A STUDY OF THE RELATIONSHIP BETWEEN PRACTICE IN THE USE OF A RADAR SIMULATION GAME AND ABILITY TO NEGOTIATE SPATIAL ORIENTATION PROBLEMS

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CHAPTER I

INTRODUCTION

Professional and military pilots have long used simulation training in order to establish proficiency in the actual environment. Orlansky (1982), while examining "transfer of training" effectiveness in aviation training for the U.S. Army, shows that pilots who were trained in simulators and aircraft did not need as much time to reach acceptable levels of performance as did pilots who were trained in aircraft only. the time saved was about half of what was spent in the simulator.

Orlansky (1982) also indicated that operating flight simulators could save as much as 90 percent of the cost of using the aircraft.

Simulation training has been used to meet Federal requirements for proficiency and accuracy and to reduce the need for pilots to train in the actual aircraft.

Civilian controllers are just beginning to use site specific radar training. Site specific training is that which is conducted at individual field facilities as opposed to a centralized location. UFA Corporation has patented a simulation air traffic controller training system which combines realistic simulation with other existing systems. The company has been awarded three contracts by the Federal Aviation Administration (FAA) to develop a working prototype and to demonstrate the effectiveness of the training at

Boston's Logan Air Traffic Control Tower (Molina, 1988, Gerstenfeld, 1988).

At the FAA Mike Monroney Aeronautical Center there is a curriculum development unit dedicated to designing scenario type exercises which controllers can use in the field to sharpen skills. Until recently the training has been generic in nature. Scenarios are currently developed to coincide with the actual traffic picture and airspace configuration indicative of each air traffic control facility.

A new high fidelity system known as Stand-Alone Radar Training System (SARTS) was designed to be a site specific program. While controllers have had to travel to Oklahoma City to receive training, site specific training could allow training within home facilities, save travel time and costs, and prepare controllers in exactly the environment they would be using (Myers, 1989).

SARTS was initiated in 1985 in the Chicago Air Route Traffic Control Center (ARTCC). Due to staffing shortages, SARTS remained site specific but had to be conducted in Oklahoma City at the Radar Training Facility. In April of 1988, a site specific experiment was conducted for a terminal location at the Los Angeles Terminal Radar Approach Control (TRACON). Responses from students indicate that site specific training provides more realism and better preparedness than does conventional facility training (Myers, 1989).

Air traffic control candidates must pass a battery of examinations prior to being hired by the government. One of the functions of these examinations is to determine whether the candidates can negotiate spatial orientation problems.

It has not been established whether or not simulation training can effectively enhance spatial orientation ability and thereby make more efficient the way the FAA hires and trains its air traffic controllers.

Computer simulation gaming may be a method by which potential controllers prepare for the field of air traffic control. If specific skills could be learned through simulation prior to on-the-job training, many problems could be alleviated. Students could make intelligent career field choice decisions and academic time could be reduced. Most importantly, potential controllers would receive pre-service training to improve and expand their skills rather than a screening program to identify and eliminate those whose skills had not been developed prior to acceptance.

Statement of the Problem

There is a concern that air traffic control candidates who would ultimately be successful in the application of air traffic skills are being prematurely rejected because of the requirement to demonstrate terminal behaviors without the benefit of training.

Purpose of the Study

The purpose of this study was to determine whether simulation training would help aviation oriented individuals to negotiate spatial orientation problems necessary for air traffic control work.

Null Hypotheses

Ho_1: There was no difference between posttest scores of treatment and control groups after radar simulation game training.

Ho_2: There was no difference between mean pretest and posttest scores of a treatment group receiving radar simulation game training.

Ho_3: There was no difference between mean pretest and posttest scores of a control group not receiving radar simulation game training.

Ho_4: There was no difference between mean score pretest to posttest gains of treatment and control groups after radar simulation game training.

Ho_5: There was no correlation between radar simulation game scores and spatial orientation posttest scores.

Definition of Terms

The following terms have been defined for use in this study.

Academy - An organizational division of the Mike Monroney Aeronautical Center in Oklahoma City. This institution serves as a centralized location for five different Federal Aviation Administration branch organizations including air traffic.

Air Traffic - Aircraft operating in the air or on an airport surface, exclusive of loading ramps and parking areas.

Air Traffic Controller - A person authorized by the federal government to provide air traffic control service.

Facility Levels - Numbers assigned from one to five which indicate the increasing complexity and volume of traffic directed at air traffic control facilities.

Federal Aviation Administration - The agency incorporated into the Department of Transportation which gives direction to a coordinated national airspace system.

Full Performance Controller - Status of an air traffic control specialist who has reached the highest non-supervisory grade level and who has been rated competent for the particular facility to which assigned.

High Fidelity - An exacting degree of realism which emulates the conditions and experiences of real life.

Instrument Flight Rules (IFR) - A set of guidelines and regulations created by the Federal Aviation Administration which defines standardized requirements and procedures for flight without visual reference to the ground.

On-the-Job Training - Training conducted on positions of operations, under direct supervision, to enable the student controller to demonstrate the ability to perform air traffic control duties.

Operational Error - The violation of minimum longitudinal, lateral or vertical distances of separation for aircraft. Generally, these are three miles horizontally and 1,000 feet vertically.

Part-Task Training - Training that divides a complex process into a number of difference components. Subjects are then trained on each component in a systematic hierarchy.

Pilot Certificate - An authorization for a pilot to operate an aircraft for which he is rated under the rules of the Federal Air Regulations (FAR's).

Pilot Certificate Types - These certificates include Student, Recreational, Private, Commercial, Airline Transport, Certified Flight Instructor (CFI), and Certified Flight Instructor-Instrument (CFII).

Radar - Acronym for Radio Detection and Ranging.. A device which by measuring the time interval of radio pulses, provides information of range, azimuth, and/or elevation of objects.

Radar Simulation Game - A computer simulation which generates the typical conditions in which an air traffic controller is exposed. Simulations can vary in complexity on demand and keep score based upon pre-set standards.

Radar Training Facility - A radar simulation facility located at the Federal Aviation Administration's radar training operation at the Mike Monroney Aeronautical Center in Oklahoma City, Oklahoma. Prior to facility radar certification, students must pass a month-long program consisting of generic radar problems.

SARTS - An acronym for Stand Alone Radar Training System. SARTS is a radar training system that simulates actual traffic flows and airspace configurations from a student air traffic control specialist's facility.

Screen - A program conducted at the Academy where student controllers are given initial exposure to air traffic control procedures and where a pass/fail evaluation is made of the student's potential.

Spatial Orientation - A reference to time and place in space. Spatial orientation is the mental ability to rotate or transform figures viewed at varying angular representations in order to perceptually view these figures under altered conditions.

TRACON - An acronym for Terminal Radar Approach Control. A TRACON is the air traffic control facility responsible for radar separation and coordination in the relative vicinity of an airport.

Vertigo - A sensation of rotary motion in the external world and/or dizziness with a feeling of movement within the head.

Visual Cue - An environmental visual feature of varying fidelity that causes a reaction beneficial for the acquisition of associated learning in a simulation.

Visual Flight Rules (VFR) - A set of governmental regulations and guidelines for aircraft which are flying by visual reference to the ground and which are not under the continuous control of an air traffic control facility.

Assumptions

The following assumptions were identified for this study.

1. All subjects expended their best efforts on both the pretest and posttest.

2. All subjects were equally challenged and subsequently fatigued by activities in both treatment and control groups.

3. The subjects understood all directions given for both the pretest and posttest and for the treatment exercises.

4. The spatial orientation pretest and posttest were valid measures of spatial orientation skill.

Limitations

1. The study was limited to three institutions that provided personnel involved in pilot training.

2. Subjects who did not have previous aviation training or experience were excluded from the study.

3. Subjects with previous or current air traffic control experience were excluded from the study.

4. Subjects were solicited only from the Oklahoma City and Stillwater, Oklahoma areas.

Summary

Simulation training could be a viable method to initiate training in air traffic by teaching skills necessary to perform successfully in the field environment. Spatial orientation is a skill which air traffic controllers need to perform proficiently. It is important when choosing candidates for air traffic control work that these individuals ultimately possess this particular skill. This study, using a game as simulation training, is a way to determine whether candidates can be trained or acquire spatial orientation skills.

Chapter II examines the research in the areas of existing hiring and entrance requirements. It also examines the types of people who are selected for air traffic control work. It includes a discussion of the difficulty of air traffic work, showing some similarities between requirements for both controllers and pilots. The research reveals an extensive current use of simulation training for pilots, but only a minimal use for air traffic controllers. Finally, Chapter II examines spatial orientation and why it is a key skill for both pilots and controllers.

Chapter III examines the methodology used to identify the population and to collect and analyze the data.

Chapter IV reports the data and Chapter V provides a summary, conclusion, and recommendations for practice and further research.

CHAPTER II

REVIEW OF RELATED LITERATURE

This study was concerned with the process of how air traffic controller skills can be developed prior to on-the-job training. Learning while on the job has been regarded as an inefficient way to prepare developing controllers (University of Oklahoma, 1989).

Pilot training is related to air traffic control training when speaking of task complexity and of the ability to organize spatially. For pilots, spatial skills and ability relate directly to the successful control of an aircraft's attitude and motion as it relates to the configuration of the earth (Ramachandran, 1986). For air traffic controllers, spatial orientation ability relates directly to the correct judgment of speed, distance, movement, altitude and the future position of an aircraft.

Data collected by Karson and O'Dell (1974) indicate what kind of personality characteristics air traffic controllers have in common with pilots and with men in the general population. These data were obtained through the Sixteen Personality Factor examination (16PF). For the most part, no significant differences were found between controllers and pilots on the 16 personality variables.

These personality variables were:

a) reserved versus outgoing

b) less intelligent versus more intelligent

c) affected by feelings versus emotionally stable

d) humble versus assertive

e) sober versus happy-go-lucky

f) expedient versus conscientious

g) shy versus venturesome

h) tough-minded versus tender-minded

i) trusting versus suspicious

j) practical versus imaginative

k) forthright versus shrewd

l) self-assured versus apprehensive

m) conservative versus experimenting

n) group-dependent versus self-sufficient

o) undisciplined self-conflict versus controlled

p) relaxed versus tense.

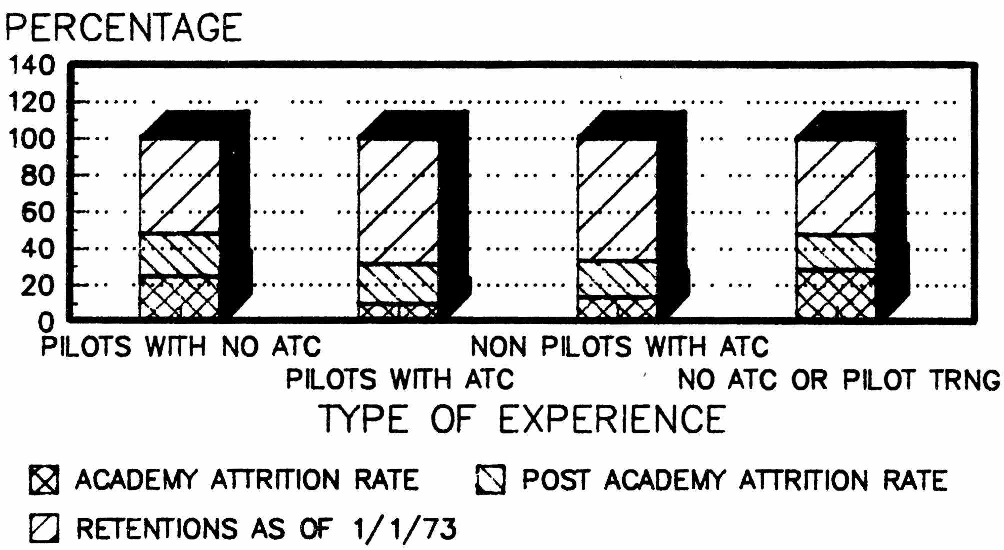
There is one area in which controllers excelled over men in the general population. This area was intelligence (b). Additionally, controllers scored slightly more conscientious (f) and more tough-minded (h) than did the population in general in 11 of the 16 factors as compared to the three demonstrated by controllers. The five factors pilots had in common with the general population were a, d, k, m, and n, as indicated above. However, pilots and controllers alike had a similar shaped profile in most of the 16 items, suggesting similar tendencies in responses (Smith, 1974).

The California Test of Mental Maturity shows that controllers, in comparison with the general population, score in the upper 20 percent. Other testing indicates that controllers as a group do well on tests of spatial visualization, spatial orientation, numerical ability, memory, and abstract reasoning. However, relatively few controllers pursue higher education goals, even though this research shows they have the ability (Smith, 1974).

There is no consensus about whether pilot experience makes a difference in the success of an air traffic control specialist candidate. In January of 1970, the Air Traffic Controller Career Committee and the subsequent publication of the Corson Report (1970) supported the position that any type of pre-Federal Aviation Administration (FAA) experience other than previous air traffic work could not be relied upon as an indicator of training progress or of satisfactory performance in field facilities. Figure 1 identifies attrition rates from both the FAA Academy and post Academy training during 1969 among those with and without previous pilot experience (Sells, 1984). Figure 1 indicates that pilots as well as non-pilots with previous air traffic control background have a lower attrition rate than do those with no air traffic control background.

The Civil Aeromedical Institute (CAMI) conducts numerous studies concerning varying aspects of functioning air traffic controllers. Some studies conducted between 1960 and 1973 indicate that

> Chronological age at time of entry into Air Traffic Control Specialist Training to be inversely related to measures of performance in the FAA Academy's basic ATC training courses and post-Academy attrition-retention status. Such studies have revealed that personnel under 31 years of age who possessed little or no pre-FAA ATC related experience, as well as former military controllers no older than 35, were much more



Source: Sells, S. B., Dailey, J. T., and Pickrel, E. W. Selection of Air Traffic Controllers-Report No. FAA-AM-84-2. Washington, DC: Federal Aviation Administration, 1984.

Figure 1. Attrition and Retention Rates by Pre- FAA-Experience in the Enroute and Terminal Options During 1969 Training Courses

> apt to succeed in ATCS training than their older colleagues. Moreover, research has repeatedly demonstrated that trainees over 35 years old also tend to score significantly lower than those of a younger age on a wide variety of aptitude tests having validity for prediction of training performance (Cobb, 1973, p. 1).

In this research, Cobb (1973) is indicating that age is a factor in the performance of air traffic controllers.

Pre-hire Screening

In 1981, over 12,000 air traffic controllers decided to strike against the United States Government. The action presented President Reagan with a dilemma which he solved by firing all controllers who did not return to work. One result was a massive hiring of new applicants. Approximately 70,000 individuals applied for jobs as controllers and were tested by the Office of Personnel Management (OPM) assessment battery. Only two percent of this group was selected for training. Of this two percent, about half did not succeed in training and were dismissed from the agency (Regian, 1988).

Pretesting by use of a battery of examinations to determine who would make successful air traffic controllers dates to 1960 when CAMI administrated a battery of tests to newly hired air traffic controllers. At that time, the students attended the academy for nine weeks. Their training was divided into two parts, academic and laboratory. The scores for both parts formed a composite score and were compared by means of the Pearson product-moment formula against the composite score obtained on the battery of tests. Coefficients ranged from 0.35 to 0.54 (Sells, 1984).

It was decided from this point that this battery of tests could enhance the selection of new air traffic controllers. The tests could enhance the selection of new air traffic controllers. The tests that were given, however, were commercially available, so to reduce the possibilities of compromise, similar examinations were developed and administered by the Civil Service Commission (CSC) (Boone, 1979).

Through additional research, five predictors of successful performance in air traffic control were identified by regression analysis:

1. Spatial Patterns: Identify solid figures that can be made from an unfolded pattern, or from various views of an object, identify the object in a series of alternatives.

2. Computations: Test of arithmetic computational skill.

3. Abstract Reasoning: Indicate which of a series of choices (figures) properly carries out of a principle of logical development exhibited by a sequence of figures.

4. Oral Directions: From orally presented information, decisions must be made regarding performance of simple tasks.

5. Air Traffic Problems, Part I: Determine whether aircraft may be permitted to change attitude without violating a specified time-separation rule (Boone, 1979, pg. 2) (sic).

The battery of tests that have been administered to air traffic control applicants since 1961 has been modified, but the ability to recognize and negotiate spatial patterns in the performance of required duties continues as a critical factor.

The current practice of hiring controllers contains these elements:

1. Background of each candidate.
2. The Office of Personnel Management selection test battery scores.
3. Successful completion of a selection interview.
4. Medical qualification.
5. A security clearance.
6. Successful completion of the Academy screening process
7. Successful completion of all field training requirements (Manning, Kegg, and Collins, 1988).

