# A Study of the Relationship between Novice Pilots' Performance and Multi-Physiology Signals

Yanyu Lu, Jingjing Wu, and Shan Fu

School of Aeronautics and Astronautics, Shanghai Jiao Tong University, Shanghai, China
luyanyu@sjtu.edu.cn

**Abstract.** The performance of pilots are related to the physiological response. In this study, we investigated the correlation between the pilot performance and physiological meters through recording the multiple physiological parameters in a flight. The results showed that in the flight phase from cutting off auto-pilot and auto-throttle, the performance of the subjects correlated strongly with heart rate and also correlated with fixation time or blink interval while the correlation between the performance and the saccade frequency or blink duration was weaker. When the subjects adjusted the flaps or controlled landing gear, the correlation between the performance and multiple physiological parameters, specially the cardiovascular parameters and fixation time, were more stronger compared with that at the other time.

**Keywords:** pilots' performance, physiological response, simulated flight, mental workload.

## 1 Introduction

Safety is one of the key element of civil aviation since the air transport system plays an important role in the world economic activity. The number of accidents decreased significantly as the level of technology and management increased, while human factors becomes more and more serious cause of the accidents. Therefore, to study and improve human factor is an important way to reduce accident rate and improve aviation safety.

An important aspect of human factor is assessment of workload since either excess workload or underload can degrade performance. Workload measurement has been used in a number of areas, such as military and industries. Workload measurement technologies can be classified into three categories: subjective ratings, physiological recordings and performance measures [1].

Subjective ratings include uni-dimensional and multi-dimensional scales. There are a lot of subjective measures applied in the different studies, such as modified Cooper-Harper scale, SWAT, and NASA-TLX [2]. Although subjective measures are easy to assign ratings and accepted by operators, it is difficult to compare workload on different task according to the rating scales.

Physiological recordings are based on the premise that the physiological responses in the body based on the nervous regulation and autoregulation are sensitive to the

D. Harris (Ed.): EPCE 2014, LNAI 8532, pp. 344–350, 2014.

change of the workload [3]. The physiological measures are continual and objective measurement of the operate state, and not be affected by the subjective measures [4]. It is demonstrated that many physiological signals are sensitive to workload. The P300 EPR appears to respond to workload [5]. The cardiovascular response can reflect the aroused levels and be used in a variety of studies [6]. The eye blink measure is sensitive to the visual workload and eye movement can reflect the attention allocation and decision making [7].

Performance measures can be divided into primary-task and secondary-task measures. The primary-task measures consider the workload induced by the interested task, and can provide a direct indication of performance on the interested task. The secondary task is one that is subordinate to the primary task where dual tasks are required, and can provide a index of spare capacity. The rationale is that performance on the secondary task will decline as a function of the demands of the primary task [4].

Because of the different advantage of three kinds of workload measures, many researchers assessed or predicted pilots' workload though multiple measures. Jorna [8] reported the objective and subjective measurements on human interaction with air traffic control systems. Miyake [9] integrated physiological parameters and one subjective parameter through Principle Components Analysis into the multivariate workload evaluation index to assess the metal workload. Sonderegger and Sauer [10] examined the influences of situational factors on use behavior through taking performance data, subjective measures and physiological parameters. However, the relation between the pilots' performance and physiological response remains unclear. Pilots' performance depends on a number of factors: pilots' training levels, age, workload, their mood, etc. For the novice pilots with less training and skills, their performance is quite relative to the workload. In this study, we investigated the correlation between the pilot performance and physiological meters through recording the multiple physiological parameters in a flight.

## 2 Materials and Methods

### 2.1 Subjects

Six subjects with normal or corrected visual acuity (20/20; 3 males, 3 females, 20-30 years old ) were recruited from Shanghai Jiao Tong University. All subjects were informed of the purpose and procedures of the experiments and signed an informed consent form prior to participation. The subjects had basic knowledge about aviation and were trained 8 times to familiarize with the flight in the simulator before the formal experiment. Before the experiment, they were given enough rest according to their mental and psychological status. At the end, they were given awards for their contribution to our research.

