IASDR07
INTERNATIONAL ASSOCIATION OF SOCIETIES OF DESIGN RESEARCH THE HONG KONG POLYTECHNIC UNIVERSITY 12TH TO 15TH NOVEMBER 2007

A STUDY OF COMPATIBILITY BETWEEN CONTROLLERS AND DISPLAYS FOR ULTRALIGHT PLANE

ABSTRACT:

The present research included three studies: an investigation of the conceptual compatibility between the controls and instrument displays on ultralight planes, a test of the laterality effects of rudder pedals on pilot performance, and an experiment in the effects of the positioning of the controls and seats on pilot performance. The results of study 1 indicated that: 1) positioning the throttle to the left and the elevator to the right of the seat was the most compatible combination; 2) placing the airspeed indicator on the left, the heading indicator at the center, and the altimeter on the right was the most compatible arrangement; 3) the mode proposed by this study (right rudder pedals pushed to turn the plane turn left) was more compatible than the traditional one; 4) pushing the elevator forward made the plane descend; 5) pushing the elevator forward moved the pointer of the altimeter at 12 o'clock counter-clockwise; 6) pushing the throttle forward moved the pointer of the airspeed indicator counter-clockwise. 7) half of the subjects considered that pushing the right rudder forward moved the pointer of the heading indicator clockwise. The conclusions from study 2 and study 3 were: 1) the new developed mode was more compatible with human understanding. The result could be considered an important reference for further research and design; 2) the pilot performance with the rudder on the center was better than that on the left or the right ; 3) seat pushing effect had stronger impact on the performance than throttle pushing seat positioning the s**eat** on the center resulted in better than positioning it on the left and the right sides. Positioning the throttle near the center resulted in better performance than positioning it far from the center; 4) the effect of elevator positioning had stronger impact on pilot performance than the seat positioning. Positioning the elevator on the right results in better performance than positioning on the center or the left, while seat positioning had no significant.

Keywords: ultralight plane, compatibility, controller and display, flight simulation.

1. INTRODUCTION

People in Taiwan have been taking leisure activities more seriously due to rising national income and increasing leisure time. Flying ultralight planes is one of these leisure activities and is becoming popular in Taiwan. However, operating an ultralight plane is more difficult and dangerous than operating the other aircrafts such as hang gliders, paragliders, parachutes, and hot air balloons. Two main types of components to operate when flying an ultralight plane are the controls and instrument displays. The controls include elevator, rudder pedals, throttle and brake (Microsoft, 2003; Liao, 1994). The instrument displays included altimeter, heading indicator, and airspeed indicator.

Various studies have been conducted on this (Proctor, & Reeve, 1990; Hass, 1995; Wickens, Miller, & Tham, 1996; Breedveld et al, 1998; Chan & Chan, 2006; Proctor, & Vu, 2006). However, few focus on ultralight planes. According to the statistics (Lee, 1997), 70% of the air accidents in the lost 15 years were caused by human errors. A combination or arrangements of controls and instrument displays of an ultralight plane to match human understanding will facilitate learning, remembering, and operation.

The study included three parts: 1) an investigation of the conceptual compatibility between controls and the displays of ultralight planes; 2) a test of the laterality effects of the rudder pedals of ultralight planes. and 3) an experiment in the effects of the positioning of the controls and the seat on pilot performance.

2. STUDY 1

2.1 EXPERIMENTAL DESIGN

The objective of this study is to investigate the conceptual compatibility of the controls and instrument displays on ultralight planes.

Seven questions in a questionnaire included three aspects: the compatible arrangements of controls and displays of ultralight planes, the relationship between the controls movements and the plane responses, as well as the compatibility of the movements with the responses of the displays.

The subjects were 30 university students (19 males and 11 females) aged from 20 to 26 years with a mean age of 24.5 (SD= 2.01). They were all right-handed. All of them were informed about the aim and the procedure of the investigation. The survey was conducted in an ergonomic laboratory at National Yunlin University of Science and Technology. The plane MXL-II (Eipper) was selected from the software Flight Simulation 2004. The hardware was constructed by the researchers. The projector was a BENQ PB2240 with a brightness of 2000 lm and a contrast ratio of 2000:1. After subjects had become familiar with the functions of the controls and displays of the ultralight planes, then the investigation began.