The test battery that is presently used to select candidates for the Academy screen consists of three parts: The Multiplex Controller Aptitude Test (MCAT), the Civil Service Commission 157 Examination (CSC 157), and the Occupational Knowledge Test (OKT). The MCAT is a paper and pencil test that simulates a non-radar air traffic environment and is designed to measure the ability to read tables and follow directions, estimate distances of hypothetical moving targets, and to negotiate basic math problems (Manning, 1989).

In a taxonomy of cognitive abilities identified in research by Toquam, Corpe, Dunnette, and Keyes (1986), nine cognitive abilities were identified and further divided into sub-factors. One of the cognitive abilities was spatial ability. Spatial ability was sub-divided into four areas identified as:

Cognitive Ability	Definition
Spatial Ability	Ability to visualize or rotate objects and figures in space.
Sub-factors	Definition of sub-factors
Space Visualization	Ability to visually manipulate or transform the components of a two or three dimensional figure to see how items would look under altered conditions.
Two-Dimensional Mental Rotation	Ability to identify a two-dimensional figure when seen at different angular orientations.
Three-Dimensional Mental Rotation	Ability to identify a three-dimensional object projected on a two-dimensional plane, when seen at different angular orientations either within the picture plane or about the axis in depth.
Spatial Scanning	Ability to visually survey a complex field to find a particular configuration representing a path-way through a field (Toquam, Corpe, Dunnette, and Keyes, 1986).

A study was completed by the University of Oklahoma , which subcontracted to two educational consulting firms, the Northern NEF, Inc., (NEF), and the Human Resource Research Organization (HumRRO).

These firms are members of the OPM continuing contract agreement and their services are available to the FAA upon request. They employ both instructional system design specialists and educational psychologists. A job analysis was conducted to identify logical steps and criteria that would be necessary in redefining a method of hiring controllers for the FAA.

This study included personal interviews of FAA controllers at the varying levels of air traffic control facilities in order to determine a list of critical job tasks (University of Oklahoma, 1989, Means, 1988).

On site visits were made to 32 FAA facilities where 257 full-performance controllers (FPL's) were interviewed. In addition, 600 FPL controllers were mailed a survey by FAA Washington Headquarters. Of those 600, 323 responded.

Controllers were asked to rank 50 knowledges and skills as to their importance to the job of a controller. Of particular interest to this study was the area of visual and spatial ability, which was further divided into six sub-segments.

The sub-segments included the abilities to:

a) visually scan objects and information

b) accurately remember visual pictures

c) see object positions in two to three dimensional space

d) see pathways through air/ground space

e) detect movement and estimate speed and direction

f) predict future positions of moving objects

One of the findings of these interviews and surveys was that all controllers rated visual and spatial abilities as extremely important. When comparing the 50 knowledge and skill items identified for the survey with the above subsegments dealing with spatial abilities, seven were ranked higher than the ability to visually scan objects (a), 15 were ranked higher than the ability to remember visual pictures (b), 14 were ranked higher than the ability to see object positions in two to three dimensional space (c), 13 were ranked higher than the ability to see pathways through air/ground space (d), ten were ranked higher than the ability to detect movement and estimate speed (e), and five were ranked higher than the ability to predict future positions of moving objects (f) (University of Oklahoma, 1989). These rankings were specific to those FPL controllers employed in a Terminal Radar Approach Control (TRACON) facility.

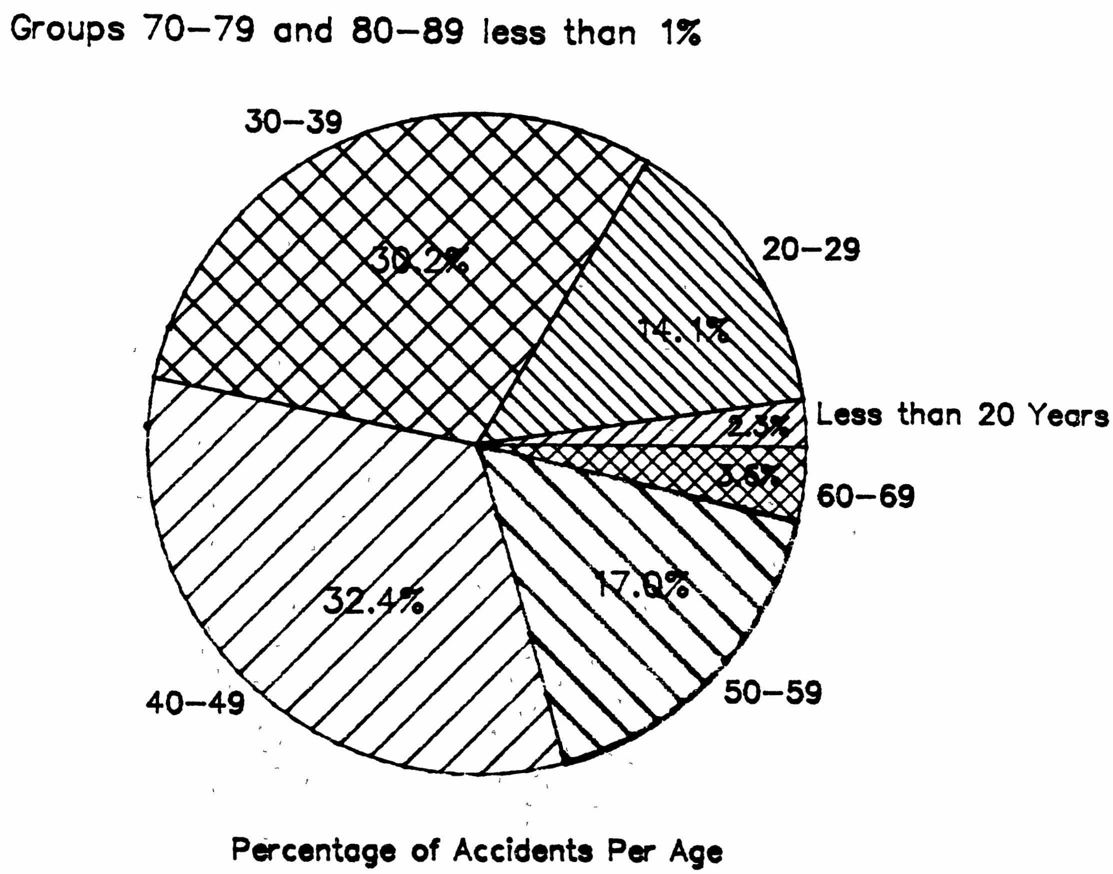
In a job analysis report submitted by NEF, spatial ability was defined as the ability to (1) visually scan information and objects, (2) accurately remember visual pictures, (3) see object positions in two to three dimensional space, (4) detect movement and estimate speed and direction, and (5) predict future positions of moving objects.

According to the NEF study, all representative air traffic control facilities ranked spatial skills and abilities as extremely important. The area of spatial ability was ranked eighth out of a total of 50 items which included the areas of math, English, science, psychomotor ability, visual and spatial ability, information processing ability, analytical/thinking ability, speaking and listening skills, motivation and stability. Each of these areas included between two and eight sub-tasks (University of Oklahoma, 1989).

For pilots, spatial skills and ability relate directly to flight training and the ability to perceive multiple visual cues and stimuli simultaneously. In general aviation, most spatial disorientation difficulties occur when flight in visual flight rule conditions (VFR) continues into instrument flight rule (IFR) conditions. An inevitable question arises as to how well student pilots are being prepared for IFR conditions. In a 1977 study, only 27 percent of surveyed flight schools indicated a specific required number of hours utilizing some form of flight simulator training (Collins, 1977).

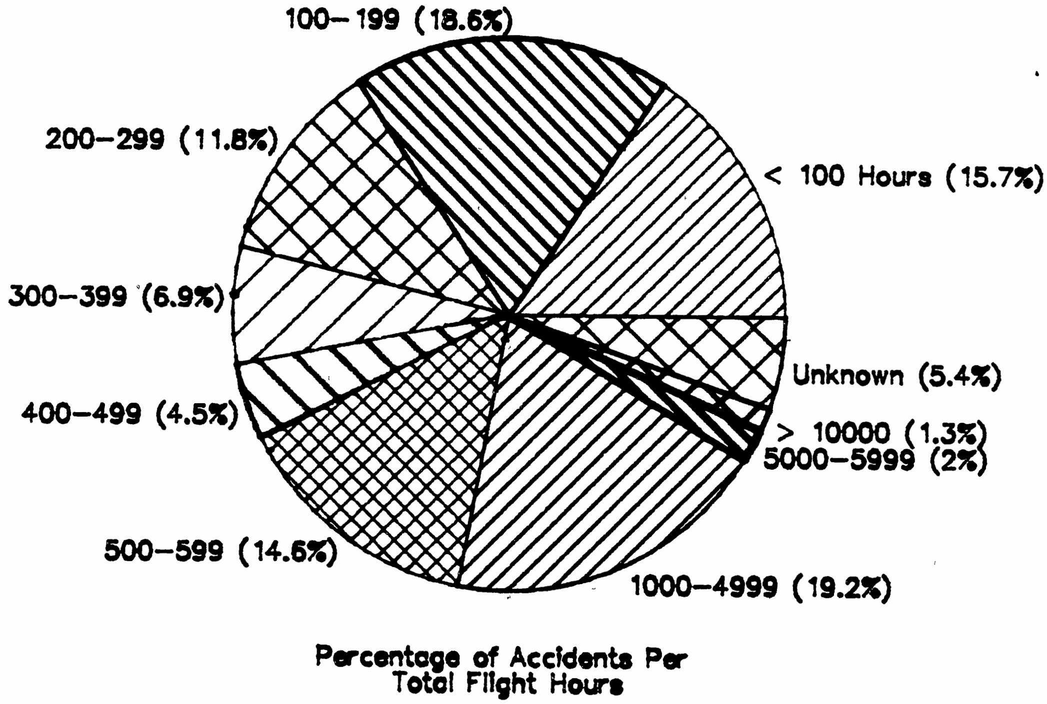
Aircraft manipulation taxes the senses beyond what is felt by standing on firm ground because the sensations of yaw, pitch and roll are added. Spatial disorientation in an aircraft is often associated with vertigo which can cause a pilot to maneuver an aircraft violently and incorrectly. Violent maneuvers can stress an aircraft beyond its designed limits and can lead to the destruction of the aircraft. Figures 2, 3, and 4 show the percentages of fatal general aviation accidents in which spatial disorientation was a cause or factor (Kirckham, 1978).

In 1985, spatial orientation tests were given to 21 student pilots to determine if there were correlations between scores on the spatial orientation tests and the ability to construct a cognitive



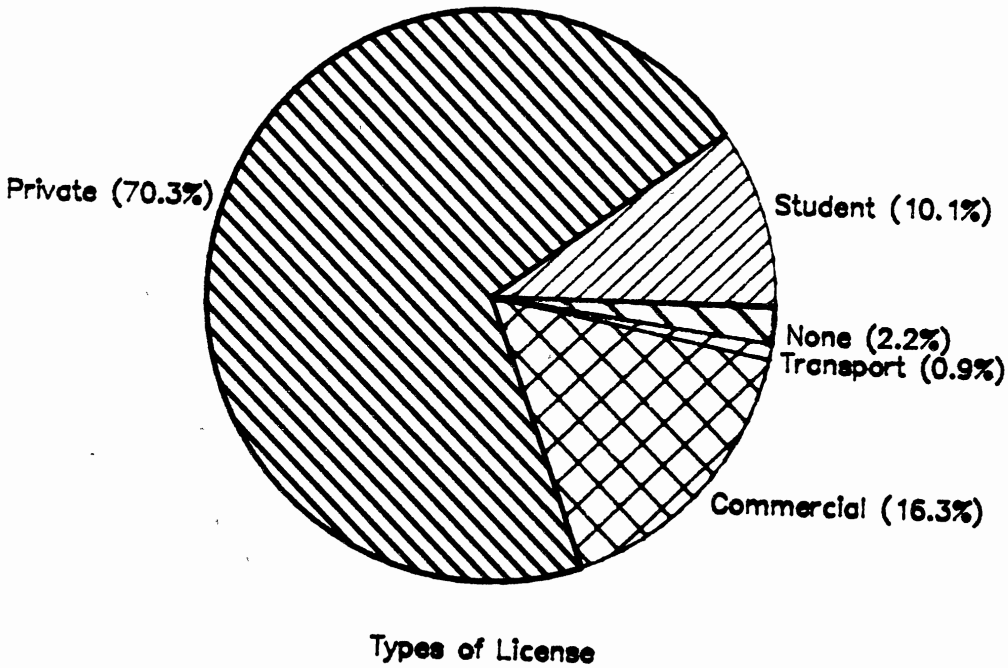
Source: Kirckham, W. R., Collins, W. E., Grape, P. E., Simpson, J. M., and Wallace, T. F. Spatial Disorientation in General Aviation Accidents (Report No. FAA-AM-78-13). Washington, DC: Federal Aviation Administration, 1978.

Figure 2. Related Accidents with Spatial Disorientation as A Cause/Factor



Source: Kirckham, W. R., Collins, W. E., Grape, P. E., Simpson, J. M., and Wallace, T. F. Spatial Disorientation in General Aviation Accidents (Report No. FAA-AM-78-13). Washington, DC: Federal Aviation Administration, 1978.

Figure 3. Related Spatial Accidents Considering Flight Hours



Source: Kirckham, W. R., Collins, W. E., Grape, P. E., Simpson, J. M., and Wallace, T. F. Spatial Disorientation in General Aviation Accidents (Report No. FAA-AM-78-13). Washington, DC: Federal Aviation Administration, 1978.

Figure 4. Related Spatial Accidents Considering Type of License

three dimensional space. One of the tests was an aircraft orientation task where the pilots were required to determine their relative positions by virtue of reading and interpreting automatic direction finding (ADF) equipment.

The tests of spatial orientation that correlated at the .05 level were the Shepard-Metzler and the Wheatley Cube test. The Shepard-Metzler determines the ability to assimilate an entire visual stimulus. The image is rotated and complex comparisons must be made. The Wheatley Cube is a computer managed test in which students find an invisible dot that is hidden within the cube. Students estimate accuracy and the computer gives feedback. The student is entitled to 18 chances. Both tests predict the ability of student pilots to orient themselves in simulated flight. Tests such as these are used as training devices for pilots to concentrate on multiple visual stimuli (McDaniel, 1985).

For air traffic controllers, spatial orientation skills are measured on the CSC 157 examination by means of pattern recognition items divided into latter series recognition and symbol recognition exercises. In the latter series, controller candidates are asked to distinguish relationships among sets of letters that suggest a certain logical order. In the pattern recognition tests, candidates ascertain similarities and differences among sets of patterns (Turner, 1986).

Continuing cognitive analysis of air traffic control skills indicates, through feedback from controllers, that a specific need for spatial orientation skills exists (University of Oklahoma, 1989, Toquam, 1986). Spatial orientation goes beyond vision and the ability to determine patterns. It includes an element that is physiologically based, i.e. the ability to correctly judge relative position and motion while suspended in space (Ramachandran, 1986).

Simulation

Pilot and controller training are often regarded as work consisting of many tedious complex tasks. One of these tasks is the ability to organize spatially. Research conducted for the Office of the Chief of Research and Development for the U.S. Army in Washington, DC indicates that standard computer assisted instruction is not sufficient to teach all of the required tasks of these professions.

> Skills such as maneuvering and navigation are too complex to be taught through standard computer-assisted instructional lessons. The procedures to be taught are richer and more varied, and the scope of student learning difficulties much greater, than those encountered in teaching simpler skills such as stenotypy or telegraph keyset operation. To handle these harder problems effectively, an instructional program must include procedures enabling the computer to diagnose the student's learning difficulties as he tries to carry out the tasks being taught. To do this, the computer must be given a means of tracking a student's behavior and of generating and testing hypothesis about his difficulties . . . (Feurzeig, 1971, p. 1).

As well as many other agencies, United Airlines has used Control Data Corporation's PLATO system, which is an on-line computer based instruction system. United uses the system to measure individualized learning progress against pre-established learning objectives. United indicates that proficiency is the most important aspect of pilot training, considering aircraft complexity.

United is also making extensive use of flight simulators in order to reduce training time and cost. "It will allow them to work with problems and situations that are too expensive, risky and even impossible to stage in an airplane" (Staff, 1979, p. 23).

