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Impact of subject related factors and position of flight control stick on acquisition of simulated flying skills using a flight simulator

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IMPACT OF SUBJECT RELATED FACTORS AND POSITION OF FLIGHT CONTROL STICK ON ACQUISITION OF SIMULATED FLYING SKILLS USING A FLIGHT SIMULATOR

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ABSTRACT

Increasing demand on aviation industry calls for more pilots. Thus, pilot training systems and pilot-candidate screening systems are essential for civil and military flying training institutes. Before actual flight training, it is not easy to determine whether a flight trainee will be successful in the training. Due to the high cost of actual flight training, it would be better if there were low cost methods for screening and training candidates prior to the actual flight training.

This study intended to determine if subject related factors and flight control stick position have an impact on acquisition of simulated flying skills using a PC-based flight simulator. The experimental model was a factorial design with repeated measures. Sixty-four subjects participated in the experiment and were divided into 8 groups. Experiment consisted of 8 sessions in which performance data, such as heading, altitude and airspeed were collected every 15 seconds. Collected data were analyzed using SAS statistical program.

Result of multivariate analysis of variance indicated that the three independent variables: nationality, computer game experience, and flight stick position have significant impact on acquiring simulated flying skill.

For nationality, Americans recorded higher scores in general (mean: 81.7) than Koreans (mean: 78.9). The difference in mean scores between Americans and Koreans was 2.8 percent.

Regarding computer game experience, the difference between high experience group (82.3) and low experience group (78.3) is significant. For high experience

group, American side-stick group recorded the highest (mean: 85.6), and Korean side-stick group (mean: 77.2) scored the lowest. For the low experience group, American center-stick group scored highest (80.6), and the Korean side-stick group (74.2) scored the lowest points. Therefore, there is a significant difference between high experience group and low experience group.

The results also reveal that the center-stick position is easier to learn than side-stick position. The difference in performance score between group of center-stick (mean: 82.1) and side-stick (mean: 76.8) is considerable.

CHAPTER 1

INTRODUCTION

As a result of the rapid development of aviation technology, the operations of aircraft in both civil and military purposes have been increased dramatically in quantity as well as quality. Consequently, demand for human resources, specifically for pilots, has also been increasing. It is reported that training cost for a qualified pilot exceeds one million dollars (Driskell and Olmstead, 1989).

On the other hand, a cockpit of aircraft is one of the most complicated and compact workstations. In a small space, numerous instruments show the status of the aircraft, and numerous switches and control devices are arranged within the pilot's reach. To operate the aircraft properly in this type of working environments, pilots should be trained systematically.

There are various kinds of simulators in use to meet the above requirements - enhancing the effectiveness of training while reducing the cost. However, the need for high realistic flight simulators has resulted in a high cost of training using the simulators. Research has proved that low realistic simulation, such as PC-based simulation programs, has almost the same effect on reducing training-time and cost as high realistic ones.

This research examines the impact of subject related factors and physical position of the flight control stick on acquisition of flying skill by using a PC-based flight simulation program. The result of this research will be useful in training pilots at the beginning phase of flight training, and in selecting candidates for the flight school.

1.1 Research Rationale

The U. S. Air Force has continuously been developing and using the pilot-candidate screening system. However, there is no organized system for the pilot-candidate screening in Korea Air Force. The training attrition rate in Korea Air Force is about double of those of the U. S Air Force. These points are the main reasons why this research is being conducted.

Before actual flight training, it is not easy to determine whether a flight trainee will be successful in the training or not. However, due to high cost of actual flight training, it would be better if there were low cost methods for screening and training candidates prior to the actual training. There have been many researches related to flight training and flight simulation. Among many factors, attention control or attention distribution has been distinguished as a primary element in manipulating an aircraft. On the other hand, researches have proved the positive effectiveness of the flight simulation on acquisition of flying skill. Thus, the flight simulation has been an important part of flight training. Through the flight simulators, it has been possible for the military department as well as civilian airliners to save costs in pilot's flying training. It is reported that PC-based flight simulation programs have almost the same effects on flight training as million-dollar simulators.

Most research on the flight simulators as well as actual flights have been carried out with a limited source of subjects such as same race, same group of pilots (Gopher, 1992; Moroney *et al.,* 1994). Furthermore, the past research on the side-stick has not focused on the performance of the beginners in the flight training. This research is unique in its kind in investigating the effect of stick position with combined subject background factors such as nationality and experience in computer games. This research may be a part of evaluation of the pilot-candidate selection program in the beginning phase of flying training with combinations of the position of flight control stick and basic subject factors.

1.2 Objectives of Research

The purpose of this research is to study the impact of subject related factors and position of the flight control stick on the acquisition of flight skills during flight training with a computer flight simulator. Specifically, the objectives of this research were:

1. To determine the effect of subject related factors in acquiring flight skills.
2. To examine whether the position of flight control stick has any effect on flight training.
3. To examine transfer effect of physical position of flight control stick on flight training; i.e. changing from center to side position and vice versa.
4. To determine relationship between simulated flying training using a simulator and actual flying training.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Background

Based on centuries endeavor to fly in the sky, the Wright brothers made a self-powered flight in the air for the first time in 1903 (Anderson, 1985). Since then, there have been drastic developments in aerospace technology and industry, as well as air transportation in both quality and quantity. The speed, size, safety, convenience, and automation in control of the aircraft are the major features among the developments (Jackson, 1996). According to a recent report, there are over twelve thousand jet airplanes - excluding military, private aircraft - in service in the worldwide commercial airlines (Shifrin, 1996). The total number of the aircraft in the world including military and private aircraft is over one hundred thousands (Jackson, 1996).

Consequently, with the dramatic increase in the air transportation demand, it is expected that airlines in the United States of America alone to carry about one billion and two hundred million passengers per year by 2015, doubling today's level (Deitz *et al.*, 1991; Shifrin, 1996). This means there will be more demand in number of aircraft, facilities, equipment, as well as human resource -such as aircrew, ground controllers and supporters.

On the other hand, most aircraft accidents are fatal to the large number of passengers and crew members due to high speed as well as large size of the aircraft. Shifrin (1996) quotes a recent report of Boeing Commercial Airplane Group that sixty-four percent of total aircraft accidents with known causes from 1959 to 1995 has been classified as the "flight crew" as a primary factor which caused the accidents. Thus, the flight training for the pilots will be one of major issues for the accommodations of the increased demands in the future. The importance of flight training that is a vital, crucial element in safe as well as successful and profitable aviation operations cannot be overemphasized.

2.2 Introduction to the Flying Training

2.2.1 Basic Concepts of Flight

The following is an introduction to basic concepts of flight, which consists of movement of the aircraft, cockpit display of the aircraft, and control of the aircraft as well as role and structure of the flying training.

2.2.1.1 Movement of the Aircraft

Unlike the automobiles, the aircraft moves in three dimensions. The movements of the aircraft in the air consist of pitching - up and down, rolling - left and right, yawing - left and right, individually or in combinations of any two or three factors (Bos, 2002).

Aircraft are thrust by their engine power. There are various kinds of engines such as reciprocating, turbojet, turbofan, ramjet, and rocket engines (Anderson, 1985). Aerodynamically, thrust induces the lift force, which enables the heavy aircraft to fly in the air.

The lift force is proportional to the airspeed and angle of attack to the relative wind. The aircraft should maintain higher speed than stall speed, which varies depending on the type of aircraft and configuration.

2.2.1.2 Control of the Aircraft

Aircraft control is composed of three components: pitch control, bank control, and power control. The pitch and bank control are made by flight control stick or wheel - pushing forward or pulling backward (toward pilot's body), pushing to the left hand side or right hand side.

Pitch changes the vertical attitude of the aircraft – upward or downward. Pilots get the information about the change of pitch through the cockpit window in relation to the horizon as well as the attitude indicator. If a pilot pulls the flight control device backward, nose of the aircraft goes up (climbing), and the miniature aircraft in the attitude indicator will be in sky position with some amount of deviation from the horizon, and vice versa for pushing the control device forward.

Aerodynamically, bank makes the aircraft turn to the direction of declination due to the lateral component of lift vector. Bank control is performed by pushing the flight control stick to the left or right-hand side, or turning the flight control wheel either side.

Change of the bank can be monitored through the cockpit window and the attitude indicator which provides information about the bank attitude or bank pointers in relation to the bank scale. The bank scale is located at the top of the attitude indicator. If the flight control stick or wheel is pushed to the left-hand side, the bank pointer will go to the right hand side in a moving horizon type attitude indicator (McCormick and Sanders, 1987), and the aircraft will make left turn.

Power changes are made by adjustments of throttle in reference to the power indicators. Power controls are attempted when changing airspeed or altitude become necessary.

2.2.1.3 Flight Control Instrument and Performance Instrument

All the information about status of the aircraft is sensed and converted into perceptible signal - mainly visual signal, and displayed in the cockpit in individual instruments. All the controls for an aircraft including power and mobility controls are done in the cockpit by pilot(s). Aircraft performance is achieved by controlling the aircraft attitude and power. Attitude of the aircraft is determined by relationships of the longitudinal and lateral posture to the horizon. Instruments of the aircraft can be classified into three groups; control instruments, performance instruments, and navigation instruments (Department of the Air Force, 1986).

Control instruments display immediate attitude of the aircraft and power indications and are calibrated to permit attitude and power adjustments in definite amounts. The attitude indicator shows aircraft's relative attitude in relation to the horizon in the instrument - such as, level flight, climbing, descending, banked angle - with a three-axes-gyro and a miniature aircraft (Department of Transportation, 1980). Typical types of attitude indicator are vacuum-driven attitude indicator, electric attitude indicator.

On the other hand, power indicators vary with the type of aircraft and may include tachometer or RPM, exhaust pressure ratio, manifold pressure indicator.

Performance instruments indicate the aircraft's actual performance. Performance is determined in reference to the altitude, airspeed, vertical velocity, flight heading, turn and slip rate, etc.

Navigation instruments indicate the position of the aircraft in relation to a selected navigation facility or fix. This group of instruments includes various types of indicators such as, course indicator, range indicator, glide slope indicator, and bearing pointers (Department of the Air Force, 1986).

2.2.2 Flight Control Devices

2.2.2.1 Position of Flight Control Devices

Among three elements of the aircraft control, pitch and bank control are done by a flight control stick or wheel. Most fighter aircraft and helicopters have sticks as flight control devices, while most passenger and cargo carriers and light airplanes have dual yoke type wheels as flight control devices with some exceptions (Sexton, 1988). This research is focused on the stick-type flight control devices used in most of the fighter aircraft and helicopters.

Conventionally, designers have placed the flight control stick at the center of cockpit, between knees of the pilot. In the biomechanical aspect, the flight control stick is placed in the mid sagittal plane of human body just like the axes of steering wheels of most automobiles are placed in the mid sagittal plane of the drivers' body (Chaffin and Anderson, 1991). Most jet trainers, fighter aircraft, and helicopters such as T-37, T-38, T-33 jet trainers, F-4, F-5, F-14, F-15, F-18, F-111 fighters, AH-1, UH-1, UH-60, and AH-64 helicopters have center stick. Typical cockpit arrangement of the center-stick is shown in Figure 1. In this type of arrangement, pilot controls the flight control stick with right hand, and adjusts throttle with left hand. There is a little flexibility in controlling a switch or device, which is beyond of the left-hand sweep. For a specific switch or equipment at extremely right-hand side, pilot may hold the flight control stick with left hand while he/she operates the switch with right hand. However, the flight control stick is so sensitive that a pilot cannot keep one's hand off unless in a well trimmed flight condition.

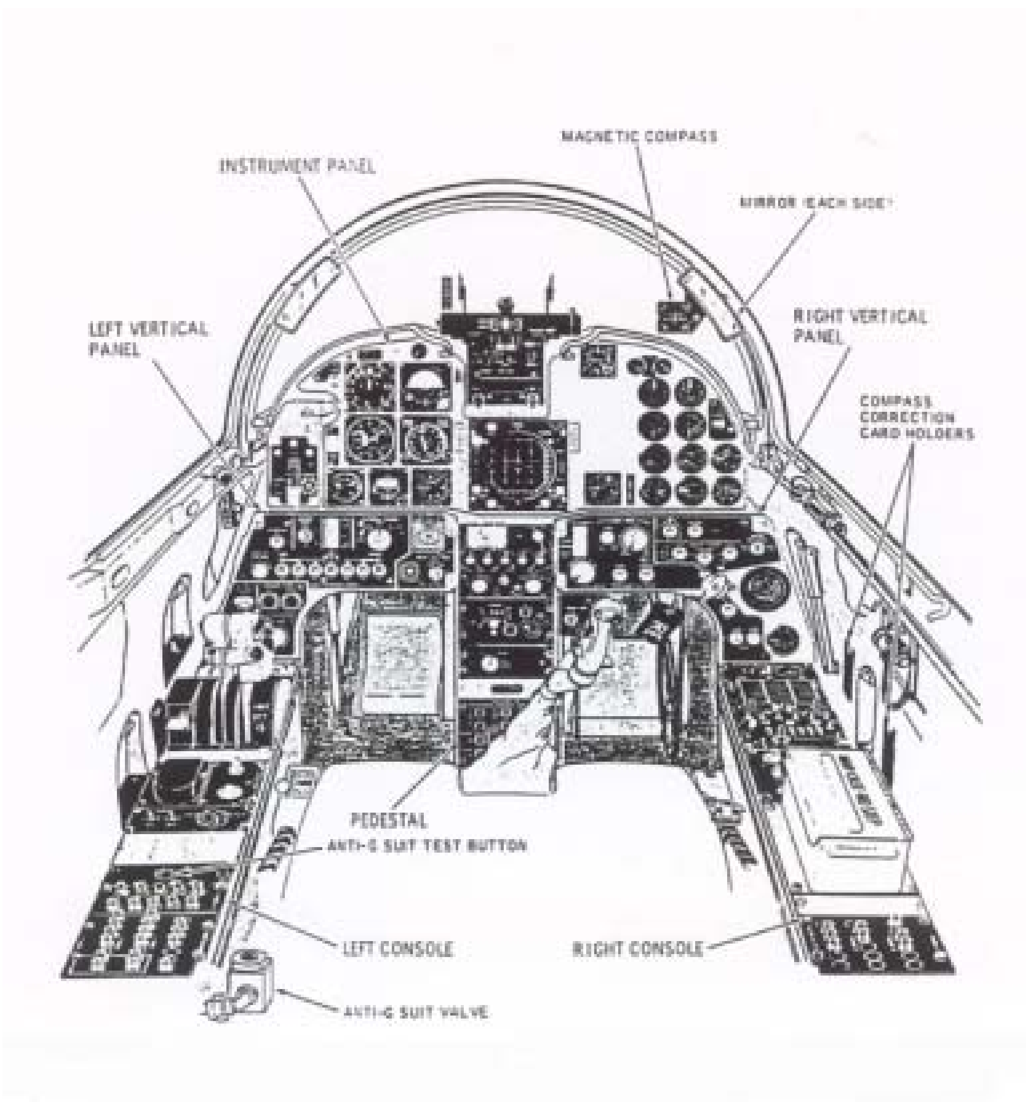


Figure 1. Cockpit Arrangement of F-5E/F
(Source: U. S. Department of Air Force, 1990)

On the other hand, some modern fighter aircrafts, such as F-16 and F-22 have side-stick, which are mounted on the right armrest of pilots' seat. Main reason why designers placed the stick on right-hand side is to enhance the tolerance to high gravity (G)-force, which is resulted by increased maneuverability of modern fighter aircraft. To endure the high G-force, seat for pilots of the side-stick aircraft is slanted to backward. To avoid extension of the distance from to pilot, and possibility of damage of the pilot during ejection, the designer should move the stick to right-hand side.

Side-stick may reduce the physical forces and displacements required to input commands, allowing pilots to assume a more comfortable posture (Hart, 1988). This fact is the primary advantage of the side-stick controller, and other advantages are simplicity, reliability, and low parts count (Aiken, 1985).

On the contrary, the primary disadvantage of side-stick controllers is that they do not provide explicit feedback about the amount of movement of the stick to the pilot. The amount and direction of movement needs to be changed. Since the stick is on the side of the pilot, he/she cannot see it. The pilots have to estimate the amount and direction of movement based on the information displayed on cockpit instruments, or the sensation of aircraft movement, which may increase the likelihood of cross-coupling, over control, and pilot induced oscillation. The fact that failure in flight control or propulsion system may cause the aircraft to become uncontrollable is another disadvantage (Aiken, 1985). As an example of side-stick controller, Figure 2 shows the typical cockpit arrangement of F-16C/D.

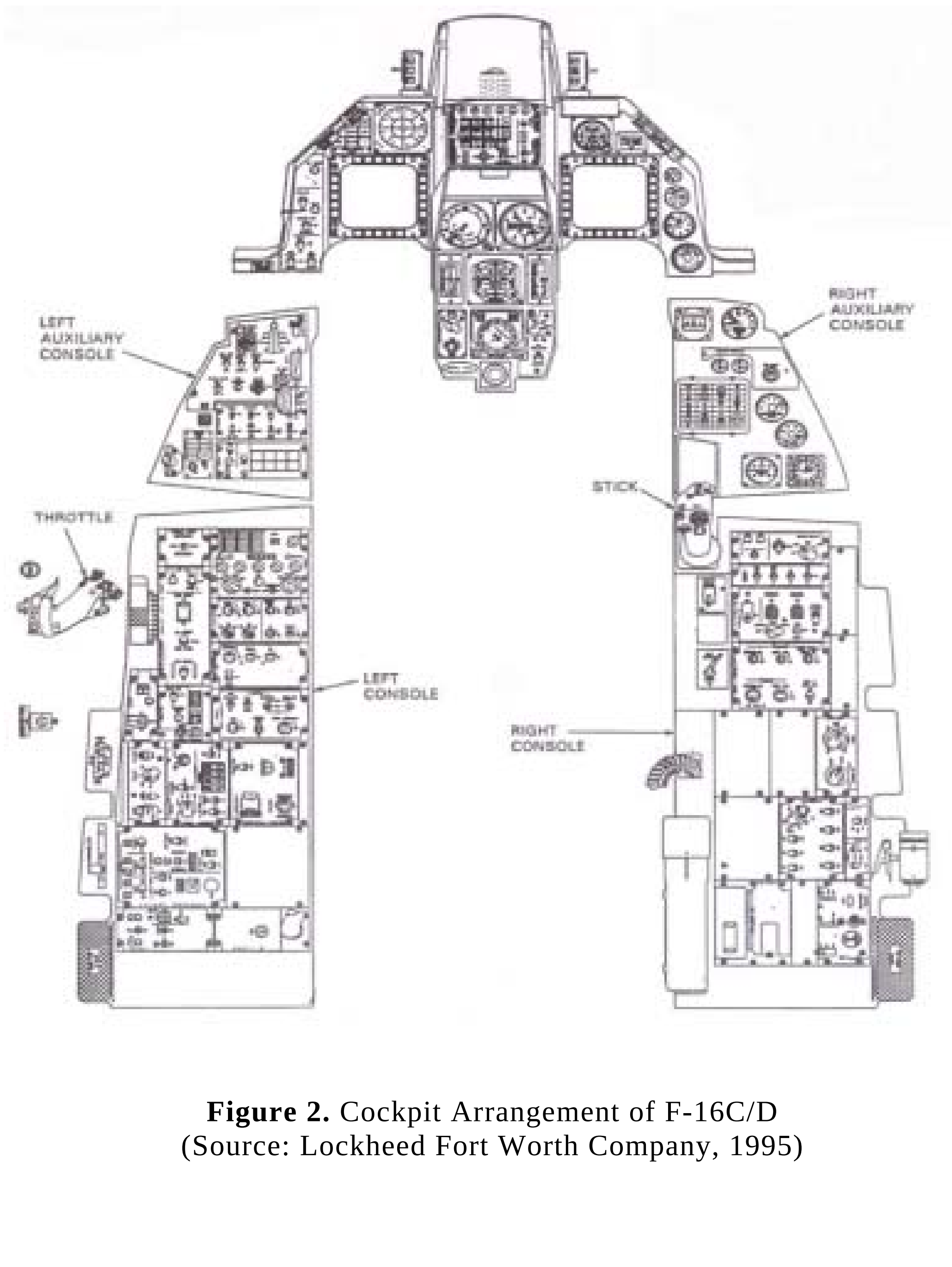


Figure 2. Cockpit Arrangement of F-16C/D
(Source: Lockheed Fort Worth Company, 1995)

2.2.2.2 Previous Research on Side-Stick

There have been many researches on the other positions of the flight control stick. Hart (1988) quotes Marsh stating that replacing conventional controls with integrated side-stick controls liberated designers from having to make the best of the fundamentally poor human factors situation presented by conventional controls.

