Predictive Probability Model of Pilot Error Based on CREAM

Xiaoyan Zhang[1], Hongjun Xue[1], Yingchun Chen[2], Lin Zhou[2], and Gaohong Lu[1]

[1] School of Aeronautics, Northwestern Polytechnical University, Shanxi Xi'an 710072, China
[2] Commercial Aircraft Corporation of China, Ltd. Shanghai 201210, China
zxyliuyan@sina.com, xuehj@nwpu.edu.cn

Abstract. Prediction of pilot error is key of human-machine interface design in the cockpit, and is also an effective way on the reduction of accident ratio caused by human error. CREAM (Cognitive Reliability and Error Analysis Method) has been chosen to build the predictive probability model of pilot error based on investigation of various methods. The pilot error model built can be used not only to analysis the reason of accident but predict the error probability in particular scene. The model is validated through the experiment that pilots read the altitude during flight in different visibilities and time limits. The CPC (common performance conditions) including cockpit design, crew communication and other environment such as weather condition is always analyzed and calculated during the whole task analysis and then the reason of pilot error can be discovered qualitatively. The results are important for cockpit design to improve the airplane safety.

Keywords: pilot error, CREAM, error probability prediction, human-machine interface, cockpit design.

1 Introduction

Human error during flight is an inaccuracy decision or action which influences system performance or efficiency even safety. The researcher and engineer always use the following models to analysis the human error such as SHEL[1], Reason[2, 3], HFACS[4, 5], CREAM[6,7,8,9,10] and MEDA[5]. The methods all have their advantages and disadvantages. CREAM as the typical second generation human reliability analysis method considers the error probability can be controlled by the ability of people controlling the situation. The model emphasizes the human performance is not a isolated random action but depends on the task condition or the environment. The task condition can determine the human response through influencing the human cognitive mode and the following effects in different cognitive situations. CREAM can not only analysis the reason of accident but predict the error probability in particular scene. The paper analysis the pilot error probability during approach and landing

S. Yamamoto (Ed.): HIMI 2014, Part II, LNCS 8522, pp. 296–304, 2014.

based on CREAM. The causation of error is also be analyzed. The method is validated by the experiment in the pilot simulator.

2 Error Probability Predictive Method Based on CREAM

The essence of CREAM is used to predict the error probability. for the purpose, First, analyze the people's task and the actual effect of the action, and then the basic CFP(cognitive failure probability) can be calculated, the final predictive error probability can be got by the analyzing the CPC(common performance condition) which can revise the basic CFP.

CREAM divide the cognitive action as observe, interpret, plan and execute, and every group has some failure modes. the cognitive action includes coordinate, communication, comparison, diagnose, evaluation, execution, maintain, monitor, observe, plan, record, adjustment, glance, inspection. And different cognitive action has its own cognitive performance. For CREAM the responding relation of the two is shown in table 1, and the basic CFP is shown in table 2.

Table 1. Cognitive activity and corresponding cognitive function

activity	cognitive function			
	observe	interpret	plan	execute
coordinate			√	√
communication				√
compare		√		
diagnose		√	√	
evaluate		√	√	
execute				√
identification		√		
maintain			√	√
monitor	√	√		
observe	√			
plan			√	
record		√		√
adjust	√			√
scan	√			
examine	√	√		

Table 2. Basic failure probability of cognitive failure mode

Cognitive function	failure mode	Basic value
observe	O1 Observable object error	0.001
	O2 wrong recognize	0.07
	O3 no observe action	0.07
interpret	I1 fail to diagnose	0.2
	I2 decision error	0.01
	I3 delay to interpret	0.01
plan	P1 wrong priority	0.01
	P2 inappropriate plan	0.01
execute	E1 wrong execution mode	0.003
	E2 wrong execution time	0.003
	E3 wrong execution object	0.005
	E4 wrong execution sequence	0.003
	E5 execution omission	0.03

CREAM has 9 CPC factors and everyone has its own three level, which affects the human performance as improving, inducing, and inapparent. Table 3 is the basic weight value of CFP.

$$P=1-\prod_{i=1}^{4}(1-CFP) \tag{1}$$

Where, $CFP_{revised} = CFP_{basic} \times \sum weight$.

CFP_{basic} is the basic value of CFP in table 2, and $\sum$weight is the product of all weight coefficient of CPC in table 3.

Table 3. CPC and its influence for reliability

No.	CPC	level	Impact of human reliability	Weight factor of cognitive function			
				observe	interpret	plan	execute
1	Perfectness of organiza-tion	Highly effective	improve	1.0	1.0	0.8	0.8
		effective	non- significant	1.0	1.0	1.0	1.0
		ineffective	lower	1.0	1.0	1.2	1.2
		Bad effect	lower	1.0	1.0	1.2	1.2
2	Working condition	superior	improve	0.8	0.8	1.0	0.8
		matching	non- significant	1.0	1.0	1.0	1.0
		mismatching	lower	2.0	2.0	1.0	2.0

Table 3. (*continued*)

