

Effect of Video-Game Experience and Position of Flight Stick Controller on Simulated-Flight Performance

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The purpose of this study was to determine the effects of video-game experience and flight-stick position on flying performance. The study divided participants into 2 groups; center- and side-stick groups, which were further divided into high and low level of video-game experience subgroups. The experiment consisted of 7 sessions of simulated flying, and in the last session, the flight stick controller was switched to the other position. Flight performance was measured in terms of the deviation of heading, altitude, and airspeed from their respective requirements. Participants with high experience in video games performed significantly better ($p < .001$) than the low-experienced group. Also, participants performed significantly better ($p < .001$) with the center-stick than the side-stick. When the side-stick controller was switched to the center-stick position, performance scores continued to increase (0.78 %). However, after switching from a center- to a side-stick controller, performance scores decreased (4.8%).

flight simulator flight performance pilot training game experience flight stick position

1. INTRODUCTION

The high cost of student pilot and flight officer attrition from aviation training has been a major problem for the naval aviation industry. In fiscal year 2007, the average investment in each attrited student naval aviator from commencement of training to separation from training was ~89 000 USD. Similarly, the average investment in each attrited student naval flight officer was ~43 000 USD [1]. This cost estimation accounted for recoverable costs only, without considering fixed costs. Arnold accounted for both recoverable and fixed costs, which produced even higher estimates of attrition costs [2]. He found that the average attrition cost in 2002 was ~160 000 USD per student naval aviator and 115 000 USD per student naval flight aviator. From fiscal year 2003 to 2007,

there was a total of 1558 student attrition cases reported [3]. Any marginal reduction to this attrition rate will produce significant cost savings to the naval aviation industry.

1.1. Center Stick Versus Side Stick Controller

One of the top causes of aviation training attrition is flight failure, which accounted for 24% of all attrition during fiscal years 2003–2007 [4]. One factor that may affect flight performance is the location of the flight control stick with respect to the trainee. A conventional cockpit design has the flight control stick placed in the center between the knees of a pilot (e.g., T-38 jet trainers, F-117 fighter aircraft, and UH-72 helicopters). Another cockpit design has the flight control stick mounted

on the right armrest of the pilot's seat (e.g., F-22 fighter aircraft and T-50 jet-trainers).

Several studies investigated the effects of side- and center-stick controllers on the flight performance of experienced pilots. Hall and Smith found that side-stick controllers were considered satisfactory for the landing approach tasks, but not for up-and-away flight tasks, which included formation, air-to-air tracking, and acrobatic maneuvering [5]. Geiselhart, Kemmerling, Cronburg, et al. concluded that side-stick controllers were feasible for use in relatively high-speed aircraft flying at low altitudes [6]. A more recent study found that side- and center-stick controllers did not affect performance and that there was no clear preference for either controller [7]. Mayer and Cox compared the effect of two unique side-stick controllers and the standard center-stick on flight performance [8]. They found that aggressive pilots preferred the center-stick because the side-stick was underdamped, causing overshoots and oscillations when large motions were executed. The less aggressive pilots preferred the side-stick because of the smooth motion and low breakout forces. Most of these studies suggested that experienced pilots, for the most part, preferred the side-stick controller over the center-stick. However, more research is necessary to validate this conclusion.

1.2. Impact of Attention Distribution Skills and Video-Game Experience on Flight Performance

Flying a modern, high-performance aircraft is a complex, cognitively demanding task that requires many talents and skills, especially in attention distribution. Pilots must be able to focus attention on relevant aspects of tasks, rapidly switch from one task to another, avoid interference of irrelevant information, and divide resources properly while multitasking [9]. Gopher investigated the significance of incorporating selective attention tests in the pilot selection battery of the Israeli Air Force [9]. He found that flight cadets who had completed a 2-year training program successfully had significantly lower error scores on all attention measures than cadets who failed in training. In another study, Tham

and Kramer investigated attention-distribution abilities of students and instructor pilots, and concluded that instructor pilots were more efficient in task switching and focused attention than novice pilots [10].

Several studies suggest that video games can improve basic perceptual and cognitive abilities, including attention [11, 12, 13, 14, 15]. For instance, playing video games significantly improves reaction times to a stimulus [16, 17]. Another study demonstrated that individuals with video-game experience were able to monitor more moving objects simultaneously than individuals without game experience [12]. Also, Boot, Kramer, Simons, et al. found that expert video-game players (those who play 7 or more hours of video games per week for 2 years) were able to track objects moving at higher velocities, better detect changes to objects stored in visual short-term memory, switch quicker between tasks, and mentally rotate objects more efficiently [15].

Since playing video games can improve attention capabilities, they may also be able to improve flight performance. Gopher, Well, and Bareket studied the effects of playing Space Fortress (a video game) on actual flight performance [18]. One group of cadets played Space Fortress for 10 h, while another group (control group) did not play at all. They found that the game group significantly outperformed the control group in actual flight performance. Also, Hart and Battiste conducted research to determine whether the workload-coping and attention-management skills developed through structured video-game experience (10 h of Space Fortress) could be applied to flight training [19]. Flight school records were monitored for 18 months to compare performances of the game and no-game groups during initial flight training. Check ride ratings began to show an advantage for the game group by the instrument stage of training. Furthermore, the game group had lower attrition rates than the no-game group.

