Ergonomic evaluation of aircraft maintenance based on VACP model

Xiao Chen [1], *Zhen Zhang* [2], *Xin Song* [3], *Xiang Xu* [2], *Jianwei Niu* [2,*]

[1] *Military Institute of Engineering and Technology, Academy of Military Sciences, Beijing, China100088*

[2] *School of Mechanical Engineering, University of Science and Technology Beijing, China 100083*

[3] *Ocean University of China, Shandong, China 266100*

ABSTRACT

With the increasing workload of civil aircraft maintenance personnel, it is of great significance to study the workload assessment of civil aviation maintenance personnel. However, the existing workload assessment methods have problems. The VACP model, a powerful cognitive tool, proposes that workload consists of Visual (V), Auditory (A), Cognitive (C), and Psychomotor (P). The VACP model can reflect the nature of workload more comprehensively. This paper designs a workload evaluation system based on VACP model. This system can be anticipated to be applied to aircraft maintenance workload assessment, and to greatly improve maintenance efficiency, which has a great significance for the ergonomic status of the maintenance personnel.

Keywords: VACP model, Ergonomic evaluation, Maintenance workload assessment

INTRODUCTION

With the continuous growth of China's aircraft traffic and the continuous ex-pansion of fleet size, higher requirements are put forward in the field of aircraft maintenance and design in order to ensure the safe operation of aircraft. Due to limited resources such as the operator's information processing capacity, memory and attention, unreasonable workflows and unbalanced workloads can lead to operator performance degradation and even errors when conducting heavy and time-critical tasks. Therefore, it is of great significance to study the workload of civil aviation maintenance personnel (Sahay A, 2012).

At present, the main methods of workload assessment, such as questionnaire sur-vey, secondary task evaluation and physiological index evaluation, provide great help for workload assessment (Rubio S et al. 2004). Whereas the questionnaire method is susceptible to the influence of expert experience, the secondary task evaluation method has higher requirements for experimental design and control, and the physiological index evaluation method has more complicated physiological sig-nal acquisition procedures, long cycle and high experimental cost (Haapalainen E et al. 2010) (Ryu K and Myung R. 2005). The VACP model (Mitchell D K, 2000), a powerful cognitive tool, proposes that workload consists of Visual (V), Auditory (A), Cognitive (C), and Psychomotor (P). The VACP model can reflect the nature of workload more comprehensively.

This paper designs a workload evaluation method based on VACP model. We set up the therblig's analysis function module, a workload evaluation module based on the VACP model. In addition, in order to verify the effectiveness of the second function, this paper took civil aviation aircraft maintenance tasks as the research object and recruited a total of 6 male college students to participate the maintenance experiment. The experiment verifies the accuracy and validity of the system output.

METHOD

Therblig's analysis

In the early stages of his research, Gilbreth broke down hand-centered tasks into 17 movements and labeled them with different markers. A therblig is the smallest unit that constitutes the action of an operation. According to the effects of therbligs on operation, therbligs can be divided into three categories: effective therbligs, auxiliary therbligs and ineffective therbligs. The goal of kinetic element analysis is to delete invalid therbligs, reduce auxiliary therbligs, optimize and analyze the actual operation process, develop standardized operation process, and improve work efficiency.

Description	Abbreviate	Category
Transport empty	TE	Effective therbligs
Grasp	G	
Transport load	TL	
Position	P	
Assemble	A	
Disassemble	DA	
Use	U	
Release load	RL	
Inspect	I	
Search	SH	Auxiliary therbligs
Select	ST	
Plan	PN	
Pre-position	PP	
Hold	H	Ineffective therbligs
Unavoidable Delay	UD	
Avoidable Delay	AD	
Rest	R	

Figure 1 Descriptions and categories of Therbligs

VACP model

The VACP model, a powerful cognitive tool, proposes that workload consists of Visual (V), Auditory (A), Cognitive (C), and Psychomotor (P). The VACP model can reflect the nature of workload more comprehensively. VACP models are primarily used to assess the workloads in jobs and their associated tasks. When the operator completed the maintenance task, the four channels in each task were rated on a scale of 1 to 7 based on the VACP scale, and the four scores were later summarized to calculate the total unit task load. The method is highly diagnostic, highly effective, and relatively easy to understand.