3	Perfectness of HMI and operation support	support	improve	0.5	1.0	1.0	0.5
		general	non-significant	1.0	1.0	1.0	1.0
		tolerable	lower	1.0	1.0	1.0	1.0
		inadaptation	lower	5.0	1.0	1.0	5.0
4	Availability of plan/procedure	appropriate	improve	0.8	1.0	0.5	0.8
		accept	non-significant	1.0	1.0	1.0	1.0
		inappropriate	lower	2.0	1.0	5.0	2.0
5	The number of simultaneous objects	less than capability	improve	1.0	1.0	1.0	1.0
		Match with capability	non-significant	1.0	1.0	1.0	1.0
		more than capability	lower	2.0	1.0	5.0	2.0
6	Available time	enough	improve	0.5	0.5	0.5	0.5
		insufficient temporarily	non-significant	1.0	1.0	1.0	1.0
		insufficient always	lower	5.0	5.0	5.0	5.0
7	Working time	Daytime （adjust）	non-significant	1.0	1.0	1.0	1.0
		Nighttime （non-adjust）	lower	1.2	1.2	1.2	1.2
8	sufficient of training and experience	sufficient, experienced	improve	0.8	0.5	0.5	0.8
		sufficient, limited experience	non-significant	1.0	1.0	1.0	1.0
		insufficient	lower	2.0	5.0	5.0	2.0
9	Cooperation of the whole team	Highly effective	improve	0.5	0.5	0.5	0.5
		effective	non-significant	1.0	1.0	1.0	1.0
		ineffective	non-significant	1.0	1.0	1.0	1.0
		Bad effect	lower	2.0	2.0	2.0	5.0

3 Experiment

Experiment Settings. Experiment scene is assumed that an airplane of single engine landings under low visible condition and depends on the instrument to complete the task.

First group is a relative perfect CPC, and the altitude panel is digital, and the response time is not limited.

Second group models pilot has inadequate time to response, other conditions are the same as the first group.

Third group models pilot has inadequate time to response, and the interface is not so matching for pilot, which is the same as the first group.

The response time and the accuracy of the objects are both recorded.

The experiment is executed in man-machine-environment lab and the lighting, humidity, temperature and so on are all as usual.

The testees are all students who have sufficient train for the task; everyone will be tested 20 times.

Experiment Results. The experiment results are recorded as shown in table 4.

Table 4. The record data of experiment

No.	Altimeter (m)	Correct axtion	action by testee	accuracy	Reaction time(ms)
Group one	810	g	g	1	3338
	430	g	g	1	979
			……		
	190	e	e	1	1172
	830	g	e	0	3806
	Error probability 0.0278		RT 1435.628ms		Over time 0
Group two	810	g	g	1	3338
	430	g	g	1	979
			……		
	190	e	e	1	1172
	830	g	e	0	3806
	Error probability 0.0367		RT 1053.306ms		Over time 2
Group three	810	g	g	1	3338
	430	g	g	1	979
			……		
	190	e	e	1	1172
	830	g	e	0	3806
	Error probability 0.0778		RT 1159.611ms		Over time 3

The predictive error probability based on CREAM. For the CREAM method, the cognitive process of testee is simplified as four actions that are shown in figure 1.

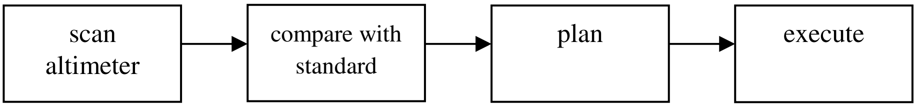

Fig. 1. The procedure of pilot reading altimeter

As mentioned before, there are four steps to calculate the predictive probability.

1. the CPC level and the weight coefficient

For the first experiment group, the conditions are all effective. The CPC level and the weight coefficients are shown in table 5.

Table 5. CPC and weight factor of first group

CPC	level	Impact for human reliability	Weight factor			
			observe	interpret	Plan	execute
Perfectness of organization	Highly effective	improve	1.0	1.0	0.8	0.8
Working condition	superior	improve	0.8	0.8	1.0	0.8
Perfectness of HMI and operation support	support	improve	0.5	1.0	1.0	0.5
Availability of plan/procedure	appropriate	improve	0.8	1.0	0.5	0.8
The number of simultane-ous objects	less than capability	improve	1.0	1.0	1.0	1.0
Available time	enough	improve	0.5	0.5	0.5	0.5
Working time	daytime（adjust）	Non-significant	1.0	1.0	1.0	1.0
sufficient of training and experience	sufficient, limited experience	Non-significant	1.0	1.0	1.0	1.0
Cooperation of the whole team	Highly effective	improve	0.5	0.5	0.5	0.5

The second group has almost the same CPC as the first group except the time limit; the third group has also not so good man-machine matching comparing with the second group. The weight coefficients should be revised accordingly.

2. identify the most possible cognitive failure mode

To find the most possible cognitive failure, we should analyze the cognitive sequence.

First, during the pilot scanning the altitude panel, the most possible failure is "indentify error";

Second, during the compared process, the most possible failure is "diagnose error";

Third, when the altitude has been gotten the most possible failure is "inappropriate plan";

The last one is the testee does the action as he planned, so the most possible failure is "motion error".

