Study on Astronauts' Workload of Typical Tasks in Orbit

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ABSTRACT

In order to arrange astronauts' long-term working properly in the space station in the future, this study evaluated the workload of astronauts' typical tasks in the Shenzhou-10 spacecraft. The seven tasks were selected as typical tasks including replacing the floor, assembling a dynamometer on a bike, connecting the pipeline of the condensed water for sampling test, pulmonary function tests after exercise, tests of oxygen producing with electrolysis, and manual-control rendezvous and docking. Through subjective measurement instrument modified NASA-TLX, the results indicated that astronauts' workload of replacing the floor were the highest among the 7 tasks. And then followed was the workload from pulmonary function tests after exercise and the tests of oxygen producing with electrolysis. The workload from the task b1, Y1 was relative low. Although the task J1 was more complex and difficult, the astronauts' workload was not high.

Keywords: Astronauts' workload, subjective measurement, typical tasks in orbit

INTRODUCTION

Astronaut crews in the Shenzhou-10 spacecraft far from the earth conducted many kinds of tasks every day. Due to the astronauts working in the weightless condition, the workload of a task in orbit would be different from in earth. Therefore, the workload of astronauts' tasks in orbit should be arranged in a proper level. Only then they can maintain good performance in long time. Otherwise, overload arrangement not only affects the working efficiency, but also affect the physical and mental health of the astronauts. Therefore, the aim of this study is to evaluate the workload of astronauts' typical tasks in the Shenzhou-10 spacecraft. The results could provide support for astronauts' tasks of arrangement of long-term working in the space station in the future. At present workload could be measured by the physiological methods or subjective methods. And subjective measurement has been used as the most essential method among all workload measures. This is because subjective measures could reflect the amount of information used in working memory (Yeh and Wickens 1988, Johannsen, 1979). The subjective tests are flexible for different people with different capabilities. Among the subjective measurements, the NASA Task Load Index is one of the most widely accepted. The scale includes six dimensions. Generally, the NASA-TLX is an extremely good multidimensional scale for measuring mental workload and sensitive to changes inworkload (Byers, et al. 1989; Hill, et al., 1992). Therefore, this study measured astronauts' workload referred to NASA-TLX.

METHODOLOGY

Astronauts' typical tasks in orbit

During Shenzhou-10 spacecraft in space flight, 3 astronauts completed many tasks such as monitoring and controlling the instruments in the cabin, manual-control rendezvous and docking, some experiments and so on. Among these tasks this study selected 7 items as typical tasks for workload evaluation, which were replacing the TG-1 floor (D1, D2), assembling a dynamometer on a bike (B1), connecting the pipeline of the condensed water for sampling test (L1), pulmonary function tests after exercise (Y1), tests of oxygen producing with electrolysis (O1), manual-control rendezvous and docking (J1). The 7 tasks were divided into three groups for the three astronauts. Each group of tasks was assigned for one astronaut to complete mainly. The first group of tasks included D1, D2, and J1. One astronaut as a main operator and another one as an auxiliary person would complete this group of tasks. The second and third group of tasks contained B1, L1, Y1, and O1 respectively, which two astronauts should complete one group of tasks respectively.

The Instrument

Because of limited resources in space cabin, this study adopted a set of subjective instruments for measuring astronauts' workload. The instruments were modified NASA Task Load Index scale (NASA-TLX, Byers, et al. 1989, Hart and Staveland, 1988). The NASA-TLX is a multi-dimensional rating procedure that provides an overall workload score based on a weighted average of ratings on six subscales: Mental demands, physical demands, temporal demands, own performance, effort, and frustration. In a driving situation, Park and Cha (1998) found that the NASA Raw Task Load Index (NASA-RTLX) scale was the more sensitive to mental demand and difficulty in driving than the TLX. Therefore, the weight of each subscale was computed in the light of RTLX in this study. In addition, according to the condition in space and Chinese habits, Xiao (2005) adapted the scale into five subscales or dimensions, which are mental demands, physical demands, temporal demands, effort, and frustration. This study adopted the modified NASA-TLX including five dimensions and the full scores of each dimension are 10. After completing one task, the astronauts answer the instrument. The three astronauts answered 14 instruments for all tasks, and 13 of the answers were effective.

Procedure

First of all, typical tasks of every astronaut for workload evaluation were determined. Then, NASA-TLX scale was modified to suit for Chinese astronauts. After that, every astronaut was trained to know how to answer the instrument. At last, the instrument was installed in the tablet PC with the astronauts. After completing one task, the astronaut would answer an instrument.

RESULTS AND DISCUSSION

Reliability and validity

Reliability of an instrument is defined as the extent to which an instrument yields the same results on repeated measurements (Carmines and Zeller, 1990). Cronbach's alpha (Cronbach, 1951) is widely used as internal consistency. An alpha (α) value of 0.70 or above is considered as strong internal consistency (Nunnally, 1978). The Cronbach's alpha value of this study was 0.736. It implicated the reliability of the instrument used is strong.