Table1 VACP Scale

Channel	Score	Description
Visual	0	No vision
	1	Detection
	3.7	Identify
	4.0	Check
	5.0	Alignment, positioning
	5.4	Track, follow
	5.9	Reading
	7	Search and monitor
Auditory	0	No hearing
	1	Detection
	2	Identify the direction of sound

	4.2	Confirm the location of the sound
	4.3	Verify auditory feedback
	4.9	Explain the semantic content
	6.6	Distinguish the characteristics of sound
	7	Explain the pattern of sound
Cognitive	0	No cognition
	1	Unconscious
	1.2	Choose
	3.7	Identify
	4.6	Assessment and Judgment (considering one side)
	5.3	Decode, encode, recall
	6.8	Evaluation and Judgment (considering many aspects)
	7	Evaluation, calculation, conversion
Psychomotor	0	There is no movement
	1	Speak
	2.2	Press a button, switch
	2.6	Continuous adjustment
	4.6	Manual operation
	5.8	Turn the button and adjust
	6.5	Writing
	7	Keyboard input

For any maintenance, the module can decompose the activity into a combination of maintenance therbligs, together with related attributes such as name, type and duration. The system determines whether there are uneconomical, unbalanced, and unreasonable phenomena in the action through the Gilbreths principle, and the rational adjustment of the operator's action flow, so as to achieve the improvement of the overall efficiency of the operator's maintenance work, and to make the operator's physical and mental pleasure to a certain extent promote.

A workload evaluation module based on the VACP model design

We evaluated the workload values of the four channels according to the maintenance video. The system will calculate the workload of the maintenance operator based on the VACP function, and output the calculation results as a line graph to the system interface.

Experiment Design

Based on the A320 main wheel disassembly and maintenance task, an evaluation test was conducted on the workload of the operator in the maintenance process, and the effectiveness of a workload evaluation module based on the VACP model of the system was verified by the subjective evaluation value of the workload of the subjects. Correlation analysis was conducted between the subjective evaluation value and the calculated value of a workload evaluation module based on the VACP model to verify the accuracy and effectiveness of a workload evaluation module based on the VACP model.

Participants

In this experiment, a total of 6 subjects were male postgraduates from University of Science and Technology Beijing, aged between 23 and 25 years old, with nor-mal vision and hearing. The subjects were trained uniformly before the test to make them proficient in the maintenance task operation of A320 main wheel disassembly. In each experiment, one person participated 2 experiments, and a total of 12 experiments were conducted.

Experimental Facility and Procedure

Head-mounted camera and global camera are required to record the experiment. The test procedure was that each subject watched the maintenance video through the system software, scored each maintenance action from four aspects of VACP, and filled in the subjective evaluation table after completion of the operation, as shown in the table 1.

Table 1 Subjective evaluation table

Number	**Evaluation of project**	**Evaluation content**	**Load rating (1-10)**
1	Preparation before disassembly	Place a warning board	
2		Pull out the following jump switches and hang the warning board	
3		Put the stop brake switch to ON position	
4		Jacking the aircraft until the tire is at a certain height from the ground	
5		Deflate the tire completely	
6	The first is the working process of removing the	Remove screws and gaskets	
7		Pull the fan cover outward along the center line of the wheel shaft	
8		Cut the nut fuse that holds the fan blade	

9	fan	Take out the spring clasp at the bottom of the nut with needle-nose pliers	
10		Fix the blade, remove the nut, and take out the gasket	
11		Pull out the fan blade tray along the center line of the wheel shaft	
12	The next step is to remove the wheel pressure sensor (optional)	Loosen the electric plug, and install the electric plug protection cover	
13		Remove cotter pin and discard	
14		Remove the wheel pressure sensor fastening screw	
15		Remove the wheel pressure sensor, remove the sealing ring and discard	
16		Remove the wheel pressure vent plug and install it on the new tire	
17	This is followed by the removal of the ring cover and bracket	Remove the screw and remove the ring cover	
18		Loosen the clamp screw、clamp, remove bracket	
19	Finally, the working process of removing the wheel	Split pins of two safety nuts removed and discarded	
20		Loosen and remove two sets of screws, nuts and gaskets	
21		Install the protective cover and apply grease, Remove the wheel	

