Effects of learning approach and interface design on mental workload in conducting flight operation.

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The pilot's flight parameters interpretation and flight ability are critical to aviation safety. Hence, aviation training and indicators arrangement have been recognized and considered as essential elements for flight safety. For memorizing a large number of icons, like flight indicators, chunking learning is considered a good approach to reduce mental workload and recognize icons efficiently (Gittins, 1986; Lee & Zhai, 2004). Chucking learning means people make primitive stimuli into larger conceptual groups(Gobet et al., 2001). Furthermore, the optimized or the poor design of instruments layout during operations has been associated with the level of mental workload. (Yan,2017) However, this learning approach was not applied in aviation training, and its effects with different flight indicator layouts remain unclear. The present study aims to evaluate the learning effect on mental workload, eye movement behavior, and operating performance during flight operation with different design interfaces.

Thirty subjects aged 20 to 30 years old, with normal or corrected vision and no experience operating a simulated aircraft participated in the experiment. They were divided into two different learning groups of chunk and control (teaching icons randomly). Additionally, three interfaces would be used in the experiment; they all have the same 28 instruments but with different layouts. Part of the instruments on the A interface arrange randomly, while the others arrange by functional grouping. All instruments of interface B are arranged in functional grouping and C interface layout randomly. Before the experiment, subjects were asked to test their visuospatial working memory ability to confirm that the learning performance was not affected by their working memory ability (Brooks,1967). In the learning phase, subjects needed to learn and familiarize themselves with 28 instruments through one of two learning approaches randomly. Subsequently, the subjects were instructed to click the instruments on the A interface to familiarize themselves with the icons with one of two teaching approaches. There were two phases in the official experiment, the practice phase, and the interface phase. The subjects wore the eye-tracking device during the practice phase, listened to flight emergency operation steps, and clicked the corresponding instrument. Subjects would practice 15 times on the A interface. In addition, the subjects conducted the mental workload questionnaire, NASA-TLX, after finished the 1^{st},5^{th},10^{th},15^{th} time of practice. After practicing the A interface, the subjects familiarize the B interface and C interface by clicking the instruments with one of two teaching approaches. Next, the subjects conducted the same operation steps on the B interface and C interface once as the interface phase. The reaction time, NASA-TLX, and the number of fixation and saccades were recorded and measured during both phases. Precisely, the eye metrics are measured along with the reaction time. The reaction time would be averaged by each learning group and formulate a learning curve. The learning curve in two groups would be compared by t-test. A two-way repeated measure ANOVA was conducted as one within factor (practice times) and one between factor (chunking and control) to evaluate four variables in the practice part. Owing to subjects only operate B interface and C interface once, the other two-way repeated measure ANOVA was conducted as one within factor (two interfaces) and one between factor (chunk and control) in the interface part.

The visuospatial working memory was 9.2 numbers (SD= 3.69) in the chunking group and 10.4 numbers (SD=1.55) in the control group, which was not significantly different between the two groups (t=0.23, *p*=0.82). For the practice part, the learning curve of the two learning approaches was not significantly different. A faster reaction was observed in the chunking group than the control group in the first time of the practice (Fig 1a). There was no difference between the two learning groups in the subjective mental load in the 15 times of practice (Fig 1b). Furthermore, the numbers of fixation (Fig 1c) and saccades (Fig 1d) were significantly larger in the control group compared to the chunk group throughout the 1st,5th,10th,15th time of practice. A better visual search in the whole practice was found in the chunking group than in the control group. For the interface part, the faster reaction time and the lower NASA-TLX scores were observed with the B interface than the C interface regardless of the chunking and control groups (Fig 2a, 2b). Furthermore, the numbers of fixation (Fig 2c) and saccades (Fig 2d) were significantly larger with the B interface compared to the C interface. The visual search performance of the B interface was better than that of the C interface. Under the interaction between learning and interface, it can be found that the optimized interface had the best performance using chunking learning.