2.2 RESULTS AND DISCUSSIONS

The results of the questionnaire showed the following:

1) Which combination of throttle and elevator position is the most compatible? The result showed that positioning the throttle to the left of the seat and the to the elevator in the right of the seat was the most compatible combination.

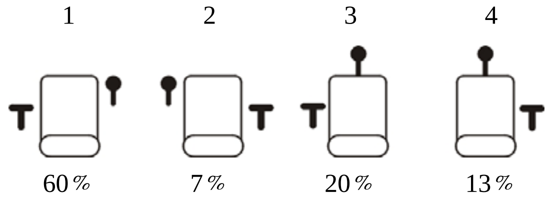

Fig. 1 Results on the throttle and elevator positioning

2) Which arrangement of the airspeed indicator, heading indicator, and altimeter is the most compatible? The results, provided in Table 1, showed that placing the airspeed indicator on the left, the heading indicator at the center, and the altimeter on the right was the most compatible arrangement.

Table 1 Results on the positioning of the three indicators

Airspeed indicator			heading indicator			altimeter		
left	center	right	left	center	right	left	center	right
70%	10%	20%	10%	76%	14%	20%	13%	67%

3) Which mode of rudder pedal operation to plane response is more compatible? The results showed that the mode proposed by this study was more compatible for the subjects than the traditional one. That is, when the right rudder pedal is pushed, the plane will turn left, and when the left rudder pedal is pushed, the plane will turn right.

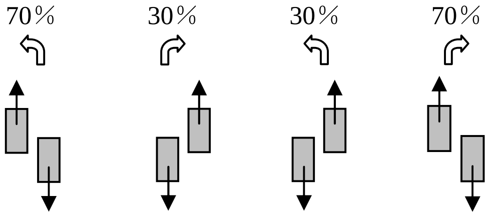

Fig. 2. Results of the two modes of rudder pedals

4) Which movement direction of the elevator is more compatible with an ascending plane? The results showed that the subjects found the following matched their thinking: when the elevator is pushed forward, the plane will ascend. When the elevator is pulled back, the plane's nose will pitch up.

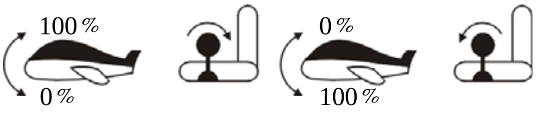

Fig. 3 Results of moving direction of elevators to an ascending plane

5) When the elevator is pushed forward, will the pointer of the altimeter (at the 12 o'clock position) move clockwise or counter-clockwise? The answer is counter-clockwise.

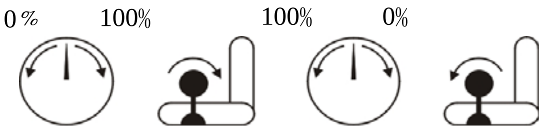

Fig. 4 Results of moving direction of elevators to turning direction of the pointer of the altimeter

6) When the throttle is pushed forward, will the pointer of the airspeed indicator (at the 12 o'clock position) move clockwise or counter-clockwise? The answer for the question is counter-clockwise.

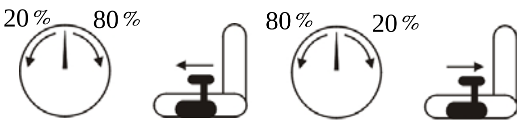

Fig. 5 Results of moving direction of throttle to turning direction of the pointer of the airspeed indicator

7) When the right rudder pedal is pushed forward, will the pointer of the heading indicator (at the 12 o'clock position) move clockwise or counter-clockwise? Half of the subjects answered counter-clockwise and the other half clockwise, the pointer here for the rudder pedals is difficult to operate and should be avoided.

