Predicting Performance in Space Teleoperation Tasks Through Vernier Acuity

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Abstract. In order to analyze whether vernier acuity index can predict space teleoperation performance or not, twelve subjects participated in the experiment. A simulated robotic arms teleoperation task was adopted to detect space teleoperation capability and four kinds of vernier acuity were also measured. Pearson correlation test was conducted between teleoperation task performance and four patterns of vernier acuity, results showed two significant positive correlations. One correlation was between position difference and vertical center vernier acuity ($p < 0.01$), and the other one was between angular difference and horizontal center visual acuity ($p < 0.01$). The positive correlations indicating that better vertical center vernier acuity meant smaller position difference in the horizontal direction and better horizontal center visual acuity caused smaller pitch deviation in space teleoperation tasks.

Keywords: Teleoperation · Vernier acuity · Robotic arms · Rendezvous and docking

1 Background

Teleoperation means a manually operation method which control the target with the physical distance between the operators and operands [1]. In this process, operators need to sensor the camera image feedback to get relevant information [2, 3]. Space teleoperation tasks means either or both of operator and operands are in special space environment. Many features of robot machine and spatial environment as well as human capacity may affect performance in space teleoperation tasks [4]. There are two key factors associated with human capacity which named remote sensing and remote operation considering the system in the perspective of ergonomics [5]. For the effective operation of the robot to perform the task, the operator needs to obtain sufficient information from the Human-Computer Interface to percept working conditions and send control commands accurately. Perceptual ability is the cognitive basis of excellent operating performance in a certain extent [6]. Visual stimuli accounted for more than 80 % in the amount of information used by human to percept external environment, so the information provided by image from Human-Computer Interface, which reflects real physical scene and other data of machine, are the most important information to ensure the completion of operation.

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There are two important aspects of Human-Computer Interface in space teleoperation tasks. One aspect is input interface from system to human, which contains distal environmental information, machine motion and sensor information transmitted to the operator from a display device. The other aspect is output interface to system from human, such as a mouse, keyboard and handles interface through which control commands are assigned to the computer system by operator [7]. Two aspects constitute the teleoperation interactive display and control interface and details on this interface are very pivotal for mission completing.

Vernier acuity is one of effective test indicators to reflect discrimination ability of spatial detail clues both in central vision field and peripheral vision field and it is a representative index in perceptual learning effect [8]. In a vernier acuity test, observers need to detect an offset between two abutting grating segments. It is thought to be a hyperacuity index mediated by fairly low-level visual mechanisms. Different purposive training methods can improve vernier acuity just like that training can improve performance in space teleoperation tasks [9, 10].

So the purpose of this research is to check the correlation between space teleoperation performance and vernier acuity. We assumed that operators with higher vernier acuity could perform better in space teleoperation tasks.

2 Method

2.1 Subjects

Twelve male participants with an average age of 23.75 years (ranging from 23 to 25) participated in this study. The participants were all right-handed. None of the participants suffer from eye diseases except eight of them are myopic and their visual acuity or corrected visual acuity was 1.0 or more. All subjects were gave informed consent prior to their participant in the study and received reward after participation.

2.2 Measurements

A typical task which named simulated robotic arms teleoperation task was adopted to detect space teleoperation capability. It is a simulated mission that request subjects to control a robotic arm with six joints to complete insert task. All the six joints suffer restricting rotational angle, but their cooperation can make the terminal of arm achieve six motion degree in the workspace. The six motion degree includes three position degree (front - back, left - right, and up – down) and three postural degree (roll, pitch and yaw). The simulation software platform was shown in Fig. 1. In the experiment, subject operator needs to observe image information provided by a liquid crystal display in perspective of a fixed camera, and then control two different handles (one for position degree and one for postural degree) with both hands to complete docking tasks.