1.3. Purpose of Study

The literature shows that playing video games for a relatively short period improves flight perform-

ance. However, the impact of previous video-game experience on flight performance has not been studied before. One of the purposes of this study was to determine whether the experience level in video/computer games affected simulated flight performance. Also, previous research indicated that trained and experienced pilots could prefer the side-stick controller over the center-stick. However, since the participants were experienced pilots, the results of those studies may have been biased to the pilots' previous experience. For instance, some pilots may have had more experience with side-stick than center-stick controllers, or vice versa, which may have had some effect on their stick position preference. Therefore, another purpose of this study was to determine the impact of stick position (center- versus side-stick) on simulated flight performance of individuals who had no previous experience in flying, or personal computer-based (simulated) flying.

This study also had two additional objectives. One was to determine whether the Air Force Officers Qualifying Test (AFOQT) was a valid predictive measure of flight performance of Korean and American pilot candidates. Over a 20-year period, the training attrition rate of Korean cadets was estimated as 45% [20], yet the Korea Air Force does not have an organized

pilot-candidate selection method. The Korea Air Force can benefit from this study in deciding whether the AFOQT is a valid test for screening Korean pilot candidates. The second objective was to determine the effects of switching from a side- to a center-stick controller, and vice versa, on flight performance after having had some experience with one stick position. The reason behind studying this objective was to determine how pilots who are experienced or comfortable with one stick position are affected by flying an aircraft with a different stick position.

2. METHOD AND PROCEDURES

2.1. Equipment

The equipment in this study consisted of a personal computer system with a standard keyboard and a mouse. IFT-PRO version 5.13 by Flight Deck Software¹ was used as the flight simulator. Though a personal computer-based flight simulator is not as realistic as other highly expensive flight simulators, several studies have proved it to be effective for training [21, 22, 23, 24, 25, 26]. A flight-stick with Game-card III by CH Products² was the flight control stick. Figure 1 shows the experimental layout of the personal computer with a center- and side-stick.

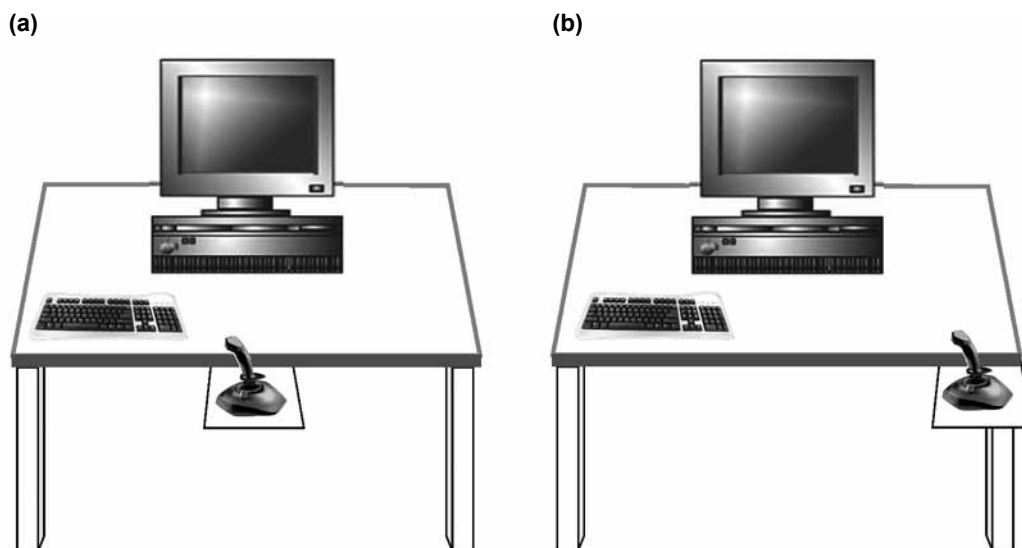


Figure 1. Experimental layout of the (a) center- and (b) side-stick controllers.

¹ <http://www.flightdecksoftware.com/>

² <http://www.chproducts.com>

2.2. Participants

Thirty-two undergraduate students from Louisiana State University’s Reserve Officers Training Corps and 32 cadets from the Korea Air Force Academy participated in this study (64 participants). Each participant received 5 USD per hour of participation. The participants had no previous experience in flying or personal computer-based flying (flight simulation). They were divided into two groups according to self-subjective ratings of their video-game experience. Those who normally played video/computer games once or less a week were considered as having low experience in video-games, and those who normally played more than once a week were considered as having high experience in video-games. The number of high- and low-experienced participants was even.