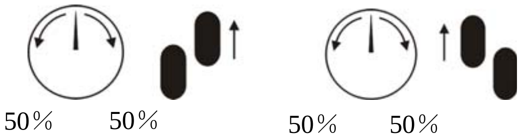

Fig. 6 rudder pedal directions to the turning direction of the pointer of the heading indicator

3. STUDY 2

3.1 EXPERIMENTAL DESIGN

In study 1, it was found that the operating mode of the rudder pedals was not familiar with the human concept. This study developed a new mode one which was shifted the matching of the rudder pedal to the plane response. Figure 7 showed the two modes. The traditional mode is pushed the right rudder pedal forward, then the plane will turn right. However the new developed one is pushed the right rudder pedal forward, then the plane turn left. A confirm experiment was then designed to test the pilot performance for the two modes.

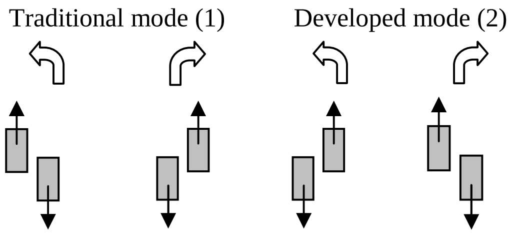

Fig. 7 two modes of the rudder pedals

A total of 10 subjects participated in the study (5 females and 5 males). Their aged from 20 to 25 years with a mean age of 24.9 years (SD= 2.4 years). None of them had ever been trained for any flight activities. The task of the subjects was to pilot the plane to follow the specified route in the air field (Figure 8, solid line). The area between the specified route (solid line) and the actual flight route (dash line) was identified as the negative pilot performance of the subjects. The air field is located in Taidong, Taiwan. Each of the subjects was randomly assigned to one of the two trials first and then participated in the other trial later.

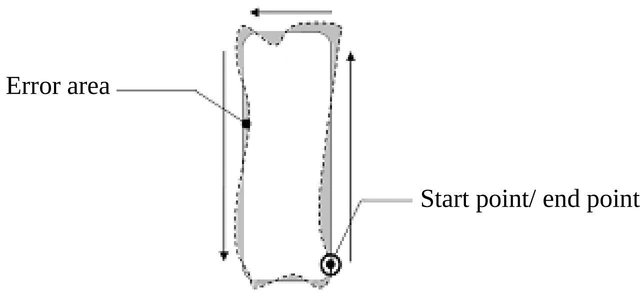

Fig. 8 Error area as negative pilot performance

3.2 Results and discussions

Table 2 shows the minimum, maximum, mean, and standard deviation of the error area of the two modes of rudder pedal operation. The table shows the error area of the traditional mode is bigger than that of the new one (241.2 vs. 123.3). That is, the newly developed mode was more suitable for the subjects. The t-test showed the newly developed mode was better than the traditional mode ($t= 2.63$, $p< 0.05$). This result could be considered an important reference for further research and design.

Table 2 statistics on the two modes of rudder pedal operation

Modes	N	min	max	Mean	Std.
Traditional	10	16.17	755.60	241.17	222.19
New	10	23.32	458.17	123.30	104.39

4. STUDY 3

4.1 EXPERIMENTAL DESIGN

This study aims to test the laterality effects of the controls on pilot performance. Two types of laterality effects are discussed in this study: seat effect and controls effect. First, the effects of rudder pedal position on pilot performance were tested. Both the rudder pedals and the seat were positioned to the left (a1) of, center of on (a2), or to the right (a3) of, the longitude axis of the plane (figure 8). Then, the effects of throttle and seat positions were tested. The seat was positioned to the left of, center of on, or to the right of, the longitude axis of the plane, with the throttle positioned either to the left or to the right of the seat. A total of six combinations were tested (b1-b6). Finally, the position of elevator and seat positions were examined. The seat and the elevator were positioned to the left of, center of on, or to the right of, the longitude axis of the plane, so that nine combinations could be tested (c1-c9). When the control was positioned to the right of the seat, the subjects used the right hand to operate it, and when it was positioned to the left of the seat the subjects used the left hand to operate it. However when the control was positioned in front of the seat, the subject used the dominant hand to operate it.