Simulation is not effective without an objective based curriculum. Problem solving by incorporating objective based skills is supported in the research across many disciplines. For example, a study undertaken with first year medical students in microbiology showed, through the use of a regression analysis, that increasing the number of laboratory hours (equated with simulation time in aviation) had an impact on the ability to solve problems. The study recommends that specific problem solving objective criteria be used in curriculum development with appropriate analysis of those specific objectives in order to improve those skills (Schuytena, 1980).

Computerized testing could temper the dilemma of having simulated programs which are not based on objective problem solving skills, because computerized testing can evaluate individuals cognitive functioning processes. Computerized testing is unbiased and accurate and allows the student to re-test and review on those items or concepts found difficult. Computers can test perceptual speed, short term memory capacity and spatial orientation ability by presenting moving objects in a variety of schemata. Computer testing can also determine an individual's information processing ability (University of Oklahoma, 1989).

One of the most valuable aspects of computer simulation training is that it provides a viable method of learning while enabling interactive methodology to center around individual cognitive differences. Computer based instruction and simulation game training like TRACON are good examples. Both allow subjects to learn at their own pace and ability. With the transition from the information age to the computer age, and with greater amounts of data available at ever increasing rates, it becomes essential for these learning environments to keep pace. Galagan (1987) refers to James J. L'Allier who claims that "the time spent on learning on the computer would be half that spent with the traditional method" (p. 73). L'Allier also refers to the Librarian of Congress, Daniel J. Boorstein, who stated that one issue of the New York Times contains as much information as a person of the sixteenth century had to process during an entire lifetime.

Evidence points to the fact that the people who design computer software should pay more attention to the fact that computer learning may attract certain types of thinkers. The individuals who design software are highly technical in nature and are predominantly left-brain deductive thinkers. Both software and user's guides are designed deductively. Individualized cognitive processes need to be examined in order to assess whether or not computerized learning is really on a par with traditional classroom instruction (Galagan, 1987, Herrmann, 1989).

Simulation training has the ability to bring students to the application level of Bloom's (1956) Taxonomy. Twelker and Kersh

(1965) indicated that on posttests, students learned correct responses to management training as a result of practiced simulated tasks. Girod, in a 1969 study, found that the analysis level of Bloom's Taxonomy could be attained when he determined that his subjects could increasingly discriminate learning cues from the simulations (Smith, 1987).

One method to insure that the application level is reached is the use of part-task training. Part-task training allows for the division of complicated curricula into singular tasks. Mastery of these tasks can be subsequently integrated, leading to satisfactory terminal behaviors. In a study compiled for the Air Force, part-task training devices were used to teach the multiple tasks required to refuel jet tankers. The training was found to be very effective (Smith, 1981).

Other research points out that computer simulations must be related to the real world. In addition, interactions between computer and student should also have an element of social influence, with the computer subservient to the learner. In computer assisted instruction, students are aided by the computer and its software but not directed by it (Crookall, 1986).

In a review of applications of simulation techniques, computer simulation was found to have advantages. It was able to portray real life situations within a compressed time frame, it provided a measure of consistency of experiences among differing learners, and it challenged learners to become involved in the decision making process in a similar way to what was expected in real life (Flaitz, 1986).

Simulation was shown to be most beneficial when determining the ability to transfer training via high fidelity or highly realistic simulation exercises. However, the only real advantage in using a high fidelity simulation device was the addition of motion, which added psychological and physiological realism (Gerathewahl, 1969).

Smith (1987) reports on research that studied the degree of fidelity or realism in producing effective computer simulations. Results indicate that greater amounts of fidelity are inversely beneficial to the student. Participants did reveal, however, that it is not the use of more realistic visual image sizes but the amount of fear, tension and frustration that the simulation evokes which makes simulations seem real. And regardless of the background of the individual receiving the simulation training, similar levels of performance are achieved.

The need for computer simulation and its associated use does not go without notice among studies conducted by the General Accounting Office (GAO). Two of the recommended training initiatives outlined to the Secretary of Transportation in a 1989 report to Congress were to increase the use of simulators and to provide more site specific training (GAO, 1989).

Learners appreciate computer simulations that do not require numerous technical responsibilities, such as studying the operating manual or having to delve into the computer's disk operating system. Empirical research shows that learners try to optimize their scores when the simulation keeps an account of their performance. When the computer is keeping score, the learner focuses on winning rather than on learning. On the other hand, it was found that learners will go back through a program a number of times to check alternatives. Learners like to experiment with "what if" conditions, to find out what would happen if another direction or alternative were chosen (Galagan, 1987).

Rosenfeld, summarized by Zemke (1982), found that (1) Simulation game training is as effective as or more effective than traditional methods of learning. Simulation game training fosters cognitive growth. (2) Individuals participating in simulation game training may have a different perception of how well they are performing and may experience an actual change in behavior due to the simulation training. (3) There can be negative outcomes of simulation game training. (4) Demographic differences in the participants may correlate with different outcomes in the learning experience. (5) Learning effectiveness varies from game to game. However, the more fidelity the game has, the more beneficial the experience becomes.

There are many reasons why the use of simulations and simulation gaming might be beneficial. Classroom learning is usually equated with theoretical learning. Learners who are task oriented sometimes find classroom learning boring and unfulfilling. Learning by simulation gaming is an active participation experience and, by its very nature, interactive (Gerathewahl, 1969).

Mistakes can often be made without consequences. In aviation, the consequence may be the loss of human life. Much of the learning can be self-directed, and much practice can take place before direct evaluation. Students can be evaluated when they are ready and comfortable rather than constantly, as is the case with on-the-job training.

Time can be compressed as needed. Since situations are simulated, problem solving situations can be chosen for their complexity or appropriateness to a student's level of development. In air traffic on-the-job training, complexity levels are determined by the available traffic. In simulation training, seldom seen situations can be fabricated. Waiting for a real life situation can be inconvenient and expensive. Simulations provide opportunities for immediate and meaningful feedback. Students can correct behaviors in complex or seldom seen situations repeatedly until they feel comfortable. Repeated practice leads to competence (Galagan, 1987).

The role of the trainer in a simulation environment can shift from one of a pedagogical nature where direct instruction is given and compliance expected, to that of facilitated learning, where instructors and students can interrelate and agree on training expectations and performance (Etington, 1989).

Simulators used in flight training and aviation combine the analog and digital simulation models. Analog models recreate physical conditions while digital models are completely computerized. Every condition that is possible has to be painstakingly programed into the simulation by a computer programmer (Pfeiffer, 1988).

In aviation, simulation training has incorporated significant high technological expansion since its inception post World War I, when a stick and chair were used. The first useful simulator for pilot training was the Link I. It was the first time in aviation when movement was incorporated along with visual display information in order to present an experience closer along the lines of reality (Stein, 1984).

Between 1950 and 1970, as computer simulation became more sophisticated and more widely used, the military began to realize that visual cue training became paramount to successful mission accomplishment. On-board flight systems were becoming more integrated and complicated and the speed capabilities of aircraft were forcing simulation curriculum designers to examine flight training closely. As a result, part-task training devices were developed to teach each individual system prior to incorporating integrated whole-task simulation exercises (Smith, 1981).

What became the primary impetus for using simulation was not mission accomplishment but the staggering costs of using real equipment. Airframe fatigue, fuel savings, a more conducive training environment, reduction in the number of actual aircraft needed, environmental considerations, and the ability to practice hazardous maneuvers and procedures without danger to pilots or aircraft were the main economic reasons for the increased use of simulation training (Advisory Group for Aerospace Research and Development [AGARD], 1980).

It has been widely accepted that simulation fidelity was essential for the transfer of training. This is true because higher fidelity means it is easier to formulate a method of evaluation for participants. However, higher fidelity means greater costs. Many improvements are being made to continually make outside visual cueing comparable to the real world environment. Some systems used by the major airlines are getting closer to this goal (Waag, 1981).

In aviation training, specifically as it relates to both pilot and controller training, questions arise about whether simulation fidelity is critically important. Concerns center around whether specific and individual learning objectives are being met. For pilot training, overall goals are expressed in terms of the safe and efficient operation of aircraft. For controllers, FAA Handbook 7110.65 (the controller's operational handbook) dictates professional responsibility as the safe, orderly and expeditious movement of air traffic. So simulation training should be concerned with the degree these obligations are met (AGARD, 1980).

American Airlines had begun part-task training to teach discrete tasks, and to teach pilots how different systems are affected by instrument manipulation. In the accomplishment of this training, American has incorporated some micro-computer type simulation (Geber, 1990).

Johnson (1981), in a study designed to determine transfer of training, established that for tasks of procedure, simulator fidelity did not have to be of the highest caliber to show effectiveness. The major consideration in the transfer of simulation training is how the subjects processed and stored information. Johnson determined that an individual curriculum should have developed within it, mechanisms that would enable students to be responsible for providing their own cueing and feedback. This procedure could be incorporated into a curricula that employs micro-computers with specific gaming programs, such as TRACON, in order to meet part-task integrative learning requirements.

Major benefits of using micro-computers for training are versatility and relative inexpense. Scenarios can also be easily changed and adjustments made to meet specific training needs of an individual trainee. This becomes an economical method in giving part-task instruction (Galagan, 1987).

Part-task devices are usually learner controlled. Therefore, by using simulation, controllers can spare instructors from routine teaching. In addition, since there is still a shortage of full-performance level controllers, trainers can maintain their own proficiency by working live traffic. Learner controlled training can meet individual as opposed to group scheduling needs and is not committed to specific time parameters. Through repetition, this type of training can serve as beneficial positive reinforcement rather than painful scrutiny (Smith, 1988).

Computer simulation gaming as a part-task learning technique offers much potential for individual growth. Computer games are generally designed to aggregate data and keep score. This aspect of the programming provides for immediate feedback.

Secondly, depending on the sophistication of the programming and the simulation, the computer can draw from a substantial data base and can emulate reality by choosing from a multitude of variables. This variety will give learners a wider berth of experiences.

Thirdly, the computer can offer multiple levels of difficulty. This enhances training by allowing mastery learning. Mastery learning through the use of skill levels enables students to fully utilize the building block technique until all possible variables have been recognized and practiced.

The most beneficial aspect of all computer game simulations is the inherent ability to forgive mistakes. In simulation training, mistakes do not become catastrophes but learning experiences (Palmer, 1986).

An in press paper by Kanfer and Ackerman cited in the University of Oklahoma study was conducted based on Anderson's cognitive phases of learning. These phases were the (1) declarative phase, where students are given needed knowledge, (2) the knowledge compilation phase, where successful methods of completing tasks are repeated and are absorbed effortlessly by the student and (3) the skill acquisition phase, where tasks become virtually automated. This research indicates that subjects who repeatedly performed an air traffic control task by the use of self regulatory practices improved their performance (University of Oklahoma, 1988).

One of the major benefits of Stand-Alone Radar Training Systems (SARTS) training is the flexibility that it offers. Flight simulators and the conventional Radar Training Facility (RTF) simulations that are currently in use at the FAA Academy provide only real time training. Real time training means that the simulations are designed to only run from beginning to end without interruption, and where the time expended in the scenario is the same as clock time. SARTS offers a number of new innovations which by application become part-task (Myers, 1989).

The system has "freeze frame" and "playback" capability. This capability allows for instant critiquing of performance and immediate feedback. Most importantly, full discussion of any particular decision making process becomes possible without hindering or endangering aircraft.

A "fast forwarding" mode is available which allows an unfolding of events. Statements to trainees like, "Let's see what would happen if . . .", are possible.

Reversal of a scenario is another feature of the SARTS system. This feature allows trainees to try different approaches to the same problem. The same conflict of two aircraft, for example, could be replayed trying a number of different potential solutions.

Adjusting the speed of scenarios allows students to determine their prevailing capacity and competence. In addition to saving training time, students benefit by having their confidence bolstered rather than deflated (Huggins, 1988).

Spatial Orientation

Spatial orientation is an umbrella term that encompasses other expressions that are used interchangeably. As a result, there is some confusion about what constitutes spatial orientation. The terms "abstract reasoning," "spatial reasoning" and "spatial visualization" are also sometimes interchangeably used. There are reasons for the confusion.

If one were to combine the definitions from the Random House College Dictionary, abstract would be "conceived apart from any concrete realities, specific object, or actual instances," or "expressing a quality or characteristic apart from any specific object or instance" (Stein, 1982, p. 6). Reasoning, on the other hand, would be defined as "the process of forming conclusions, judgments, or inferences from facts or premises" (Stein, 1982, p. 1100). Orientation is "the ability to locate oneself in one's environment with reference to time and place" (Stein, 1982, p. 937).

In an instructor's manual for Talent Training Materials from the Arlington Corporation are training exercises for vocational students designed to increase abstract reasoning skills. The skills described in this manual are categorized into three classes.

The first is simply entitled "Abstract Reasoning," which entails filling out a pattern based on a series of pictures. The second type of abstract reasoning is the ability to determine relationships between numbers and to decide the next number in a series. The third type deals with visualization in two and three dimensions, respectively. Two dimensional reasoning usually requires rotating figures mentally over or around to finish a sequence. Three dimensional thinking involves flat shapes which can be folded or bent to form a pre-determined solid shape (Dailey, 1968).

Dailey refers to some of the research leading to these exercises as "spatial visualization," although he entitles his examination "abstract reasoning."

There are other reasons why the terms spatial visualization and abstract reasoning are used interchangeably. Psychometric researchers employ a variety of testing strategies and labeling for similar testing. The most important factor in spatial visualization is the ability to mentally rotate two and three dimensional objects in space, along standard axes (Just, 1985).

Even terms such as visualization and orientation can cause confusion, however, as some psychometrists insist that the latter term uses a combination of what is classified as alternate strategies. Alternate strategies are those methods subjects use to solve spatial problems (Smith, 1984).

In an unpublished paper, other research has shown that spatial ability is a function of how quickly and accurately individuals can negotiate specific cognitive processes (Regian, 1988).

In additional research involving mental imagery, Finke (1986) discovered that subjects in a spatial orientation environment who formed anticipatory mental images of objects could facilitate the perceptual process.

A replica of the CSC 157 Examination, as depicted in Appendix C, is basically the Daily design. As an examination, the use of the two and three dimensionality pattern recognition problems is considered to be sufficient as an adequate test of spatial orientation abilities in the air traffic radar environment.

Other research conducted by the FAA focused on students taking the Civil Service examination battery between 1976 and 1977 suggests that those applicants who passed the examinations had mean scores as much as four points higher on spatial orientation portions of the test. This includes a standard deviation that dropped from 6.7 for those who failed to 3.8 among those who passed. In addition, among those who passed, men scored approximately two points higher in mean scores than did women, with a standard deviation of 4.4 for the women and 3.6 for the men. Even the men in the group who failed were able to earn three additional points in mean scores on spatial orientation than did the women, with the standard deviations approximately the same between the men and the women. Among all people who took the test during this period (N=7,412), the men scores 3.42 points higher than did the women on spatial orientation questions, with the standard deviations only 0.6 apart (Dailey, 1984). This research suggests that men do better on spatial orientation questions than women do.

In a study and review of the literature conducted by Pepin, Beaulieu, Matte, and Leroux (1985), it was found that differences in spatial abilities begin to appear between the sexes at adolescence and the differences continue to widen as individuals get older. Males perform better than do females on skills requiring mathematics and spatial orientation ability. In this particular research, the videogame "Super Breakout" was used as a measure. Twenty-eight male and 28 female children participated per group, with the mean ages of 13 in both groups. Males performed significantly better on spatial relations skills (t=3.05, p<.01.). Indications exist, however, that girls can improve the same level as boys by simple practice (Connor, Serbin, Schackman, 1977).

In earlier research conducted by Krumboltz and Christal (1960), it was shown that although spatial orientation tests have high validity in many circumstances and occupations, they are highly susceptible to practice. This study included 512 Air Force Reserve Office Training Candidate (ROTC) students assigned to groups taking either re-tests of the same examination, alternate forms of the same examination, or no examination. The groups were randomly divided into halves, with one half repeating their version of the test ten minutes later and the other half repeating their test seven hours later. The results were

1. All forms were highly subject to practice effects.
2. Administration of an alternate form yielded as much practice effect as re-administration of the same form.
3. There was no practice effect when an alternate type of spatial test was administered.
4. Practice effects on spatial tests do not diminish significantly during the first seven hours (p. 391).

There is additional evidence that through practice subjects can become "test-wise" as well as obtain other clues for increased practice effect on tests of mental ability (Wing, 1979). The benefit of practice and experimentation through the use of specific videogaming would appear to be extremely worthwhile in preparing an individual for obtaining the skills necessary for work that demanded those abilities.