### 2.2 Apparatus

**Simulator.** The Boeing 777-200ER flight simulator was built up by using three workstations ( CPU: 2.90GHz, 4GB DDR3 RAM, HP, China) and six 22-in LCD

screens (LE2201W, HP, China). The outside view of the flight simulator, which presented a real immersed experience of the flight to the subjects, was displayed on a semi-spherical screen with the diameter of 8 meters through three projectors.

**Fig. 1.** An Boeing-777 Flight Simulator

**Physiological devices .** An eye tracker (Smart Eye, Smart Eye AB, Sweden) was used to monitor and record pupil diameter, eye blink and movements signals. A physiological parameters monitoring equipment (Bio Harness, Zephry Technology, Annapolis, U.S.A) was wore by the subject to record the heart rate data, respiration amplitude and rate.

### 2.3 Procedure

The subjects were asked to perform the whole flight, including taking off, cruise and landing, which lasted about 10 minutes in the flight simulator with high fidelity. The subjects were required to take off from the runway of KJSC 30R. Before that, they had to set the auto-pilot and auto-throttle. After climbing to 2000 feet with maintaining level flight, the subjects opened the auto-pilot and auto-throttle according to the instruction, and then they only needed to supervise whether the flight was on the established route. They were required to disconnect the auto-pilot and auto-throttle and execute the landing before 10 nautical mile of the destination, and then they should maintain the aircraft about 3 to 5 degree of nose-up to descent and adjust the flaps at certain airspeed. When one dot from glideslope displayed, the subjects would hear an instruction from the experimenter to extract the gear, then they landed the aircraft on the runway. Therefore, this phrase was selected to investigate the relationship between the performance and the physiological response.