Aiken (1985) introduces Kemmerling *et al.*'s comparison of performance with a center-stick and a side-stick. The study concluded that a side-stick was feasible for use in high-speed, high-altitude maneuvering tasks; it resulted in improved performance for landings and other precision maneuvers, but it yielded degraded performance for large-amplitude maneuvers at low altitudes.

Hall and Smith (1975) conducted research on the feasibility of the side-stick for fixed-wing aircraft. The primary purpose of the flight test program was to specifically evaluate force-deflection characteristics of a side-stick controller. In their study, two pilots were both members of the U. S. Air Force Test Pilot School staff and had extensive flight and test pilot experience. One pilot had over 4000 hours total flight time with 550 hours considered flight test experience. The other pilot had over 3800 hours with 800 hours of flight test experience. Pilots completed flights which consist of fundamental flight tasks, such as, close formation tasks, air-to-air tracking tasks, gross maneuvering tasks, and up-and-away fighter tasks, landing approach tasks with various configurations. The study concludes that the fixed side-stick controller was considered satisfactory for the landing approach tasks but not for the up-and-away flight tasks.

According to Staten *et al*. (1970), the Air Force Test Pilot School tested an F-104 equipped a side-stick controller. The side-stick was unanimously preferred to the conventional center-stick, and provided superior trajectory control with reduced pilot workload. Over 60 pilots flew with the side-stick and accumulated 870 hours of flight time with no controller failures.

Deppe *et al*. (1996) reports on a flight test result of an aircraft, Learjet 25, with side and center-stick controllers and rate-limited ailerons. The purpose of the test was to evaluate the flying qualities of an aircraft with a low roll actuator rate limit. The flight evaluation program consisted of four flights and 38 evaluations of test configurations. However, they did not find any differences in performance between side-stick and center-stick.

2.2.3 Flying Training

2.2.3.1 Role of Training

In considering the number of instruments and control system in the cockpit, it seems that there are too much information which pilots perceive and interpret to control the aircraft properly (Rapmund, 2002). Nevertheless, it is possible for the pilots to operate the aircraft through the appropriate training. Through researches and applications, the concept of controls has been made compatible to the sense and movement of human body in the directions of turning, climbing, and descending (Grandjean, 1997).

2.2.3.2 Structure of Flying Training

Flying training consists of ground lectures on flight procedures and aircraft system, basic air-works, tactical operations, and instrument flight including emergency procedures (Korea Air Force, 1994). Those courses are highly interrelated rather than independent. Length of training and allocation of the courses depend upon the type of aircraft and purpose of the flight training institute.

Actual flights are made under two categories of rules: visual flight rule (VFR) and instrument flight rule (IFR). In the VFR, pilot flies with outside references in accordance with the “see and avoid” rule (Leibowitz, 1988). Even during visual flight, however, pilots cross-check the instruments to get information about flight performance and control. During the instrument flight, pilots get information through instruments and radio transmission, and they control the aircraft without referring to outside references (U. S. Department of Transportation, 1980).

In the beginning phase of the flying training, the trainees learn to fly light aircrafts, which are thrust by propellers as basic flying course, like Cessna 172 (known as T-41 in the Korea Air Force) and T-3 in the U. S. Air Force (Michael, 1996). After the basic flying course, the trainees fly intermediate jet aircraft, such as T-37 trainer. After the intermediate course, the trainees are assigned to advanced course, such as the T-38, a supersonic jet trainer. Specific types of aircraft of each training phase vary from country to country. After completion of all courses, trainees are assigned to fighter, bomber, or tanker type of aircraft.

2.3 Human Information Processing in Flight

As it is seen in the previous section, controlling aircraft is a complex task. It is much more complicated to control aircraft than riding a bike, driving a car, and so on. It deals in three dimensions: it requires a high degree of human information processing. Allnut (1982) categorizes the human information processing in flight into five steps: sensation, perception, attention, decision, and action.

2.3.1 Sensation Process

Sensation is done by human sensory system which consists of sight, hearing, touch, smell, taste, rotation, falling and rectilinear movement, vibration, pressure, temperature, cutaneous pain, subcutaneous pain, and position and movement (Foley and Moray, 1987). In flight, pilots get information through visual system primarily and through auditory system secondarily. Allnut (1982) states that in order to be seen or heard, the incoming signal to the human body must register on the appropriate sense organ. However, these sense organs are both limited and, in some cases, missing. Thus, humans can hear sounds only within a fairly narrow frequency band and when they are of sufficient loudness. For example, if a pilot is controlling his aircraft in constant climbing rate in accordance with an instruction of the Air Traffic Control to level off at a certain altitude, the pilot will check the altitude while maintaining the aircraft attitude. In this case, sensing the information from the instruments is called sensation.

2.3.2 Perception Process

Perception is the process of interpreting and the sensations, giving them meaning and organizations (Matline, 1988). The fact that the visual nerves pass a particular message to the brain is no guarantee that the brain will always deduce the same meaning from that message. What is perceived will depend on the stimulus, i.e. passed, and on the observer’s experience. In the climbing pilot’s case, the process of finding - what the pilot sensed is the altimeter- is the perception.

2.3.3 Attention Process

Attention is the third step of the information processing. Incoming messages arrive irregularly rather than at convenient intervals. This fact is important, since research has shown that humans possess only a single decision channel, and all information must be passed sequentially through this channel.

In the climbing pilot's case, attention is given when the pilot notices that he is approaching the instructed altitude.

2.3.4 Decision Process

Decision process is the next step. A pilot's judgment and decision-making abilities are critical to aerospace safety. Wickens and Falch (1988) states that:

> "There are three general characteristics that define the decision-making task. First, the pilot must evaluate several sources of information in assessing the situation or understanding the current state. This assessment forms the basis for choosing an appropriate action. Second, the information the pilot deals with is probabilistic. The cues used for situation assessment may be unreliable, and the projected consequences of an action into future are uncertain. This probabilistic element means that the right decision can often produce an unfortunate outcome and the wrong decision can often fortune result. Third, the elements of value and cost underlie most decisions. For example, a pilot may have to balance the benefit of continuing a flight through bad weather and satisfying the passenger's need to reach their destination on time against the potential greater cost of an accident."

In the decision phase, in the climbing pilot's case, immediately after he/she notices that he is reaching the desired altitude, he/she makes decision what to do. To make decision, the pilot compares all the information he/she got, and realizes that what kind of action should be taken.

2.3.5 Action Process

Action is the final phase of the information processing. This action is completed when the pilot's brain receives feedback information from his/her hand, and perhaps visual confirmation from the appropriate instruments (Grandjean, 1997).

In the case of climbing pilot, the pilot manipulates the aircraft to the level attitude upon the former decision of leveling off in this step. The whole processing from sensation to action is usually completed in a short time. As Roscoe (1980) quoted Williams (1947) stating that the pilots have to determine moment-to-moment throughout a flight - the altitude, the heading, the speed, the length of flying, and the operating conditions of the aircraft and its subsystem, human information processing is continuously at work during flight.

2.4 Research on Flight Simulation

2.4.1 Necessity of Flight Simulation

Edwards (1990) states that the most elaborate training devices, true flight simulators, attempt to simulate all aspects of the flight. Simulators provide replicas of specific cabins, sounds, communications, and control feel. Motion cues and visual scenes are simulated as necessary. Edward also introduced the worldwide survey of air transport simulators in 1982, which describes 340 machines manufactured by twelve companies and operated by 103 flight schools, primarily airlines. Driskell and Olmstead (1989) estimate that cost to train a modern pilot may exceed one million dollars. Furthermore, it takes a long time, a couple of years in some cases, for a candidate to be trained as a skilled pilot (Strickler, 1982; U. S. Department of Transportation, 1980).

It has been reported that many airliners save training costs and time by using the flight simulators rather than training their trainees through actual flight (Strickler, 1982). Flight simulation has been an essential part of the training since when in 1980 the United States Department of Transportation, Federal Aviation Administration issued Advisory Circular 121-14C entitled “Aircraft Simulator and Visual System Evaluation and Approval.”

2.4.2 Development of Flight Simulator

According to Caro (1988), three-dimensional highly realistic flight simulators were developed by Link in 1940's. In 1950's, flight simulators became much more important than before due to the rapidly increasing complexity of aircraft and corresponding increases in the complexity and cost of pilot training. Attempts were made to develop devices. As a result, the modern aircraft simulator advanced in motion simulation was born.

With the introduction of digital computers in the mid-1960's, more faithful simulation of flight dynamics and aircraft system performance became possible. Realism became an increasingly important factor in simulator design, and training programs that incorporated realistic aircraft simulators generally were judged to be superior to those that did not. By the late 1970s, training in realistic simulators began to be accepted as a partial substitute for training in aircrafts. The U. S. military services increased their use of flight simulators substantially, and the Federal Aviation Administration placed heavy emphasis on the value of realistic simulators in its regulation of commercial aviation.

However, because the highly realistic simulator costs ten to fifteen million dollars, the original purpose of using simulator has been diluted. Thus, there are many PC-based programs, which can be used as a flight simulator. Even though they are low realistic, the effectiveness of training has been proved by many researchers (Moroney *et al*., 1994, Trollip and Roscoe, 1980).

2.4.3 Benefits and Transfer Effect from Flight Simulation

Many researchers report that flight simulation have positive effects on flight training. Jacobs and Roscoe (1980) introduce Koonce's (1974) research report stating that subjects who were trained by flight simulator in both motion and fixed-base, showed better performance in actual flight than those who were not trained. Furthermore, it was reported that the difference between motion and fixed-base was not significant.

Recently, the fairly positive effect of flight simulation on computer display screen on acquiring flying skill has been reported (Caro, 1988). Gopher *et al.* (1994) studied transfer of skills from a computer game to the flight performance of cadets in the Israeli Air Force flight school. Flight performance scores of two groups of cadets who received ten hours of training in the computer game were compared with those of a matched group without game experience. The authors concluded that game group performed significantly better than the no game group in the subsequent test flights. The results supported the relevance of the game with reference to the theoretical framework within the context. The game has now been incorporated into the regular training program of the Israeli Air Force.

Hart and Battiste (1992) conducted a field study to determine whether workload coping and attention-management skills developed through structured video game experience, could be applied to flight training. Three groups of twenty-four trainees were compared:

(1) One received ten hours of training on an IBM-PC version of Space Fortress, replicating an earlier study.

(2) The second group played a commercial video game (Apache Strike) for ten hours, which also required tracking, monitoring, situation assessment, and memory.

(3) The third matched group received no game training. Flight school records were monitored during the next eighteen months to compare performance of the three groups during initial flight training.

As predicted, check ride ratings began to show an advantage for the group trained with Space Fortress by the Instrument stage of training. Furthermore, attrition rates were lower for this group than other group, replicating the results of an earlier study conducted by Gopher (1990) in the Israeli Air Force Flight School. Shebilske and Regian (1992) utilized Space Fortress in a basic research program that designed to integrate cognitive and social learning theory in the development of group protocols for training complex skills. They present evidence that groups of 2, 3 and 4 could learn Space Fortress as well as one using 1/2, 1/3, and 1/4 the trainer time and resources, respectively.

They also presented preliminary empirical steps towards individualizing training within groups according to individual differences in selective attention. They discuss implications for developing automated instruction that is designed for small groups rather than for individuals. .

On the other hand, Moroney *et al*. (1994) state that there is no significant difference in the subject's in-flight performance between $60,000 highly generic flight simulator and $4,600 personal computer based simulator. In addition, high realistic simulators cause motion sickness (So *et al,* 2001). Thus, the authors recommend that steps be initiated to qualify PC-based training devices as Flight Training Devices, in which instrument rating training credit can be accrued.

2.5 Research and Regulations of the Pilot-Candidate Screening of the U. S. and Korea Air Force

2.5.1 Research on the Pilot-Candidate Screening

Human beings have different abilities in most areas. In other words, there are individual differences in every aspect within certain ranges (Gopher and Kahneman, 1971; Magill, 1993; Morrow, 1996; Tirre and Raouf, 1994). Piloting a modern, high-performance aircraft is a highly demanding, complex task that requires many talents and skills (Gopher, 1982). Training programs are long and expensive. Development of an efficient selection procedure is a professional challenge that is strongly motivated by economic necessity (Strickler, 1982: Driskell and Olmstead, 1989). After World War II, simple mental abilities and perceptual-motor coordination skills were emphasized on pilot selection procedures (Youngling *et al.*, 1976).

However, in recent efforts, the emphasis has moved to consideration of more complex cognitive functions and higher information-processing capabilities. A natural candidate for investigation in this group of cognitive functions is the ability of human operators to control their processing resources. More specifically, this involves the ability to focus attention on relevant aspect of tasks, to switch rapidly from one task to the other, to avoid interference from distracting sources of information, and to divide resources properly in current task (Gopher, 1982). Gopher investigated the role of a selective attention test as a predictor of success in flight training and concluded that flight cadets who had

completed a two-year training program had significantly lower error scores on all attention measures.

Cox (1989) summaries the development of psychomotor screening for U. S. Air Force pilot candidates, and introduces his research on the psychomotor screening which consists of two tests; two hand coordination and complex coordination, In the investigation, a relatively strong relationship has been observed between psychomotor performance and pilot success.

Carretta reports many research results and development in the pilot selection system of the U. S. Air Force with his colleagues (1992, 1994, 1995, 1996) emphasizing that future measures of pilot aptitude may include tests based on cognitive components, chronometric methods, and so on. This trend of shift reflects the change in the role of pilots from direct controllers to monitors and supervisors of numerous, rapidly changing flight systems.

Tham and Kramer (1994) investigated differences in abilities of attention-distribution between student and instructor pilots, and concluded that instructor pilots displayed evidence of more efficient task switching, and focused attention than novice pilots. In addition, Endsly and Smith (1996) also emphasized the importance of attention distribution in tactical air combat.

Many other researches have studied the methods of flight screening because most organizations and companies, which operate aircraft, adopt criteria in screening candidates for pilots. Sterman *et al*. (1992) introduce their research about topographic EEG correlation of the basic attributes test for Air Force candidate selection. McFadden (1994) compared two contrast sensitivity tests and their usefulness as a screener for aircrew. Another research was done by Kohen-Raz *et al*. (1994) on postural control in pilot and candidates for flight training. King and

Flynn (1995) report on defining and measuring the “right stuff”: neuro-psychiatrically enhanced flight screening. Kobayashi (1996) performed research on trace element and hormonal responses during flight aptitude test.

2.5.2 Regulations for Pilot-Candidate Screening of the U. S. and Korea Air Force

Based upon the research, the U. S. Air Force developed a written test system, named Air Force Officers Qualifying Test (AFOQT); it is used to select individuals for Officer Training School (OTS) and Air Force Reserve Officer Training Corps (AFROTC, Skinner and Ree, 1987, Arth *et al.*, 1990). The AFOQT consists of sixteen paper-and-pencil sub-tests; verbal analogies, arithmetic reasoning, data interpretation, word knowledge, math knowledge, mechanical comprehension, electrical maze, scale reading, instrument comprehension, block counting, table reading, aviation information, rotated blocks, general science, and hidden figures. In general, individuals wishing to enroll in the AFROTC program take the AFOQT prior to their first year of enrollment. Upon selection into the program, cadets enroll in the Professional Officer Course (POC) beginning in the junior year. Successful graduates then enter the Air Force as a second lieutenant. Individuals wishing to enter OTS take the AFOQT during their senior year of college or after having completed the Bachelor’s degree. Successful candidates are commissioned as a second lieutenant. In both AFROTC and OTS potential cadets must have a minimum percentile score of 15 on the verbal composite and 10 on the quantitative composite.

The AFOQT is also used to select AFROTC and OTS candidates for Undergraduate Pilot Training (UPT) and Undergraduate Navigator Training (UNT).

Air Force Instruction 36-2205 (U. S. Department of Air Force, 1997) provides guidance on the use of the Pilot and Navigator composite. To be considered for UPT, applicants must score a minimum of 25th percentile on the Pilot composite, 10th percentile on the Navigator composite, and a combination of 50th when Pilot and Navigator are added together. The validity of the AFOQT as a pilot-candidate selection method has been supported by many researchers and is currently being studied. Hunter (1994) reports that typical training attrition rate over the last 20 years has been 25%, with an average cost for each failure ranging from $50,000 to $80,000 for the U. S. Air Force. The purpose of the pilot candidate selection is to reduce the training attrition rate.

On the contrary, Korea Air Force does not have an organized pilot-candidate selection method. The training attrition rate in Korea Air Force for the last 20 years has been estimated as 45% (Korea Air Force, 1996). Therefore, it is essential for Korea Air Force to develop the pilot-candidate selection system as well as to improve the flight training efficiency.

CHAPTER 3

METHODOLOGY

3.1 Experimental Design

3.1.1 Experimental Design

The experiment is a factorial three-factor repeated measures design. Specifically, the design is a fixed model with seven replications for each third level. Because all sources of variability between subjects are excluded from the experimental error, method of repeated measures design provides good precision for comparing treatments.

The experiment has three factors: nationality, level of experience in computer games, and position of flight control stick. The question can be hypothesized whether the nationality, computer game experience, and flight control stick position have significantly different on the performance score and Qualifying Test score of the subjects. Grouping of subject was done in accordance with the number of factors and levels.

Mathematically, the hypotheses can be formulated as follows:

1. $H_0 : a_i = 0$ for all $i = 1, 2$
2. $H_0 : b_j = 0$ for all $j = 1, 2$
3. $H_0 : d_k = 0$ for all k = 1, 2
4. $H_0 : (ab)_{ij} = 0$ for all i, j
5. $H_0 : (ad)_{ik} = 0$ for all i, k
6. $H_0 : (bd)_{jk} = 0$ for all j, k.

The statistical model is:

$$Y_{ijkl}\ (\text{or } \acute{Y}_{ijkl}) = \mu + a_i + b_j + d_k + (ab)_{ij} + (ad)_{ik} + (bd)_{jk} + (abd)_{ijk} + \mathbf{e}_{ijkl}$$

Where Y_{ijkl} and $\acute{Y}_{ijkl}$ are for flight performance score and Qualifying Test score for nationality i, experience j, stick position k,

μ is the general mean,

a_i is main effect of nationality $i = 1,2$,

b_j is main effect of computer game experience $j = 1,2$,

d_k is main effect of stick position $k = 1,2$,

$(ab)_{ij}$ is the effect of interaction between nationality and computer game experience,

$(ad)_{ik}$ is the effect of interaction between nationality and stick position,

$(bd)_{jk}$ is the effect of interaction between computer game experience and stick position,

$(abd)_{ijk}$ is the three-factor interaction effect,

$\mathbf{e}_{ijkl}$ is the error term.

3.1.2 Independent Variables

The first subject related independent variable has two levels {a_i, $i = 1,2$, Korean or American} nationality. The second independent variable is also a subject related with two-level factor, computer game experience {b_j, $j = 1,2$, high or low}. The third independent variable is a two-level factor {d_k, $k = 1,2$: center, side}.

3.1.3 Dependent Variables

The dependent variables are performance scores in simulated flying training and scores of the Qualifying Test.