A study commissioned by the FAA found that controllers feel that spatial orientation abilities are keys to success on the job (University of Oklahoma, 1989).

There is additional evidence that computer simulation games, through practice, add to one's ability to reason spatially.

> Spatial skills are another area of cognitive skills that many computer games require and therefore must promote as players become more skilled . . . Many computer games require the ability to coordinate visual information coming from multiple perspectives. This skill is emphasized in Piaget's account of intellectual development (Greenfield, 1984, p. 115).

Lowery and Kirk (1982) have listed characteristics that correspond with the acquisition of spatial abilities through the use of video games. Among those are (1) repeated practice, (2) strong motivation by the user, (3) short play durations, (4) the ability to manipulate two and three dimensional objects and (5) the ability to process images holistically. These are the exact requirements and/or abilities that air traffic controllers have identified for themselves (University of Oklahoma, 1989).

In a study involving the use of the videogame "Steller," McClurg and Chaille (1987), attempted to determine whether fifth, seventh and ninth graders would improve their scores on a spatial orientation measure. The measure of spatial ability used was the Mental Rotations Test because it shows a high correlation with other tests of spatial ability.

"Steller" involves many of the characteristics associated with high spatial skill: three dimensional object discrimination, anticipation and negotiation of objects moving at different speeds at different distances, and the continuous updating of cognitive mapping. The results indicate that for those playing the "Steller" game, the spatial ability of males improved more than that of females. Although all groups improved, the control group improved the least in all three grades (McClurg, 1987).

In research by Pepin and Dorval (1986), studies were cited, ranging in time from 1958-1974, which supported the premise that boys maintained superiority over girls in spatial orientation skills. Results showed that among adults, there was no effect accountable for sex differentiation. Both men and women alike gained significantly on scores as measured by the Space Relations Test of the Differential Aptitude Tests. The subjects in Pepin and Dorval's study were posttested after six weeks (French Canadian version).

Pepin and Dorval (1986) conducted their own study using the videogame "Zaxxon." This particular videogame was determined to be unique to the researchers due to the fact that it simulates three dimensional thinking. One of the tested groups consisted of adult (university undergraduate) subjects. The researchers determined that videogames are particularly appropriate in learning spatial skills through motivation for "individuals having few experiences or little success in any particular field" (p. 2).

Motivation enhances participation in computer games and subsequently enhances spatial orientation skill acquisition. Furthermore, the interaction of the games contribute to the transfer of learning (Greenfield, 1984).

Spatial ability research has also been conducted by the military, emphasizing the importance of visual cuing, spatial ability and visual perception for pilots. McDaniel conducted a study for 21 students in pilot training in order to determine the effectiveness of the Wheatly Cube to measure spatial ability (McDaniel, 1985).

Molina (1985) set out to test instructional variables on reading aircraft instruments relating to spatial visualization tasks. The study was conducted to help improve female Air Force Cadet performance on the Aircraft Instrument Comprehension Test. The results showed that females gained substantially in the ability to read aircraft instrumentation.

Martin (1985) conducted a study to determine cognitive training method strategies in order to allow pilots in flight training to concentrate on multiple visual stimuli and to validate a "learning by doing" methodology. Results indicate that the more practice one has with multiple stimuli, the greater the increase in learning.

In a study concerning visual cuing, military researchers discovered that the distribution of environmental features substantially aided a pilot's ability to perceive spatially, and that these perceptions increased as the density of these features increased. This research indicates that compacted visual cues increase the ability of a subject to perceive spatially (DeMaio, Rinalducci, Brooks, and Brunderman, 1985).

These studies and others like them (AGARD, 1980, McDonald, 1987) indicate the need for pilots as well as air traffic controllers to have similar skills in spatial orientation. The need for spatial orientation skill ability is indigenous for military pilots who maneuver fast moving, earth-hugging aircraft. There is no opportunity for error. All decisions must be correct. Similarly, controllers make numerous decisions based on concepts of time, space and relative position. Like pilots, controllers operate with very little room for error.

In the years prior to the 1981 air traffic controller strike, controller ranks were filled by those with a prior military background. Military controller experience was weighted heavily in the selection of new controllers since there was statistical evidence that retention of these individuals would be high. To a lesser degree, any type of aviation experience was thought to be positively related with success of air traffic control candidates. Other candidates had to have a four-year degree or show evidence of a three year background in other generally related work experiences (Cobb, 1974).

Although not specifically stated in the literature, it is implied that while there is not a strong relationship between general aviation experience and retention of controllers, there is a relationship between the ability to orient spatially and the retention of controllers. Since both pilots and controllers rely heavily upon this skill, pilots make good subjects for determining if a specific radar simulation game would affect a pilot's ability to orient spatially.

Summary

In the review of the literature, various studies were examined in which it was shown that both pilots and air traffic controllers have a need for spatial orientation ability and skill. Other research indicated that through part-time and simulation training, spatial orientation skill can be acquired.

The remainder of this study is presented in the following format: Chapter III, Methodology, Chapter IV, Findings, and Chapter V, Summary, Conclusions, and Recommendations. In Chapter III the methodology is examined by observing the pilot study, population, instrumentation, experimental design, and data collection procedures. Chapter IV examines the findings of the t tests and Pearson Product Moment Correlation. Chapter V includes a summary of the study, conclusions based upon the research, and recommendations for both further studies and practice in the field of air traffic control.

CHAPTER III

METHODOLOGY

Pilot Study

The purpose of this study was to determine whether radar simulation game training would help aviation oriented individuals to negotiate spatial orientation skills necessary for air traffic control work.

Prior to conducting this research, a pilot study was undertaken at Rose State College with five participants.

The pilot study was an opportunity to determine whether the Terminal Radar Approach Control (TRACON) simulation game could be taught to a group of people with diverse aviation backgrounds. It was also an opportunity to determine whether the game could be taught and learned within limited time parameters and whether the process of conducting the experiment contained any flaws. Included in this process was the administration of the pretest, posttest, and demographic questionnaire. The pilot study determined the amount of time needed for each of these activities, and whether adjustments in the process should be made.

In preparation for the pilot study it was discovered that the laboratories at Rose State College and Oklahoma State University utilized different computer systems. Even though both were IBM compatible, as required by the TRACON game, the system at Rose State did not contain a disk operating system (DOS). This was a problem because it required a separate DOS disk for each computer in order to load the game. It also required a little extra set-up time prior to the arrival of the participants.

The computers at Rose State and Oklahoma State used different size disks. The computers at Rose State only used the three and one-half inch format, those at Oklahoma State used the five and one-quarter inch format. A complete set of TRACON in each format had to be prepared for the research. Neither school had hard drive capability.

During the pilot study it was discovered that some floppy disks malfunctioned and were no longer usable. Apparently, data can only be sorted on the disk under a single name. Trying to save data with multiple names causes the program to stop. As a result, it was decided to make more copies of the program in case a similar event happened during the research sessions.

Additionally, there was a problem with the layout of the laboratory at Oklahoma State. The room is long and narrow with the computers on rows of tables placed against the wall. This room design made it difficult to circulate among the participants in order to check their progress. Students were strategically placed in the rooms to minimize this effect. Students were placed in a staggered pattern in order to allow the instructor movement among the subjects with minimal physical interference.

Subjects who participated in the pilot study were randomly selected. Three people participated in the experimental (treatment) group, and two were selected for the control group.

The pilot study was conducted as if it were a regular research session. It was easier to work with this group because the number of individuals was small.

At the end of the pilot study, all participants were asked to complete a written critique asking for their impressions of the design of the experiment, including the identification of problems or other suggestions. They were also given an opportunity to comment verbally, with free interchange among the group members. The subjects participating in the pilot study felt that there were no problems with the design, structure or organization of the activities. A demographic representation of the pilot group is provided in Table I. Pretest, posttest and TRACON Scores of the pilot group are not included or reviewed since they do not pertain to the statistical results of this study.

TABLE I

PILOT GROUP DEMOGRAPHIC INFORMATION AND MEANS

SUBJECT	AGE	SEX	AVIATION HOURS	NUMBER OF CERTIF	MILITARY EXPERIENCE
A	63	F	78	1	NO
B	58	M	350	2	YES
C	60	F	670	4	NO
D	21	F	22	0	NO
E	40	F	85	1	NO
MEANS	48.4		241	1.6	
S.D.	17.756		271.471		

A suggestion was made to provide a summary of control commands next to each computer as the simulation game was taught. Even though the game provides this same information by depressing either the ALT/F1 key for information on what the "ALT" keys provide, or the F1 key alone for additional game information, subjects did not want to change screens during the scenarios to retrieve this information. This was due to the level of demand of the subjects' attention by the scenarios, and they did not want to be diverted from the visual action.

The control commands were also written on the chalk boards on the side of the room, but subjects wee required to exert a lot of effort to see it. It was decided that paper and pencil would be provided to all subjects so that they could make a copy of the commands during the teaching sessions. It was felt that retention of the information would be enhanced in this manner.

The control group was given a complex jigsaw puzzle to solve. A jigsaw puzzle was chosen as the control group activity because it was challenging enough to mentally fatigue the subjects. The group enjoyed the activity since it was self paced and not strictly regulated like that of the treatment group, although it indicated a preference for playing the TRACON simulation.

The Population and Sample

The study was conducted on two separate occasions, once at Rose State College and once at Oklahoma State University. The population was solicited from individuals who are currently involved in aviation training. For the purpose of this study, these students can be defined as those enrolled in undergraduate studies in aviation who have had various amounts of aviation experience, or adults in the Oklahoma City Squadron of the Civil Air Patrol who as a regular course of action, pursue higher credentials as pilots.

The reason for choosing subjects with some degree of pilot or aviation ground training was to be consistent with the literature which indicates that pilots require spatial orientation skills to be functionally successful and safe (Kirkham, 1978, McDaniel, 1985, Molina, 1985, Martin, 985, Brunderman, 1985, and AGARD, 1980). Therefore, like controllers, pilots should already have a baseline understanding and ability to negotiate spatial orientation problems. Furthermore, pilots have a command of aviation vocabulary. Pilots would not have to be extensively trained in aviation principles in order to understand and play the computer simulation game.

Air traffic controllers were not considered for this study because they have an existing knowledge of radar procedures and its application, as well as strong spatial orientation skills.

As a result, subjects were obtained from the Aviation Department at Rose State College, from the Aviation and Space Education Department at Oklahoma State University, and from Squadron 35113 of the Civil Air Patrol in Oklahoma City. The subjects were randomly assigned to either the experimental or the control group.

Random assignment was accomplished at the site of each experiment location. It could not be determined in advance which of the invited participants from the selected groups would eventually participate as either treatment or control subjects. Therefore, randomization was delayed until the day of the research.

Before the randomization process, every participant filled out a questionnaire which provided information about background and degree of experience with aviation and computers (Appendix B). Secondly, each participant was given the spatial orientation pretest (Appendix C). One half hour was allotted for this pretest after directions were explained and questions were exhausted.

At the conclusion of the pretest, the groups were randomized by the use of three by five inch pieces of paper. Each participant wrote his name on the piece of paper and the papers were put into a hat. The participants' names were drawn by the experimenter one at a time with the first assigned to group "A", and the second to group "B." This procedure was continued until the names were exhausted. Group "A" names were assigned to the treatment group, and group "B" names were assigned to the control group.

Subjects were not informed as to whether they were selected for the treatment or the control group. Instead, participants were informed that both activities were being conducted to determine the effect the activities had on spatial orientation skill.

Instrumentation

The Office of Personnel Management (OPM) administers a civil service examination for air traffic control candidates. The portion of this test which measures spatial orientation skills is commonly referred to as the Civil Service Commission 157 Examination

(CSC 157). Since this test is not available to the public, it was necessary to emulate as closely as possible the types of items on the CSC 157. This task had already been accomplished by the Arco Publishing Company (ARCO), which developed a study guide for air traffic control candidates to use in preparing for the CSC 157 (Turner, 1986). The pretest and posttest used in this study were made from questions extracted from the ARCO study guide because they closely resemble the CSC 157 examination. Three sections of questions were available with the last two selected for use. Each of these two sections contained 15 questions. The examination administered is depicted in Appendix C. The answers are in Appendix D.

A questionnaire was developed for this research to gather demographic information concerning the subjects. Information collected included age, sex, pilot experience, military experience, computer experience, and simulation gaming experience. This information was necessary in order to aggregate data in the resolution of Ho5 and to identify whether there was a relationship between scores on the TRACON game and on the spatial orientation posttest.

Experimental Design and Hypotheses

This study incorporated a true experimental design, using equivalent groups achieved by random assignment from a closely defined population. The design appears as:

RO_1 x O_2

RO_2 x O_4

Each experimental session lasted approximately seven hours. All testing was done during this time in order to eliminate certain internal validity factors such as history, maturation, and experimental mortality.

Null Hypotheses

The following hypotheses were tested.

Ho_1: There was no difference between mean posttest scores of treatment and control groups after radar simulation game training.

Ho_2: There was no difference between mean pretest and posttest scores of a treatment group receiving radar simulation game training.

Ho_3: There was no difference between mean pretest and posttest scores of a control group not receiving radar simulation game training.

Ho_4: There was no difference between mean score pretest to posttest gains of treatment and control groups after radar simulation game training.

Ho_5: There was no correlation between radar simulation game scores and spatial orientation posttest scores.

The level of significance for the rejection of the null hypotheses was set at p=<.05.

Data Collection

All participants completed demographic questionnaires (Appendix B). In addition, all subjects were administered the spatial orientation pretest (Appendix C). The subjects were then randomly assigned to either the treatment group or the control group, as previously described.

The treatment that was used is a computer simulation game program called "TRACON." The word TRACON is an acronym for Terminal Radar Approach Control. The program can simulate the radar environment in five major air traffic hubs: Los Angeles, Miami, San Francisco, Boston, and Chicago. The game is able to realistically simulate a number of different requirements and tasks an employed air traffic controller faces every day (Wesson, 1988).

The treatment group (Group A) received instructions in how to play the TRACON game based on the operations manual. Key stroke clues that were used to manipulate the action of the game were written on the chalk board in order to provide a quick reference to directions and keystroke operations. In addition, participants were given paper and pencil as recommended by the pilot group.

All participants received the same instruction. In order to insure the elimination of as many variables in teaching the game as possible, the instructor used a lesson plan so that all pertinent material would be covered in the same order (Appendix E). It was considered that a video tape might be used to eliminate variables in instruction, but that idea was rejected in order that an environment of interaction could be established and so that pertinent questions could be answered immediately.

The instructor, Dr. Phillip L. Fuller, is a section supervisor for the Quality Assurance Staff at the Federal Aviation Administration Academy in Oklahoma City. This individual was chosen due to his multi-faceted background. He was able to lend credibility and experience to the process and eliminate variability in the presentation of materials. Dr. Fuller holds the credentials of an attorney, instructor, air traffic controller and pilot.

The procedures and rules of the game were taught for one hour. After a break, the subjects were allowed 45 minutes to practice in any way they found profitable, including restarting any scenario at any point. Questions and clarifications were permitted.

The game allowed for one of five different high level traffic areas in the country to be used. Randomly chosen was the Miami area. This mapping area was used consistently throughout the teaching, practice and testing phases. The testing phase lasted for 45 minutes.

The game also allowed for control over variables by the setting of certain parameters, such as the number of aircraft, the time allowed, weather conditions and skill level of pilots. In the teaching mode of this experiment, parameters were set at increasing levels of difficulty in order to allow participants to acclimate more fully to the game mechanism.

During the testing portion, all subjects were given the following conditions:

1. Ten aircraft were introduced into the scenario within the 45 minute time frame. Fewer aircraft over a longer period of time would have simplified the problem. More aircraft over a shorter time frame would have complicated the problem scenario.

2. Weather was chosen to simulate Instrument Flight Rule (IFR) conditions. This is the easiest weather situation in the game menu. It kept the Visual Flight Rule (VFR) "non-professional" pilots on the ground, and every aircraft that flew in a tabulation (TAB) list. The TAB list is an inventory of aircraft that depicts aircraft in-bound to an airport, ready for departure, or flying within the airspace in a selected scenario.

3. The pilots flying were in the "perfect" category. This means that the pilots did not make any mistakes, such as ignore commands from the controller (treatment group participant), execute a command meant for another aircraft, misinterpret a command, or make a missed approach. A missed approach meant the participant would have to control the aircraft again.

4. Wind was set at ten knots, to which the game automatically defaults. the wind at this setting had no appreciable effect on the aircraft.