Validity is concerned with the study's success at measuring what the researchers want to measure. Construct validity is defined as the extent to which the instrument measures the concept it is presumed to measure (Carmines and Zeller, 1990). The modified instrument has been tested by Exploratory Factor Analysis (EFA). The results indicated that 76.53% of total variance could be explained. All of factor loadings were more than 0.85. So, construct validity of the instrument is satisfied.

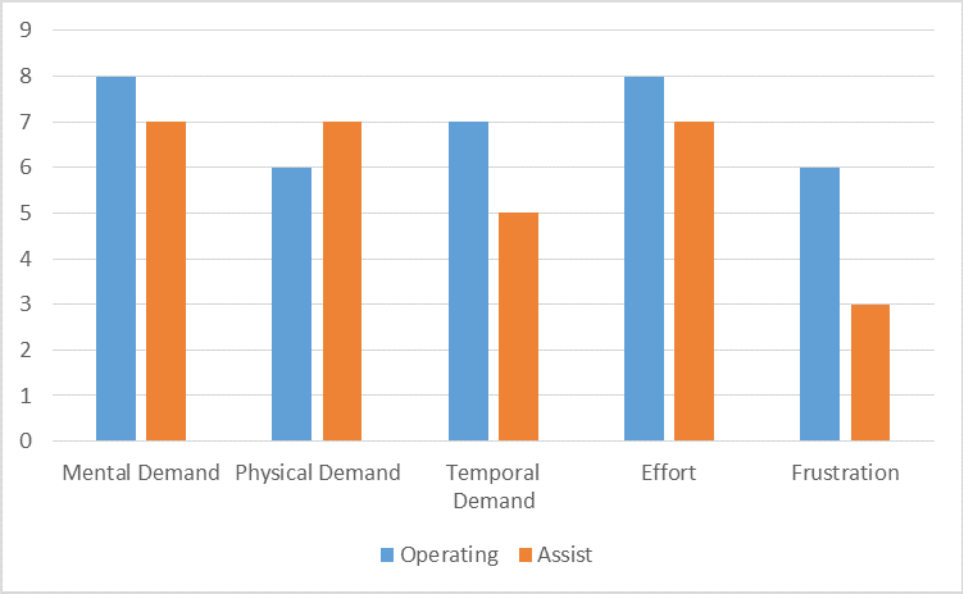
Results from the modified NASA-TLX scale

Table 1 The scores from the modified NASA-TLX scale

Subject	Task	Mental demands	Physical demands	Temporal demands	Effort	Frustration	Total scores
1	D1	8	6	7	9	6	66
1	D2	9	8	8	9	6	69.49
1	B1	3	3	4	4	2	38.01
1	L1	2	4	4	4	2	33.17
1	Y1	7	7	8	7	6	66.51
1	O1	6	4	5	6	6	49.49
1	J1	9	1	9	8	3	48
2	D1	7	7	5	7	3	56.67
2	D2	7	8	7	5	5	61.34
2	B1	5	4	5	3	1	38.34
2	L1	1	2	2	1	0	31.66
2	O1	5	6	4	5	5	49.84
2	J1	4	5	6	5	4	47.99

Workload analysis of D1, D2, and J1

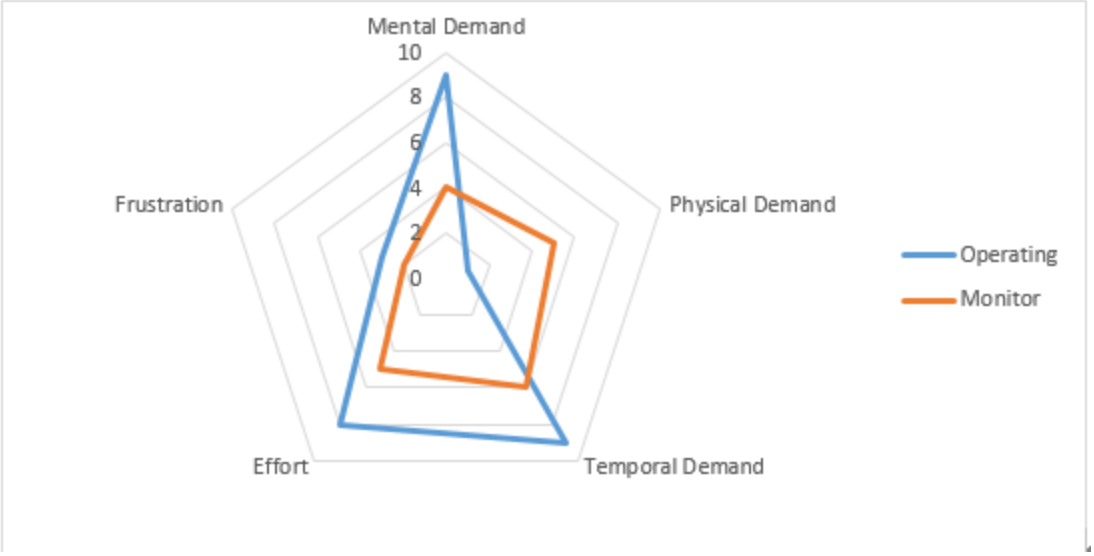
For the tasks D1 and D2, the total scores from the modified NASA-TLX scale were the highest among the 7 tasks. The total scores of main operating astronaut were 66.00 and 69.49, and the total scores of auxiliary astronaut were 56.67 and 61.34. Figure 1 showed the further comparison of the two persons in five dimensions. The scores of each dimension was the average value of two tasks' measurement. The results in the figure 1 indicated that the scores of the two dimensions mental demands and effort were higher than the others' for the operating astronaut, followed by temporal demands and physical demands. And for the auxiliary astronaut the scores of the two dimensions physical demands and mental demands were higher than the others'. These results illustrated that the workload of the two tasks is relatively high. The first reason is that in the course of conducting tasks D1 and D2, the astronaut not only needs to transit and fix the floor, but also exactly install and check them. What is important was that these jobs were completed in the condition of weightless. The condition was different from environment in the earth, which the astronaut was not easy to control their position. In addition, the number of times of being trained in the earth of changing the floor was least.



