symptoms of motion sickness for different sample scenes which reflect different visual forms of the whole orientation cues.

**Figure 9.** Comparison of the accuracy rate of orientational task for different samples.

In figure 9, the accuracy rate of orientational task corresponding to B4 (text mark) was significantly lower than others (P<0.05); the accuracy rate of the orientational task corresponding to B1 (color contrast), B2 (brightness gradient) and B3 (graphic arrangement) were significantly higher than B5 (graphic identification) (P<0.05).

In figure 10, the average time of path-finding task corresponding to B4 (text mark) was significantly higher than others (P<0.05); the average time of path-finding task corresponding to B1 (color contrast), B2 (brightness gradient) and B3 (graphic arrangement) were significantly lower than B5 (graphic identification).

**Figure 10.** Comparison of the average time of path-finding task for different samples.

**Figure 11.** Comparison of the accuracy rate of psychological map task for different samples.

In figure 11, the accuracy rate of psychological map task corresponding to B4 (text mark) was significantly lower than others (P<0.05); the accuracy rate of psychological map task corresponding to B1 (color contrast), B2 (brightness gradient) and B3 (graphic arrangement) were significantly higher than B5 (graphic identification) (P<0.05).

In figure 12, there was no significant difference in the proportion of symptoms of mild, moderate and severe motion diseases in all samples.

**Figure 12.** Comparison of the proportion distribution of symptoms of motion sickness for different samples.

Conclusion and analysis: compared with different visual forms of the whole orientation cues, the visual form of color and graphics are more effective in improving navigation task performance than text; large area distribution is more effective in improving navigation task performance than small area distribution; but the symptoms of motion diseases such as dizziness have not been significantly improved.

4. Conclusion

With the need to enhance the navigation ability of the astronauts, based on a method study on space station intra-vehicular navigation simulation including both VR visual simulation and physiological HDBR simulation, multiple different sets of sample scenes are designed for the orientation cues numbers reflected by the whole visual orientation cues that have similar form, and the specific form of
the whole visual orientation cues that reflects same orientation numbers. Through the experimental data analysis, the influence law of the whole station's interior orientation cues on the navigation task performance and associated physiological effect in the cabin are obtained. The research could provide reference for the space station interior design engineering in the orientation of the cabin visual navigation capability.

5. References

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