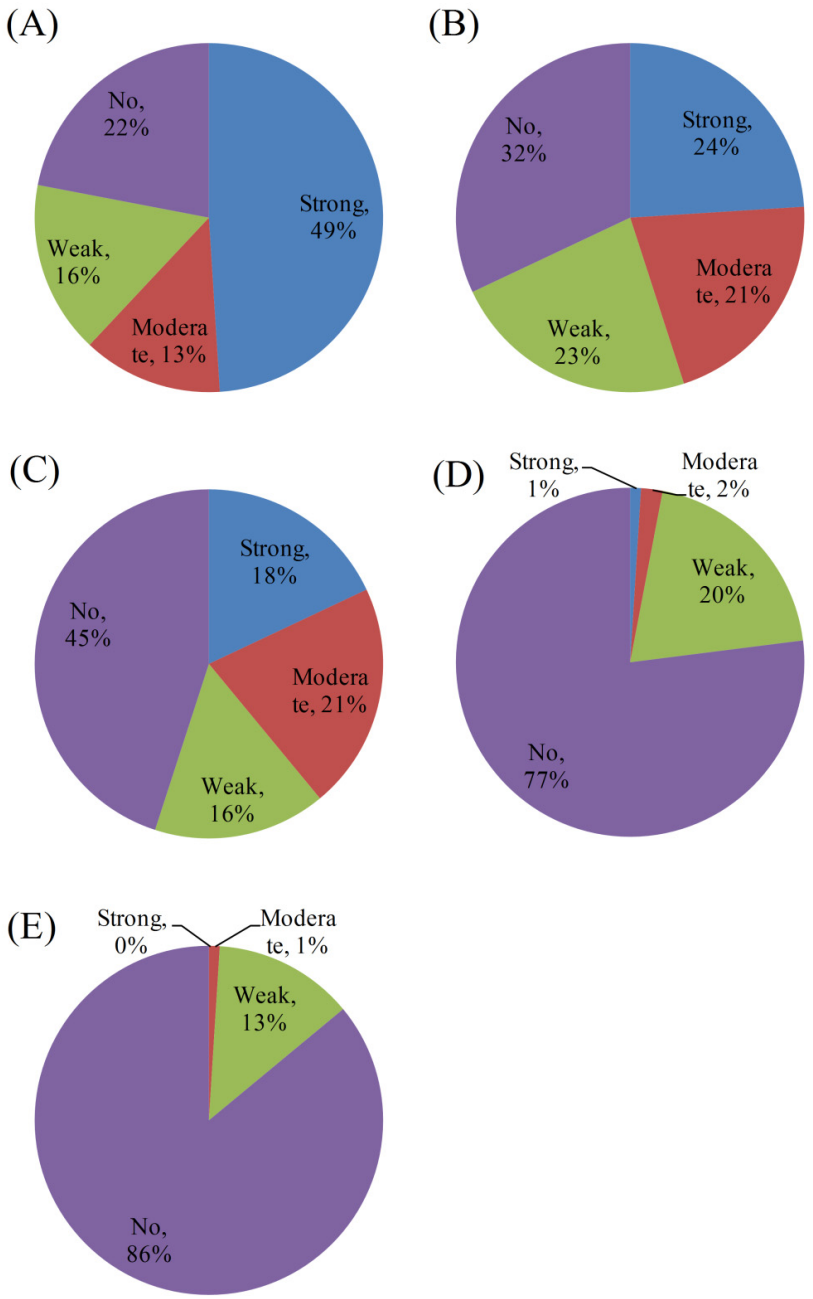


**Fig. 2.** The correlation between the performance and (A) heart rate, (B) fixation time, (C) blink interval, (D) blink duration and (E) saccade frequency. The correlation coefficient |R| >0.7: strong; 0.3<|R|<0.7: moderate; 0.3<|R|<0.1: weak; |R|<0.1: no.

### 2.4 Data Analysis

The performance, which represents the pilot's control, was integrated by the flight path deviation and acceleration. The physiological parameters contained heart rate, blink duration/interval, fixation time and saccade frequency. All the values recorded in the flight were normalized. The correlation between the performance and physiological parameters at each moment of the selected phase was analyzed using the Pearson chi-square test.

## 3 Results

The correlation analysis between the performance and physiological parameters in a simulated flight were shown in the results. In the flight phase from cutting off autopilot and auto-throttle, the performance of the subjects correlated with heart rate strongly (correlation coefficient > 0.7 ) for about 50% sampling sites and moderately (correlation coefficient: 0.3-0.7 ) for 13% sampling site; the correlation coefficient between the performance and fixation time or blink interval was more than 0.3 for about 30%-50% sampling site while the correlation between the performance and the saccade frequency or blink duration was weaker.

Taking into account the performance referring to the control, we analyzed the correlation at the moment when the subjects had a control action. When the subjects adjusted the flaps or controlled landing gear, the correlation between the performance and multiple physiological parameters, specially the heart rate, fixation time and blink interval, were more stronger compared with that at the other time.

**Table 1.** The correlation coefficient between the performance and multiple physiological parameters at different control action

| | Heart rate | Fixation time | Blink interval | Blink duration | Saccade frequency |
|---|---|---|---|---|---|
| Flap1 | 0.984 | 0.872 | -0.909 | -0.268 | -0.652 |
| Flap2 | -0.749 | -0.841 | 0.476 | 0.536 | 0.589 |
| Flap3 | 0.965 | -0.515 | -0.346 | -0.006 | 0.103 |
| Flap4 | 0.990 | 0.734 | -0.897 | 0.513 | -0.448 |
| Landing | 0.898 | 0.464 | -0.506 | 0.760 | -0.753 |
| Others | 0.094 | -0.413 | -0.519 | 0.331 | 0.417 |

## 4 Discussion and Conclusion

The results showed that multiple physiological parameters were correlated with the performance, especially the heart rate, blink interval and fixation time. As we know, heart rate is related with the variation of the emotional states of the human. It has been demonstrated that the change of heart rate can reflect the change of the workload, task difficulty, and human emotion. Moreover, it is well knew that the ocular motor

behavior was linked to the attention or cognition load [11]. It was proved that the increased subjective effort, and behavioural and physiological costs could improve the performance [12, 13], which are consistent with our results.

Beyond our expectations, the saccade frequency was less related with the performance of a novice pilot. The saccades, including frequency, distance and accuracy, are important indexes of acquiring and processing the information. The eye-scanning pattern is different between expert and novice [14, 15]. In our study, all the subjects were novice and only trained 8 times before the formal test. They might not have efficient saccade or link the eye-scanning activities to their performance in the simulated flight.