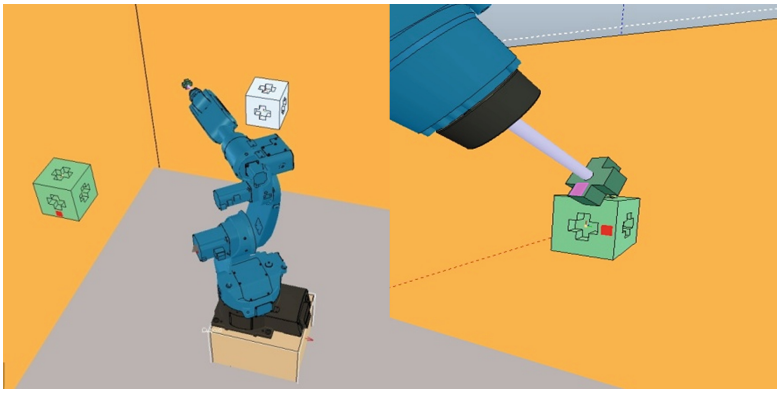
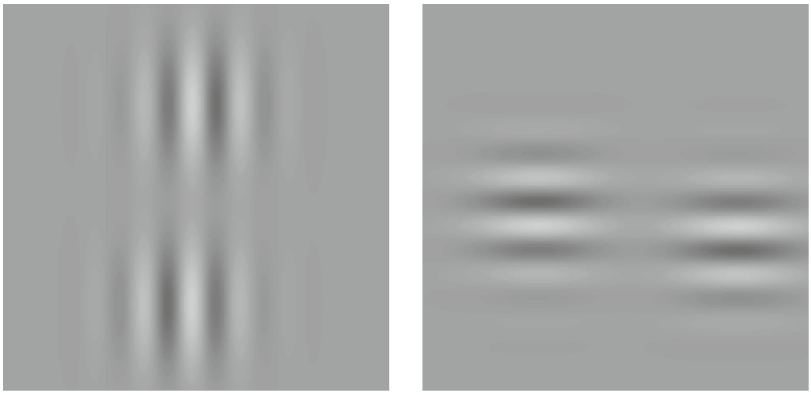


Fig. 1. Simulation software platform of robotic arms

Vernier acuity test was generated using Psychtoolbox Packages in Matlab 2012b. In the test, subjects need to detect an offset between two abutting grating segments (Fig. 2). There are two types of stimuli with different arrangements of two gratings (horizontally or vertically aligned), and the contrast of gratings were 45 % in both types. In addition, there are two positions (center and top left of the screen) for stimulus presentation. In order to ensure that subjects gaze at center of the screen, a letter H or N would present at the center of the screen simultaneously with gratings which presented at top left and subjects were asked to response letter name firstly before detect offset of gratings. So we measured four kinds of vernier acuity values from each subject using limit method in psychology.



a) b)

Fig. 2. Different arrangements of two gratings for vernier test. (a) vertically aligned for vertical vernier acuity measurement; (b) horizontally aligned for horizontal visual acuity measurement.

2.3 Procedure

In the experiment, subjects need to complete six teleoperation tasks with same difficulty through simulation software platform and then underwent vernier acuity test. In the test, the subject viewed the stimuli binocularly from a distance of 4 m with darkroom environment. A chinrest was used to ensure that the central visual field was in the center of the display screen. The whole process lasted for about one hour.

3 Results

Cumulative position difference and angular difference of four teleoperation tasks excluding the worst two operations were chosen to represent for teleoperation performance. Four kinds of vernier acuity were represented by minimum viewing angle value. Data of twelve subjects was shown in Fig. 3.