A subject's score increased with the appropriate handling of an aircraft. Each successful exchange of aircraft to another controller was worth points, but if an aircraft were allowed to travel a distance beyond its flight plan without being appropriately exchanged, points were deducted. If aircraft were held on the ground after the scheduled departure time according to the TAB list, or if aircraft went into an automatic holding pattern because an exchange was not taken, points were also deducted. Points were deducted likewise for every control command. Control commands needed to be encompassing. The more "interference" with an aircraft's planned flight, the greater the penalty.

Points were awarded proportionally to an aircraft's type. Larger, more complex aircraft burned more fuel, so credits were awarded for conservation efforts. Major point deductions occurred with operational errors. Forgetting to exchange aircraft before leaving assigned airspace and failing to maintain separation between aircraft were serious deficiencies. Having two aircraft collide would have nullified all scores.

While group A was receiving the treatment, control group subjects were taken to a separate room where their task was to assemble a 1,000 piece jigsaw puzzle. The puzzle depicted the image of the cockpit of a Lear jet. The primary purpose of this group activity was to impose the approximate amount of fatigue into the control group as was being experienced by those who were learning how to use the TRACON game.

Both groups were allowed breaks at strategic points approximately every hour. The posttest (Appendix C) was administered to both groups simultaneously upon the completion of the sessions.

Analysis of Data

A t test was computed to examine differences in mean scores between the posttests of the control group and the posttests of the treatment group. Two other t tests examined the differences in pretest and posttest scores for the treatment group and for the control group. A fourth t test examined mean gain differences between the control group and the treatment group. The level of significance selected was p=<.05.

Additionally, a Pearson r correlation coefficient was calculated in order to determine the relationship between scores on the simulation game and scores on the spatial orientation test. Again, a p=<.05 was selected as the appropriate level of significance.

In addition to testing the formal hypotheses, certain demographic differences in relation to spatial orientation skills were examined in regard to differences in performance.

CHAPTER IV

FINDINGS

Background

Twenty-seven subjects were part of this experiment; 13 participated in the treatment group, and 14 acted as control subjects.

As indicated in Chapter III, subjects were selected from three institutions: The Oklahoma State University Aviation and Space Education Department in Stillwater, the Aviation Department at Rose State College in Oklahoma City, and Squadron 35113 of the Civil Air Patrol, also in Oklahoma City.

The Oklahoma State subjects were tested as an entity. The other administration contained individuals from both Rose State College and the Civil Air Patrol. Tables II through VII provide demographic information about age, sex, aviation hours, number of aviation certificates held and military experience. Means and standard deviations were calculated separately for each institution, for the individual groups as a whole, and for those who were selected for the treatment and control groups.

Demographic information and pretest and posttest scores are provided for all subjects who participated in the treatment group (Table VIII), and for all those individuals who served as control group subjects (Table IX).

TABLE II

DEMOGRAPHIC INFORMATION AND MEANS FOR OKLAHOMA STATE PARTICIPANTS

SUBJECT	AGE	SEX	AVIATION HOURS	NUMBER OF OF CERTIF	MILITARY EXPERIENCE
A	23	M	305	4	NO
B	25	M	220	3	NO
C	23	F	193	1	NO
D	22	M	320	3	NO
E	21	M	217	1	NO
F	22	M	60	1	NO
G	21	M	63	1	NO
H	22	M	200	1	NO
I	18	M	275	5	NO
J	21	M	200	2	NO
K	20	M	162	1	NO
L	24	M	330	4	NO
M	20	M	160	2	NO
MEANS	21.7		208	2.2	
S.D.	1.8		86.24	1.4	

TABLE III

OKLAHOMA STATE TREATMENT GROUP SCORE SUMMARY

SUBJECT	PRE TEST	POST TEST	TRACON GAME
A	70.0	83.3	75.7
B	73.3	73.3	85.4
C	60.0	73.3	21.0
D	43.3	60.0	71.8
E	80.0	76.6	85.8
F	66.6	90.0	16.4
MEANS	65.5	76.0	59.3
S.D.	12.77	10.19	31.98

TABLE IV

DEMOGRAPHIC INFORMATION AND MEANS FOR ROSE STATE COLLEGE PARTICIPANTS

SUBJECT	AGE	SEX	AVIATION HOURS	NUMBER OF OF CERTIF	MILITARY EXPERIENCE
A	26	M	73	1	NO
B	57	F	215	1	NO
C	25	F	112	1	YES
D	42	F	2000	6	NO
E	47	M	80	1	YES
F	23	F	0	0	NO
G	32	M	0	0	YES
H	28	F	120	2	YES
MEANS	35		325	1.5	
S.D.	12.3		680.3	1.92	

TABLE V

ROSE STATE TREATMENT GROUP SCORE SUMMARY

SUBJECT	PRE TEST	POST TEST	TRACON GAME
B	43.3	73.3	12.1
C	66.6	86.6	11.4
D	83.3	80.0	67.6
MEANS	64.4	79.9	30.3
S.D.	20.09	6.65	32.24

TABLE VI

DEMOGRAPHIC INFORMATION AND MEANS FOR CIVIL AIR PATROL PARTICIPANTS

SUBJECT	AGE	SEX	AVIATION HOURS	NUMBER OF OF CERTIF	MILITARY EXPERIENCE
A	54	M	670	2	NO
B	42	M	260	3	YES
C	52	F	85	2	NO
D	45	M	5800	9	YES
E	43	M	410	2	YES
F	50	M	450	4	YES
MEANS	47.7		1279	3.7	
S.D.	5.0		2223.4	2.7	

TABLE VII

CIVIL AIR PATROL TREATMENT GROUP SCORE SUMMARY

SUBJECT	PRE TEST	POST TEST	TRACON GAME
A	63.3	66.6	68.2
B	63.3	73.3	88.0
D	70.0	70.0	76.5
E	66.6	76.6	65.7
MEANS	65.8	71.6	74.6
S.D.	3.2	4.29	10.05

TABLE VIII

DEMOGRAPHIC AND SCORE INFORMATION OF ALL TREATMENT GROUP PARTICIPANTS

SUB	TRACON SCORE	PRETEST SCORE	POSTTEST SCORE	AGE	HOURS AV.EXP	SEX	# OF CERTIF.
A	88.0	63.3	73.3	42	260	M	3
B	68.2	63.3	66.6	54	670	M	2
C	75.7	70.0	83.3	23	305	M	4
D	85.4	73.3	73.3	25	220	M	3
E	21.0	60.0	73.3	23	193	F	1
F	16.4	66.6	90.0	22	60	M	1
G	71.8	43.3	60.0	22	320	M	3
H	85.8	80.0	76.6	21	217	M	1
I	65.7	66.6	76.6	43	410	M	2
J	11.4	66.6	86.6	25	112	F	1
K	67.6	83.3	80.0	42	2000	F	7
L	76.5	70.0	70.0	45	5800	M	9
M	12.1	43.3	73.3	57	215	F	1

MEANS AND STANDARD DEVIATIONS

VARIABLE	MEAN	STANDARD DEVIATION
TRACON	57.35539	30.13271
PRETEST	65.35384	11.75228
POSTTEST	75.62307	8.115434
AGE	34.15385	13.29064
HOURS	829.3846	1575.138
CERTIFICATES	2.93077	2.498718

TABLE IX

DEMOGRAPHIC AND SCORE INFORMATION OF ALL CONTROL GROUP PARTICIPANTS

SUB	PRETEST SCORE	POSTTEST SCORE	AGE	HOURS AV.EXP	SEX	# OF CERTIF.
A	56.67	66.67	50	450	M	4
B	36.67	43.33	47	20	M	1
C	73.33	66.67	23	0	F	0
D	76.67	76.67	32	0	M	0
E	93.33	90.00	28	120	F	2
F	60.00	66.60	21	63	M	1
G	76.60	76.60	22	200	M	1
H	53.30	46.60	18	405	M	5
I	63.30	56.60	21	200	M	2
J	40.00	36.60	20	162	M	1
K	66.60	73.30	24	330	M	4
L	53.30	60.00	20	160	M	2
M	63.30	73.30	57	130	F	2
N	76.60	83.30	26	78	M	1

MEANS AND STANDARD DEVIATIONS

VARIABLE	MEAN	STANDARD DEVIATION
PRETEST	63.54785	15.32184
POSTTEST	65.44571	15.40241
AGE	29.21428	12.6745
HOURS	165.5714	142.836
CERTIFICATES	1.857143	1.511858

Results

The null hypotheses to be tested are as follows:

Ho_1: There was no difference between mean posttest scores of treatment and control groups after radar simulation game training.

Ho_2: There was no difference between mean pretest and posttest scores of a treatment group receiving radar simulation game training.

Ho_3: There was no difference between mean pretest and posttest scores of a control group not receiving radar simulation game training.

Ho_4: There was no difference between mean score pretest to posttest gains of treatment and control groups after radar simulation game training.

Ho_5: There was no correlation between radar simulation game scores and spatial orientation posttest scores.

The first null hypotheses was tested by a t test of mean differences, assuming unequal population variances. The assumption of unequal population variances was necessary because the variability within the posttest treatment group is significantly different ($F=3.602$, $p=<.05$) from the variability within the posttest control group.

The posttest scores of the treatment group were significantly higher ($t=2.169$, $p=<.025$) than were the posttest scores of the control group. (See Table X for the table of means and standard deviations.) Therefore, Hypothesis 1 was rejected.

TABLE X

T TEST OF THE POSTTEST SCORES BETWEEN TREATMENT AND CONTROL GROUP

	TREATMENT	CONTROL
SAMPLE MEAN	75.62307	65.44571
SAMPLE STANDARD DEVIATION	8.115434	15.40241
SAMPLE VARIANCE	65.86027	237.2342
SAMPLE SIZE	13	14

TEST OF TWO MEANS: ASSUMING UNEQUAL POPULATION VARIANCES

STUDENT'S t= 2.169 WITH d.f.= 25

The second null hypothesis was also tested by a t test of mean differences, assuming equal population variances. The variability within the pretest group is not significantly different from the variability within the posttest group, so equal population variances may be assumed.

The posttest scores of the treatment group are significantly higher (t=2.593, p=<.01) than are the pretest scores of the treatment group. (See Table XI for the table of means and standard deviations.) Therefore, Hypothesis 2 was rejected.

The third null hypothesis was also tested by a t test of mean differences, assuming equal population variances. The variability within the pretest group is not significantly different from the

TABLE XI

T TEST OF THE PRETEST AND POSTTEST SCORES TREATMENT GROUP

	PRETEST	POSTTEST
SAMPLE MEAN	65.35384	75.62307
SAMPLE STANDARD DEVIATION	11.75228	8.115434
SAMPLE VARIANCE	138.1161	65.86027
SAMPLE SIZE	13	13

TEST OF TWO MEANS: ASSUMING EQUAL POPULATION VARIANCES

STUDENT'S t= -2.593 WITH d.f.= 24

variability within the posttest group, so equal population variances may be assumed.

The posttest scores of the control group are not significantly higher (t=0.327) than are the pretest scores of the control group. (See Table XII for the table of means and standard deviations.) Therefore, Hypothesis 3 is not rejected.

The fourth null hypothesis was tested by a t test of mean gain differences. Mean gain scores were calculated by subtracting pretest scores from posttest scores for both the treatment and control groups (See Table XIII).

A t test for equal population variances was significant (F=2.776, p=<.05) indicating the variability in the mean gain scores for the treatment group was significantly different from the

TABLE XII

T TEST OF THE PRETEST AND POSTTEST SCORES CONTROL GROUP

	PRETEST	POSTTEST
SAMPLE MEAN	63.54785	65.44571
SAMPLE STANDARD DEVIATION	15.32184	15.40241
SAMPLE VARIANCE	234.7587	237.2342
SAMPLE SIZE	14	14

TEST OF TWO MEANS: ASSUMING EQUAL POPULATION VARIANCES

STUDENT'S t= -0.327 WITH d.f.= 26

TABLE XIII

MEAN GAIN SCORES FOR CONTROL AND TREATMENT GROUPS

SUBJECT	POSTTEST SCORE	PRETEST SCORE	GAIN SCORE
	CONTROL GROUP		
A	66.6	56.6	10.0
B	43.3	36.6	6.7
C	66.6	73.3	-6.7
D	76.6	76.6	0
E	90.0	93.3	-3.3
F	66.6	60.0	6.7
G	76.6	76.6	0
H	46.6	53.3	-6.7
I	56.6	63.3	-6.7
J	36.6	40.0	3.4
K	73.3	66.6	6.7
L	60.0	53.3	6.7
M	73.3	63.3	10.0
N	83.3	76.6	6.7
	TREATMENT GROUP		
A	73.3	63.3	10.0
B	66.6	63.3	3.3
C	83.3	70.0	13.3
D	73.3	73.3	0
E	73.3	60.0	13.3
F	90.0	66.6	23.4
G	60.0	43.3	16.7
H	76.6	80.0	-3.4
I	76.6	66.6	10.0
J	86.8	66.6	20.2
K	80.0	83.3	-3.3
L	70.0	70.0	0
M	73.3	43.3	30.0

variability in the mean gain scores for the control group. Therefore, the assumption of unequal population variances was necessary.

The t test of mean gain scores for the treatment group was significantly higher ($t=2.462$, $p=<.025$) than the mean gain scores for the control group. Therefore Hypothesis 4 is rejected. (See Table XIV for the table of means and standard deviations.)

The fifth null hypothesis was tested by a series of Pearson Product Moment correlations depicted by the matrix of correlation coefficients (See Table XV). The reported correlation between TRACON scores and spatial orientation posttest scores is not significant ($r = -0.4$), therefore, hypothesis 5 is not rejected. The required level of significance for the fifth hypothesis was $r =.47$ at the $p=.05$ level.

Summary of Findings

Subjects in the treatment group achieved posttest scores substantially higher than the posttest scores of the control group. This indicates that those who played the Terminal Radar Approach Control (TRACON) simulation game were able to negotiate spatial orientation problems more effectively.

Second, there is also a statistically significant correlation ($r=0.91$, $p<.01$) between the pretest and posttest scores in the control group. This relationship accounts for 84 percent of the variability ($r2=0.835$) between the two tests. This strong relationship is another indication that the TRACON treatment

TABLE XIV

T TEST OF THE MEAN GAIN SCORES BETWEEN TREATMENT AND CONTROL GROUP

	TREATMENT	CONTROL
SAMPLE MEAN	10.26923	1.900000
SAMPLE STANDARD DEVIATION	10.60922	6.367224
SAMPLE VARIANCE	112.5556	40.54154
SAMPLE SIZE	13	14

TEST OF TWO MEANS: ASSUMING UNEQUAL POPULATION VARIANCES

STUDENT'S t= 2.462 WITH d.f.= 25

TABLE XV

MATRIX OF CORRELATION COEFFICIENTS

	TRACON	PRE TEST	POST TEST	AGE	HOURS	SEX	MILIT EXPER	# OF CERT
TRACON	1.000	0.397	-0.429	0.020	0.261	0.675	0.070	0.482
PRETEST	0.397	1.000	0.479	-0.200	0.248	0.121	0.075	0.357
POSTTEST	-0.429	0.479	1.000	-0.314	-0.208	-0.233	0.090	-0.182
AGE	0.020	-0.200	-0.314	1.000	0.344	-0.136	0.240	0.256
HOURS	0.261	0.248	-0.208	0.344	1.000	0.088	0.360	0.874
SEX	0.675	0.121	-0.233	-0.136	0.088	1.000	0.083	0.117
MILITARY	0.070	0.075	0.090	0.240	0.360	0.083	1.000	0.230
CERTIFIC	0.482	0.357	-0.182	0.256	0.874	0.117	0.230	1.000

CONTROL GROUP

	POST TEST	PRE TEST	AGE	HOURS	SEX	MILIT EXPER	# OF CERT
POSTTEST	1.000	0.914	0.101	-0.160	-0.395	0.159	-0.140
PRETEST	0.914	1.000	-0.152	-0.188	-0.464	0.098	-0.187
AGE	0.100	-0.152	1.000	0.004	-0.290	0.518	0.058
HOURS	-0.160	-0.188	0.004	1.000	0.312	-0.083	0.920
SEX	-0.395	-0.467	-0.290	0.312	1.000	-0.055	0.188
MILITARY	0.159	0.098	0.520	-0.083	-0.055	1.000	-0.047
CERTIFIC	-0.140	-0.187	0.058	0.920	0.188	-0.047	1.000

influenced posttest scores.

Third, a t test of mean gain scores indicated that the treatment group scores were significantly different from those of the control group ($p<.025$).

Fourth, assuming equal population variances ($F=1.70$), pretest scores of the control group were not significantly different from pretest scores of the treatment group ($t=0.34$). (See Table VIII and Table IX.) Therefore, without the TRACON experimental simulation intervention, pretest and posttest scores in the treatment group would have remained essentially the same.