(the operating astronaut, the auxiliary astronaut)

Figure 1 Workload comparisons of the two persons in five dimensions (Tasks D1 and D2)

The task J1 is an important operation for the astronaut, which another astronaut monitored the operation while one astronaut was operating. The total scores of operating astronaut and monitoring astronaut were 48.00 and 47.99. Figure 2 showed the further comparison of the two persons in five dimensions. The scores of the three dimensions mental demands, temporal demands and effort were higher than the others' for the operating astronaut. And for monitoring astronaut the scores of the five dimensions were low and little fluctuation compared with the operating astronaut. The results indicated that this task was an important and complex job and needed higher reliability and accuracy. Compared with the tasks D1 and D2, the total scores were lower, although the task J1 was more complex and difficult. The first reason was that the number of times of being trained in the earth was more than those of the tasks D1 and D2. And the astronauts were bound in the course of operating. So the astronauts could control their position while operating relatively.



(Operator, monitor)

Figure 2 Workload comparisons of the two persons in five dimensions (Tasks J1)

Workload analysis of B1, L2, Y1 and O1

For the tasks B1, L1, Y1, and O1, the total scores from the two astronauts' were shown in figure 3. Except for the task Y1 that only one astronaut completed it the other tasks were completed by the two astronauts. Through the result of the total scores of the task Y1, workload of the astronaut was higher than those of the other tasks. And the workload from the task O1 was relative high. In addition, the total scores of these tasks from the two astronauts' were very close.

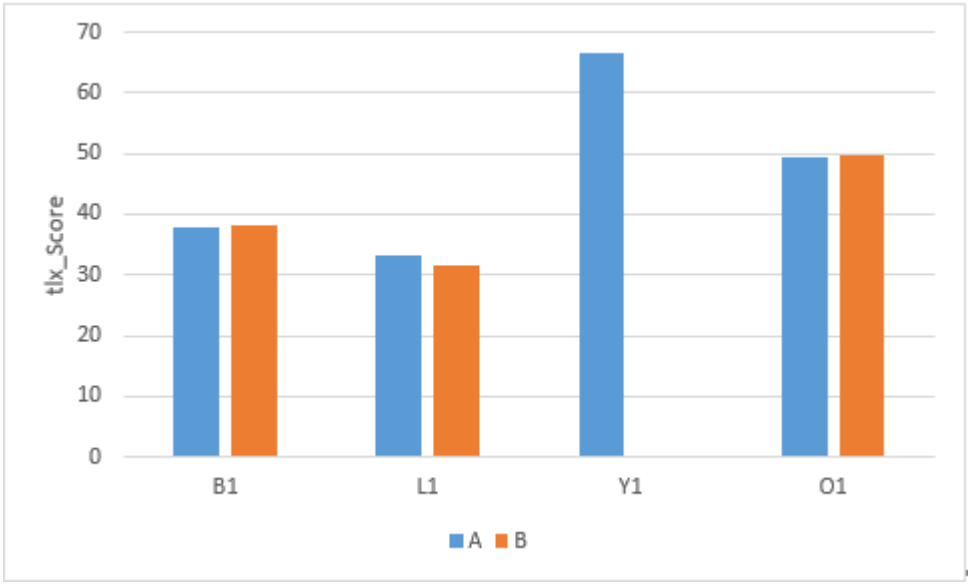


Figure 3 Workload comparisons of the two persons (Tasks B1, L1, Y1, and O1)

CONCLUSIONS

The aim of this study is to evaluate the workload of astronauts' typical tasks in the Shenzhou-10 spacecraft. Seven tasks were selected for subjective measurements by modified NASA-TLX. The results indicated that astronauts' workload of tasks D1 and D2 were the highest among the 7 tasks. And the workload from the task Y1, O1 was relative high and the workload from the task B1, L1 were relative low. From the results presented in the previous section, this study suggested that the number of times and methods of being trained in the earth are very important for reducing astronauts' workload in orbit. Then simple manipulation and few steps could also decrease the workload, for example the task L1. The astronauts' workload of typical tasks from this study will provide data and methods support for further study on space experimental tasks. And the results also provide support for astronauts' tasks of arrangement in cabin of space station in the future.

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