The subjects were 20 university students (10 females and 10 males) who were aged from 20 to 26 years with a mean age of 24.05 years ($SD= 1.70$), and who were interested in flying.

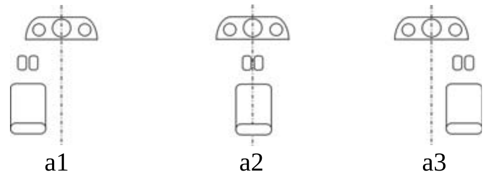

Fig. 9 test positions of the rudder pedals

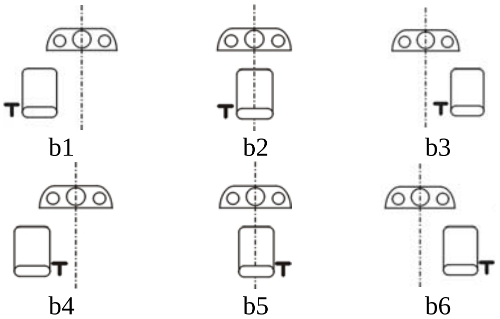

Fig. 10 test positions of the throttle

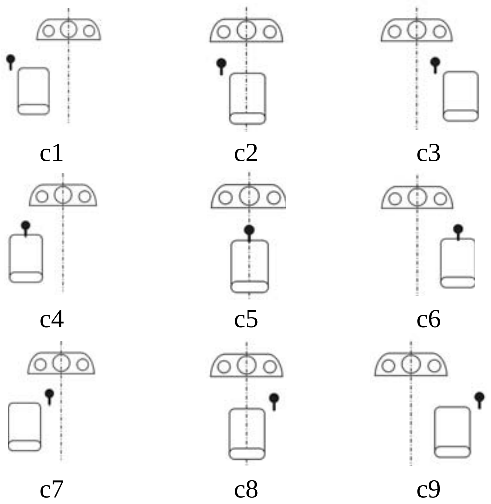

Fig. 11 test positions of the elevator

The material, apparatus, dependent variable, and the procedure used in this study were the same as those used in study 2. A trial comprised six subtasks. Each subtask took 20 seconds. So each trial took 120 seconds to complete. The task details are listed in table 3.

Table 3 the subtasks of each trial

Trials	Subtasks
Rudder	1. takeoff and climb out at 400 ft high
	2. keep at 400 ft height, airspeed= 50m/hr
	3. turn right with 90^o, keep straight, height, and speed
	4. turn left with 90^o, keep straight, height, and speed
	5. turn right with 90^o, keep straight, height, and speed
	6. turn left with 90^o, keep straight, height, and speed
Throttle	1. airspeed= 20m/hr
	2. throttle up to 50m/hr, keep
	3. throttle down to 40m/hr, keep
	4. throttle down to 20m/hr, keep
	5. throttle up to 30m/hr, keep
	6. throttle off, brake to stop
Elevator	1. takeoff to 200 ft high
	2. throttle up to 300 ft high, keep
	3. throttle up to 400 ft high, keep
	4. throttle down to 300 ft high, keep
	5. throttle down to 200 ft high, keep
	6. throttle up to 300 ft high, keep

4.2 RESULTS AND DISCUSSIONS

Table 4 shows the pilot performance when the rudder and seat were positioned at each of the three different positions. The ANOVA results showed that the rudder position effect was significantly ($F(2,38)= 4.43$, $p> 0.05$) impacting pilot performance. The Duncan Test result indicated that pilot the performance when the rudder was at the center position was better than that when the rudder was on the left or the right.