There was no significant relationship between TRACON scores and spatial orientation posttest scores. In fact, this relationship was negative. Practice with simulation gaming does not necessarily insure mastery of the game.

There was no significant relationship between hours of aviation experience and scores on the spatial orientation posttest. This relationship was also negative. Spatial orientation ability is not affected by aviation experience.

Females who participated in the treatment group improved more than did males on posttest scores. However, male scores were considerably higher than were female scores on the TRACON simulation game (See Table XVI).

TABLE XVI

MEAN SCORES AND PERCENTAGES MALES VERSUS FEMALES TREATMENT GROUP

	PRETEST	POSTTEST	PERCENT GAIN	TRACON SCORE
MALES	66.26	74.41	12.4	70.3
FEMALES	63.30	78.30	23.6	28.0

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Chapter V is divided into four sections. A summary of the study is presented in the first section followed by the conclusions of the study. The final sections contain the recommendations for further research and for practice.

Summary

The purpose of the study was to determine whether simulation training would help aviation oriented individuals to negotiate spatial orientation skills necessary for air traffic control work. It was conducted by means of experimental sessions of treatment and control groups at computer laboratory sites. The experiments were held at Oklahoma State University and at Rose State College. Participants were solicited from the Oklahoma State University Aviation and Space Education Department, the Aviation Department at Rose State College and Squadron 35113 of the Oklahoma City Civil Air Patrol.

The review of the literature shows that both pilots and air traffic controllers need spatial orientation abilities. Pilot training and controller performance are similar in task complexity. Spatial skills for pilots relate directly to the safe operation of aircraft. Many studies (as well as controller responses in survey data) have determined that spatial skill ability is a critical task in successful job performance.

The research indicates that controllers are hired through a screening process that eliminates some candidates who do not have adequate spatial orientation skill. Other research indicates that through an objective based cognitive process, and through part-task simulation training, spatial orientation skill can be adequately acquired. Many studies incorporating simulation game training have also shown effectiveness in the acquisition of spatial orientation skill.

The study attempted to test five null hypotheses. The first four hypotheses were examined by t tests to determine whether there are significant differences between posttest mean scores of treatment and control groups, whether there were significant differences between mean scores of the control group, and whether there were significant differences in mean gain scores between the treatment and control groups.

The fifth hypothesis was tested by means of a Pearson Product Moment correlation to determine whether there was a relationship between simulation game scores and spatial orientation posttest scores.

Posttest scores on a t test of spatial orientation of the treatment group were significantly higher than the posttest scores of the control group. Second, posttest scores of the treatment group were significantly higher than the pretest scores of the treatment group. Third, posttest scores of the control group were not significantly higher than the pretest scores of the control group. Fourth, mean gain scores for the treatment group were significantly higher than mean gain scores for the control group.

A correlation between scores on the spatial orientation posttest and scores on the TRACON game were not significant.

Female subjects received posttest scores 23.6 percent higher than their pretest scores. Male subjects received posttest scores which increased by 12.4 percent.

Conclusions

The following conclusions resulted from the findings of the research.

Females who participated in the treatment group of this study improved more than their male counterparts on posttest scores. After limited exposure to the TRACON simulation game female subjects, who comprised 31 percent of the treatment group, received posttest spatial orientation scores 23.6 percent greater than their pretest scores. Male subject posttest scores increased by 12.4 percent. That is, female scores increased nearly twice as much as did male scores after the radar simulation game training. However, the mean score for females playing TRACON was 28.02 percent. For males, the mean was 70.38 percent (Table XVI).

Two factors were identified which, in all likelihood, limited the females' ability to score well on the game itself. None of the females who participated indicated they had had any prior experience with computer simulation games. As a result, the females may have had a more difficult time acclimating to the simulation environment and may not have been as adept at manipulating the keyboard and associating the correct control functions.

Secondly, since females were not as familiar with computer gaming, they may have had a greater tendency to take more risks without a full appreciation of the consequences. The females made a total of 11 operational errors, while more than three times as many males made only three.

The TRACON game penalizes risk-takers. In fact, the penalties are dramatic for losses of separation (operational errors), and the females experienced many more of these types of errors than did their male counterparts. However, what is important is <u>not</u> the score per se on the TRACON game, but that the practice of experimenting in the air traffic environment improved posttest spatial orientation scores significantly.

At first these results may seem somewhat paradoxical until research by Pepin and Dorval (1986), Molina (1985), and Martin (1985) is reviewed. The inference in Pepin and Dorval's study is that females do not do as well with spatial orientation tasks as do males. And, similar to the results of this study, female scores increased through training. Molina showed that females improved on visualization tasks through the use of instructional variables. Martin determined that cognitive strategies and "learning by doing" helped pilots focus upon visual stimuli. These results could be related to the reduced exposure of females to training in these spatial orientation tasks.

Within the treatment group, both males and females who scored the highest on the pretest of spatial orientation also earned high scores on the posttest (Table VIII). This result would be expected. However, they also scored higher as a group on the TRACON simulation. Therefore, people with initially high spatial orientation abilities maintained these abilities and were able to apply them successfully and beneficially in the negotiation of the TRACON scenarios.

Thirty-eight percent of the treatment group owned their own computers compared to 43 percent of the control group. It would not appear that owning a computer makes a difference in scoring.

Fifty-four percent of the treatment group had written computer programs, compared to 36 percent in the control group. However, for those who had written computer programs, their mean TRACON score was 49.08. For those individuals who did not write programs, their TRACON mean score increased to 67.00. Therefore, experience in writing computer programs may not affect the ability to play computer simulation games.

In the treatment group, 69 percent of the participants said they classified themselves as having "never" played computer games. Twenty-three percent indicated that they had played "often." In the control group, 57 percent reported that they "never" played computer games. Twenty-one percent indicated they had played "often." Therefore, since more subjects in the treatment group indicated they had "never" played computer games, the lack of computer game experience may not affect the ability to learn from computer simulation games.

Sixty-two percent of the treatment group said that they had had experience in aircraft simulators, while only 65 percent of the control group reported that they had had aircraft simulator experience. Therefore, experience in aircraft simulators may not affect the ability to play computer simulation games.

Treatment group participants had considerably more flying experience than did participants in the control group. The mean number of hours for the treatment group was 829.4 compared to 165.6 for the control group. This may have had a minor effect in the results since the correlation between hours of aviation experience ($r=0.25$) and pretest results for the treatment group was positive. The equivalent correlation for the control group was negative ($r = -0.19$) (See Table XV).

In the treatment group, there was a correlation (0.874) between "hours of flying time" and "number of certificates held." However, this is an expected result. Additionally, a correlation (0.360) existed between "hours of flying time" and "military experience." This may be due to military flying experiences and/or the desire to continue the experience in civilian life. However, the latter correlation has no appreciable effect since military experience was categorized in the questionnaire as qualitative data.

Recommendations for Further Research

It is recommended that studies be accomplished concentrating on other required air traffic skills. Practice of "real-life" air traffic control tasks by using computer simulation gaming is a way air traffic control candidates can acquire necessary skill in modular form (part-task training). An example would be the ability to visually scan objects and information through the use of a videogame.

It is recommended that further studies concerning spatial orientation ability have "captive" subjects. Ideally, similar studies could be attempted by aviation instructors who have ready made populations available, or by the Civil Aeromedical Institute (CAMI) who is funded for this type of research.

It is recommended that future studies be conducted longitudinally. Simulation game training needs to be incorporated in an initial air traffic training program parallel to the existing screen program in order to compare traditional versus simulation game based instruction.

Future research needs to examine the possibility that non-aviation oriented subjects could respond as well to aviation based computer simulation game training as do those with an established interest in aviation.

Research is also needed in the cognitive area of brain dominance and lateralization. What needs to be determined is whether air traffic terminal behaviors are more closely related to either left brain or right brain functions, and whether the air traffic selection process skews training toward either left or right brain characteristics.

Recommendations for Practice

It is recommended that controller applicants in the future be screened through part and whole task simulations which determine whether they can be trained to acquire spatial orientation skills requisite to the profession of air traffic control. It is envisioned that this screening process would entail training in spatial orientation skills as long as spatial orientation skills remain as one of the areas mandated by the Office of Personnel Management (OPM) as a prerequisite to job success. These skills could therefore be acquired through the use of commercial products such as TRACON or other agency created site specific designed scenarios.

In order to facilitate the process of the certification of air traffic control specialists (ATCS'), it is recommended that either private or academic institutions be established for the sole purpose of identifying individuals who possess the aptitude, attitude and mentality to succeed in an air traffic training program. Initial selection could be accomplished by the evaluation of past training histories, intelligence tests, standardized academic scores, past work experience, psychological suitability and present work ethics. This procedure would include simulation training similar to the TRACON model and would serve as an "audition" for assessing candidates for their abilities to apply computer simulation strategies in solving typical and basic "real world" air traffic control problems. Identified candidates would then make up a "pool" of eligibles that would be cycled through a training process for ultimate placement in field facilities.

It is recommended that air traffic students should be given the opportunity to progress in the acquisition of basic skills in a self-paced and individualized curriculum. This curriculum would be designed to insure mastery of all fundamental skills through diagnosis and remediation of learning. Included in this process could be a design similar to Knowles' "organic curriculum" in which students and instructors collaborate on the optimal individualized learning environment. Incorporated also should be a system that allows for individualized learning styles and preferences (e.g., computer-based, text, or highly visualized).

It is recommended that assessment of candidate abilities in the area of spatial orientation be accomplished with computer-based simulation scenarios. A cognitive analysis could identify the appropriate processes and measures to be developed in order to evaluate acceptable levels of acquisition. Each scenario design would gauge mental skills and other complex cognitive routines inherent to ATCS operations. This battery of scenarios needs to be administered in non-contaminated surroundings which eliminate all distractions and interference.

Following selection, candidates should enter a mastery learning archetype that provides multiple learning paths to full performance level (FPL). As a product, current developmental successes could be exceeded. The training recommended focuses upon competency acquisition and includes effective diagnosis, feedback and remediation of learning difficulties. Initially, students need to be provided training in basic aviation and air traffic knowledge and procedures. This initial training in procedures could include a series of degraded tasks in which the students could demonstrate mastery prior to entering the next task hierarchy.

A voucher system is recommended to improve air traffic control training. American Airlines is a corporation that functions with a voucher system for prospective pilots. Each candidate is given an established amount of financial support in the early stages of training. This program is self-paced and competency based and allows candidates to extend the training program at their own expense if they exceed established time parameters. In this manner candidates needs are met by the likelihood of success, and company resources are maximized.

It is recommended that the government rely more upon private and/or academic programs as alternatives which could alleviate the screen versus training dilemma inherent in the existing program. Students would be able to select their own training through the normal academic process and become available candidates for the ATCS profession upon graduation. However, they would also have an additional alternative of converting the same training to other aviation career fields.

Distance training is also recommended due to the tremendous cost savings potential. The Federal Aviation Administration (FAA) is currently exploring and implementing up-link training for supervisory, management and general training from its facilities in

Palm Coast, Florida. This is an area that may hold promise for the future of technical air traffic training, particularly in the domain of simulation. A combination of satellite and personal computers using modem and facsimile devices could be very effective in both centralizing training and simultaneously saving money.

It is recommended that as training technology continues to become more sophisticated and refined, alternatives in achieving air traffic screening, selection and proficiency training should be increasingly explored. The incumbent screening process has been in place since 1981. The refinement that took place at this time, however, was primarily generated by the controller's strike, and was a modification of the screen process that had been in effect for three decades. The infrastructure and design of the original air traffic screening process were developed through training models and research that have outlasted their usefulness. The existing processes, in part influenced by the military, have a dubious relationship with current procedures and practices in the management of the national airspace system.

BIBLIOGRAPHY

Advisory Group for Aerospace Research and Development. (1980). Fidelity of Simulation for Pilot Training. (AGARD No. AR-159) Surshine, France: North Atlantic Treaty Organization. (DTIC Report No. AD A096825).

Boone, J. O. (1979). Toward the Development of a New Selection of Battery for Air Traffic Control Specialists. (Report No. FAA-AM-79-21). Washington, DC: Department of Transportation.

Boone, J. O., Van Buskirk, L., and Steen, J. (1980). The Federal Aviation Administration's Radar Training Facility and Employee Selection and Training. (Report No. FAA-AM-80-15). Washington, DC: Federal Aviation Administration.

Cobb, B. B., Nelson, P. L., and Matthews, J. J. (1973). The Relationships of Age and ATC Experience to Job Performance Ratings of Terminal Area Traffic Controllers. (Report No. FAA-AM-73-7). Washington, DC: Department of Transportation.

Cobb, B. B. and Nelson, P. L. (1974). Aircraft-Pilot and Other Pre-Employment Experience as Factors in the Selection of Air Traffic Controller Trainees. (Report No. FAA-AM-74-8). Washington, DC: Department of Transportation.

Collins, W. E., Hasbrook, A. H., Lennon, A. O., and Gay, D. J. (1977). Disorientation Training in FAA-Certified Flight and Ground Schools: A Survey. (Report No. FAA-AM-77-24). Washington, DC: Department of Transportation.

Connor, J. M., Serbin, L. A., and Schackman, M. (1977). Sex Differences in Children's Response to Training on a Visual-Spatial Test. Developmental Psychology, 13, 293-294.

Crookall, D., Martin, A., Saunders, D., and Coote, A. (1986). Human and Computer Involvement in Simulation. Simulation and Games, 345-375.

Dailey, J. T. (1968). Instructor's Manual for Talent Training Materials. Alexandria, VA: Allington Corporation.

DeMaio, J., Rinalducci, E. J., Brooks, R., and Brunderman, J. (ND). Visual Cueing Effectiveness: Comparison of Perception and Flying Performance. Williams Air Force Base, AZ: Air Force Human Resources Laboratory, (NTIS No. AD-P003-458).

Ettington, J. E. (1989). The Winning Trainer. Houston, TX: Gulf Publishing Company.

Feurzeig, W. (1971). Automated Instructional Monitors for Complex Operational Tasks: Final Report. (Report No. R-2272). Washington, DC: Office of the Chief of Research and Development (Army) (ERIC Document Reproduction Service No. ED 058-740).

Finke, R. A. (1986). Mental Imagery and the Visual System. Scientific American, 93, 88-95.

Flaitz, J. (1986, November). A Review of the Simulation in Teacher Education Training. Paper presented at the Midsouth Educational Research Association Annual Meeting, Memphis, Tennessee.

Galagan, P. (1987). "Computers and Training: Allies or Enemies?" Training and Development Journal, April, 73-76.

Geber, B. (1990). Simulating Reality. Training, 27(4), 41-46.

General Accounting Office. (1989). FAA Training Continued Improvements Needed in FAA's Controller Field Training Program. Washington, DC: GAO Publication No. GAO/RECD-89-83.

Gerathewohl. S.J. (1969). Fidelity of Simulation of Training: A Review of the Program. (Report No. AM-69-24). Washington, DC: Federal Aviation Administration.

Gerstenfeld, A. (1988). "Simulation Combined with Cooperating Expert Systems: An Aid for Training, Screening, and Plans and Procedures." Journal of ATC (April/June), pp. 33-35.

Greenfield, P. M. (1984). Mind and Media: The Effects of Television, Video Games and Computers. Cambridge, MA: Harvard University Press.

Harris, P. A. (1986). A Construct Validity Study of the Federal Aviation Administration Multiple Controller Aptitude Test. Unpublished Manuscript.

Herrmann, N. (1989). The Creative Brain. Lake Lure, NC: Brain Books.

Huggins, A. W. F., Newman, D., Grignetti, M., and Feurzeig, W. (1988). Intelligent Technology for ATC Training. Proceedings of the Symposium on Traffic Control Training for Tomorrow's Technology. Oklahoma City, OK: Federal Aviation Administration.

Johnson, S. L. (1981). Effect of Training Device on Retention and Transfer of a Procedural Task. Human Factors, 23(3), 257-272.

Just, M. A. and Carpenter, P. A. (1985). Cognitive Coordinate Systems: Accounts of Mental Rotation and Individual Differences in Spatial Ability. Psychological Review, 92(2), 137-172.

Karson, S. and O'Dell, J. W. (1974). Is the 16PF Factorially Valid? Journal of Personality Assessment, 38, 104-114.

Keiser, T. C. and Seller, J. H. (1987). Games and Simulations. in R. L. Craig (Ed.) Training and Development Handbook. New York, NY: McGraw-Hill Book Company.