RESULTS

We put the system results and subjective evaluation table results into a table for analysis, as shown in the Table 2. In the workload study, correlation analysis was used to verify the effectiveness of the system. Since the dimensions of the evaluation results obtained by the system and subjective evaluation are not uniform, the z-Score standardization method was first used to standardize the calculation results of the two methods. Then, data analysis software was used for correlation analysis, and the correlation coefficient was 0.93 ($p < 0.05$), which was a significant correlation. Figure 2 shows the workload values obtained by applying the two methods. The trend of lines is basically synchronous and relatively consistent, indicating that the load model has certain validity and reliability.

Table 2 Comparison between System results and Subjective assessment results

Number	System results	Subjective assessment results
1	14	3
2	16.8	4
3	22.4	6
4	22.4	6
5	22.4	6
6	25.2	7
7	22.4	6
9	16.8	4
10	16.8	4
11	22.4	6
12	28	7
13	25.2	6
14	28	10
15	22.4	6
16	22.4	6
17	14	4
18	30.8	9
19	22.4	6
20	30.8	8
21	22.4	6

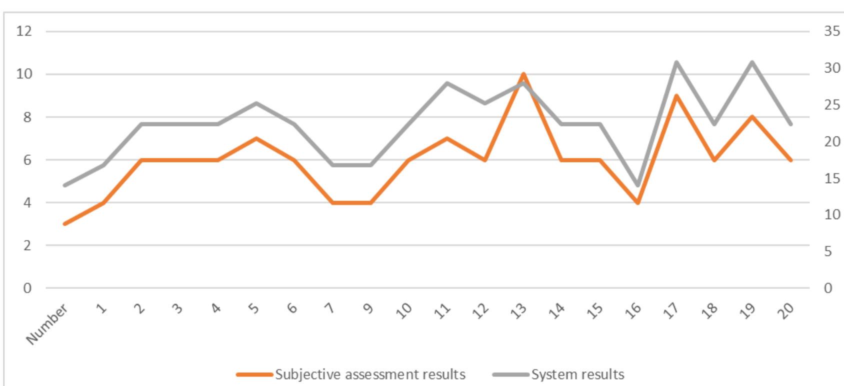

Figure 2 Comparison between System results and Subjective assessment results

CONCLUSIONS

For the maintenance task, the A320 main wheel disassembly and assembly maintenance task test was carried out. The output result of this system is significantly related to the subjective evaluation result. And compared with the current existing evaluation model, the model proposed in this paper is more accurate and effective. However, the function model of the system based on the VACP model ignores the time factor, because the length of the task will affect the operator workload. Therefore, the function model should consider the maintenance work-load with the time variable in the future. This system can be anticipated to be applied to aircraft maintenance workload assessment, and greatly improve maintenance efficiency, which has a great significance for the ergonomic status of the maintenance personnel.

REFERENCES

Sahay A. Leveraging information technology for optimal aircraft maintenance, repair and overhaul (MRO). Elsevier, 2012.

Rubio S, Díaz E, Martín J, et al. Evaluation of subjective mental workload: A comparison of SWAT, NASA - TLX, and workload profile methods. Applied psychology, 2004,53(1):61-86.

Haapalainen E, Kim S, Forlizzi J F, et al. Psycho-physiological measures for assessing cognitive load//: Proceedings of the 12th ACM international conference on Ubiquitous computing, 2010.

Ryu K, Myung R. Evaluation of mental workload with a combined measure based on physiological indices during a dual task of tracking and mental arithmetic. International Journal of Industrial Ergonomics, 2005,35(11):991-1009.

Mitchell D K. Mental workload and ARL workload modeling tools. Army Research Lab Aberdeen Proving Ground MD, 2000.