3.2 Method and Procedures

3.2.1 Equipment

Equipment consisted of a personal computer system with a standard keyboard and a mouse. A “Flightstick” with Gamecard III by CH Product was used as the flight control stick. The flight control stick was attached to the front edge of the desk. The IFT-PRO Version 5.13 by Flight Deck Software was utilized as the flight simulator. Excluding personal computer set, the apparatus cost approximately $500. Figure 3 and 4 show layout of center-stick and side-stick.

3.2.2 Subjects

Subjects were recruited from undergraduate students of Louisiana State University who were enrolled in ROTC program, and Korea Air Force Academy cadets (KAFA) on a voluntary basis.

3.2.2.1 Screening the Subject (Exclusive Criteria)

For the normality of the data, subjects who could speak both Korean and English at the same level were excluded. For the experience in computer games, subjects were grouped by subjective ratings, which is marked on the information sheet. Excluding criteria for the experience in computer games were also applied. Any one who had played similar or same flight simulation, and was expert in computer games was excluded.

3.2.2.2 Skim of Grouping the Subject

Subjects were divided into two major groups by their nationality: 32 cadets of Korean Air Force Academy, and 32 U. S. Air Force ROTC students. Then the groups were divided into two sub-groups according to their computer game experience: 16

Koreans who had high experience in computer games (KH), 16 Korean cadets with low experience in computer games (KL), 16 U. S. Air Force ROTC students who had high experience in computer games (AH), and 16 U. S. Air Force ROTC students who had low experience in computer games (AL).

Each group was divided randomly into two groups: subjects in one group began with the center-stick (Figure 3, KHC, KLC, AHC, and ALC) then switched to the side-stick (Figure 4). The other group began with the side-stick (Figure 4, KHS, KLS, AHS, and ALS) then switched to the center-stick (Figure 3). Summary of grouping the subjects were as follows:

(1) 8 **K**AFA Cadets, **H**igh Computer Game Experience, **C**enter → Side-stick

(2) 8 **K**AFA Cadets, **H**igh Computer Game Experience, **S**ide → Center-stick

(3) 8 **K**AFA Cadets, **L**ow Computer game Experience, **C**enter → Side-stick

(4) 8 **K**AFA Cadets, **L**ow Computer game Experience, **S**ide → Center-stick

(5) 8 US**A**F ROTC Cadets, **H**igh Computer Game Exp., **C**enter → Side-stick

(6) 8 US**A**F ROTC Cadets, **H**igh Computer Game Exp., **S**ide → Center-stick

(7) 8 US**A**F ROTC Cadets, **L**ow Computer Game Exp., **C**enter → Side –stick

(8) 8 US**A**F ROTC Cadets, **L**ow Computer Game Exp., **S**ide → Center-stick

Table 1 shows the grouping of the subject in a matrix format. Numbers at the bottom indicate session numbers.

Prior to the experiment, subjects were asked to fill out the information sheet (Appendix A) and consent form (Appendix B) in voluntary basis. Subjects were also paid five dollars per hour for the experiment.

Table 1. Matrix for Grouping the Subjects

Korean				**A**merican			
High Experience		**L**ow Experience		**H**igh Experience		**L**ow Experience	
Center Stick (**KHC**)	**S**ide Stick (**KHS**)	**C**enter Stick (**KLC**)	**S**ide Stick (**KLS**)	**C**enter Stick (**AHC**)	**S**ide Stick (**AHS**)	**C**enter Stick (**ALC**)	**S**ide Stick (**ALS**)
1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7

Figure 3. Experimental Layout of the Center-Stick

Figure 4. Experimental Layout of the Side-Stick

3.2.3 Procedures

Before the main experiment, a sample set of the U. S. Air Force Officer Qualifying Test (Weiner, 1997) was administrated. The test consists of sixteen parts and took three hours and thirty-three minutes. The sixteen parts are 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.

The main experiment consisted of eight sessions. The first session was an orientation to the flight simulation. Subjects were individually explained about the procedures of the flight simulation using cockpit display (Figure 5) and control devices as well as a condensed manual (Appendix C) about basics of flight and the flying training course (Figure 6).

The condensed manual was edited to cover the basic concepts of flight as well as substantial instructions for controlling the aircraft in various situations. The manual includes detailed procedures about controlling technique such as level flight, changing airspeed, turning left and right, climbing, descending, leveling-off from climbing or descending, and power control related to specific items of control.

The simulated flying training course is also designed to train the subjects in how to control the aircraft not only in the basic maneuvering but also in the intended altitude, airspeed, and flight course. Required maneuverings by time are shown in Table 2. Sessions 2 to 7 were composed of 15-minute practice flight sessions and a 15-minute score-recording flight. During the practice flights, subjects were allowed to fly on their intention to grasp various flying characteristics, such as sensitivity and controllability of the flight control stick and thrust response as throttle application. During the second 15-minutes recording flight, flight performance data, such as heading, altitude and airspeed were recorded every 15 seconds on the data collection form (Table 3).

During first 7 sessions, including the orientation session, subjects were trained at an assigned position of the flight control stick. During the last session, the flight control stick was switched to the other position and flight performance data were collected. The duration of the experiment for each subject was limited to four days in minimum and three weeks in maximum for learning purpose. The number of sessions a day was also limited to two sessions because flying more than three sessions in a day is undesirable for retention and learning.

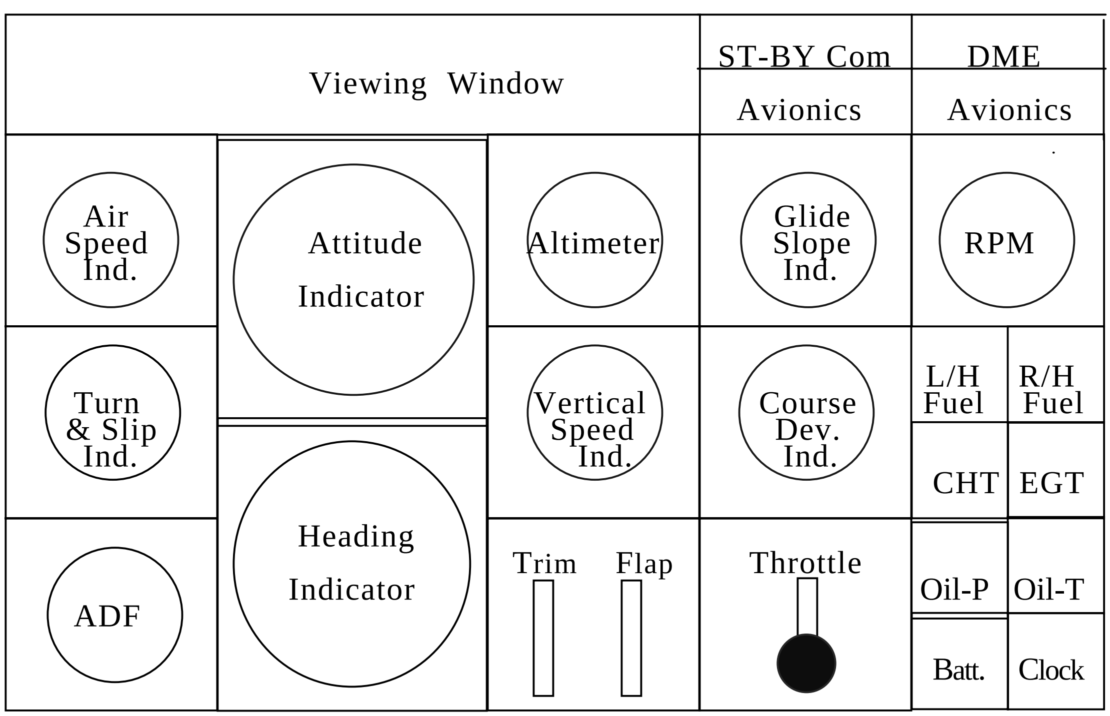


Figure 5. Instrument Panel of the Flight Simulator

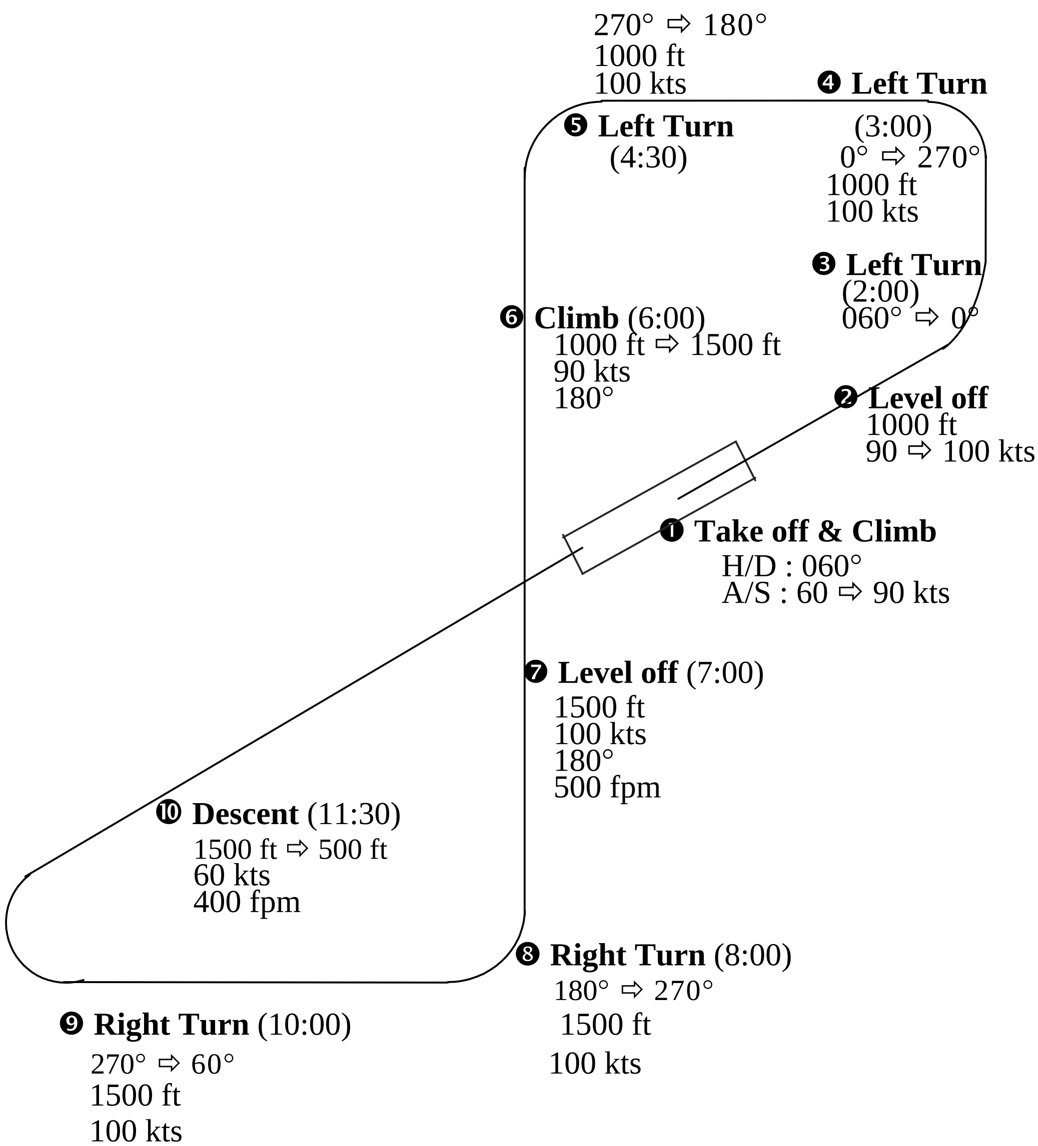


Figure 6. Simulated Flying Training Course

Table 2. Required Maneuverings by Time

Time (min:sec)	Maneuvering	Heading (°)	Altitude (feet)	Air Speed (kts)
0 : 00	Take-off Roll	60	500	0 ⇨ 60
0 : 30	Take-off & Climb	60	500	60 ⇨ 90
1 : 30	Level-off	60	1000	90 ⇨ 100
2 : 00	Left Turn	60 ⇨ 0	1000	100
3 : 00	Left Turn	0 ⇨ 270	1000	100
4 : 30	Left Turn	270 ⇨ 180	1000	100
6 : 00	Climb	180	1000 ⇨ 1500	100 ⇨ 90
7 : 00	Level-off	180	1500	90 ⇨ 100
8 : 00	Right Turn	180 ⇨ 270	1500	100
10 : 00	Right Turn	270 ⇨ 60	1500	100
11 : 30	Descent	60	1500 ⇨ 500	60
13 : 30	Touch Down	60	500	60

Table 3. Data Collection Form

Last 4 digits of S. S. No: (   ), Nationality: (   ), Computer Game Exp. : (   )

Position of Stick: (   ),   Session   : (   )

Time min:sec	Heading			Altitude			Air Speed			Sum of Score
	Required (degree)	Actual (degree)	Conv. Score	Required (feet)	Actual (feet)	Conv. Score	Required (kts)	Actual (kts)	Conv. Score	
0:15	60			394			50			
0:30	60			450			85			
0:45	60			575			90			
1:00	60			700			90			
1:15	60			825			90			
1:30	60			950			100			
1:45	60			1000			100			
2:00	60			1000			100			
2:15	30			1000			100			
.	.			.			.			
.	.			.			.			
6:15	180			1000			90			
6:30	180			1225			90			
6:45	180			1350			90			
.	.			.			.			
.	.			.			.			
13:15	60			525			60			
13:30	60			400			60			
13:45	60			394			60			
Mean of Total Converted Scores										

3.3 Data Processing

The collected data were converted into percentile scores in accordance with the conversion table based on Instrument Rating Standards of Federal Aviation Administration (1986) and Korean Air Force Manual for Evaluation of the Aircrew (1994). Table 4 shows the conversion table. A 33, in the 'converted scores' column, was indicated as a perfect score; the sum of three areas of testing added up to 100.

Table 4. Conversion Table

Heading		Altitude		Air Speed	
Deviations (± degrees)	Converted Scores	Deviations (± feet)	Converted Scores	Deviations (± kts)	Converted Scores
0	33	0	34	0	33
1	32	10	33	1	32
2	31	20	32	2	31
3	30	30	31	3	30
4	29	40	30	4	29
5	28	50	29	5	28
6	27	60	28	6	27
7	26	70	27	7	26
8	25	80	26	8	25
9	24	90	25	9	24
10	23	100	24	10	23
Deviations in degree > 10	0	Deviations in feet > 100	0	Deviations in kts > 10	0

3.3.1 Considerations in Designing the Conversion Table

The guideline provided pass-fail criteria for heading (10 degrees deviation), altitude (100 feet deviation), and airspeed (10 kts deviation) individually for various phases of flight. If any one of these criteria was not satisfied, the overall result of performance was evaluated as "fail."

For each element of performance, the acceptable (pass) ranges were divided into 10 classes in order to assign converted score in accordance with the rate of closeness to the required performance. The sum of converted scores represents the overall rate of closeness to the required performance at a specific point of time.

3.3.2 Data Analysis

The converted data (Table 5 to 12) were analyzed statistically using Excel and SAS software program. The repeated measures of multivariate analysis of variance (MANOVA) was used to test the hypotheses.

3.4 Hypotheses

The hypotheses tested in the study are as follows:

(1) Nationality does not impact on acquisition of simulated flying skill.

(2) There is no effect of computer game experience on acquiring simulated flying skill.

(3) Position of flight control stick has no impact on acquisition of the skill.

(4) There is no interaction effect between nationality and computer game experience in acquiring of the skill.

(5) No interaction effect between nationality and stick position in obtaining the flying skill exists.

(6) There is no interaction effect between computer game experience and stick position on the acquiring of the skill.

Table 5. Converted Scores of Korean-High Exp.-Center Stick Group

Subject Code	1	2	3	4	5	6	7	QT
KHC-1	78.2	79.8	84.4	87.1	89.5	92.3	89.6	69.0
KHC-2	76.7	73.2	79.1	83.6	86.5	89.2	83.5	65.6
KHC-3	77.6	81.3	88.9	85.7	87.0	89.7	80.4	73.5
KHC-4	84.7	84.6	87.3	94.5	93.4	95.5	96.3	75.8
KHC-5	74.3	76.2	81.7	82.3	83.6	85.1	83.3	61.7
KHC-6	82.7	81.9	85.2	88.4	93.5	95.8	94.2	72.1
KHC-7	77.2	79.3	82.6	86.8	90.1	93.4	87.7	64.3
KHC-8	67.4	72.5	77.3	76.7	84.6	87.2	81.5	61.2

Table 6. Converted Scores of Korean-High Exp.-Side Stick Group

Subject Code	1	2	3	4	5	6	7	QT
KHS-1	75.3	76.9	79.5	81.2	83.8	86.1	90.3	67.9
KHS-2	74.6	77.8	80.1	82.3	84.5	85.7	86.4	66.8
KHS-3	78.5	73.3	82.7	84.6	88.1	91.3	90.5	72.3
KHS-4	69.4	71.2	42.5	72.3	68.9	73.2	74.9	61.4
KHS-5	70.1	72.9	74.2	76.8	79.7	81.5	79.6	62.3
KHS-6	72.7	73.4	78.5	82.7	82.9	84.8	87.7	68.2
KHS-7	68.2	67.5	68.9	72.3	74.6	79.1	80.3	70.3
KHS-8	64.3	67.4	67.1	69.0	73.2	82.7	85.9	61.7

Table 7. Converted Scores of Korean-Low Exp.-Center Stick Group

Subject Code	1	2	3	4	5	6	7	QT
KLC-1	79.7	81.3	83.6	85.5	88.2	90.3	83.6	68.2
KLC-2	75.2	75.9	79.1	76.8	78.1	80.7	78.2	64.3
KLC-3	66.3	67.5	75.3	77.7	80.4	84.5	71.7	63.5
KLC-4	82.8	79.1	83.9	85.6	86.2	87.1	86.3	67.2
KLC-5	69.5	71.2	74.3	81.4	82.3	83.6	79.8	62.1
KLC-6	70.8	75.6	77.1	85.2	85.7	86.2	82.7	61.4
KLC-7	71.7	76.2	78.6	84.9	82.0	84.5	80.9	65.3
KLC-8	68.4	70.3	73.8	76.5	80.8	86.3	81.2	66.8

Table 8. Converted Scores of Korean-Low Exp.-Side Stick Group

Subject Code	1	2	3	4	5	6	7	QT
KLS-1	65.1	56.3	67.2	69.8	73.5	79.8	75.4	64.7
KLS-2	63.6	64.8	68.7	70.3	74.2	73.5	71.1	59.0
KLS-3	62.3	72.5	75.3	74.1	76.4	77.0	77.8	64.2
KLS-4	72.4	69.7	73.8	75.2	75.9	83.1	88.3	66.5
KLS-5	61.5	71.3	81.1	62.2	80.7	84.4	86.2	62.7
KLS-6	70.7	68.4	69.1	70.3	72.6	84.5	85.5	64.2
KLS-7	68.8	70.2	71.3	74.5	76.7	86.1	84.8	65.3
KLS-8	71.2	69.7	72.4	73.1	76.9	92.6	90.0	66.8

Table 9. Converted Scores of American-High Exp.-Center Stick Group

Subject Code	1	2	3	4	5	6	7	QT
AHC-1	81.7	84.5	84.0	88.9	91.3	93.7	87.9	86.2
AHC-2	78.5	80.2	79.3	85.4	89.6	94.2	94.5	88.6
AHC-3	79.8	82.3	84.7	83.5	88.9	91.4	90.1	85.8
AHC-4	82.6	86.4	91.2	90.3	91.8	94.0	90.8	92.5
AHC-5	77.2	83.5	82.7	87.3	89.4	90.7	88.5	91.1
AHC-6	76.5	82.8	88.6	89.3	91.4	90.8	89.0	87.3
AHC-7	74.4	81.5	83.7	86.1	88.2	89.5	87.7	89.4
AHC-8	73.1	78.3	76.8	77.5	81.6	84.2	80.1	84.2