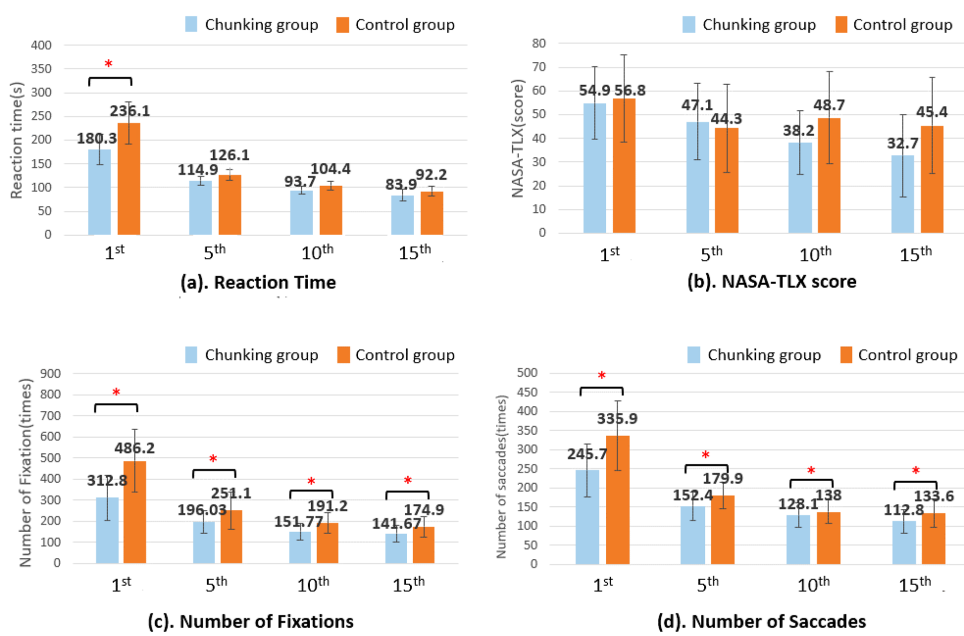

Figure 1 Comparisons of (a) reaction time, (b) NASA-TLX, (c) number of fixations, and (d) number of saccades after 1st,5th,10th,15th practice in the chunking group (blue bars) and the control group (orange bars).

In conclusion, memorizing a large number of icons with chunking learning could lead to better performance in searching with the interface. Furthermore, the subjects showed better interface searching efficiency when operating the flight emergency steps with the optimized interface. A learning approach and interface design could have compatibility and should be taken into consideration in training pilots. A limitation should be noted that the experiment design of the present study was not too hard for subjects. Hence, it might be difficult to show the significant difference between the two groups for subjective mental load assessment. For future study and potential applications, it is recommended to add instrument interpretation in the practice part and flight scenario in the interface part, which would profoundly reflect learning performance and the actual flight situation.

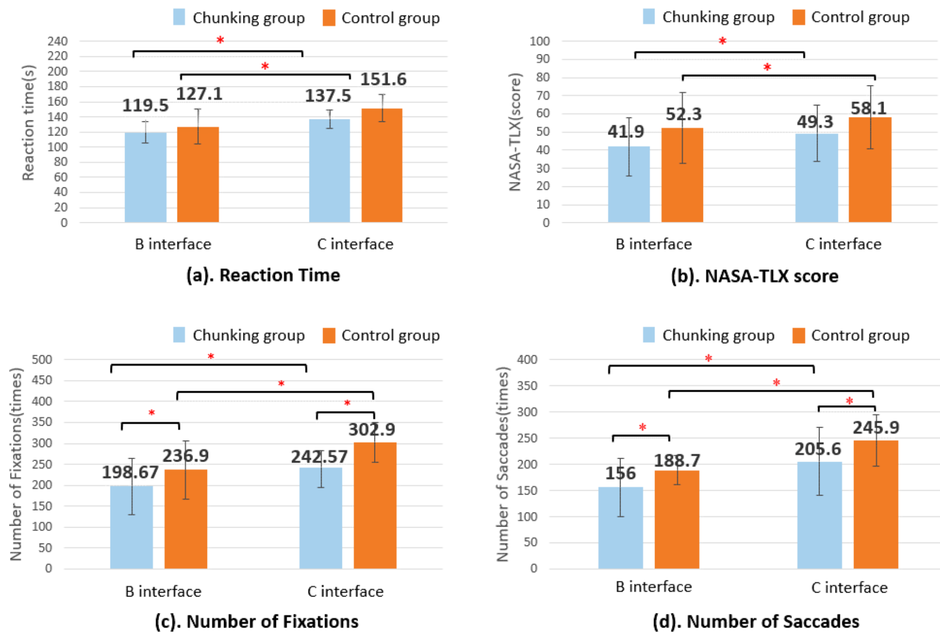

Figure 2 Comparisons of (a) reaction time, (b) NASA-TLX, (c) number of fixations, and (d) number of saccades between the B and C interfaces in the chunking group (blue bars) and the control group (orange bars).

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