Furthermore, each group was randomly divided into two subgroups: one group began the experiment with the center-stick (Figure 1a) and then switched to the side-stick (Figure 1b); the other began with the side-stick and then switched to the center-stick. The participants’ groupings were as follows:

- 16 participants: high video-game experience, center- to side-stick (HC);
- 16 participants: high video-game experience, side- to center-stick (HS);
- 16 participants: low video-game experience, center- to side-stick (LC);
- 16 participants: low video-game experience, side- to center-stick (LS).

2.3. Experimental Task

The participants performed a simulated flying task requiring various maneuvers (e.g., take-off, climb, level-off, and turn left/right) and following a specific course. Table 1 shows the required maneuvering, heading, altitude, and airspeed with respect to time during the simulated flight. Figure 2 shows the flying course that the participants had to follow based on the required maneuverings.

2.4. Experimental Design

A two-factor repeated measures experimental design was used. The independent variables were the experience level (high or low) in video games and the position (center or side) of the flight control stick. The dependent variables were the test scores on the U.S. AFOQT and the performance scores in simulated flying.

2.5. Data Collection and Processing

Before the experiment, the AFOQT was administered [27]. The participants had 3.5 h to complete it. The test consisted of 16 parts: verbal analogies, arithmetic reasoning, reading comprehension, data interpretation, word knowledge, math knowledge, mechanical comprehension, electronic maze, scale reading, instrument comprehension, block counting, table reading, aviation information, rotated blocks, general science, and hidden figures.

TABLE 1. Required Maneuverings Schedule

Time (min:s)	Maneuvering	Heading (°)	Altitude (feet/m)	Air Speed (kt)
0:00	take-off roll	60	500/152	0 → 60
0:30	take-off & climb	60	500/152	60 → 90
1:30	level-off	60	1000/305	v90 → 100
2:00	left turn	60 → 0	1000/305	100
3:00	left turn	0 → 270	1000/305	100
4:30	left turn	270 → 180	1000/305	100
6:00	climb	180	1000/305 → 1500/457	100 → 90
7:00	level-off	180	1500/457	90 → 100
8:00	right turn	180 → 270	1500/457	100
10:00	right turn	270 → 60	1500/457	100
11:30	descent	60	1500/457 → 500/152	60
13:30	touch down	60	500/152	60