Table 10. Converted Scores of American-High Exp.- Side Stick Group

Subject Code	1	2	3	4	5	6	7	QT
AHS-1	74.5	76.2	77.8	83.2	85.0	84.1	87.3	91.7
AHS-2	77.0	78.4	81.3	84.7	86.9	90.5	93.2	94.4
AHS-3	75.9	81.4	79.6	85.5	86.4	88.9	90.8	92.1
AHS-4	80.2	78.1	85.7	88.4	90.3	91.0	92.7	91.6
AHS-5	75.8	76.2	75.6	79.3	85.7	87.1	87.4	87.6
AHS-6	72.3	74.8	77.1	75.4	80.6	84.2	83.9	85.2
AHS-7	74.7	75.6	78.5	79.2	81.5	85.3	87.8	86.1
AHS-8	73.2	76.6	75.7	77.2	84.0	86.1	88.6	84.4

Table 11. Converted Scores of American-Low Exp.-Center Stick Group

Subject Code	1	2	3	4	5	6	7	QT
ALC-1	71.8	72.3	76.8	78.4	84.2	85.6	82.0	84.9
ALC-2	70.7	71.1	73.4	76.5	82.7	89.3	87.4	91.5
ALC-3	76.2	76.9	80.6	85.3	86.8	87.1	83.7	89.3
ALC-4	77.5	80.3	83.7	87.1	89.9	93.4	91.3	92.7
ALC-5	76.4	76.7	80.0	83.4	85.5	87.2	82.9	90.0
ALC-6	69.8	69.2	73.6	77.7	81.3	86.7	81.4	83.5
ALC-7	72.3	74.7	75.9	81.5	84.5	88.2	82.8	86.8
ALC-8	71.6	74.5	77.2	79.6	82.3	86.9	84.1	87.2

Table 12. Converted Scores of American-Low Exp.- Side Stick Group

Subject Code	1	2	3	4	5	6	7	QT
ALS-1	72.5	71.2	85.1	86.3	89.0	91.1	91.6	90.2
ALS-2	71.3	72.7	76.4	75.6	80.5	83.2	86.2	87.7
ALS-3	68.1	69.9	72.5	77.6	78.1	82.4	83.4	85.1
ALS-4	71.4	73.7	81.2	83.4	88.3	90.7	91.5	87.0
ALS-5	59.1	65.3	68.6	73.7	76.2	83.6	79.2	84.8
ALS-6	63.7	64.4	65.2	68.3	77.1	81.4	80.8	83.9
ALS-7	73.1	75.5	78.8	81.7	79.2	84.5	89.3	91.4
ALS-8	77.8	76.5	76.1	81.9	90.4	94.7	95.8	92.2

CHAPTER 4

RESULTS AND DISCUSSION

4.1 General Results

The results were analyzed using multivariate analysis of variance (MANOVA) with SAS 6.12 statistical software to see the overall effect of the independent variables and their interactions. Prior to the multivariate analysis of variance, correlation analysis between performance score and Qualifying Test was done. Figure 7 shows scatter plot of the scores of Korean subjects and American subjects.

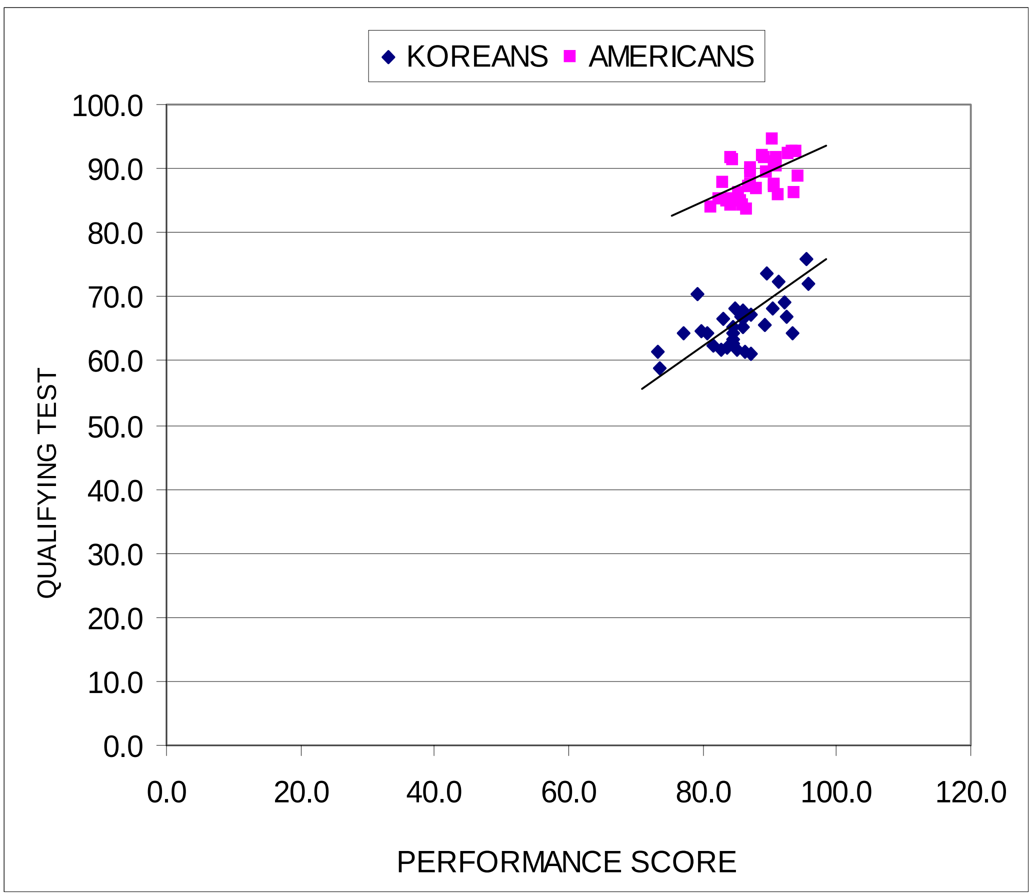


Figure 7. Scatter Plot of the Performance Scores and Qualifying Test Scores of Korean Subjects and American Subjects

For Korean subjects, the correlation coefficient between the performance score and Qualifying Test of Korean subject is 0.627, and the slope of the linear regression line is 0.884. Regarding the American subjects, the correlation coefficient between the performance score and Qualifying Test is 0.52, and the slope was 0.61. The results reveal that performance score and Qualifying Test are positively correlated. Further, the multivariate analysis of variance was done with and without the Qualifying Test as covariate (Tables 13, 14).

The analysis was done with full model for all the factors of main effect and interaction effect. In the reduced model, interaction effects, which had no significant impact on the performance score, were eliminated.

4.1.1 Result of Analysis in Full Model

Table 13 shows the result of repeated measures analysis of variance in full model with the Qualifying Test as the covariate.

Table 13. Result of Repeated Measures Analysis of Variance - Full Model with Covariate

The GLM Procedure

Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F
nation	1	1657.346933	1657.346933	34.94	<.0001
position	1	2414.102956	2414.102956	50.90	<.0001
nation*position	1	190.962185	190.962185	4.03	0.0497
experi	1	783.429536	783.429536	16.52	0.0002
nation*experi	1	90.634221	90.634221	1.91	0.1724
position*experi	1	76.473278	76.473278	1.61	0.2095
nation*positi*experi	1	19.267638	19.267638	0.41	0.5265
qt		2539.184996	2539.184996	53.54	<.0001
Error	55	2608.549795	47.428178		

The overall effect of nationality, experience in computer games, position of stick, and interactions of nation and position of stick are significant at 0.0001, 0.0001, 0.0002, and 0.497 levels of significance, respectively. With an established α value of 0.05, all the levels of significance are smaller than the α level. Therefore, we reject hypotheses (1), (2), (3), and (5). The rejections mean that nationality, experience in computer games, position of stick, and interaction of nation and position have significant impact on acquiring simulated flying skill.

For other two-factor interactions, levels of significance are 0.2095, 0.5265, respectively, which are greater than the α value. Therefore, hypotheses (4) and (6) are accepted. The acceptance means there is no significant interaction between factors. As a result, three main effects of the independent variables and interaction effect of between nation and position are considered.

Table 14 shows the result of analysis full model without covariate.

Table 14. Result of Repeated Measures Analysis of Variance
– Full Model without Covariate
–

The ANOVA Procedure
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Anova SS	Mean Square	F Value	Pr > F
nation	1	712.042734	712.042734	7.75	0.0073
position	1	2741.878151	2741.878151	29.83	<.0001
nation*position	1	364.845026	364.845026	3.97	0.0512
experi	1	1683.793776	1683.793776	18.32	<.0001
nation*experi	1	4.441901	4.441901	0.05	0.8268
position*experi	1	58.359609	58.359609	0.63	0.4289
nation*positi*experi	1	0.002109	0.002109	0.00	0.9962
Error	56	5147.734792	91.923836		

4.1.2 Result of Analysis in Reduced Model

Tables 15 and 16 show the results of analyses after elimination of the factors of no effect.

Table 15. Result of Repeated Measures Analysis of Variance
- Reduced Model with Covariate

The ANOVA Procedure
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Anova SS	Mean Square	F Value	Pr > F
nation	1	1550.398030	1550.398030	32.19	<.0001
position	1	2426.292272	2426.292272	50.38	<.0001
experi	1	810.722185	810.722185	16.83	0.0001
nation*position	1	196.606111	196.606111	4.08	<.0480
qt	1	2417.334748	2417.334748	50.20	<.0001
Error	58	2793.203664	48.158684		

The reduced models show exactly same results of testing hypotheses as the full model. Through the results, all the main factors in the models have significant impact on the performance score.

Table 16. Result of Repeated Measures Analysis of Variance
- Reduced Model without Covariate

The ANOVA Procedure
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

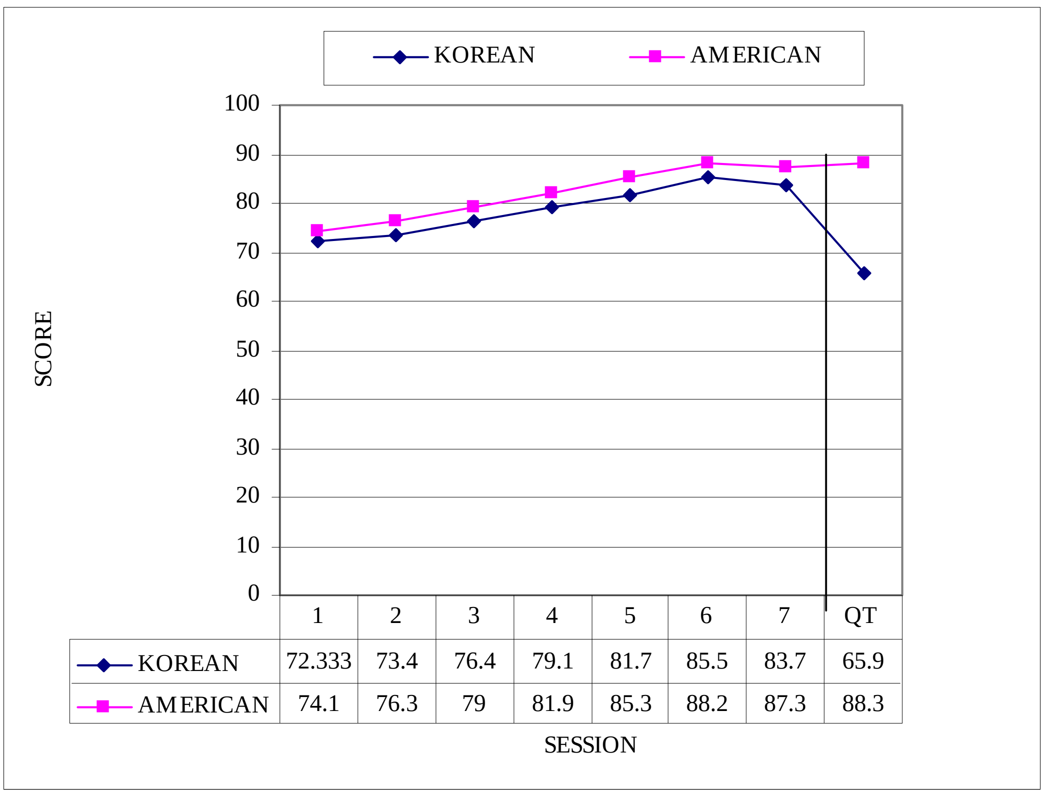
Source	DF	Anova SS	Mean Square	F Value	Pr > F
nation	1	712.042734	712.042734	8.06	0.0062
position	1	2741.878151	2741.878151	31.05	<.0001
experi	1	1683.793776	1683.793776	19.07	<.0001
nation*position	1	364.845026	364.845026	4.13	0.0466
Error	59	5210.538411	88.314210		

4.2 Nationality

4.2.1 Performance Scores and Qualifying Scores

The result of MANOVA indicates that nationality has a significant impact on the performance score. Figure 8 shows that Americans recorded higher scores (mean: 81.7) than Koreans (mean: 78.9) by 2.8%. The fact that the unit marked in the cockpit instruments is in American customary system caused the low score of Korean subjects.

The last markings are the scores of Qualifying Test. Significance of the differences in performance between Americans (mean: 88.3) and Koreans (65.9) is definite by 22.4%. The large difference in the Qualifying Test can be explained by the fact that the Qualifying Test is in English, and English is the native language of Americans.

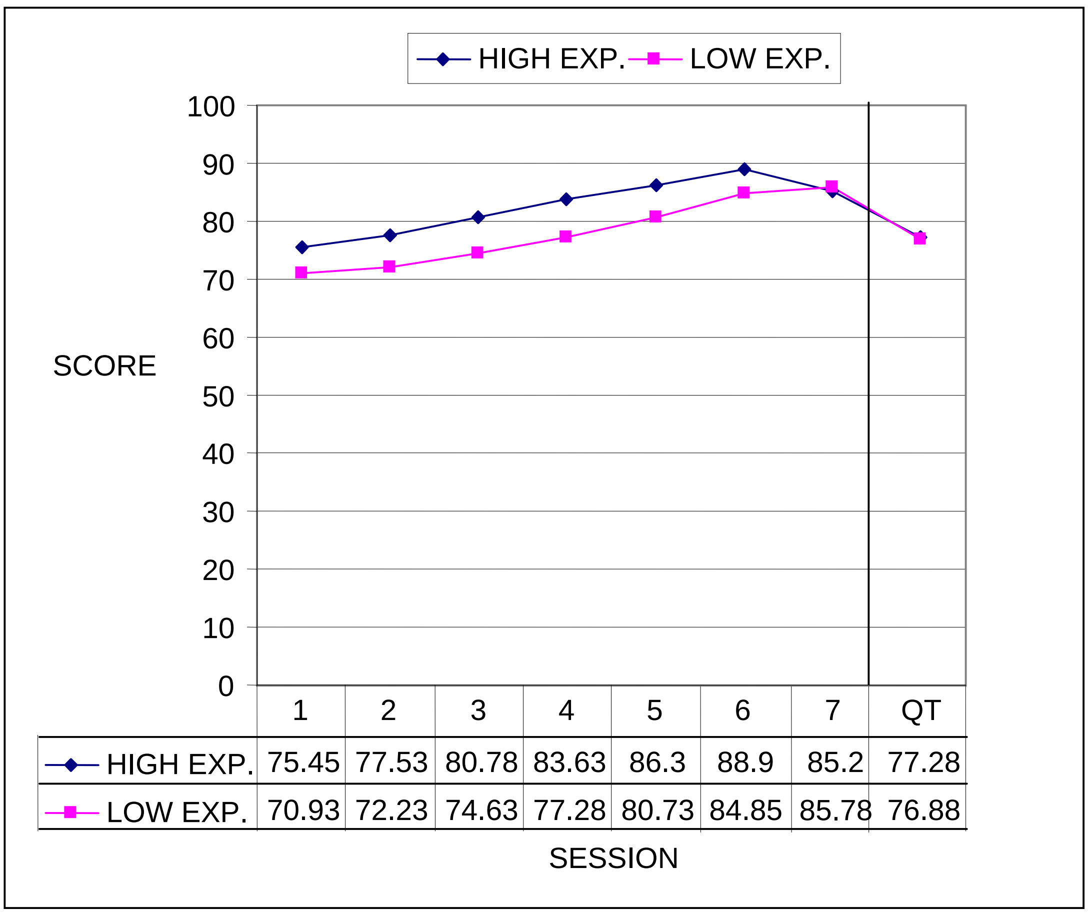


	1	2	3	4	5	6	7	QT
KOREAN	72.333	73.4	76.4	79.1	81.7	85.5	83.7	65.9
AMERICAN	74.1	76.3	79	81.9	85.3	88.2	87.3	88.3

Figure 8. Comparison of Grand Mean Scores Between Korean and American Subjects

4.3 Experience in Computer Games

Experience in Computer games was proved to have strong impact on the level of the score. Figure 9 shows comparison of mean performance scores between high experience group and low experience group. Mean score of the high and low experienced group was 82.5 and 78.1, respectively. The difference was 4.4%, which indicates that the computer game experience has a significant impact on acquiring the simulated flying skills.

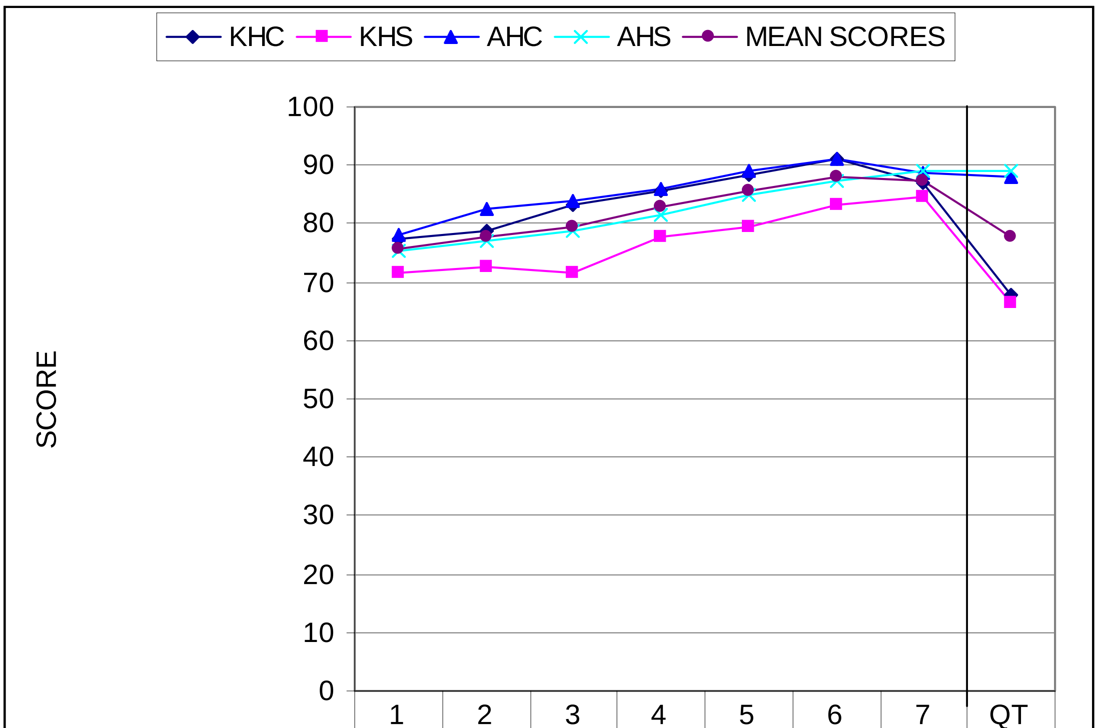


	1	2	3	4	5	6	7	QT
HIGH EXP.	75.45	77.53	80.78	83.63	86.3	88.9	85.2	77.28
LOW EXP.	70.93	72.23	74.63	77.28	80.73	84.85	85.78	76.88

Figure 9. Comparison of Mean Scores Between High and Low Experience in Computer Games

4.3.1 Comparison of Mean Scores within High Experience Groups

Among high experience groups, American center-stick group recorded the highest score (mean: 85.6), and Korean side-stick group record the lowest (77.2). The difference in the performance scores between the best group and the worst group, 8.4 percent, was as considerable. Figure 10 shows the comparison of mean scores within high experience groups.