Kirckham, W. R., Collins, W. E., Grape, P. M., Simpson, J. M., and Wallace, T. F. (1978). Spatial Disorientation in General Aviation Accidents. (Report No. FAA-AM-78-13). Washington, DC: Federal Aviation Administration.

Krumboltz, J. D. and Cristal, R. E. (1960). Short-Term Practice Effects in Tests of Spatial Aptitude. Personnel and Guidance Journal, 38, 385-391.

Manning, C. A., Kegg, P. S., and Collins, W. E. (1988). Studies of Poststrike Air Traffic Control Specialist Trainees: II Selection and Screening Programs. (Report No. FAA-AM-88-3). Washington, DC: Federal Aviation Administration.

Manning, C. A., Della Rocco, P. S., and Bryant, K. D. (1989). Prediction of Success in FAA Air Traffic Control Field Training as a Function of Selection and Screening Test Performance. (Report No. DOT/FAA-AM-89-6). Washington, DC: Office of Aviation Medicine.

Martin, D. W. (1985, April). Applied vs. Basic Research: On Maintaining Your Balance with a Foot in Each Camp. Paper presented at the Annual Meeting of the Rocky Mountain Psychological Association, Tucson, Arizona.

McClurg, P. A. and Chille, C. (1987). Computer Games: Environments for Developing Spatial Cognition? Journal of Educational Computing Research, 3(1), 95-111.

McDaniel, E. (1985, August). Measuring Spatial Ability with A Computer Managed Task. Paper presented at the Annual Meeting of the American Psychological Association, Los Angeles, California.

McDonald, B. and Whitehill, B. V. Visual Recognition Training: Effectiveness of Computer Graphics. (NPRDC No. TR 87-21). San Diego, CA: Navy Personnel Research and Development Center, (DTIC No. AD-A179 996).

Means, B., Mumaw, R., Roth, C., Schlager, M., McWilliams, E., Gagne, E., Rice, V., Rosenthal, D., and Heon, D. (1988). ATC Training Analysis Study: Design of the Next Generation ATC Training System. (OPM Work Order 342-036). Washington, DC: HumRRO International.

Molina, R. R. (1985, January). The Effects of Selected Variables on Learning a Spatial Visualization Task: A Report of Research in Progress. Paper presented at the Annual Convention of the Association for Educational Communications and Technology, Anaheim, California.

Myers, K., Hendriz, S. B., and Guthrie, A. (1989). Stand-Alone Radar Training System Implementation Specifications Kansas City ARTCC (ZKC). Unpublished manuscript.

Netrolgoic, Inc. (1989). Neural Networks for Air Traffic Control. (DOT Contract Report No. DTRS-57-88-C-00 115). San Diego, CA: D. Greenwood, Principal Investigator.

Orlansky, J. (1982). Current Knowledge and Projection of Assessing the Effectiveness of Training. Arlington, VA: Institute for Defense Analysis. (ERIC Document Reproduction Service, No. ED 230 170).

Palmer, J. and Snyder, T. F. F. (1986). Computer Simulations Come of Age. New Directions for Continuing Education, 30, 15-24.

Pepin, M., Beaulieu, R., Matter, R., Leroux, Y. (1985). Microcomputer Games and Sex-Related Differences: Spatial, Verbal, and Mathematical Abilities. Psychological Reports, 56, 783-786.

Pepin, M., Dorval, M. (1986, April). Effect of Playing A Video Game on Adults' and Adolescents' Spatial Visualization. Paper presented at the Annual Meeting of the American Educational Research Association, San Francisco, California.

Pfeiffer, J. W. and Ballew, A. C. (1988). Using Case Studies, Simulations and Games in Human Resource Development. San Diego, CA: University Associates, Inc.

Ramachandran, V. S. and Anstis, S. M. (1986). The Perception of Apparent Motion. Scientific American, 254, 102-109.

Regian, J. W. and Schneider, W. (1988). Assessment Procedures for Predicting and Optimising Skill Acquisition After Extensive Practice. Manuscript submitted for publication.

Schuytema, E. C. (1980, April). Development and Evaluation of Problem-Solving Skills in Microbiology. Paper presented at the Annual Meeting of the American Educational Research Association, Boston, Massachusetts.

Sells, S. B., Dailey, J. T., and Pickrel. E. W. (1984). Selection of Air Traffic Controllers. (Report No. FAA-AM-84-2). Washington, DC: Federal Aviation Administration.

Smith, I. M. (1984). Spatial Ability: Its Educational and Social Significance. San Diego, CA: Robert R. Knapp.

Smith, J. (1988). Using Models, Mock-Up and Simulators. In J. Gordon, R. Zemke and P. Jones (Eds.). Designing and Delivering Cost Effective Training and Measuring the Results. Minneapolis, MN: Lakewood Books.

Smith, J. F. (1981). Experience with Flight Simulators-Training Effectiveness and Future Developments. (AFHRL Report No. TP-81-11). Williams Air Force Base, AZ: Air Force Human Resources Laboratory, NTIS No. AD A108087).

Smith, P. E. (1987). Simulating the Classroom with Media and Computers. Simulation and Games, 395-413.

Smith, R. C. (1974). A Realistic View of the People in Air Traffic Control. (Report No. FAA-AM-74-12). Washington, DC: Department of Transportation.

Staff. (February, 1979). Computer Based Education Tests Pilots, Manages Training Program at United Airlines. Technological Horizons In Education, 6(2), 37.

Stein, E. L. and Kobrick. J. L. (1984). A Brief History of the Use of Simulation Techniques in Training and Performance Assessment. (Report No. M22/84). Natick, MA: U.S. Army Research Institute of Environmental Medicine. (DTIC No. AD-A140763).

Stein, J. (Ed.). (1982). The Random House College Dictionary Revised Edition. New York, NY: Random House.

Toquam, J. L., Corpe, V. A., Dunnette, M. D., and Keyes, M. A. (1986). Cognitive Abilities-Theory, History and Validity: A Review of the Literature. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Turner, J. E. (1986). Civil Service Test Tutor: Air Traffic Controller. New York, NY: ARCO.

University of Oklahoma, NEF, HumRRO. (1989). The Development of a New Air Traffic Screening System. (DOT Contract DTFA-02-85-D-85047). Oklahoma City, OK: University of Oklahoma Continuing Education and Public Service.

Waag, W. L. (1981). Training Effectiveness of Visual and Motion Simulation. (AFHRL Report No. TR-79-72). Williams Air Force Base, AZ: Air Force Human Resources Laboratory (NTIS No. AD A094530).

Wesson, R. B. and Young, D. (1988). Tracon, Air Traffic Control Simulator for IBM PC and Compatible Microcomputers. Austin, TX: Wesson International

Wing, H. (1978, November). Practice Effects with Traditional Mental Test Items. Paper presented at the Nineteenth Annual Meeting of the Psychonomic Society, San Antonio, Texas.

Zemke, R. (1982). Can Games and Simulations Improve Your Training Power? Training, 19(2), 24-27.

APPENDIXES

APPENDIX A

TERMS AND DEFINITIONS USEFUL IN

PLAYING TRACON

This area defines acronyms and definitions that will be helpful both in reading this thesis and in understanding terms associated with playing the radar simulation game, TRACON.

Air Route Traffic Control Center (ARTCC) -- A centralized location where numerous enroute controllers have jurisdiction over a large amount of airspace divided into sectors. It is frequently referred to by pilots as the "Center".

Air Traffic Control (ATC) --Ground based coordination of aircraft utilizing radar and pilot/controller radio telephony intended to prevent midair collisions and expedite the safe and orderly flow of air traffic.

Approach Control -- The ATC facility responsible for radar separation and coordination of aircraft in the vicinity of an airport. Approach Control's jurisdiction extends about 20-40 miles form the airport horizontally and up to 10-12 thousand feet vertically.

Automated Radar Terminal Systems (ARTS) -- The generic term for computer-mediated radar data processing facilities located in most TRACON's. ARTS II systems are used at low to medium density facilities, while ARTS III systems are available for high density situations.

Automatic Altitude Reporting -- That function of a transponder which responds to Mode C interrogations by transmitting the aircraft's altitude in 100-foot increments.
Below Minimums -- Weather conditions below the minimums prescribed by regulation for the particular action involved; e.g., landing minimums.

Clearance -- A set of flightpath parameters, generated by an ATC facility and similar, if not identical to a pilot's requested flightplan, which specifies how the IFR aircraft will proceed to its destination. The clearance consists of assigned altitudes, airways, radio frequencies, etc and must be obeyed until superseded by an amended clearance.

Cleared for (type of) Approach -- ATC authorization for an aircraft to execute a specific instrument procedure to an airport.

Conflict -- A situation in which one or more aircraft, through controller inaction, has been allowed to violate a governmental directive such as radar separation minima. A controller is charged with the prevention of conflicts as his primary job task.

Conflict Alert -- A function of certain air traffic control automated systems designed to alert radar controllers to existing or pending situations that require his immediate attention/action.

Control Tower -- The ATC facility responsible for the visual separation and coordination of aircraft in the immediate vicinity of an airport. The tower's airspace generally extends five miles from the airport.

Controller -- Person who mans the radar scope and towers and performs the functions of air traffic control.

Departure Control -- The ATC facility which compliments Approach control, coordinating departing aircraft via radar near a major air terminal. It is colocated with Approach control in the TRACON.

Final Approach Fix (FAF) -- The geographical point at which a pilot, referring solely to a published approach procedure and his instruments, begins a final descent to an airport. This point is generally specified by a fix location and an altitude from which the approach must begin.

Fix -- A specified geographical location used in air navigation. Usually, fixes are easy-to-locate points formed by radio beacons.

Flightstrip -- As an aircraft transits the various sectors and receives clearances, the current flightplan parameters are continually printed out by the computer on strips of paper. These strips are then used by each controller responsible for that aircraft as a memory aid.

Fly Heading (degrees) -- Informs the pilot of the magnetic heading (0-359) degrees that he should fly.

Handoff -- To release control of an aircraft and give it to another ATC facility or sector as a flight proceeds past the limits of a control jurisdiction.

Hold -- A command which directs the aircraft to fly in a oval pattern (holding pattern) stopping its forward progress for a specified period of time.

Instrument Flight Rules (IFR) -- A set of guidelines and regulations created by the FAA which define standardized requirements and procedures for flight without visual reference to the ground.

Missed Approach -- When conditions prevent a pilot from completing an instrument approach to a landing, a missed approach is declared and the pilot may elect to try again and proceed to an alternate destination airport.

Outer Marker -- The radio fix form which a particular kind of instrument approach--called a precision approach--is begun.

Radar -- Acronym for Radio Detection and Ranging. A device which, by measuring the time interval between transmission and reception of radio pulses and correlating the angular orientation of the radiated antenna beam or beams in azimuth and/or elevation of objects in the path of the transmitted pulses.

"Resume Normal Navigation" -- A command which directs an aircraft to fly back to the track and speed from which it had been vectored and proceed as specified in its clearance.

Squawk -- Controller instruction to activate specific modes/codes/functions on the aircraft's transponder; e.g., "Squawk code zero three two zero.

Terminal Area -- A general term used to describe airspace in which approach control service is provided.

Track -- The airway segment along which an aircraft would ideally fly. Pilot inattention and controller vectors both cause an aircraft to fly "off-track".

TRACON -- Acronym for Terminal Radar Approach Control.

Transponder -- An airborne receiver/transmitter combination which replies to the ground-based radar interrogation pulse with a coded signal uniquely identifying the aircraft.

Vector -- To issue a specific heading change command to an aircraft, usually as a collision-avoidance technique. The aircraft is said to be "on a vector" until another command such as "resume normal navigation", cancels it.

Visual Flight Rules (VFR) -- A set of governmental regulations and guidelines for aircraft not necessarily under continual control of an ATC facility and flying by visual reference to the ground.

Vortac -- Also called VOR or omni, a VORTAC is a navigational radio beacon broadcasting in the VHF frequency band.

Adapted from the operators manual for TRACON, by Wesson International, 1988, and from the Airman's Information Manual, a regular publication of the U.S. Government.

APPENDIX B

DEMOGRAPHIC QUESTIONNAIRE

LAST NAME________________________ FIRST NAME____________________

1. What is your age______________.

2. Are you male_______ Female _______.

3. Are you pursuing a degree YES__________NO__________

4. Are you pursuing certification YES__________ NO__________

5. What is your area of study ___________________________
____
____.

6. Are you currently employed YES___________ NO___________

7. If YES, do you work PART TIME ___________ FULL TIME____________

8. Is your job function aviation related

YES____________NO____________

9. Do you have any military experience YES _______ NO ______.

10. If YES, how much time did you spend in military service
____

11. What military career field were/are you in _______________
____.

12. Check which aviation certificates you hold

NONE	____________		
PRIVATE	____________	GROUND INSTRUCTOR	__________
COMMERCIAL	____________	CFI	__________
INSTRUMENT	____________	CFII	__________
MULTI-ENGINE	____________	A&P	__________
SEA-PLANE	____________	OTHER (PLEASE SPECIFY)	______

____

13. If NONE, how many hours of aviation experience do you have ____________________________

14. Referring to question #12, In what area(s) do you have the above experience__________________________________
____

15. Have you ever had any air traffic control experience

YES ________ NO _________ If YES, in which of the following areas

CTO	____________
RADAR CERTIFIED	____________
DEVELOPMENTAL	____________
MILITARY CONTROLLER	____________
OTHER	____________ (PLEASE SPECIFY)________________.

_____________________________.

16. How much total time for the experience listed above ______________.

17. Have you ever trained in an aviation simulator
    YES ________ NO ________

18. How much computer experience do you have

NONE (HOURS)	________
SOME, BUT COMPUTERS SCARE ME	________
WORD PROCESSING ONLY	________

Would you classify yourself as:

BEGINNER	________
ELEMENTARY	________
INTERMEDIATE	________
WORD PROCESSING ONLY	________
ADEPT	________
EXPERT	________

19. Do you know how to write computer programs
    YES ______ NO ______

20. On the average, how often do you play computer games
    ____

21. Do you own your own computer YES _____ NO _____

APPENDIX C

SPATIAL ORIENTATION TEST AND DIRECTIONS

DIRECTIONS FOR TAKING THE SPATIAL ORIENTATION TEST

Each question has two sets of symbols that are analogous to each other. That means the sets share a common characteristic, while they differ in a specific aspect of that characteristic. In each question, the first set contains three symbols, and the second set two symbols and a question mark. Following the symbol sets are five alternatives labelled A, B, C, D, and E. You must choose the one lettered symbol which can best be substituted for the question mark. The correct choice will have the characteristic common to both sets of symbols and yet maintain the same variation of that characteristic as the two symbols in the second set.

These directions and subsequent exam and answers were extracted from:
Turner, J.E., (1986) Civil Service Test Tutor: Air Traffic Controller. New York: Arco.