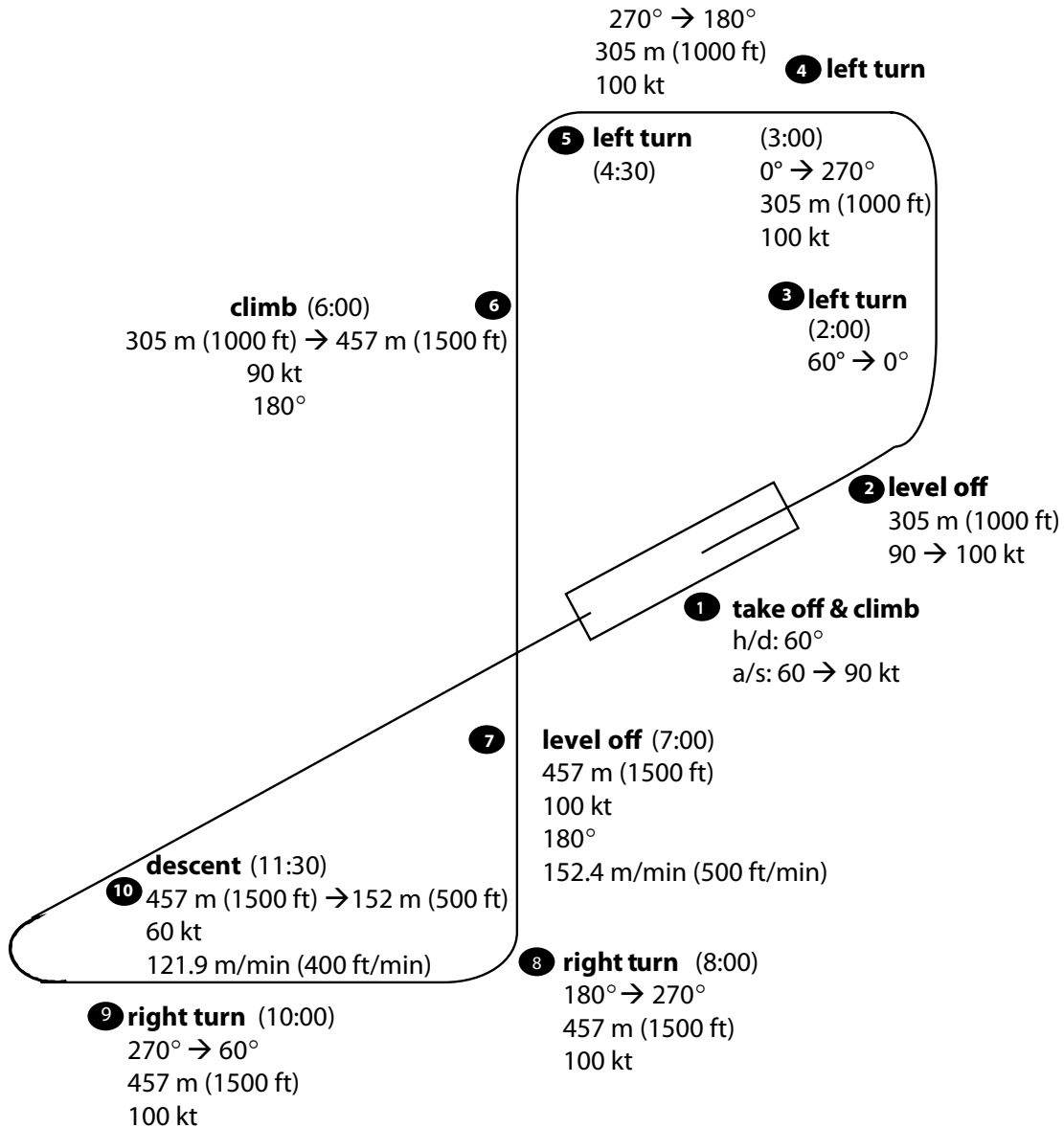


Figure 2. Simulated flying training course. Notes. H/D—heading, A/S—air speed.

After the AFOQT, the participants were introduced to the cockpit display (Figure 3), the control devices, and the flying course (Figure 2). They were also provided with a condensed manual, which further discussed the operating procedures of the flight simulation with the control devices and the cockpit display. The manual also explained the basic procedures of performing various functions, such as changing airspeed, turning, climbing, descending, and leveling.

The experiment consisted of seven 30-min sessions. During the first 15 min of each session, the participants were allowed to fly on their intention

to grasp various flying characteristics, such as sensitivity and controllability of the flight control stick. During the second 15 min, flight performance data (i.e., heading, altitude, and airspeed) were recorded every 15 s on the data collection form (Table 2).

During the orientation and the first six sessions, the participants performed the simulated flying task with the control-stick in one position (either center- or side-position depending on the group). This allowed the participants to become familiar with one stick position. Then, in the seventh session, the position of the control stick was

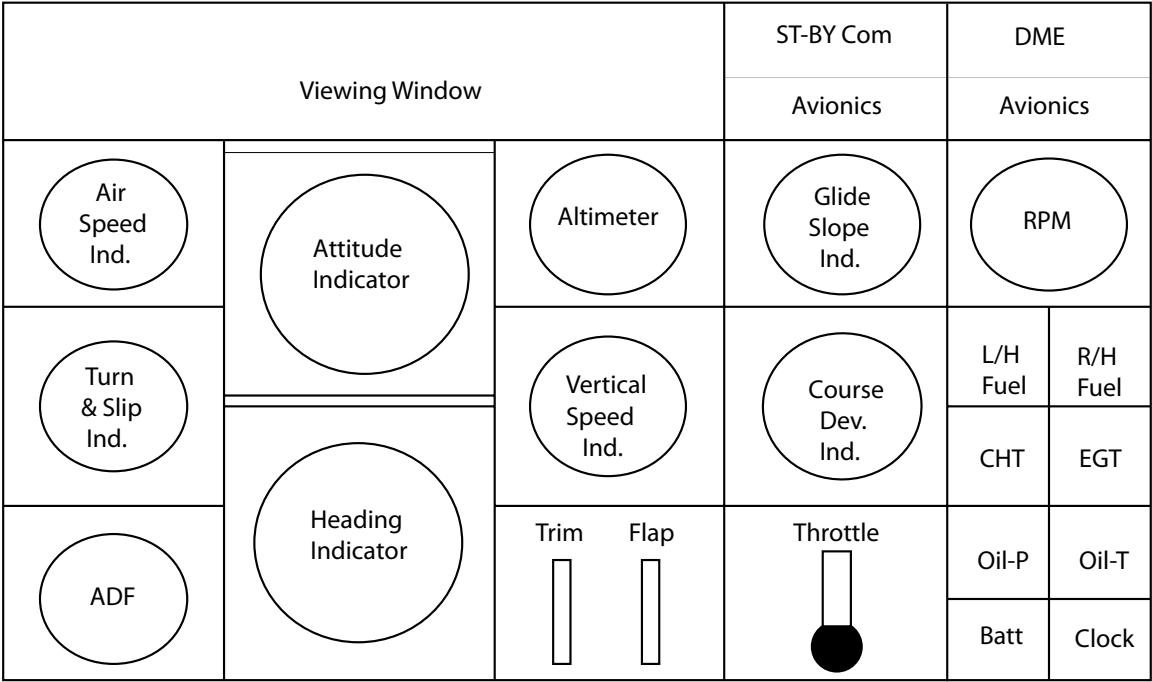


Figure 3. Instrument panel of the flight simulator. Notes. ST-BY com—stand-by command, DME—distance measuring equipment, ind.—indicator, ADF—automatic direction finding, dev.—deviation, RPM—revolutions per minute, L/H fuel—left-hand (side) fuel tank, R/H fuel —right-hand (side) fuel tank, CHT—cylinder head temperature, EGT—exhaust gas temperature, P—pressure, T—temperature, batt—battery.