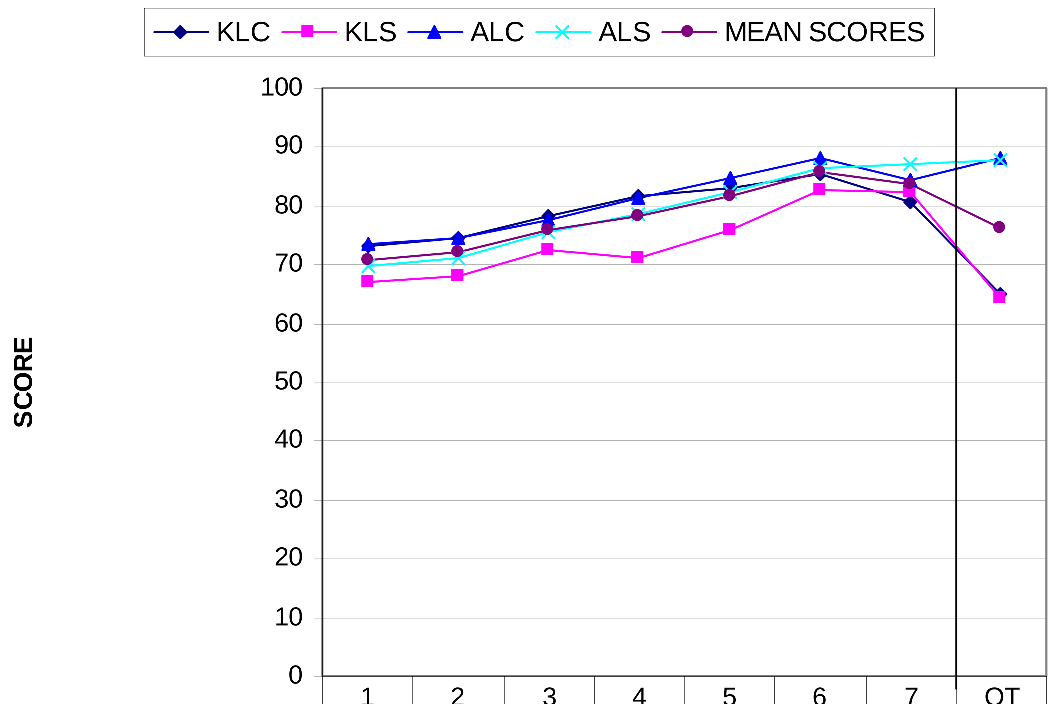


	1	2	3	4	5	6	7	QT
KHC	77.4	78.6	83.3	85.6	88.5	91	87.1	67.9
KHS	71.6	72.6	71.7	77.7	79.5	83.1	84.5	66.4
AHC	78	82.4	83.9	86	89	91.1	88.6	88.1
AHS	75.5	77.2	78.9	81.6	85.1	87.2	89	89.1
MEAN SCORES	75.63	77.7	79.45	82.73	85.53	88.1	87.3	77.88

Figure 10. Comparison of Mean Scores within High Experience Groups

4.3.2 Comparison of Mean Scores within Low Experience Groups

For the low experience group, American center-stick group recorded the highest score (mean: 80.6), and Korean side-stick group record the lowest (74.2). Difference in the performance score between the best group and the worst group was 6.4 percent. An improving pattern in the low experience group and high experience group was similar. Figure 11 shows the comparison within low experience groups.



	1	2	3	4	5	6	7	QT
KLC	73.1	74.6	78.2	81.7	83	85.4	80.6	64.9
KLS	67	67.9	72.4	71.2	75.9	82.6	82.4	64.2
ALC	73.3	74.5	77.7	81.2	84.7	88.1	84.5	88.2
ALS	69.6	71.2	75.5	78.6	82.4	86.5	87.2	87.8
MEAN SCORES	70.75	72.05	75.95	78.175	81.5	85.65	83.675	76.275

SESSION

Figure 11. Comparison of Mean Scores within Low Experience Groups

4.4 Position of Flight Control Stick

Physical position of flight control stick is another independent variable of the research. Figure 12 depicts the comparison the performance scores between center-stick groups and side-stick groups. The result indicates that center-stick is superior to side-stick in acquiring simulated flying skill. Subjects of side-stick group recalled that it was uncomfortable to control the stick out of line of eye-stick-instrument at beginning phase of the experiment. It is proved that the difference in performance score between center-stick and side-stick is statistically significant.

The difference in performance score between groups of center-stick (mean: 82.5) and side-stick (mean: 78.1) was noticeable as large as 4.4 percent.

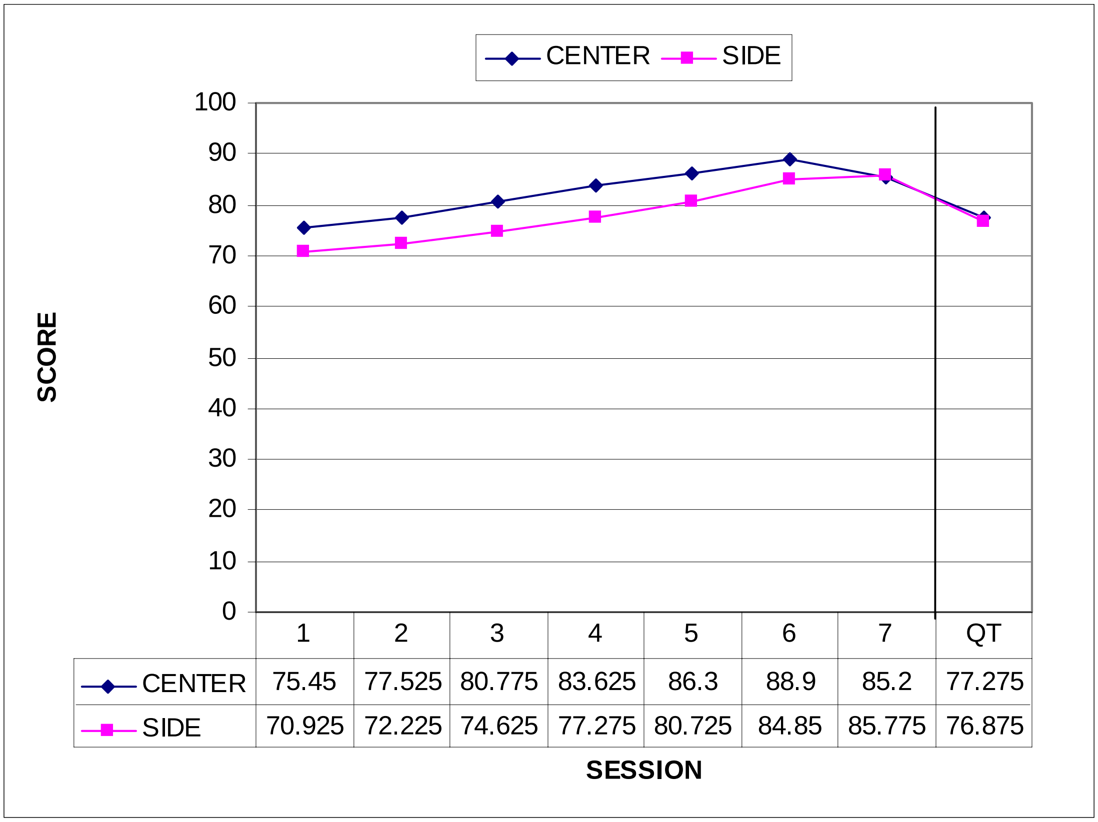
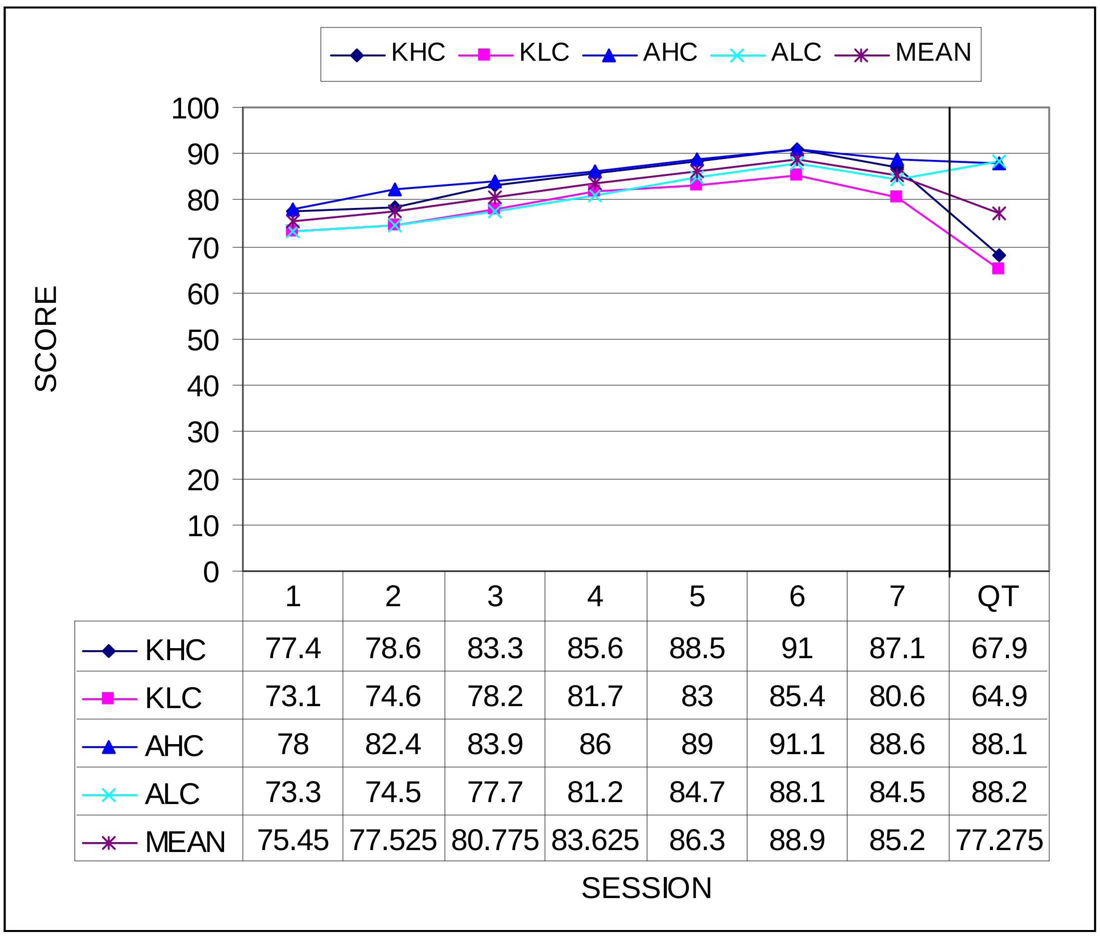


Figure 12. Comparison of Mean Scores Between Center-Stick and Side-Stick Groups

4.4.1 Comparison of Mean Scores within Center-Stick Groups

Within center-stick groups, American high experience group recorded the highest score of 85.6%. The lowest score group was Korean low experience group of which was 77.2%. The difference between two groups was 8.4%. Figure 13 depicts the comparison of mean scores of the center-stick groups

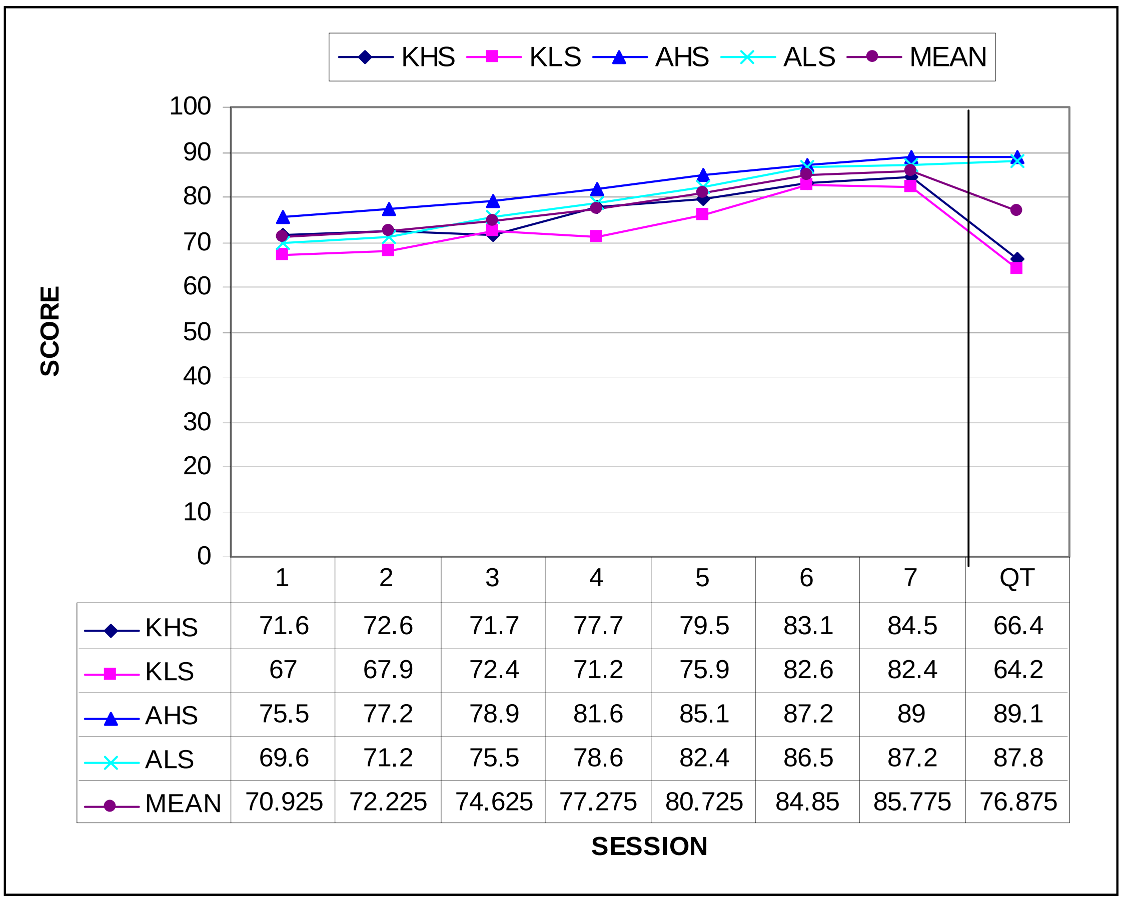


	1	2	3	4	5	6	7	QT
KHC	77.4	78.6	83.3	85.6	88.5	91	87.1	67.9
KLC	73.1	74.6	78.2	81.7	83	85.4	80.6	64.9
AHC	78	82.4	83.9	86	89	91.1	88.6	88.1
ALC	73.3	74.5	77.7	81.2	84.7	88.1	84.5	88.2
MEAN	75.45	77.525	80.775	83.625	86.3	88.9	85.2	77.275

Figure 13. Comparison of Performance Mean Scores within Center-Stick Groups

4.4.2 Comparison of Mean Scores within Side-Stick Groups

For side-stick groups, there were big differences between the highest score group and the lowest group. American high experience group scored 82.1%, whereas Korean low experience group recorded 74.2%. The differences were as large as 7.9%. Figure 14 shows the performance scores within the side-stick groups.



	1	2	3	4	5	6	7	QT
KHS	71.6	72.6	71.7	77.7	79.5	83.1	84.5	66.4
KLS	67	67.9	72.4	71.2	75.9	82.6	82.4	64.2
AHS	75.5	77.2	78.9	81.6	85.1	87.2	89	89.1
ALS	69.6	71.2	75.5	78.6	82.4	86.5	87.2	87.8
MEAN	70.925	72.225	74.625	77.275	80.725	84.85	85.775	76.875

Figure 14. Comparison of Mean Scores within Side-Stick Groups

4.4.3 Switching Effect

Pattern of changing improvement after switching the flight control stick to the other position is noticeable. When the stick was switched from center to side, most subjects in the group recorded lower performance scores than the last session with the center position. The amount of change was 4.8% below zero. On the other hand, when the stick was switched from center to side position, the scores were increasing or similar to the last session of the former position. The changes of the scores were averaged as 0.78% above zero.

4.5 Comparison of Simulated Flying Training and Actual Flying Training in the Korea Air Force

Twenty-four officers out of thirty-two Korean subjects, who participated the experiment, successfully completed all the actual flying training course of Korea Air Force and became pilots. Failed trainees in the actual flying training recorded low performance score in simulated flying training. Figure 15 shows mean score of passed group and failed group in the Korea Air Force flying training. A separate analysis proved that there is significant difference in performance score between the passed group (mean: 80.7, standard deviation: 7.41) and the failed group (mean: 73.4, standard deviation: 7.24).

Figure 16 depicts scatter plot of the performance scores and Qualifying Test scores of both passed group and failed group. Subjects, who got "zero" point in any element of performance among heading, altitude, or air speed during simulated training, failed in the actual flying training.

More than 70% of the pilots who participated in the experiment stated that simulated flying practice with personal computer was useful in enhancing the abilities of attention-distribution as well as eye-hand coordination. They also recalled that those abilities are essential and key points to be successful in flying training.