In the selected flight phase from cutting off auto-pilot and auto-throttle, subjects performed more tasks when adjusting the flaps or controlling landing gear, which made novice pilots take on more workload. Subjects should pay more effort and attention to maintain performance. Therefore, the correlation between the performance and multiple physiological parameters were more stronger compared with that at the Leisure time.

In conclusion , we studied the relation between the performance and multiple physiologies of novice pilots. The results in the study revealed that most physiological parameters (cardiovascular and ocular information) in a flight were relevant to the pilot's performance. Especially during tasks, the correlation was much stronger compared with that at the other time. On this basis, we will establish the model to predict the pilot's performance through monitoring the physiological parameters.

**Acknowledgement.** This research is supported by The National Basic Research Program of China (973 Program, 2010CB734103), China Postdoctoral Science Foundation (2013M540363) and The National Natural Science Foundation of China (61305141).

## References

1. O'donnell, R., Eggemeier, F.T.: Workload assessment methodology. Measurement Technique 42, 5 (1986)
2. Rubio, S., Diaz, E., Martin, J., Puente, J.: Evaluation of Subjective Mental Workload: A Comparison of SWAT, NASA-TLX, and Workload Profile Methods. Applied Psychology 53, 61–86 (2004)
3. Lean, Y., Shan, F.: Brief review on physiological and biochemical evaluations of human mental workload. Human Factors and Ergonomics in Manufacturing & Service Industries 22, 177–187
4. Farmer, E., Brownson, A.: Review of workload measurement, analysis and interpretation methods. European Organisation for the Safety of Air Navigation 33 (2003)
5. Fowler, B.: P300 as a measure of workload during a simulated aircraft landing task. Human Factors: The Journal of the Human Factors and Ergonomics Society 36, 670–683 (1994)

6. Wierwille, W.W., Connor, S.A.: Evaluation of 20 workload measures using a psychomotor task in a moving-base aircraft simulator. Human Factors: The Journal of the Human Factors and Ergonomics Society 25, 1–16 (1983)
7. Wilson, G., Fullenkamp, P.: Psychophysiological assessment of pilot and weapon system operator workload. Stress and error in aviation (A 92-13015 02-53). Aldershot, England and Brookfield, VT, Avebury Technical, pp. 27–34 (1991)
8. Jorna, P.: Human Machine interfaces for ATM: objective and subjective measurements on human interactions with future Flight deck and Air Traffic Control systems. In: FAA/Eurocontrol ATM R&D Seminar, Paris, France (1997)
9. Miyake, S.: Multivariate workload evaluation combining physiological and subjective measures. International Journal of Psychophysiology 40, 233–238 (2001)
10. Sonderegger, A., Sauer, J.: The influence of laboratory set-up in usability tests: effects on user performance, subjective ratings and physiological measures. Ergonomics 52, 1350–1361 (2009)
11. Just, M.A., Carpenter, P.A.: Eye fixations and cognitive processes. Cognitive Psychology 8, 441–480 (1976)
12. Robert, G., Hockey, J.: Compensatory control in the regulation of human performance under stress and high workload: A cognitive-energetical framework. Biological Psychology 45, 73–93 (1997)
13. Yeo, G.B., Neal, A.: A multilevel analysis of effort, practice, and performance: effects; of ability, conscientiousness, and goal orientation. Journal of Applied Psychology 89, 231 (2004)
14. Law, B., Atkins, M.S., Kirkpatrick, A.E., Lomax, A.J.: Eye gaze patterns differentiate novice and experts in a virtual laparoscopic surgery training environment. In: Proceedings of the 2004 Symposium on Eye Tracking Research & Applications, pp. 41–48. ACM (2004)
15. Beck, M.R., Trenchard, M., van Lamsweerde, A., Goldstein, R.R., Lohrenz, M.: Searching in clutter: Visual attention strategies of expert pilots. In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting, vol. 56, pp. 1411–1415. Sage Publications (2012)