TABLE 2. Data Collection Form

Time (min:s)	Heading			Altitude			Air Speed			Sum of Score
	Required (°)	Actual (°)	Converted Score	Required (feet/m)	Actual (feet/m)	Converted Score	Required (kt)	Actual (kt)	Converted Score	
0:15	60			394/120			50			
0:30	60			450/137			85			
0:45	60			575/175			90			
1:00	60			700/213			90			
1:15	60			825/251			90			
1:30	60			950/290			100			
1:45	60			1000/305			100			
2:00	60			1000/305			100			
2:15	30			1000/305			100			
6:15	180			1000/305			90			
6:30	180			1225/373			90			
6:45	180			1350/411			90			
...	...			...			...			
13:15	60			525/160			60			
13:30	60			400/122			60			
13:45	60			394/120			60			
mean of total converted scores										

switched to the other position. This was done to determine the effects on flight performance of switching from a familiar to an unfamiliar stick position. In the real world, pilots may have a preferred stick position and, in some cases, they may have to operate an aircraft with a differently positioned control stick. Hence, the switching in this study was an attempt to determine the impact on flight performance of operating an aircraft with an unfamiliar stick position. The duration of the experiment for each subject was limited to a minimum of 4 days and a maximum of 3 weeks. The number of sessions a day was also limited to two sessions to enhance retention and learning.

The flight performance score in each session was a function of heading, altitude, and airspeed data. The deviations of each parameter from their respective requirements (Table 2) were computed. Then, the deviations were converted into percentile scores in accordance with Table 3 [20]. For instance, a deviation in 10 ft (3 m) of altitude would be converted into a score of 33, and a 4° deviation in heading would be converted into a score of 29. The converted scores of heading, altitude, and airspeed were summed to compute flying performance scores; a perfect score would be 100 ($33 + 34 + 33 = 100$). If any of the deviations in heading, altitude, or airspeed exceeded 10°, 100 ft (30 m), or 10 kt, respectively, the overall performance was evaluated as *fail*.

2.6. Statistical Analysis

To determine the effect of the independent variables (level of game experience and stick position) and their interactions, we performed a two-factor repeated measures analysis of variance (ANOVA) with SAS version 6.12. We also performed a correlation analysis between the AFOQT scores and flying performance scores to determine whether the AFOQT was a valid predictive measure of flight performance. The significance level was set at 5% for all statistical tests.

3. RESULTS

3.1. Relationship Between AFOQT Scores and Flight Performance Scores

Figure 4 is a scatter plot of the AFOQT scores and the flying performance scores of the Korean and American participants. This graph also includes the regression lines of the plotted points, showing a positive correlation between AFOQT scores and flying performance scores. For the Korean participants, the correlation coefficient between the two scores was .627, the slope of the regression line was .884, and the mean score in the AFOQT was 65.9%. For the American participants, the correlation coefficient was .520, the slope of the line was .610, and the mean score in the AFOQT was 88.3%.

TABLE 3. Conversion Table

Heading		Altitude		Air Speed	
Deviation (°)	Converted Score	Deviation (feet/m)	Converted Score	Deviation (kt)	Converted Score
0	33	0/0	34	0	33
1	32	10/3	33	1	32
2	31	20/6	32	2	31
3	30	30/9	31	3	30
4	29	40/12	30	4	29
5	28	50/15	29	5	28
6	27	60/18	28	6	27
7	26	70/21	27	7	26
8	25	80/24	26	8	25
9	24	90/27	25	9	24
10	23	100/30	24	10	23
>10	0	>100/30	0	>10	0

3.2. Effect of Flight Control Stick Position

Figure 5 is a linear graph of the performance scores in the simulated flying task of the center- and side-stick groups. This graph shows that, in six of the seven sessions, the center-stick group attained a higher average performance score than the side-stick group. The mean scores of the center- and side-stick groups were 82.5 and 78.1, respectively, which were significantly different from each other ($p < .001$).

3.3. Transfer Effect of Switching Stick Position

During the seventh and final session of the experiment, the flight control stick of each group was switched to the other position. The seventh session in Figure 5 shows the performance scores of each group after the switch. In the case of the group that switched from a side- to a center-stick, the performance score increased by an average of 0.9. However, in the case of the group that switched from a center- to a side-stick, the performance score decreased by an average of 3.7.

3.4. Effect of Experience in Video Games

The study found that the experience level in video games significantly affected performance scores in simulated flying ($p < .001$). Performance scores of the high- and low-experienced groups were 82.3 and 78.3, respectively. Figure 6 is a linear graph of the performance scores of the high- and low-experienced groups in the seven sessions. In all the sessions, the high-experienced group attained a higher score than the low-experienced one.