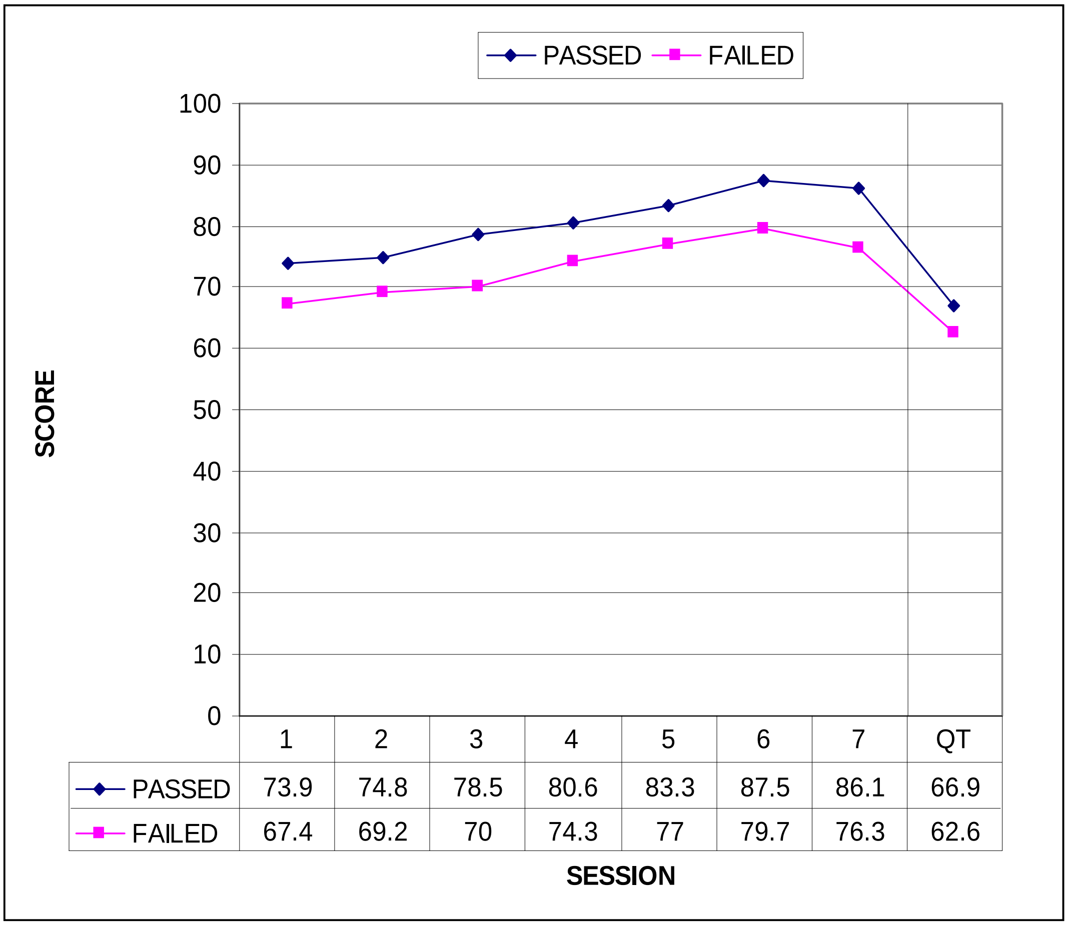


Figure 15. Comparison of the Mean Scores of the Passed Group and the Failed Group of the Korean Subjects

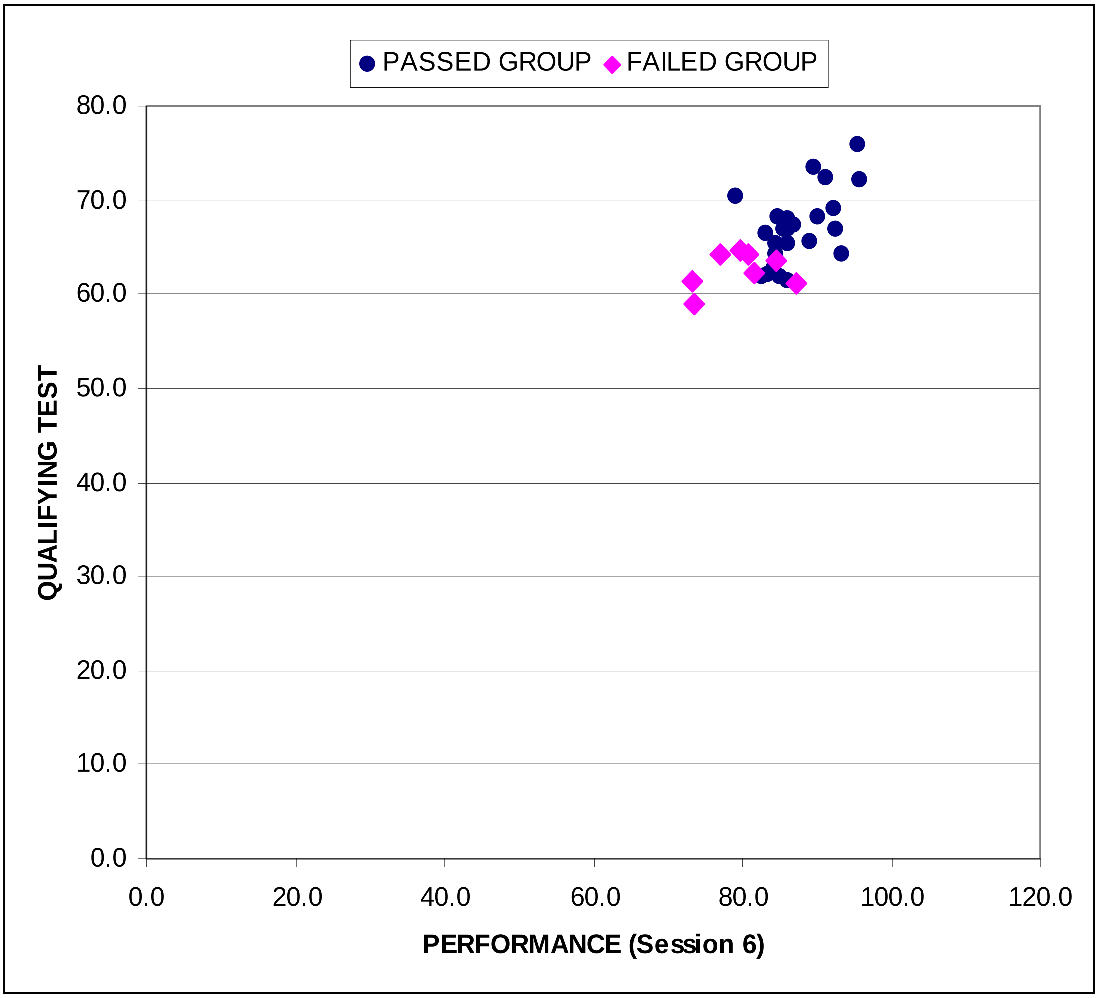


Figure 16. Scatter Plot of the Performance Scores and Qualifying Test Sores of the Passed Group and the Failed Group of Korean Subjects

CHAPTER 5

SUMMARY, CONCLUSION, AND RECOMMENDATION FOR FURTHER STUDY

Literature review indicates that because flying an airplane is a complicated task, it is important to develop a screening system for the pilot-candidates prior to actual flying training to reduce training cost. Flying training system is also necessary to enhance efficiency of the training. Previous research has proved effectiveness of computer-based flying simulator.

The U. S. Air Force has developed a pilot-screening system and has conducted and performed research for improvement of the system. However, Korea is in the beginning phase in those areas.

This study intended to determine whether subject related factors have an impact on acquiring simulated flying skill using a flight simulator. The independent variables including the position of the flight control stick and subject related factors of nationality and experience in computer games. Dependent variables were performance scores in the simulated flying training and Qualifying Test. Sixty-four subjects participated in the experiment. Subjects were grouped by three factors in two levels (2x2x2) with repeated measures.

Prior to the experiment, subjects were given a sample Qualifying Test. After six sessions, flight control stick was switched to the other position for the last recording. Upon completion of the experiment, collected data were converted and analyzed. As a result of multivariate analysis of variance with repeated measures, the following conclusions are made:

As results of correlation analysis of performance score and Qualifying Test, the correlation coefficient between the performance score and Qualifying Test of Korean subject is 0.627, and the slope of the linear regression line is 0.884. Regarding the American subjects, the correlation coefficient between the performance score and Qualifying Test is 0.52, and the slope was 0.61. The results prove that performance score and Qualifying Test are positively correlated. Thus, the multivariate analysis of variance was done with and without the Qualifying Test as covariate.

For the nationality, Americans recorded higher performance scores in general (mean: 81.7%, standard deviation 5.5%) than Koreans (mean: 78.9%, standard deviation 5.5%). Result of testing of hypothesis indicates that nationality has a significant impact on the performance score. The fact that the unit marked in the cockpit instruments is in American customary system caused the low score of Korean subjects.

There are considerable difference between the best-scored group and the worst-scored group. American-High-Center group recorded the highest (mean: 85.7%, standard deviation 4.5%), and Korean-Low-Side group recorded the lowest (mean: 75.2%, standard deviation: 5.6%).

Another interested point is the big difference in Qualifying Test scores between Americans (88.3%) and Koreans (65.9%). The reason for this difference is that the test is in English.

Computer game experience was the second independent variable. Hypothesis was that the experience does not affect the performance score. This hypothesis was rejected. Therefore, computer game experience has a significant impact on the performance score.

The difference between high experience group (82.3%) and low experience group (78.3%) is significant. For high experience group, American side-stick group recorded the highest score (mean: 85.6%), and Korean side-stick group (mean: 77.2%) got the lowest score. For the low experience group, American center-stick group scored highest (80.6%), and the Korean side-stick group (74.2%) scored the lowest points.

The results of analysis reveal that the stick-position also has significant impact on acquiring the simulated flying skill. The results also reveal that center-stick is easier than to learn. The difference in performance score between group of center-stick (mean: 82.1%) and side-stick (mean: 76.8%) was considerable.

Switching effect on acquiring flying skill was also detected. When the stick was moved from the center to the side position, the mean amount of change at the final session was negative 4.8%. When switching from side to center the change of score was 0.78%. Therefore, we can conclude that the center-stick is easier to than the side-stick.

As an extension of the study, performance scores of Korean subjects were compared to the result of their actual flying training. Difference in mean scores between the passed group (mean: 80.7%, standard deviation: 7.4%) and failed group (mean: 73.4%, standard deviation: 7.2 %) was noticeable.

In the beginning phase of this research, several factors were examined to determine whether they could be the indicating factors of becoming a pilot. This study proves that some factors positively affect learning how to fly using a flight simulator. This study may be useful to Korea Air Force for improving the flying training system and developing the pilot-candidate screening system.

Compared to the past research, the result of this research shows a few similar points as well as differences. Similar points are as follows:

(1) Similar to Caro (1988) and Gopher (1994), the effectiveness of PC-based flight simulation on acquisition the flying skill has been proved.

(2) The fact that high experienced groups in computer games showed better performance than low experience groups both in simulated flying training and in actual flying training supports the past research.

(3) Validity of Qualifying Test has been supported by the result of this research.

And differences are as followings:

(1) The result of this research reveals that using side-stick is more difficult to acquire flying skills than center-stick in the beginning phase of the flying training, whereas Staten *et al*. (1970) and Aiken (1985) concluded that side-stick was feasible and preferred to center-stick by the experienced test pilots.

(2) In addition, this research detects a difference in performance between Korean subjects and American subjects, whereas the past research used subjects from same race and same group of pilots.

Performing this research and surveying the literature lead us to make the following recommendation for further study:

(1) Other factors may be included to enhance the reliability of the result. For example, personal characteristics, behavioral characteristics, and emotional stability may be considered.

(2) Extension of the study to the completion of actual flying training is recommended to strengthen the validity of the study. Comparison of the performance of this research using "movement based flight simulator" is also recommended.

(3) Using more subjects including females to enhance the validity of the research. The proportion of female to male cadets in Korea Air Force is about 8 percent.

(4) The investigation should be extended to include flying helicopters.

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APPENDIX A: INFORMATION SHEET FOR SUBJECTS

1. Last 4 digits of Social Security Number: (   )

2. Age (Optional): (   )

3. Dominant hand: left (   ),   right (   )

4. In general, how often do you play computer games?

   Low : (   ) Less than once a week,   (   ) Once a week,

   High: (   ) 2-3 times per week,   (   ) More than 4 times a week

5. When the flight control stick was switched to the other side, how did you feel?

   (   ) It was awkward and difficult to control.

   (   ) It was awkward, but not too difficult to control.

   (   ) It was easier than the former position to control.

6. Have you ever taken the AFOQT?

   (   ) Yes

   (   ) No

7. If your answer is "yes" for the question 6, how do you compare the actual test with the sample test you took during the experiment?

   (   ) The sample test was easier than the actual test.

   (   ) The sample test was almost same as the actual test.

   (   ) The sample test was more difficult than the actual test.

APPENDIX B: CONSENT FORM

Research Project Title

Impact of Subject Related Factors and Position of Flight Control Stick on Acquisition of Simulated Flying Skills Using a Flight Simulator

Performance Site

Human Factors Laboratory, LSU, 3412 CEBA

Investigator

Dr. Fred Aghazadeh, Phone: (504) 388-5367

Ph. D. dissertation of

Bo-Keun Cho, Phone: (504) 388-5377

Research Purpose

The objective of this research project is to determine the impact of position of the flight control stick and subject related factors on acquisition of flight skills during flight training using a flight simulator.

Description

Experiments are conducted in eight sessions for each subject. Subjects are recruited from undergraduate students of Louisiana State University who were enrolled in ROTC program, and Korea Air Force Academy cadets (KAFA) on a voluntary basis. For the normality of the data, subjects who could speak both Korean and English at the same level are excluded. For the experience in computer games, subjects are grouped by subjective ratings, which is marked on the information sheet. Excluding criteria for the experience in computer games are also applied. Any one who has played similar or same flight simulation, and is expert in computer games is excluded.

Before the main experiment, a sample set of the U. S. Air Force Officer Qualifying Test is administrated. The test consists of sixteen parts and takes three hours thirty-three minutes.

The main experiment consisted of eight sessions of thirty-minutes flight simulation. The first session is an orientation to the flight simulation. From session two to session six, fifteen-minute practice flight and fifteen-minute recording flight training will be done at a designated position of stick- center or side. At session seven, the stick will be switched to the other position, and same pattern of flight training will be conducted.

Benefits

Useful reference for a pilot-candidate screening system will be provided.

Risks

Risks resulting from the experiments are minimal, just like playing computer games.

Right to Refuse

Subjects may choose NOT to participate or to withdraw from the experiment at any time without any penalty or negative consequences.

Privacy

All data collected are coded and reported in such a way that confidentiality is protected.

Release of Information

No part of the data will be disclosed.

The study has been discussed with me and all my questions have been answered. I understand that additional questions regarding the study should be directed to investigators listed above. I understand that if I have any questions about subject rights, or other concerns, I can contact Dr. Charles D. Graham, Chairman, Institutional Review Board at 388-1492. I agree to the terms above and acknowledge I have been given a copy of the consent form.

____
Signature of the Subject Date

____
Witness Date

____
Investigator(s) Date

APPENDIX C: CONDENSED MANUAL FOR THE FLIGHT SIMULATOR

CONDENSED MANUAL FOR THE FLIGHT SIMULATOR

by Bo-Keun CHO

Department of

Industrial & Manufacturing Systems Engineering

Louisiana State University

I. PURPOSE OF THIS RESEARCH

- To determine the effect of subjects related factors in acquiring simulated flying skills.
- To examine whether the position of flight control stick has any effects on flying training.
- To determine transfer effect of position of flight control stick on flying training.

II. CONTENTS OF THE RESEARCH

- The experiment consists of eight sessions.
- Flight simulation Orientation at the first session.
- Each session, except the first session, consists of 15-minute practice and 15-minute course flight for data collection.
- During the first seven sessions, subjects will fly with one of the two positions of the stick.
- The stick position will be switched to the other position in the last session.

III. GUIDANCE FOR THE FLIGHT SIMULATION

- Control Systems

  ◆ Movement of an airplane is in three dimensions;

  * Vertical : up & down - called pitching (scaled by pitch angle)
  * Longitudinal : left & right roll - called rolling (scaled by bank angle)
  * Lateral : left & right - called yawing (indicated by ball)

  ◆ Control Systems

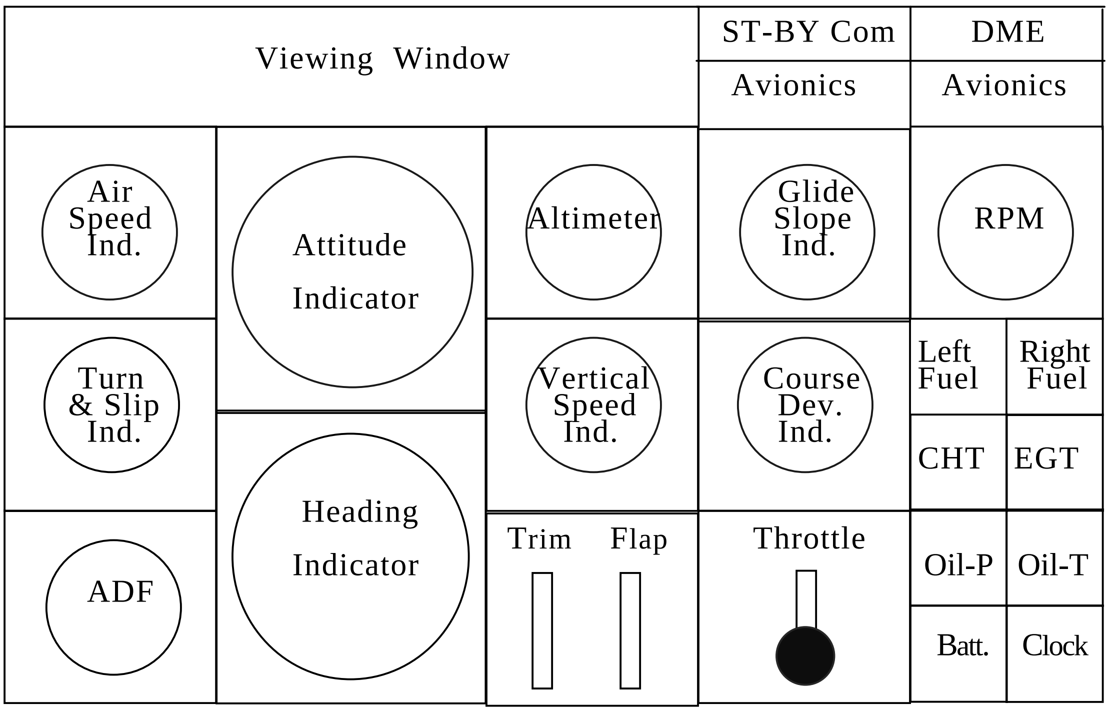
  * Flight control stick (right hand) - controls flight attitude :
    - Pitching: up (pulling stick backward : climb)
      down (pushing stick forward : descend)
    - Rolling: left & right roll make turns(left bank & right bank).

* Power control(left hand)

- Throttle: controls engine RPM (page-up & page down keys)

◆ Flying consists of combinations of power and flight attitude control: refer to the table for recommended control for the required performance.

● Instrument Panel



◆ Viewing Window: shows front outside view.

◆ Air Speed Indicator: tells air speed in knots - nautical miles per hour (100 kts = 185.2 km/hour= 165 static miles/hour)

◆ Attitude Indicator: shows the airplane's attitude in pitch and bank angle between the miniature aircraft and horizontal line.

◆ Altimeter: indicates the airplane's altitude from sea level in feet (long needle shows 100 ft, short needle indicates 1000 ft).

◆ RPM (Revolution per Minute): shows the engine power (in 100 RPM).

◆ Vertical Speed Indicator: shows climbing or descending rate in 100 ft/minute

◆ Heading Indicator: shows the direction the aircraft is flying in 10° (North: 0, or 360°, East: 90°, South: 180°, West: 270°).

IV. PROCEDURES IN FLIGHT

1. Before Take Off (using mouse)
   - Trim - middle position.
   - Flap up.
   - Click on the viewing window.
   - Push the throttle up to maximum (using mouse or page-up key).
   - Click on "PAUSE"

2. Take Off and Climbing
   - Click on "BRAKE".
   - Wait until the air speed reaches 50 kts.
   - At 50 kts, pull the stick up to 6° pitch (put the yellow dot on the first line of scale in the attitude indicator).
   - After take off, adjust the stick to maintain vertical speed of 500 feet per minute (fpm), the indicated air speed (IAS) of 90 kts, and flight heading 60°.
   - Adjust RPM also.

3. Leveling Off (Climbing ⇨ Level flight)
   - Push the flight control stick forward until yellow bars and dot touch the horizon of the attitude indicator.
   - Check the air speed increases (up to 100 kts), VSI goes to zero, altimeter stops increasing.
   - Reduce the RPM to 2300.
   - Recheck air speed (100 kts), VSI (0), and altimeter to adjust attitude and RPM.

4. Turning (Level Turn)
   - Push the stick to the direction you want to turn.
   - When the bank angle of the attitude indicator reaches 15°, move the stick to the opposite direction slightly to maintain the bank angle.

- Check attitude, altimeter, air speed and VSI to maintain level turn.
- To stop turning:
  - When the desired heading comes near, make the attitude level with lead point of 10°.
  - Recheck the heading, and correct as required.

5. Climbing (Level Flight ⇨ Climbing)

- Pull the stick backward up to 6° pitch.
- Increase the RPM to maintain 90 kts, 500 fpm (RPM 2500 is recommended).
- Good combinations of controlling the pitch (6°) and RPM (2500) will give you a good performance as desired.
- Check air speed, attitude, VSI, RPM, and adjust the pitch and RPM as required.

  ❋ Examples of correction (assuming RPM: 2500) to maintain 90 kts, 500 fpm:
  - Air speed 100 kts, VSI 200 fpm

    ⇨ Increase pitch angle (Pull the stick backward).
  - Air speed 80 kts, VSI 800 fpm

    ⇨ Reduce pitch angle (Push the stick forward).