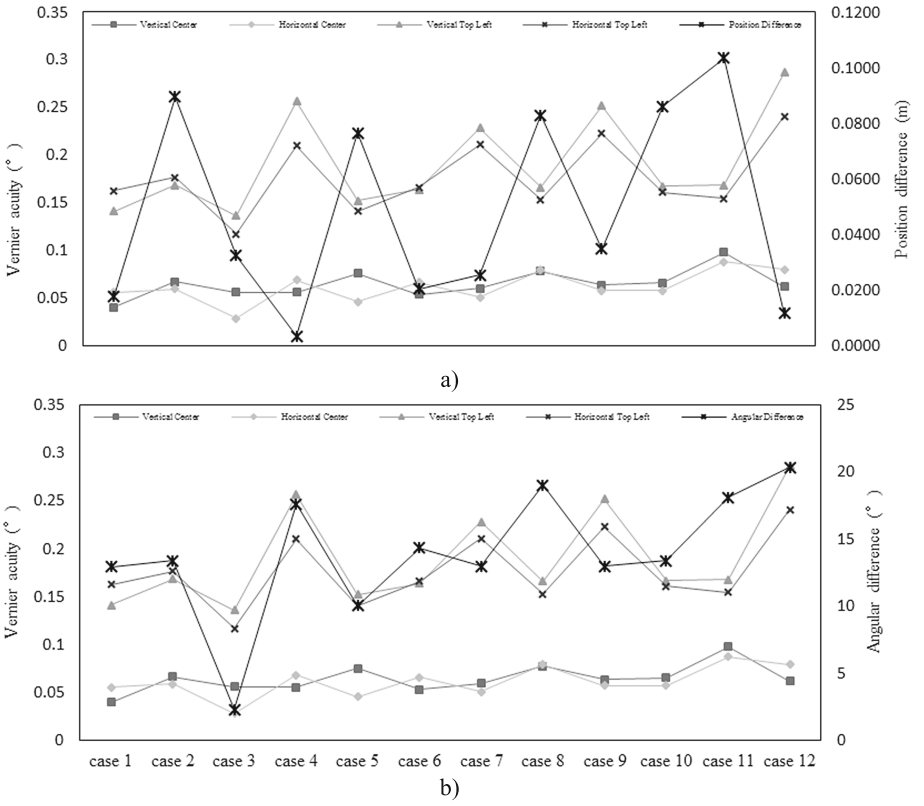


Fig. 3. Teleoperation performance and vernier acuity data of twelve subjects

Average value of subjects' data was calculated. Average position difference was 0.04866 m and average angle difference was 10.34°. Four kinds of vernier acuity average value were shown in Fig. 4.

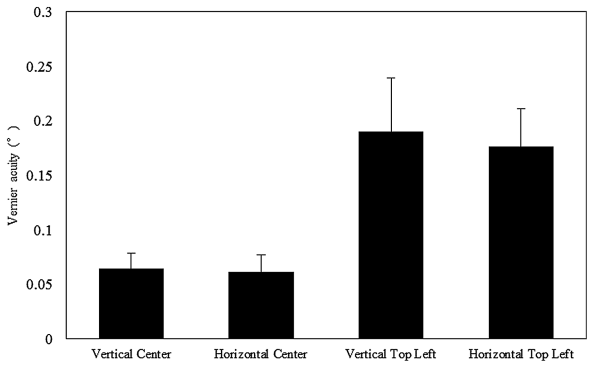


Fig. 4. Average value of subjects' four kinds of vernier acuity

Pearson correlation test was conducted between teleoperation task performance (positional difference and angle difference) and four patterns of vernier acuity, results were shown in Table 1.

Table 1. The correlation coefficient by pearson correlation test

Vernier acuity	Vertical center	Horizontal center	Vertical top left	Horizontal top left
Position difference	0.793[a]	0.196	–0.499	–0.499
Angular difference	0.311	0.947[a]	0.517	0.562

[a]Correlation is significant at the 0.01 level (2-tailed).

4 Discussion

In order to check the correlation between space teleoperation performance and vernier acuity, twelve subjects participated in simulated robotic arms teleoperation tasks and vernier acuity measurement. Subjects' teleoperation performance and four kinds of vernier acuity were generally similar except case 3's angular difference (2.31°) indicating their operating capacity and visual ability was approximately the same to a certain degree. Comparison between four kinds of vernier acuity showed that central vernier acuity (0.0645° and 0.0613°) was better than peripheral vernier acuity (0.1904° and 0.1763°), which was consistent with human visual characteristics.

There are only two significant positive correlations through pearson correlation test conducted between teleoperation task performance and vernier acuity. One correlation was between position difference and vertical center vernier acuity ($p < 0.01$), and the other one was between angular difference and horizontal center visual acuity ($p < 0.01$). The interesting result indicated that center vernier acuity did affect teleoperation performance while peripheral vernier acuity did not, and different kinds of center vernier acuity influenced different aspects of teleoperation performance. Vertical center vernier acuity which measured ability to distinguish horizontal differentiation

was closely linked with position difference indicating that position difference in the horizontal direction (left – right) was a key factor in the teleoperation performance. Similarly, horizontal center visual acuity which measured ability to distinguish vertical differentiation was closely linked with angular difference indicating that angular difference in the vertical direction (pitch) was also a key factor in the teleoperation performance.

5 Conclusion

Central vernier acuity of young men was better than their peripheral vernier acuity. Performance in space teleoperation task could be predicted by vernier acuity to some extent. Operators with higher center vernier acuity could perform better in space teleoperation tasks. Specifically, better vertical center vernier acuity meant smaller position difference in the horizontal direction and better horizontal center visual acuity caused smaller pitch deviation.

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