3.5. Combination Effect of Stick Position and Experience in Video Games

Figure 7 shows the performance scores of different combinations of stick position and experience level in video games. The high-experienced center-stick group received the highest score in all seven sessions, attaining a mean score of 85.0. On the other hand, the lowest recorded score in nearly all the sessions was from the low-experienced side-stick group, which attained a mean score of 76.5. However, the interaction effect between stick position and game experience was

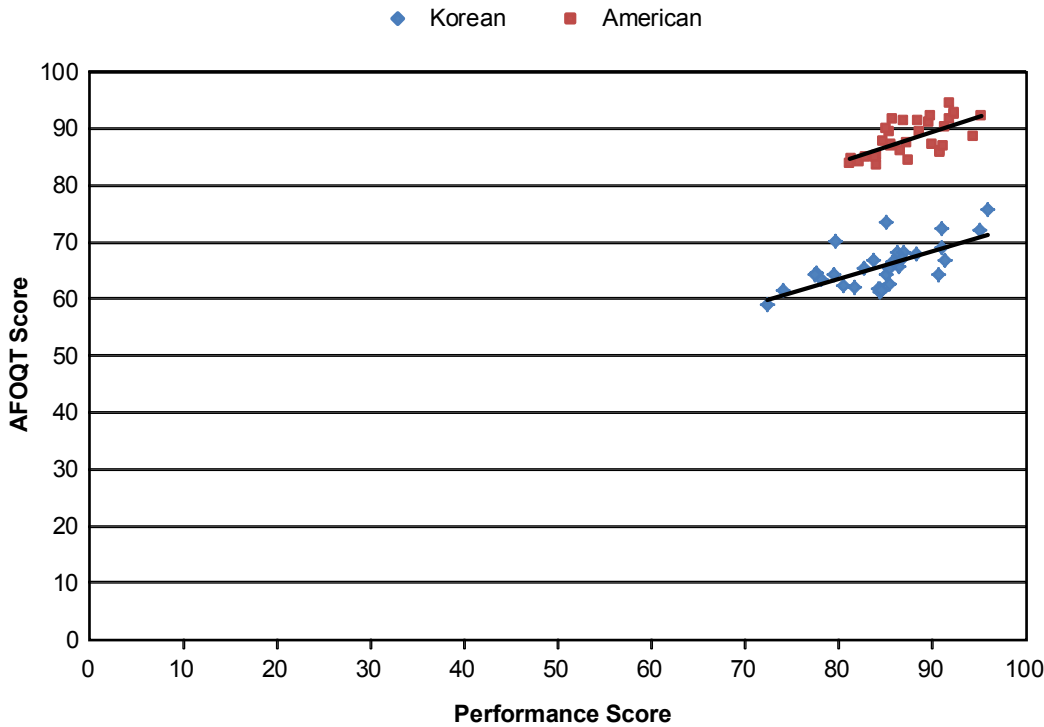


Figure 4. Scatter plot and regression lines of the Air Force Officers Qualifying Test (AFOQT) scores and the flying performance scores of Korean and American participants.

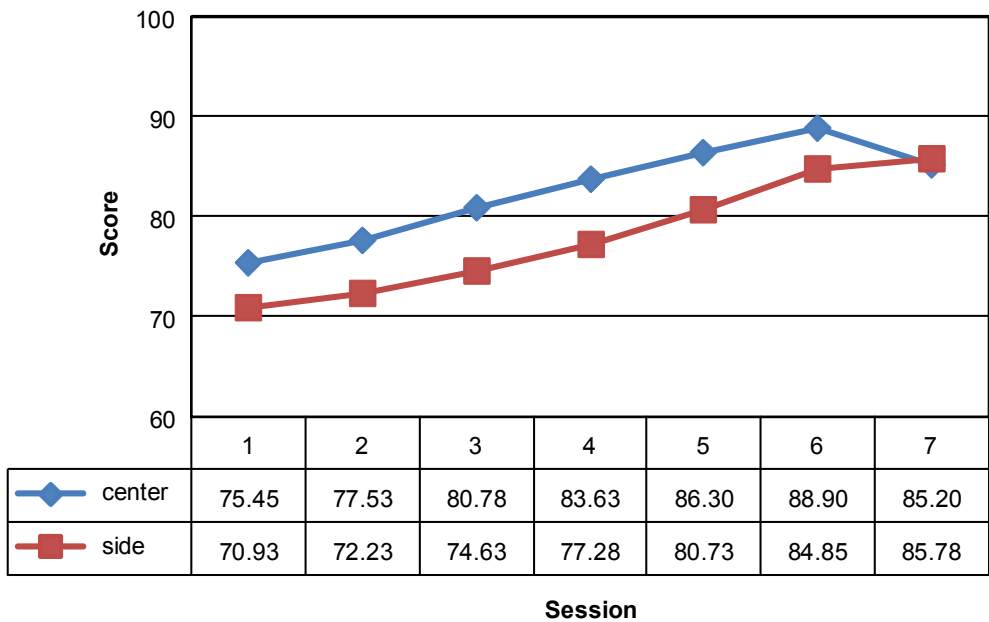


Figure 5. Mean scores for the center- and side-stick groups.