6. Descending (Level Flight ⇨ Descending)

- Reduce the RPM to 1600 while maintaining pitch attitude
- Check and decrease the air speed to 90 kts, push the stick forward slightly to make 2.5° of pitch below the horizon.
- Adjust the RPM and pitch to maintain 90 kts, 500 fpm.
- To level off from descent:
  - When the desired altitude comes near, pull the stick backward slightly to make the attitude level (put the yellow bars and dot on the horizon).
  - Increase the RPM to 2300 for the level flight (100 kts, zero VSI).
  - Check the air speed, attitude, VSI, and RPM, and adjust pitch angle and the RPM.

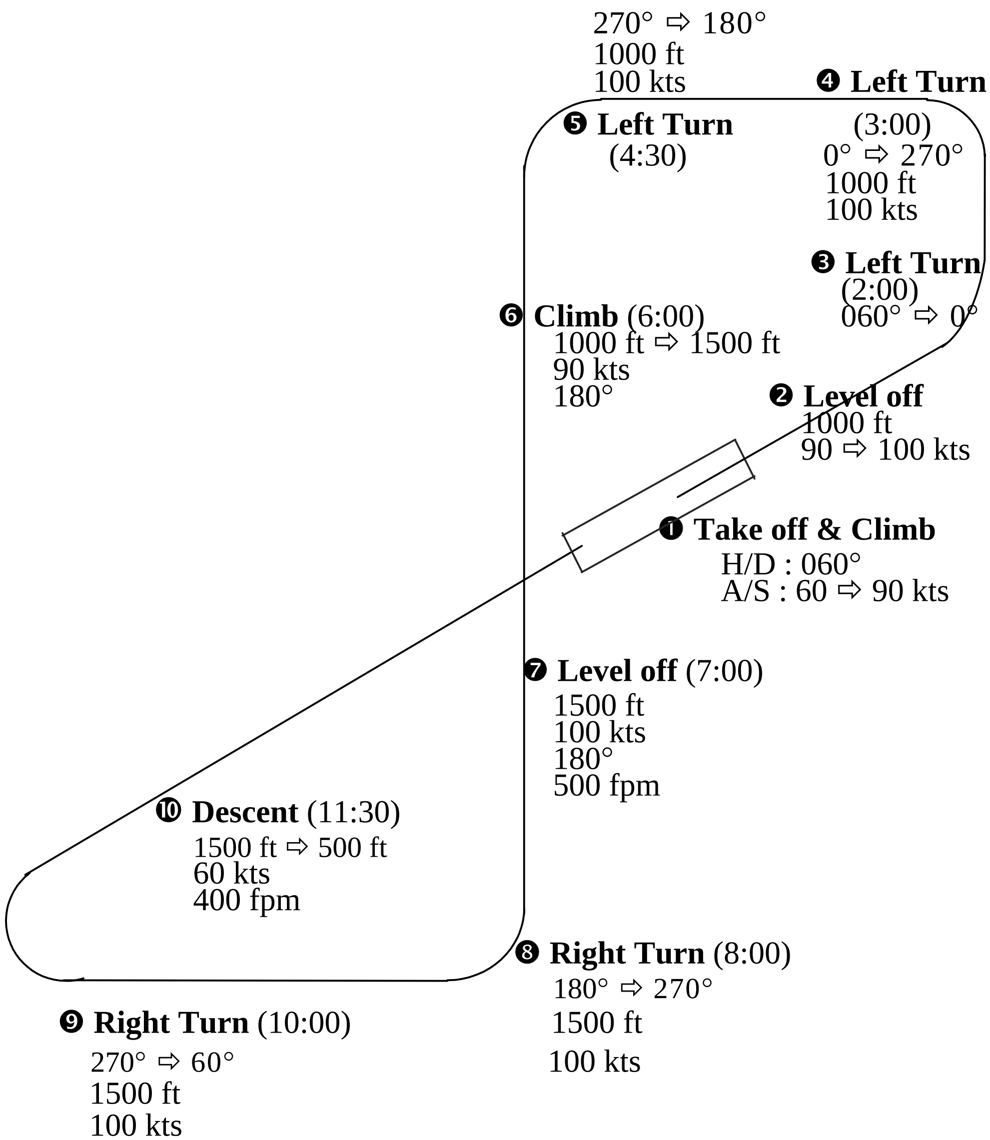
7. Required Performance and Recommended Control

	Required Performance		Recommended Control		
Classification	Air Speed (kts)	VSI (fpm)	Pitch (deg)	Bank (deg)	RPM
Level Flight	100	0	0	0	2300
Climbing	90	500	6	0	2500
Descending	90	500	-2.5	0	1600

8. Required Maneuverings by Time

Time (min:sec)	Maneuvering	Heading (°)	Altitude (feet)	Air Speed (kts)
0 : 00	Take-off Roll	60	500	0 ⇨ 60
0 : 30	Take-off & Climb	60	500	60 ⇨ 90
1 : 30	Level-off	60	1000	90 ⇨ 100
2 : 00	Left Turn	60 ⇨ 0	1000	100
3 : 00	Left Turn	0 ⇨ 270	1000	100
4 : 30	Left Turn	270 ⇨ 180	1000	100
6 : 00	Climb	180	1000 ⇨ 1500	100 ⇨ 90
7 : 00	Level-off	180	1500	90 ⇨ 100
8 : 00	Right Turn	180 ⇨ 270	1500	100
10 : 00	Right Turn	270 ⇨ 60	1500	100
11 : 30	Descent	60	1500 ⇨ 500	60
13 : 30	Touch Down	60	500	60

9. Flight Course



APPENDIX D: DATA COLLECTION FORM

Last 4 digits of S. S. No: (   ), Language: (   ), Computer Game Exp. : (   )

Position of Stick: (   ),   Session   : (   )

Time min:sec	Heading			Altitude			Air Speed			Sum of Scores
	Required (degree)	Actual (degree)	Conv. Score	Required (feet)	Actual (feet)	Conv. Score	Required (kts)	Actual (kts)	Conv. Score	
0:15	60			394			50			
0:30	60			450			85			
0:45	60			575			90			
1:00	60			700			90			
1:15	60			825			90			
1:30	60			950			100			
1:45	60			1000			100			
2:00	60			1000			100			
2:15	30			1000			100			
2:30	0			1000			100			
2:45	0			1000			100			
3:00	0			1000			100			
3:15	330			1000			100			
3:30	300			1000			100			
3:45	270			1000			100			
4:00	270			1000			100			
4:15	270			1000			100			
4:30	270			1000			100			
4:45	240			1000			100			
5:00	210			1000			100			
.	.			.			.			
.	.			.			.			
.	.			.			.			
13:15	60			525			60			
13:30	60			400			60			
13:45	60			394			60			
Mean of Total Converted Scores										

APPENDIX E: SAS INPUT PROGRAM AND DATA

```
LIBNAME z 'a:\' ;
options pagesize=66 ls=100 ;
DATA z.data1 ;
    INFILE 'a:\data.txt' ;
    INPUT nation $ position $ experi $ qt y7 y7_6 ave y1-y6 ;
RUN ;

PROC GLM DATA=z.data1 ;
CLASS nation position experi ;
MODEL y1-y6=nation|position|experi qt /nouni ;
REPEATED time 6 (1 2 3 4 5 6)  ;
RUN ;

PROC ANOVA DATA=z.data1 ;
CLASS nation position experi ;
MODEL y1-y6=nation|position|experi /nouni ;
REPEATED time 6 (1 2 3 4 5 6) ;
RUN ;

/* model pooling */

PROC GLM DATA=z.data1 ;
CLASS nation position experi ;
MODEL y1-y6=nation position experi nation*position qt /nouni ;
REPEATED time 6 (1 2 3 4 5 6)  ;
RUN ;

PROC ANOVA DATA=z.data1 ;
CLASS nation position experi ;
MODEL y1-y6=nation position experi nation*position  /nouni ;
REPEATED time 6 (1 2 3 4 5 6) ;
RUN ;


PROC GLM DATA=z.data1 ;
CLASS nation position experi ;
MODEL y7_6=nation|position|experi qt ;
RUN ;

PROC ANOVA DATA=z.data1 ;
CLASS nation position experi ;
MODEL y7_6=nation|position|experi  ;
RUN ;


PROC GLM DATA=z.data1 ;
```

```
CLASS nation position experi ;
MODEL y7_6=nation position experi qt ;
RUN ;

PROC ANOVA DATA=z.data1 ;
CLASS nation position experi ;
MODEL y7_6=nation position experi  ;
RUN ;
```

```
kor center high 69 89.6 -2.7 85.21666667 78.2 79.8 84.4 87.1 89.5 92.3
kor center high 65.6 83.5 -5.7 81.38333333 76.7 73.2 79.1 83.6 86.5 89.2
kor center high 73.5 80.4 -9.3 85.03333333 77.6 81.3 88.9 85.7 87 89.7
kor center high 75.8 96.3 0.8 90 84.7 84.6 87.3 94.5 93.4 95.5
kor center high 61.7 83.3 -1.8 80.53333333 74.3 76.2 81.7 82.3 83.6 85.1
kor center high 72.1 94.2 -1.6 87.91666667 82.7 81.9 85.2 88.4 93.5 95.8
kor center high 64.3 87.7 -5.7 84.9 77.2 79.3 82.6 86.8 90.1 93.4
kor center high 61.2 81.5 -5.7 77.61666667 67.4 72.5 77.3 76.7 84.6 87.2
kor side high 67.9 90.3 4.2 80.46666667 75.3 76.9 79.5 81.2 83.8 86.1
kor side high 66.8 86.4 0.7 80.83333333 74.6 77.8 80.1 82.3 84.5 85.7
kor side high 72.3 90.5 -0.8 83.08333333 78.5 73.3 82.7 84.6 88.1 91.3
kor side high 61.4 74.9 1.7 66.25 69.4 71.2 42.5 72.3 68.9 73.2
kor side high 62.3 79.6 -1.9 75.86666667 70.1 72.9 74.2 76.8 79.7 81.5
kor side high 68.2 87.7 2.9 79.16666667 72.7 73.4 78.5 82.7 82.9 84.8
kor side high 70.3 80.3 1.2 71.76666667 68.2 67.5 68.9 72.3 74.6 79.1
kor side high 61.7 85.9 3.2 70.61666667 64.3 67.4 67.1 69 73.2 82.7
kor center low 68.2 83.6 -6.7 84.76666667 79.7 81.3 83.6 85.5 88.2 90.3
kor center low 64.3 78.2 -2.5 77.63333333 75.2 75.9 79.1 76.8 78.1 80.7
kor center low 63.5 71.7 -12.8 75.28333333 66.3 67.5 75.3 77.7 80.4 84.5
kor center low 67.2 86.3 -0.8 84.11666667 82.8 79.1 83.9 85.6 86.2 87.1
kor center low 62.1 79.8 -3.8 77.05 69.5 71.2 74.3 81.4 82.3 83.6
kor center low 61.4 82.7 -3.5 80.1 70.8 75.6 77.1 85.2 85.7 86.2
kor center low 65.3 80.9 -3.6 79.65 71.7 76.2 78.6 84.9 82 84.5
kor center low 66.8 81.2 -5.1 76.01666667 68.4 70.3 73.8 76.5 80.8 86.3
kor side low 64.7 75.4 -4.4 68.61666667 65.1 56.3 67.2 69.8 73.5 79.8
kor side low 59 71.1 -2.4 69.18333333 63.6 64.8 68.7 70.3 74.2 73.5
kor side low 64.2 77.8 0.8 72.93333333 62.3 72.5 75.3 74.1 76.4 77
kor side low 66.5 88.3 5.2 75.01666667 72.4 69.7 73.8 75.2 75.9 83.1
kor side low 62.7 86.2 1.8 73.53333333 61.5 71.3 81.1 62.2 80.7 84.4
kor side low 64.2 85.5 1 72.6 70.7 68.4 69.1 70.3 72.6 84.5
kor side low 65.3 84.8 -1.3 74.6 68.8 70.2 71.3 74.5 76.7 86.1
kor side low 66.8 90 -2.6 75.98333333 71.2 69.7 72.4 73.1 76.9 92.6
american center high 86.2 87.9 -5.8 87.35 81.7 84.5 84 88.9 91.3 93.7
american center high 88.6 94.5 0.3 84.53333333 78.5 80.2 79.3 85.4 89.6 94.2
american center high 85.8 90.1 -1.3 85.1 79.8 82.3 84.7 83.5 88.9 91.4
american center high 92.5 90.8 -3.2 89.38333333 82.6 86.4 91.2 90.3 91.8 94
american center high 91.1 88.5 -2.2 85.13333333 77.2 83.5 82.7 87.3 89.4 90.7
american center high 87.3 89 -1.8 86.56666667 76.5 82.8 88.6 89.3 91.4 90.8
american center high 89.4 87.7 -1.8 83.9 74.4 81.5 83.7 86.1 88.2 89.5
american center high 84.2 80.1 -4.1 78.58333333 73.1 78.3 76.8 77.5 81.6 84.2
```

american	side	high	91.7	87.3	3.2	80.13333333	74.5	76.2	77.8	83.2	85	84.1
american	side	high	94.4	93.2	2.7	83.13333333	77	78.4	81.3	84.7	86.9	90.5
american	side	high	92.1	90.8	1.9	82.95	75.9	81.4	79.6	85.5	86.4	88.9
american	side	high	91.6	92.7	1.7	85.61666667	80.2	78.1	85.7	88.4	90.3	91
american	side	high	87.6	87.4	0.3	79.95	75.8	76.2	75.6	79.3	85.7	87.1
american	side	high	85.2	83.9	-0.3	77.4	72.3	74.8	77.1	75.4	80.6	84.2
american	side	high	86.1	87.8	2.5	79.13333333	74.7	75.6	78.5	79.2	81.5	85.3
american	side	high	84.4	88.6	2.5	78.8	73.2	76.6	75.7	77.2	84	86.1
american	center	low	84.9	82	-3.6	78.18333333	71.8	72.3	76.8	78.4	84.2	85.6
american	center	low	91.5	87.4	-1.9	77.28333333	70.7	71.1	73.4	76.5	82.7	89.3
american	center	low	89.3	83.7	-3.4	82.15	76.2	76.9	80.6	85.3	86.8	87.1
american	center	low	92.7	91.3	-2.1	85.31666667	77.5	80.3	83.7	87.1	89.9	93.4
american	center	low	90	82.9	-4.3	81.53333333	76.4	76.7	80	83.4	85.5	87.2
american	center	low	83.5	81.4	-5.3	76.38333333	69.8	69.2	73.6	77.7	81.3	86.7
american	center	low	86.8	82.8	-5.4	79.51666667	72.3	74.7	75.9	81.5	84.5	88.2
american	center	low	87.2	84.1	-2.8	78.68333333	71.6	74.5	77.2	79.6	82.3	86.9
american	side	low	90.2	91.6	0.5	82.53333333	72.5	71.2	85.1	86.3	89	91.1
american	side	low	87.7	86.2	3	76.61666667	71.3	72.7	76.4	75.6	80.5	83.2
american	side	low	85.1	83.4	1	74.76666667	68.1	69.9	72.5	77.6	78.1	82.4
american	side	low	87	91.5	0.8	81.45	71.4	73.7	81.2	83.4	88.3	90.7
american	side	low	84.8	79.2	-4.4	71.08333333	59.1	65.3	68.6	73.7	76.2	83.6
american	side	low	83.9	80.8	-0.6	70.01666667	63.7	64.4	65.2	68.3	77.1	81.4
american	side	low	91.4	89.3	4.8	78.8	73.1	75.5	78.8	81.7	79.2	84.5
american	side	low	92.2	95.8	1.1	82.9	77.8	76.5	76.1	81.9	90.4	94.7

APPENDIX F: RESULT OF STATISTICAL ANALYSIS

F.1: Full Model with Covariate

The GLM Procedure
Class Level Information

Class	Levels	Values
nation	2	american kor
position	2	center side
experi	2	high low

Number of observations 64

The GLM Procedure
Repeated Measures Analysis of Variance

Repeated Measures Level Information

Dependent Variable	y1	y2	y3	y4	y5	y6
Level of time	1	2	3	4	5	6

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time Effect
H = Type III SSCP Matrix for time
E = Error SSCP Matrix

S=1 M=1.5 N=24.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.76486370	3.14	5	51	0.0152
Pillai's Trace	0.23513630	3.14	5	51	0.0152
Hotelling-Lawley Trace	0.30742249	3.14	5	51	0.0152
Roy's Greatest Root	0.30742249	3.14	5	51	0.0152

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*nation Effect
H = Type III SSCP Matrix for time*nation
E = Error SSCP Matrix

S=1 M=1.5 N=24.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.77926148	2.89	5	51	0.0226
Pillai's Trace	0.22073852	2.89	5	51	0.0226
Hotelling-Lawley Trace	0.28326631	2.89	5	51	0.0226
Roy's Greatest Root	0.28326631	2.89	5	51	0.0226

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*position Effect
H = Type III SSCP Matrix for time*position
E = Error SSCP Matrix

S=1 M=1.5 N=24.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.86734819	1.56	5	51	0.1882
Pillai's Trace	0.13265181	1.56	5	51	0.1882
Hotelling-Lawley Trace	0.15293951	1.56	5	51	0.1882
Roy's Greatest Root	0.15293951	1.56	5	51	0.1882

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*nation*position Effect
H = Type III SSCP Matrix for time*nation*position
E = Error SSCP Matrix

S=1 M=1.5 N=24.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.89557467	1.19	5	51	0.3275
Pillai's Trace	0.10442533	1.19	5	51	0.3275
Hotelling-Lawley Trace	0.11660148	1.19	5	51	0.3275

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*experi Effect
H = Type III SSCP Matrix for time*experi
E = Error SSCP Matrix

S=1 M=1.5 N=24.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F

Wilks' Lambda	0.77977589	2.88	5	51	0.0229
Pillai's Trace	0.22022411	2.88	5	51	0.0229
Hotelling-Lawley Trace	0.28241975	2.88	5	51	0.0229
Roy's Greatest Root	0.28241975	2.88	5	51	0.0229

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*nation*experi Effect

H = Type III SSCP Matrix for time*nation*experi
E = Error SSCP Matrix

S=1 M=1.5 N=24.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.85816679	1.69	5	51	0.1549
Pillai's Trace	0.14183321	1.69	5	51	0.1549
Hotelling-Lawley Trace	0.16527465	1.69	5	51	0.1549
Roy's Greatest Root	0.16527465	1.69	5	51	0.1549

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*position*experi Effect

H = Type III SSCP Matrix for time*position*experi
E = Error SSCP Matrix

S=1 M=1.5 N=24.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.86227496	1.63	5	51	0.1691
Pillai's Trace	0.13772504	1.63	5	51	0.1691
Hotelling-Lawley Trace	0.15972288	1.63	5	51	0.1691
Roy's Greatest Root	0.15972288	1.63	5	51	0.1691

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*nation*positi*experi Effect

H = Type III SSCP Matrix for time*nation*positi*experi
E = Error SSCP Matrix

S=1 M=1.5 N=24.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.90895647	1.02	5	51	0.4148
Pillai's Trace	0.09104353	1.02	5	51	0.4148
Hotelling-Lawley Trace	0.10016270	1.02	5	51	0.4148
Roy's Greatest Root	0.10016270	1.02	5	51	0.4148

The GLM Procedure
Repeated Measures Analysis of Variance
Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*qt Effect
H = Type III SSCP Matrix for time*qt
E = Error SSCP Matrix

S=1 M=1.5 N=24.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.81685244	2.29	5	51	0.0596
Pillai's Trace	0.18314756	2.29	5	51	0.0596
Hotelling-Lawley Trace	0.22421131	2.29	5	51	0.0596
Roy's Greatest Root	0.22421131	2.29	5	51	0.0596