Table 4 the performances of the rudder positions

Positions	N	Min	Max	Mean	Std.	Duncan
Center	20	7.47	292.39	94.24	65.18	A
Left	20	33.73	275.91	125.66	64.72	B
Right	20	22.62	379.3	149.69	96.53	B

Table 5 shows the statistics of the performance as at the 6 modes of throttle and seat position. The Duncan results showed that the performance of the modes 5 and 2 were significantly better than that at modes 6 and 1. This implies that seat positioning had stronger impact on the performance than throttle positioning effect.

Positioning the seat on the center resulted in better performance than that positioning it on left or the right side. Positioning the throttle near the center resulted in better performed than positioning it far from the center.

Table 5 the performances of the throttle and seat positions

Modes	N	Min	Max	Mean	Std.	Duncan		
b5	20	238	554	330.95	78.01	A		
b2	20	222	491	339.35	70.57	A		
b3	20	236	497	351.40	72.88	A	B	
b4	20	253	510	374.36	75.19	A	B	
b6	20	277	580	397.50	98.23		B	C
b1	20	305	543	428.60	69.78			C

Table 6 shows the experimental results of the 9 combinations of elevator and seat. The ANOVA showed that the position had significant effect on performance. The Duncan test showed the performances at modes 8, 9, and 7 were better than those at modes 4 and 1. Positioning the elevator on the right resulted in better performance than positioning it on the center or on the left. The position of the elevator had stronger impact on the performance than the seat position.

Table 6 the performances of the elevator and seat positions

Modes	N	Min	Max	Mean	Std.	Duncan	
c8	20	34	297	122.70	54.22	A	
c9	20	74	254	129.90	45.47	A	
c7	20	87	227	140.45	46.37	A	
c2	20	46	285	168.40	73.73	A	B
c6	20	58	330	168.45	76.22	A	B
c3	20	59	405	170.10	87.13	A	B
c5	20	52	322	170.95	70.37	A	B
c4	20	76	374	190.95	67.33		B
c1	20	41	352	194.95	89.15		B

5. CONCLUSIONS AND SUGGESTION

This research aims to investigate the concept and movement compatibility between the controls and displays on ultralight planes. It included three studies. On the basis of the research results, the following conclusions could be drawn.

The conclusions from study 1 could be summarized as: 1) positioning the throttle to the left of the seat and the elevator to the right of the seat was the most compatible combination; 2) positioning the airspeed indicator on the left, the heading indicator at the center, and the altimeter on the right was the most compatible arrangement; 3) the mode proposed by this study was more compatible than the traditional one. That is, when the right rudder pedal is pushed, the plane will turn left, and when the left rudder pedal is pushed, it will turn right; 4) when the elevator is pushed forward, the plane will ascend; 5) when the elevator is pushed forward, the pointer of the altimeter (at the 12 o'clock position) will move counter-clockwise, and when the elevator is pulled back, the pointer will move clockwise; 6) when the throttle is pushed forward, the pointer of the airspeed indicator (at the 12 o'clock position) will move counter-clockwise; 7) half of the subjects considered that when the right rudder pedal was pushed forward the pointer of the heading indicator (at the 12 o'clock position) would move clockwise. The result indicated that the pointer at the 12 o'clock position is indeterminate when operating the rudder and this position should be avoided.

From study 2 and study 3 the following conclusions could be drawn: 1) the newly developed mode was more compatible with human understanding. The t-test showed the newly developed mode was better than the traditional mode. The result could be considered as an important reference for further research and design; 2) the pilot performance with the rudder on the central position was better than that with the rudder on the left or the right; 3) the seat position had stronger impact on the performance than the throttle position. Positioning the seat on the center resulted in better performance than positioning it on the left or the right. Positioning to throttle near the center resulted in better performance than positioning it far from the center. 4) the position of the elevator had stronger impact on pilot performance than the seat position. Positioning the elevator on the right resulted in better performance than positioning it on the center or the left, while the seat position had no significant effect.

ACKNOWLEDGEMENT

The authors would like to thank the National Science Council of the Republic of China in Taiwan for partial financial sponsorship of this study under contract No. NSC 93-2213-E-224-016.

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