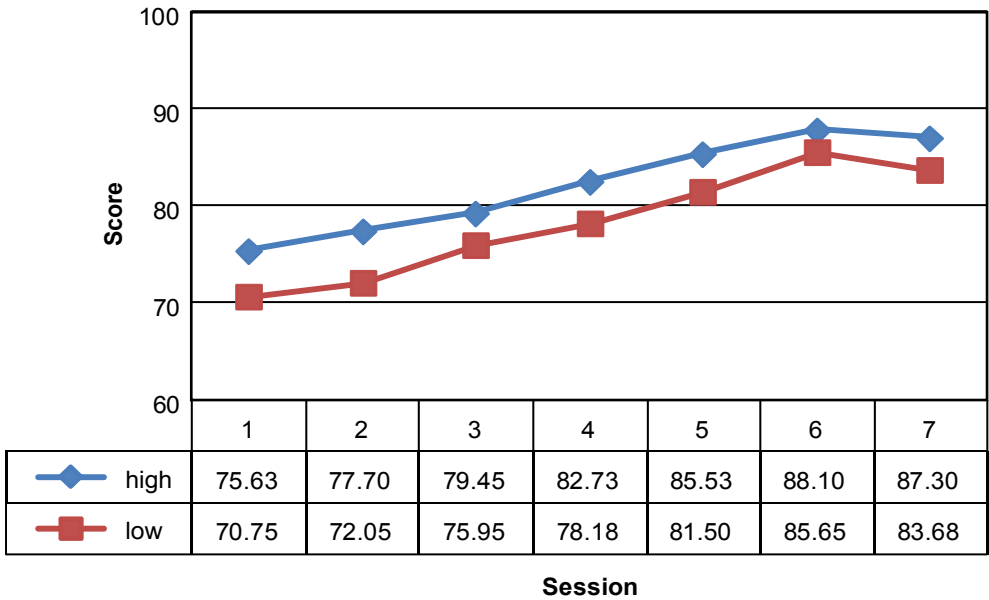


Figure 6. Mean scores for groups with high and low experience in video games. Notes. high, low—video-game experience.

not significant ($p = .429$), meaning that their effects were independent of each other.

4. DISCUSSION

One of the objectives of this study was to compare the effects of side- and center-stick controllers on the simulated-flight performance of in-

experienced individuals. Results show that the center-stick group performed significantly better than the side-stick group in all flight sessions. The participants commented that they found the side-stick controller awkward to use, since it did not line up with their eyesight as the center-stick did. This finding should encourage the naval aviation industry to primarily use center-stick controllers in flight training programs.

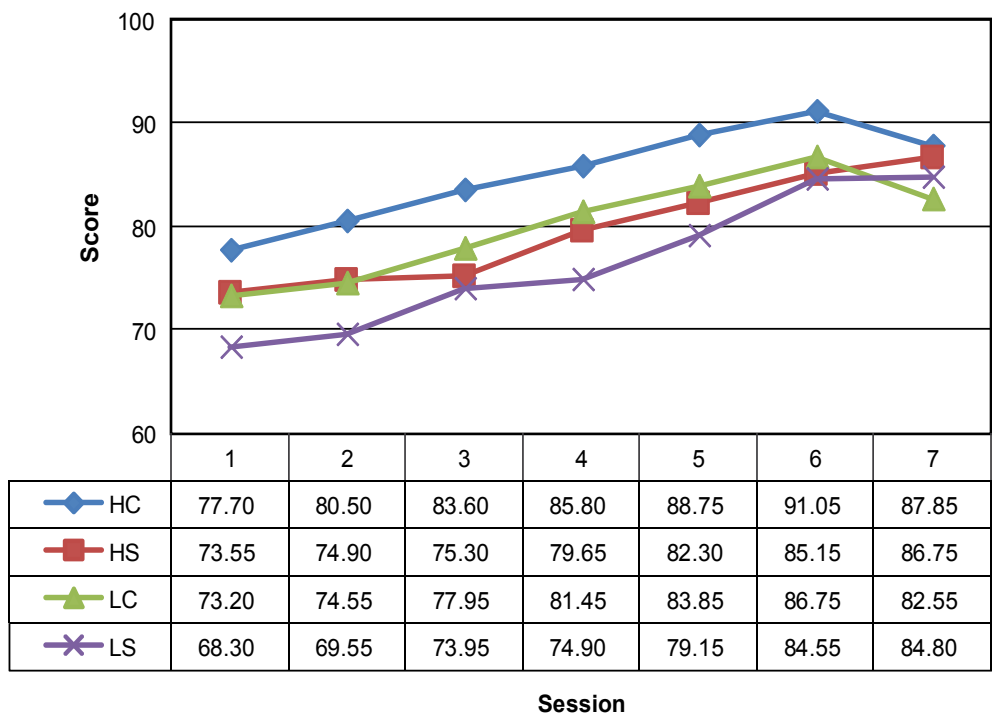


Figure 7. Mean scores for video-game experience level and stick position. Notes. HC—high video-game experience, center- to side-stick, HS—high video-game experience, side- to center-stick, LC—low video-game experience, center- to side-stick, LS—low video-game experience, side- to center-stick.