The GLM Procedure
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F
nation	1	1657.346933	1657.346933	34.94	<.0001
position	1	2414.102956	2414.102956	50.90	<.0001
nation*position	1	190.962185	190.962185	4.03	0.0497
experi	1	783.429536	783.429536	16.52	0.0002
nation*experi	1	90.634221	90.634221	1.91	0.1724
position*experi	1	76.473278	76.473278	1.61	0.2095
nation*positi*experi	1	19.267638	19.267638	0.41	0.5265
qt	1	2539.184996	2539.184996	53.54	<.0001
Error	55	2608.549795	47.428178		

The GLM Procedure
Repeated Measures Analysis of Variance
Univariate Tests of Hypotheses for Within Subject Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F	Adj Pr > F G - G	H - F
time	5	88.324675	17.664935	2.29	0.0463	0.0718	0.0578
time*nation	5	67.288289	13.457658	1.74	0.1249	0.1524	0.1383
time*position	5	63.250225	12.650045	1.64	0.1499	0.1755	0.1626
time*nation*position	5	41.627007	8.325401	1.08	0.3726	0.3638	0.3691
time*experi	5	106.561398	21.312280	2.76	0.0188	0.0369	0.0265
time*nation*experi	5	71.021233	14.204247	1.84	0.1052	0.1336	0.1188
time*position*experi	5	89.533465	17.906693	2.32	0.0437	0.0687	0.0550
time*nation*positi*experi	5	42.17103	48.434207	1.09	0.3648	0.3575	0.3620
time*qt	5	60.026078	12.005216	1.55	0.1731	0.1963	0.1847
Error(time)	275	2123.245380	7.720892				

Greenhouse-Geisser Epsilon	0.6814
Huynh-Feldt Epsilon	0.8375

F.2: Full Model without Covariate

The ANOVA Procedure

Class Level Information

Class	Levels	Values
nation	2	american kor
position	2	center side
experi	2	high low

Number of observations 64

The ANOVA Procedure
Repeated Measures Analysis of Variance

Repeated Measures Level Information

Dependent Variable	y1	y2	y3	y4	y5	y6
Level of time	1	2	3	4	5	6

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time Effect
H = Anova SSCP Matrix for time
E = Error SSCP Matrix

S=1 M=1.5 N=25

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.04598766	215.75	5	52	<.0001
Pillai's Trace	0.95401234	215.75	5	52	<.0001
Hotelling-Lawley Trace	20.74496514	215.75	5	52	<.0001
Roy's Greatest Root	20.74496514	215.75	5	52	<.0001

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*nation Effect
H = Anova SSCP Matrix for time*nation
E = Error SSCP Matrix

S=1 M=1.5 N=25

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.90050743	1.15	5	52	0.3467
Pillai's Trace	0.09949257	1.15	5	52	0.3467
Hotelling-Lawley Trace	0.11048501	1.15	5	52	0.3467
Roy's Greatest Root	0.11048501	1.15	5	52	0.3467

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*position Effect
H = Anova SSCP Matrix for time*position
E = Error SSCP Matrix

S=1 M=1.5 N=25

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.86636869	1.60	5	52	0.1754
Pillai's Trace	0.13363131	1.60	5	52	0.1754
Hotelling-Lawley Trace	0.15424301	1.60	5	52	0.1754
Roy's Greatest Root	0.15424301	1.60	5	52	0.1754

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*nation*position Effect
H = Anova SSCP Matrix for time*nation*position
E = Error SSCP Matrix

S=1 M=1.5 N=25

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.88941059	1.29	5	52	0.2812
Pillai's Trace	0.11058941	1.29	5	52	0.2812
Hotelling-Lawley Trace	0.12434011	1.29	5	52	0.2812
Roy's Greatest Root	0.12434011	1.29	5	52	0.2812

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*experi Effect
H = Anova SSCP Matrix for time*experi
E = Error SSCP Matrix

S=1 M=1.5 N=25

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.80884284	2.46	5	52	0.0450

Pillai's Trace	0.19115716	2.46	5	52	0.0450
Hotelling-Lawley Trace	0.23633412	2.46	5	52	0.0450
Roy's Greatest Root	0.23633412	2.46	5	52	0.0450

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*nation*experi Effect

H = Anova SSCP Matrix for time*nation*experi
E = Error SSCP Matrix
S=1 M=1.5 N=25

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.85908325	1.71	5	52	0.1497
Pillai's Trace	0.14091675	1.71	5	52	0.1497
Hotelling-Lawley Trace	0.16403154	1.71	5	52	0.1497
Roy's Greatest Root	0.16403154	1.71	5	52	0.1497

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*position*experi Effect

H = Anova SSCP Matrix for time*position*experi
E = Error SSCP Matrix

S=1 M=1.5 N=25

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.86236729	1.66	5	52	0.1609
Pillai's Trace	0.13763271	1.66	5	52	0.1609
Hotelling-Lawley Trace	0.15959872	1.66	5	52	0.1609
Roy's Greatest Root	0.15959872	1.66	5	52	0.1609

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*nation*positi*experi Effect

H = Anova SSCP Matrix for time*nation*positi*experi
E = Error SSCP Matrix

S=1 M=1.5 N=25

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.90552479	1.09	5	52	0.3796
Pillai's Trace	0.09447521	1.09	5	52	0.3796
Hotelling-Lawley Trace	0.10433199	1.09	5	52	0.3796
Roy's Greatest Root	0.10433199	1.09	5	52	0.3796

The ANOVA Procedure
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Anova SS	Mean Square	F Value	Pr > F
nation	1	712.042734	712.042734	7.75	0.0073
position	1	2741.878151	2741.878151	29.83	<.0001
nation*position	1	364.845026	364.845026	3.97	0.0512
experi	1	1683.793776	1683.793776	18.32	<.0001
nation*experi	1	4.441901	4.441901	0.05	0.8268
position*experi	1	58.359609	58.359609	0.63	0.4289
nation*positi*experi	1	0.002109	0.002109	0.00	0.9962
Error	56	5147.734792	91.923836		

The ANOVA Procedure
Repeated Measures Analysis of Variance
Univariate Tests of Hypotheses for Within Subject Effects

						Adj Pr > F	
Source	DF	Anova SS	Mean Square	F Value	Pr > F	G - G	H - F
Time	5	8687.786068	1737.5572	222.84	<.0001	<.0001	<.0001
time*nation	5	24.838359	4.967672	0.64	0.6716	0.6144	0.6437
time*position	5	66.489818	13.297964	1.71	0.1334	0.1592	0.1465
time*nation*position	5	48.171068	9.634214	1.24	0.292	0.2980	0.2960
time*experi	5	100.871068	20.174214	2.59	0.0262	0.0460	0.0353
time*nation*experi	5	69.744818	13.948964	1.79	0.1151	0.1419	0.1287
time*position*experi	5	89.222734	17.844547	2.29	0.0462	0.0705	0.0577
tme*nation*positi*experi	5	43.759609	8.751922	1.12	0.3486	0.3446	0.3472
Error(time)	280	2183.271458	7.797398				

Greenhouse-Geisser Epsilon 0.6935
Huynh-Feldt Epsilon 0.8373

F.3: Reduced Model with Covariate

The GLM Procedure

Class Level Information

Class	Levels	Values
nation	2	american kor
position	2	center side
experi	2	high low

Number of observations 64

The GLM Procedure
Repeated Measures Analysis of Variance

Repeated Measures Level Information

Dependent Variable	y1	y2	y3	y4	y5	y6
Level of time	1	2	3	4	5	6

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time Effect
H = Type III SSCP Matrix for time
E = Error SSCP Matrix

S=1 M=1.5 N=26

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.77481779	3.14	5	54	0.0147
Pillai's Trace	0.22518221	3.14	5	54	0.0147
Hotelling-Lawley Trace	0.29062601	3.14	5	54	0.0147
Roy's Greatest Root	0.29062601	3.14	5	54	0.0147

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*nation Effect
H = Type III SSCP Matrix for time*nation
E = Error SSCP Matrix

S=1 M=1.5 N=26

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.77990675	3.05	5	54	0.0170
Pillai's Trace	0.22009325	3.05	5	54	0.0170
Hotelling-Lawley Trace	0.28220457	3.05	5	54	0.0170
Roy's Greatest Root	0.28220457	3.05	5	54	0.0170

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*position Effect
H = Type III SSCP Matrix for time*position
E = Error SSCP Matrix

S=1 M=1.5 N=26

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.87442840	1.55	5	54	0.1897
Pillai's Trace	0.12557160	1.55	5	54	0.1897
Hotelling-Lawley Trace	0.14360421	1.55	5	54	0.1897
Roy's Greatest Root	0.14360421	1.55	5	54	0.1897

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*experi Effect
H = Type III SSCP Matrix for time*experi
E = Error SSCP Matrix

S=1 M=1.5 N=26

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.79311761	2.82	5	54	0.0248
Pillai's Trace	0.20688239	2.82	5	54	0.0248
Hotelling-Lawley Trace	0.26084706	2.82	5	54	0.0248
Roy's Greatest Root	0.26084706	2.82	5	54	0.0248

The GLM Procedure
Repeated Measures Analysis of Variance

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*nation*position Effect

H = Type III SSCP Matrix for time*nation*position
E = Error SSCP Matrix

S=1 M=1.5 N=26

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.90283085	1.16	5	54	0.3396
Pillai's Trace	0.09716915	1.16	5	54	0.3396
Hotelling-Lawley Trace	0.10762719	1.16	5	54	0.3396
Roy's Greatest Root	0.10762719	1.16	5	54	0.3396

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*qt Effect

H = Type III SSCP Matrix for time*qt
E = Error SSCP Matrix
S=1 M=1.5 N=26

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.81507416	2.45	5	54	0.0450
Pillai's Trace	0.18492584	2.45	5	54	0.0450
Hotelling-Lawley Trace	0.22688222	2.45	5	54	0.0450
Roy's Greatest Root	0.22688222	2.45	5	54	0.0450

The GLM Procedure
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F
nation	1	1550.398030	1550.398030	32.19	<.0001
position	1	2426.292272	2426.292272	50.38	<.0001
experi	1	810.722185	810.722185	16.83	0.0001
nation*position	1	196.606111	196.606111	4.08	0.0480
qt	1	2417.334748	2417.334748	50.20	<.0001
Error	58	2793.203664	48.158684		

The GLM Procedure
Repeated Measures Analysis of Variance
Univariate Tests of Hypotheses for Within Subject Effects

						Adj Pr > F	
Source	DF	Type III SS	Mean Square	F Value	Pr > F	G – G	H - F
time	5	80.832414	16.166483	2.02	0.0765	0.1050	0.0942
time*nation	5	66.450292	13.290058	1.66	0.1450	0.1712	0.1619
time*position	5	63.798086	12.759617	1.59	0.1626	0.1871	0.1785
time*experi	5	109.868144	21.973629	2.74	0.0195	0.0380	0.0302
time*nation*position	5	41.475295	8.295059	1.03	0.3977	0.3841	0.3898
time*qt	5	59.750219	11.950044	1.49	0.1930	0.2140	0.2068
Error(time)	290	2326.248401	8.021546				

Greenhouse-Geisser Epsilon	0.6788
Huynh-Feldt Epsilon	0.7882

F.4: Reduced Model without Covariate

The ANOVA Procedure

Class Level Information

Class	Levels	Values
nation	2	american kor
position	2	center side
experi	2	high low

Number of observations 64

The ANOVA Procedure
Repeated Measures Analysis of Variance

Repeated Measures Level Information

Dependent Variable	y1	y2	y3	y4	y5	y6
Level of time	1	2	3	4	5	6

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time Effect
H = Anova SSCP Matrix for time
E = Error SSCP Matrix

S=1 M=1.5 N=26.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.05155147	202.38	5	55	<.0001
Pillai's Trace	0.94844853	202.38	5	55	<.0001
Hotelling-Lawley Trace	18.39808855	202.38	5	55	<.0001
Roy's Greatest Root	18.39808855	202.38	5	55	<.0001

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*nation Effect
H = Anova SSCP Matrix for time*nation
E = Error SSCP Matrix

S=1 M=1.5 N=26.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.90379391	1.17	5	55	0.3352
Pillai's Trace	0.09620609	1.17	5	55	0.3352
Hotelling-Lawley Trace	0.10644694	1.17	5	55	0.3352
Roy's Greatest Root	0.10644694	1.17	5	55	0.3352

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*position Effect
H = Anova SSCP Matrix for time*position
E = Error SSCP Matrix

S=1 M=1.5 N=26.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.87361479	1.59	5	55	0.1779
Pillai's Trace	0.12638521	1.59	5	55	0.1779
Hotelling-Lawley Trace	0.14466927	1.59	5	55	0.1779
Roy's Greatest Root	0.14466927	1.59	5	55	0.1779

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*experi Effect
H = Anova SSCP Matrix for time*experi
E = Error SSCP Matrix

S=1 M=1.5 N=26.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.82889708	2.27	5	55	0.0600
Pillai's Trace	0.17110292	2.27	5	55	0.0600
Hotelling-Lawley Trace	0.20642240	2.27	5	55	0.0600
Roy's Greatest Root	0.20642240	2.27	5	55	0.0600

The ANOVA Procedure
Repeated Measures Analysis of Variance

Manova Test Criteria and Exact F Statistics for the Hypothesis of no time*nation*position Effect
H = Anova SSCP Matrix for time*nation*position
E = Error SSCP Matrix

S=1 M=1.5 N=26.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.89589144	1.28	5	55	0.2865
Pillai's Trace	0.10410856	1.28	5	55	0.2865
Hotelling-Lawley Trace	0.11620666	1.28	5	55	0.2865
Roy's Greatest Root	0.11620666	1.28	5	55	0.2865

The ANOVA Procedure
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Anova SS	Mean Square	F Value	Pr > F
nation	1	712.042734	712.042734	8.06	0.0062
position	1	2741.878151	2741.878151	31.05	<.0001
experi	1	1683.793776	1683.793776	19.07	<.0001
nation*position	1	364.845026	364.845026	4.13	0.0466
Error	59	5210.538411	88.314210		

The ANOVA Procedure
Repeated Measures Analysis of Variance
Univariate Tests of Hypotheses for Within Subject Effects

						Adj Pr > F	
Source	DF	Anova SS	Mean Square	F Value	Pr > F	G - G	H - F
time	5	8687.786068	1737.5572	214.83	<.0001	<.0001	<.0001
time*nation	5	24.838359	4.967672	0.61	0.6891	0.6298	0.6512
time*position	5	66.489818	13.297964	1.64	0.1482	0.1729	0.1646
time*experi	5	100.871068	20.174214	2.49	0.0312	0.0524	0.0443
time*nation*position	5	48.171068	9.634214	1.19	0.3135	0.3154	0.3154
Error(time)	295	2385.998	8.088131				

Greenhouse-Geisser Epsilon	0.6934
Huynh-Feldt Epsilon	0.7919

F.5: Switching Effect –Full Model with Covariate

The GLM Procedure

Class Level Information

Class	Levels	Values
nation	2	american kor
position	2	center side
experi	2	high low

Number of observations 64

The GLM Procedure

Dependent Variable: y7_6

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	409.9267362	51.2408420	8.36	<.0001
Error	55	337.0507638	6.1281957		
Corrected Total	63	746.9775000			

R-Square	Coeff Var	Root MSE	y7_6 Mean
0.548781	-177.6157	2.475519	-1.393750

Source	DF	Type I SS	Mean Square	F Value	Pr > F
nation	1	17.2225000	17.2225000	2.81	0.0993
position	1	347.8225000	347.8225000	56.76	<.0001
nation*position	1	1.6900000	1.6900000	0.28	0.6016
experi	1	21.8556250	21.8556250	3.57	0.0642

nation*experi	1	0.1406250	0.1406250	0.02	0.8801
position*experi	1	0.4556250	0.4556250	0.07	0.7861
nation*positi*experi	1	0.6806250	0.6806250	0.11	0.7402
qt	1	20.0592362	20.0592362	3.27	0.0759

Source	DF	Type III SS	Mean Square	F Value	Pr > F
nation	1	9.6859808	9.6859808	1.58	0.2140
position	1	356.9107057	356.9107057	58.24	<.0001
nation*position	1	3.0750628	3.0750628	0.50	0.4817
experi 1	1	2.1564277	12.1564277	1.98	0.1646
nation*experi	1	0.0840991	0.0840991	0.01	0.9072
position*experi	1	0.3322485	0.3322485	0.05	0.8167
nation*positi*experi	1	1.4592774	1.4592774	0.24	0.6275
qt	1	20.0592362	20.0592362	3.27	0.0759

F.6: Switching Effect –Full Model without Covariate

The ANOVA Procedure

Class Level Information

Class	Levels	Values
nation	2	american kor
position	2	center side
experi	2	high low

Number of observations 64

The ANOVA Procedure

Dependent Variable: y7_6

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	389.8675000	55.6953571	8.73	<.0001
Error	56	357.1100000	6.3769643		
Corrected Total	63	746.9775000			

R-Square	Coeff Var	Root MSE	y7_6 Mean
0.521927	-181.1849	2.525265	-1.393750

Source	DF	Anova SS	Mean Square	F Value	Pr > F
nation	1	17.2225000	17.2225000	2.70	0.1059
position	1	347.8225000	347.8225000	54.54	<.0001
nation*position	1	1.6900000	1.6900000	0.27	0.6087
experi	1	21.8556250	21.8556250	3.43	0.0694
nation*experi	1	0.1406250	0.1406250	0.02	0.8825
position*experi	1	0.4556250	0.4556250	0.07	0.7902
nation*positi*experi	1	0.6806250	0.6806250	0.11	0.7451

F.7: Switching Effect –Reduced Model with Covariate

The GLM Procedure

Class Level Information

Class	Levels	Values
nation	2	american kor
position	2	center side
experi	2	high low

Number of observations 64

The GLM Procedure
Dependent Variable: y7_6

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	405.0275112	101.2568778	17.47	<.0001
Error	59	341.9499888	5.7957625		
Corrected Total	63	746.9775000			

R-Square	Coeff Var	Root MSE	y7_6 Mean
0.542222	-172.7310	2.407439	-1.393750

Source	DF	Type I SS	Mean Square	F Value	Pr > F
nation	1	17.2225000	17.2225000	2.97	0.0900
position	1	347.8225000	347.8225000	60.01	<.0001
experi	1	21.8556250	21.8556250	3.77	0.0569
qt	1	18.1268862	18.1268862	3.13	0.0821

Source	DF	Type III SS	Mean Square	F Value	Pr > F
nation	1	8.2456137	8.2456137	1.42	0.2377
position	1	356.2479434	356.2479434	61.47	<.0001
experi	1	12.6922139	12.6922139	2.19	0.1442
qt	1	18.1268862	18.1268862	3.13	0.0821

F.8: Switching Effect –Reduced Model without Covariate

The ANOVA Procedure

Class Level Information

Class	Levels	Values
nation	2	american kor
position	2	center side
experi	2	high low

Number of observations 64

The ANOVA Procedure

Dependent Variable: y7_6

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	386.9006250	128.9668750	21.49	<.0001
Error	60	360.0768750	6.0012812		
Corrected Total	63	746.9775000			

R-Square	Coeff Var	Root MSE	y7_6 Mean
0.517955	-175.7669	2.449751	-1.393750

Source	DF	Anova SS	Mean Square	F Value	Pr > F
nation	1	17.2225000	17.2225000	2.87	0.0954
position	1	347.8225000	347.8225000	57.96	<.0001
experi	1	21.8556250	21.8556250	3.64	0.0611

VITA

Lieutenant Colonel Cho is an officer in the Republic of Korea Air Force. He was born in Kyoung-Book, Korea, in 1957, and graduated from Korea Air Force Academy in 1982. After graduation from the Academy, he was trained as a pilot. While he was serving as a pilot officer, he was selected as a prospective officer for further study. He studied at the University of Texas at Arlington for his master degree in the department of Industrial Engineering from 1987 to 1989. After receiving a master degree in Industrial Engineering, he returned to his flight squadron, and served as an instructor pilot. In 1993, he started the doctoral program at Louisiana State University. He will receive the degree of Doctor of Philosophy in Interdepartmental Program in Engineering Science in December 2002.