3. the predictive failure probability

For the three groups the $CFP_{revised}$ are shown in table 6 to table 8.

Table 6. The calculated result of group one

Sequence	Cognitive activity	Cognitive function	Failure mode	Basic value	Weight	CFP
scan	scan	observe	O2	0.07	0.08	0.0056
compare	compare	interpret	I1	0.02	0.2	0.004
plan	plan	plan	P2	0.01	0.1	0.001
execute	execute	execute	E1	0.003	0.064	0.000192

Table 7. The calculated result of group two

Sequence	Cognitive activity	Cognitive function	Failure mode	Basic value	Weight	CFP
scan	scan	observe	O2	0.07	0.16	0.0112
compare	compare	interpret	I1	0.02	0.4	0.008
plan	plan	plan	P2	0.01	0.2	0.002
execute	execute	execute	E1	0.003	0.128	0.000384

Table 8. The calculated result of group three

Sequence	Cognitive activity	Cognitive function	Failure mode	Basic value	Weight	CFP
scan	scan	observe	O2	0.07	0.32	0.0224
compare	compare	interpret	I1	0.02	0.4	0.008
plan	plan	plan	P2	0.01	0.2	0.002
execute	execute	execute	E1	0.003	0.256	0.000768

We can use the equation (1) to calculate the error probability as follows:

$$P1 = 1 - \prod_{i=1}^{4}(1 - CFP) = 0.010758$$

$$P2=1-\prod_{i=1}^{4}(1-CFP)=0.021448087$$

$$P3=1-\prod_{i=1}^{4}(1-CFP)=0.032904$$

So the different error probability under three different CPC is 0.01, 0.02, and 0.03.

4 Discussion

The experiment results and the calculated data are both shown in table 9.

Table 9. Comparison result

group	Calculated	experiment
one	0.0108	0.0278
two	0.0214	0.0367
three	0.0329	0.0778

The calculation result is on the rise that is the same as the experiment result in the three different CPC. But the two also have differences. The exact value is not so accordant. The experiment data is greater than calculated value and the experiment data of group three increased sharply compared with group two. The two differences of result are analyzed as: 1) in the experiment the pilot manipulating the gear is substituted as key-press which may decrease the difficult of execution; 2) cognitive failure mode is discrete with CREAM, but in fact the condition which influences the human operation is not discrete. For example, for this experiment condition, in the "sufficient of training and experience" condition, the impact for the cognitive mode maybe is between "non-significant" and "lower" according to the testee level; 3) for the most possible cognitive failure mode choose, CREAM can only choose one, but sometimes there is definitely two choices. When subject chooses the different one there is a different result.

5 Optimized Suggestions

Although the CREAM has some shortages, the method is also meaningful for the purpose to decrease human error and keep security. The CREAM used in this research is not for the quantitive probability but to find the weakness of human-machine-environment during the analysis and evaluation procedure and improve the system reliability.

There are also some advices for the use of CREAM: 1) to find the most possible failure mode, the researcher should consider the capability of human itself. For different person there is a different performance; 2) the method which can make the

"Impact for human reliability" and "weight factor" consecutive should be researched and developed.

Acknowledgement. The paper is granted under National Basic Research Program of China (No.2010CB734101).

References

1. Civil Aviation Authority. Human Factors in Aircraft Maintenance and Inspection. Prebviously ICAO Digest No.12
2. Nongxin, C., Xin, T., Rui, L.: Application of REASON model to investigation of the aviation maintenance accident. Traffic Information and Security 2(30), 96–99 (2012)
3. Zengxian, G., Yifei, Z., Linghang, M., Yizhe, X.: Design of aircraft accidents analysis software based on reason model. Journal of Civil Aviation University of China 3(31), 6–9 (2013)
4. Wiegmann, D.A., Shappell, S.A.: Applying the Human Factors Analysisand Classification System (HFACS) to the analysis of commercial aviation accidentdata. In: The 11th International Symposium on Aviation Psychology. The Ohio State University, Columbus (2001)
5. Research team of human factors in aircraft maintenance of CAAC. Human factors' cases – maintenance error in civil aircraft, pp. 230–300. Civil aviation administration of China Press, Beijing (2003)
6. Yao, W., Zupei, S.: CREAM—A second generation human reliability analysis method. Industrial Engineering and Management 10(3), 17–21 (2005)
7. Bin, L., Qin, Y., Mao, L.: Study on prediction model of human factor failure probability based on CREAM. Journal of Safety Science and Technology 8(7), 57–49 (2012)
8. Ruishan, S., Yunxiao, C.: Application of failure probability of CREAM conflict solution by ATC. In: Proceedings of 2010 (Shenyang) International Colloquium on Safety Science and Technology. Northeastern University (May 2010)
9. Ruishan, S., Xin, W.: Application of failure probability of CREAM for judgment and decision-making in the cockpit. Journal of Safety Science and Technology 6(6), 40–45 (2010)
10. Yingjie, J., Zhiqiang, S., Erling, G., Hongwei, X.: The Method to Quantify Human Error Probability in Probabilistic Cognitive Control Mode. Journal of National University of Defense Technology 33(6), 175–178 (2011)