In contrast to our results, Geiselhart et al. found that experienced pilots preferred the side-stick controller over the center-stick [6]. Also, Mayer and Cox found that aggressive pilots preferred center-stick controllers and less aggressive pilots preferred side-stick ones [8]. Since the participants of the current study were beginners, we expected their preferred stick position to be similar to the less aggressive pilots; however, that was not the case. This suggests that stick position preference may differ between experienced pilots and inexperienced individuals.

In the final session of the experiment, the flight control stick of each group was switched to the other position. In the case of the group that switched from a side- to a center-stick, the performance score increased by an average of 0.8. The side-stick curve in Figure 5 continued to increase in the seventh session after the switch; however, the increase was lower than the increase in the previous sessions. This may suggest that pilots who are experienced with side-stick controllers will hardly be affected when having to fly with a center-stick controller. However, in the case of the group that switched from a center- to a

side-stick, the performance score decreased by an average of 4.8. This, on the other hand, suggests that pilots who are experienced with center-stick would have problems with side-stick controllers. A limitation to this conclusion is that it was based on performances of individuals with no previous experience in flying. The only experience they had in flying before switching the stick position was the six experimental sessions. To improve the validity of this conclusion, a future study with experienced pilots is recommended.

Another objective of this study was to determine the effect of video-game experience on simulated-flying performance. Since previous studies showed that video games could improve basic perceptual and cognitive abilities [11, 12, 13, 14, 15], we expected the more experienced group in video games to score higher on the flight performance test, which was the case. The mean performance scores of all flight sessions of the high- and low-experienced groups were 82.5 and 78.1, respectively. The difference (4.4) was found to be statistically significant, indicating that experienced video-game players had an advantage in operating aircraft. This result supports the find-

ings of Gopher et al., who showed that playing Space Fortress for even a relatively short period (10 h) could improve flight performance [18]. Hence, this study should encourage the aviation industry to additionally screen its pilot candidates on their level of experience in video games.

However, before incorporating this into pilot screening tests, there should be more research investigating this area. This study only evaluated two levels of video-game experience (high and low). Future studies may also evaluate additional levels, such as no experience and medium-level of experience. Also, video-game expertise should be better defined in future studies. In this study, the definition was in terms of the number of times video games were played per week, which did not take into account the number of hours played. If two participants played video games once a week, but one of them played for an hour and the other played for 10 h, they would both fall under the same category of expertise. Hence, a more accurate definition would be in terms of the number of hours per week the participant played video games.

This study also administered AFOQT to determine whether it was a valid predictive measure of flight performance. Results show that the American participants scored higher than the Korean ones. The American group may have scored higher because the test was in their native language. Regardless of the score differences, the AFOQT proved to be a valid predictive measure of flight performance for not only the American participants, but also the Korean ones. Surprisingly, the correlation coefficient between the AFOQT scores and flying performance scores was greater for the Korean group (.627) than the American one (.520). This could be interpreted as the AFOQT being a better predictive measure of the Koreans' than the Americans' flight performance. Either way, this finding supports the validity of the AFOQT for American pilot candidates and suggests that the AFOQT is also a valid screening test of Korean pilot candidates

5. CONCLUSION

The results of this study demonstrate that individuals without previous experience in flying prefer a center- over a side-stick controller. The center-stick group performed significantly better in nearly all seven sessions ($p < .001$). The participants stated that they found it awkward flying with a side-stick controller since it did not line up with their eyesight as the center-stick did. This finding may encourage the naval aviation industry to primarily use center-stick controllers in flight training programs.

In the last session of the experiment, the flight control stick of each group was switched to the other position. When the side-stick controller was switched to the center-stick position, performance scores continued to increase. This may suggest that pilots who are experienced with side-stick controllers will hardly be affected when having to fly with a center-stick controller. However, when switching from a center- to a side-stick controller, performance scores decreased by an average of 3.7. This, on the other hand, may suggest that pilots who are experienced with center-stick controllers may require training before flying with side-stick ones. To improve the validity of these two conclusions, more research is necessary in this area with experienced pilots rather than inexperienced individuals.

The study also found that the experience level in video games significantly affected performance scores in simulated flying ($p < .001$). In all flight sessions, the high-experienced group attained a higher score than the low-experienced one. This finding suggested that video-game experience could be a potential screening criterion of pilot candidates. However, more research is still necessary in this area before incorporating it into pilot screening tests, such as investigating additional levels of video-game experience and using a better definition of video-game experience (e.g., number of hours played per week).

Furthermore, the AFOQT scores and flight performance scores were highly correlated for both the American (.520) and Korean (.627) participants. This indicated that the AFOQT could be a valid predictive measure of flight performances

of pilot candidates in the Korea Air Force. Hence, through administering the AFOQT as a pilot screening test, the Korea Air Force may be able to reduce its high attrition rates in aviation training.

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