Section 2

Time: 15 minutes

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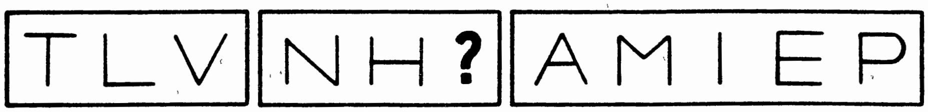

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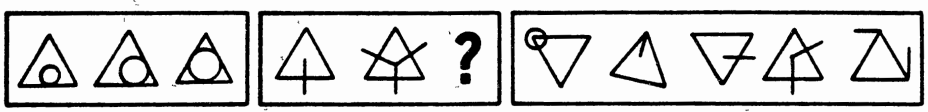

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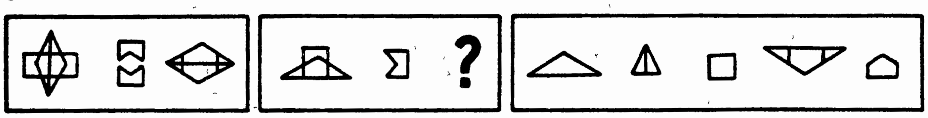

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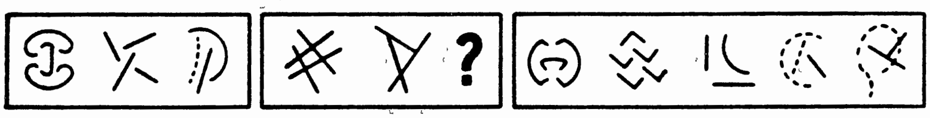

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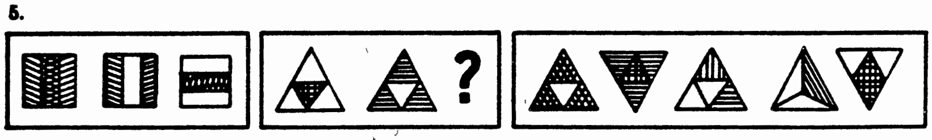

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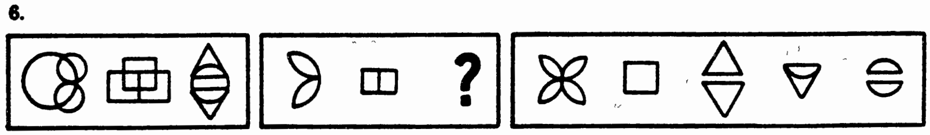

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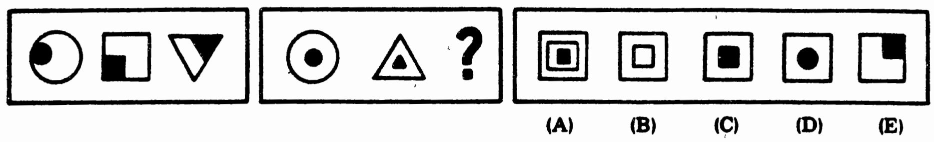

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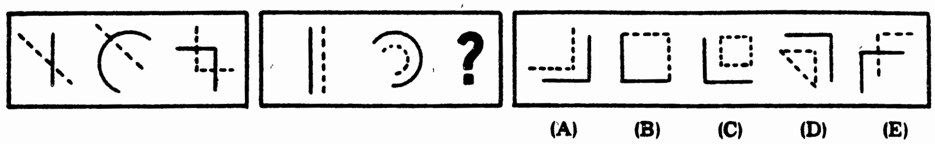

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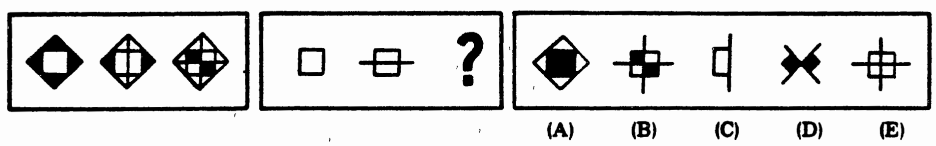

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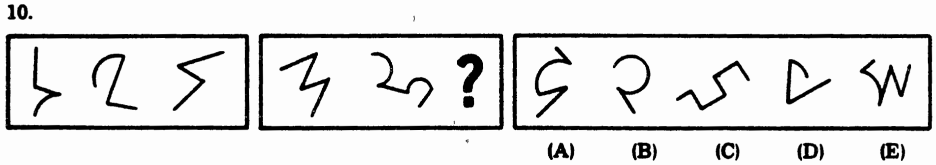

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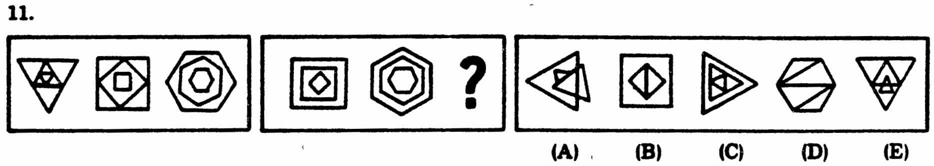

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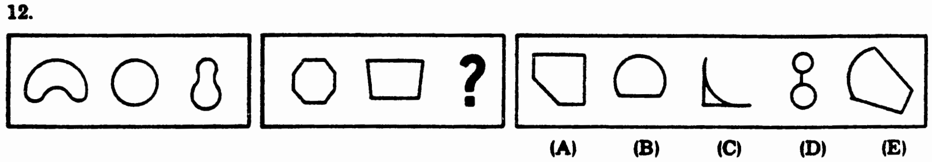

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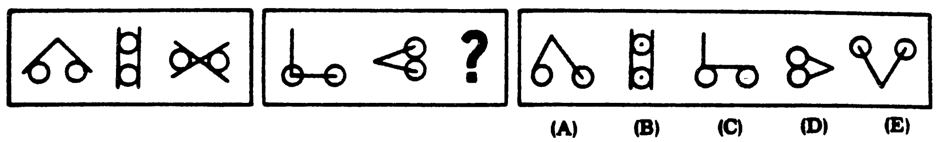

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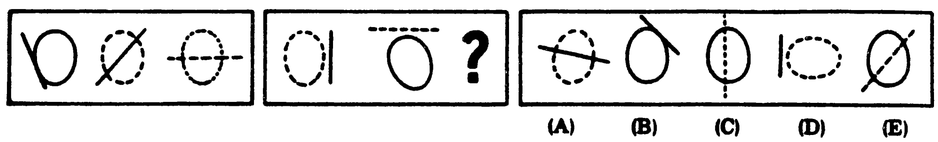

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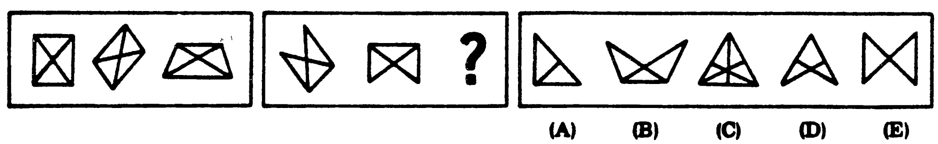

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Section 3

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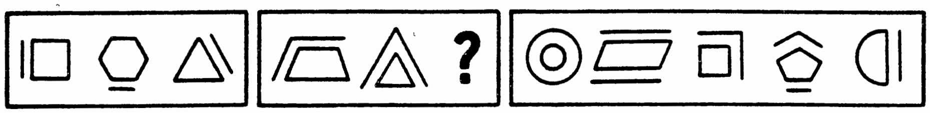

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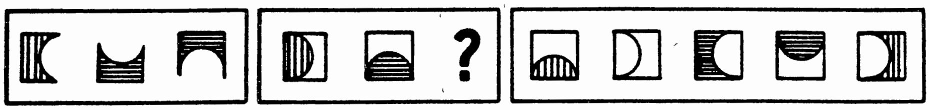

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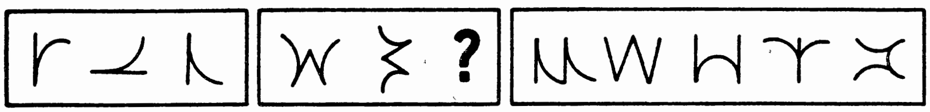

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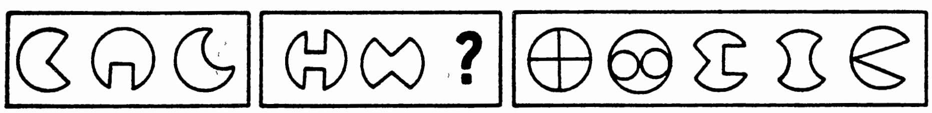

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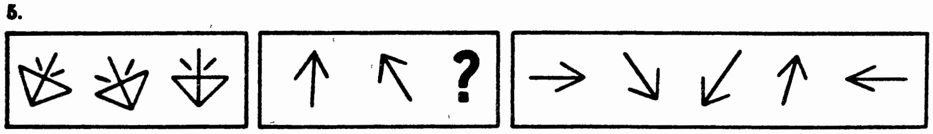

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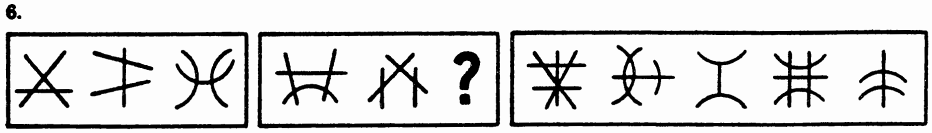

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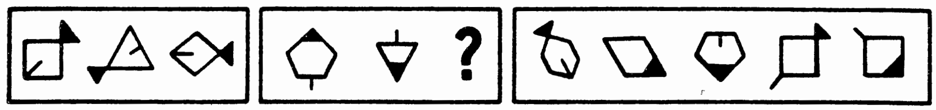
Air Traffic Controller

7.



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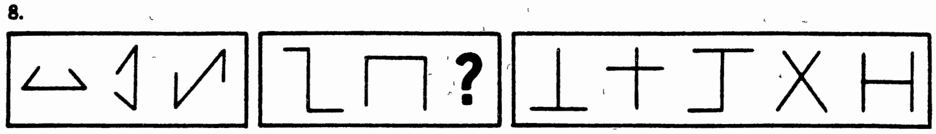

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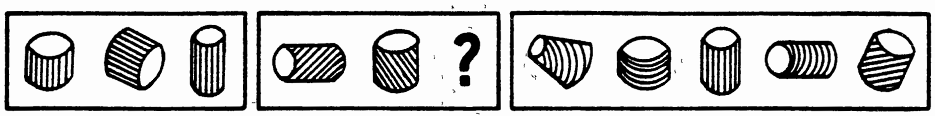

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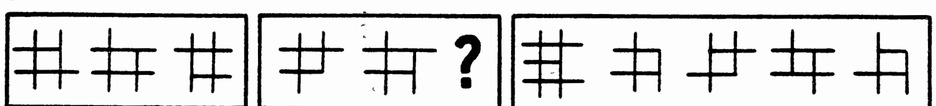
10.



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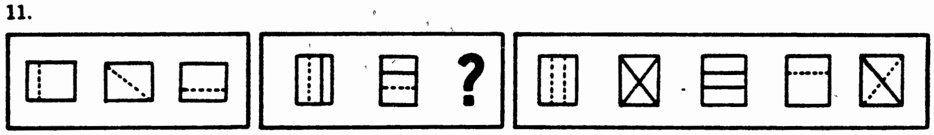

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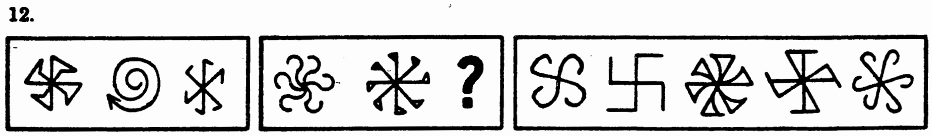

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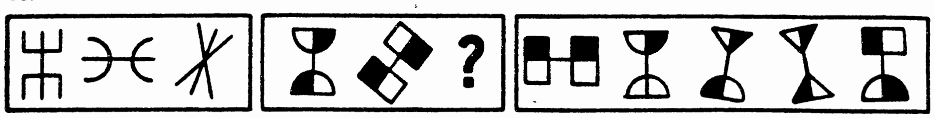

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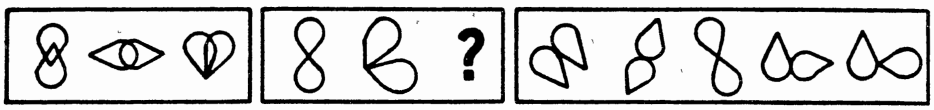

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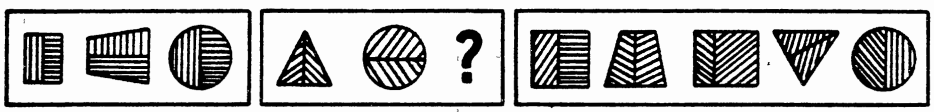

(A) (B) (C) (D) (E)

END OF TEST

APPENDIX D

ANSWER KEY FOR THE SPATIAL

ORIENTATION TEST

SECTION 2

1. A
2. D
3. D
4. E
5. B
6. E
7. C
8. A
9. B
10. A
11. C
12. A
13. E
14. D
15. B

SECTION 3

1. C
2. D
3. A
4. D
5. D
6. B
7. E
8. A
9. E
10. D
11. E
12. C
13. D
14. C
15. B

APPENDIX E

LESSON PLAN OUTLINE FOR TEACHING THE TRACON SIMULATION GAME

I. INTRODUCTION

A. PURPOSE OF THE EXPERIMENT

1. TESTING ABILITY TO THINK SPATIALLY

2. WE WILL RANDOMIZE THE GROUPS IN A MOMENT

3. HALF WILL STAY HERE

4. HALF HAVE A DIFFERENT TASK

5. EVERYONE WRITE NAME ON 3X5 CARD

B. EVERYONE FILLS OUT QUESTIONNAIRE

1. PRINT NAME ON TOP

2. USE THIS NAME ON GAME

C. HAND OUT PRE-TEST ANSWER SHEET TO ALL

1. USE SAME NAME

2. LAST NAME FIRST

3. ONE HALF HOUR TO TAKE TEST

II. RANDOMIZE THE GROUP

A. PUT 3X5 CARDS INTO A HAT

1. CHOOSE ONE CARD AT A TIME

2. FIRST CARD "A" GROUP/SECOND CARD "B", ETC

a. "A" GROUP IS TREATMENT GROUP
b. "B" GROUP IS CONTROL GROUP

B. CONTROL GROUP GOES TO DIFFERENT ROOM

III. TEACHING THE GAME

A. QUICK REFERENCE COMMANDS/KEYBOARD

1. MAKE SURE EVERYONE KNOWS WHERE THESE KEYS ARE

2. F1-WILL GIVE YOU ONLINE HELP

3. ALT/F1 WILL GIVE YOU ALT KEY HELP

a. ALT/A-TURNS AIRWAYS ON AND OFF
b. ALT/F-SHOW FLIGHTPLAN
c. ALT/G-GROUND ON OR OFF
d. ALT/I-INFO ABOUT AIRPORT OR AIRCRAFT
e. ALT/M-MAP NAMES ON OR OFF
f. ALT/S-SAVE SIMULATION TO FILE

4. DEMONSTRATE ALL ALT COMMANDS

a. HAVE SUBJECTS SIGN ON
b. GO TO MIAMI AIRSPACE
c. RUN THROUGH ALT COMMANDS
   1) CHECK WORK
   2) ASK FOR QUESTIONS

5. ARROW COMMANDS

a. RIGHT ARROW-TURN RIGHT
   1) TO A HEADING OF...
   2) TYPE IN HEADING NUMBER

b. LEFT ARROW-TURN LEFT
   1) TO A HEADING OF
   2) TYPE IN HEADING NUMBER

c. UP ARROW-"CLIMB AND MAINTAIN"
   1) REFERS TO NEW HIGHER ALTITUDE
   2) TYPE IN ALTITUDE NUMBER

d. DOWN ARROW-"DESCEND AND MAINTAIN"
   1) REFERS TO NEW LOWER ALTITUDE
   2) TYPE IN ALTITUDE NUMBER

6. DEMONSTRATE ARROW COMMANDS

7. OTHER COMMANDS

a. ENTER-EXECUTES ALL COMMANDS
b. END-CLEARED FOR APPROACH/HANDOFF
c. DEL-RESUME NORMAL NAVIGATION
d. PAGE UP-REPORT HEADING AND SPEED
e. INSERT-MAKE YOUR SPEED
   1) SLOWS AIRCRAFT DOWN
   2) TYPE IN NEW SPEED NUMBER

f. HOME-CLEARED DIRECT TO...
   1) TO INTERSECTION OR FIX
   2) TYPE IN FIX NAME

8. DEMONSTRATE THE USE OF THESE COMMAND KEYS

B. READING THE FLIGHT STRIPS

1. EXPLAIN DIFFERENCE BETWEEN PENDING AND ACTIVE

a. CAN ACTIVATE ONLY ACTIVE STRIPS
b. HOW DO YOU HIGHLIGHT STRIP TO "TALK TO"

2. FIRST LINE
   a. FIRST NUMBERS ARE AIRCRAFT IDENTIFICATION
   b. SECOND SET IS AIRCRAFT TYPE
      1) LEAR, B-727, ETC
      2) EXPLAIN DIFFERENCES IN PERFORMANCE

   c. NEXT SET IS SPEED IN KNOTS
   d. LAST SET IS ALTITUDE-LAST ZERO DROPPED

3. SECOND LINE

   a. EXPLAIN ROUTE OF FLIGHT
   b. EXPLAIN DESTINATION
   c. EXPLAIN DIFFERENCE BETWEEN
      1) LANDING
      2) OVERFLIGHTS

C. COMMUNICATIONS READOUT

1. THERE WILL BE NO SOUND

   a. TOO MANY IN ROOM
   b. CONFUSING TO OTHERS

2. BOTTOM OF SCREEN

   a. AIRCRAFT TALKING BY AIRCRAFT ID NUMBER
   b. CONTROLLER TALKING BY APP/DEP CUE

IV. SIT DOWN ON VACANT CONSOLE AND DEMONSTRATE

A. SET UP PARAMETERS
   1. PARTICIPANT'S NAME
   2. MIAMI
   3. IFR WEATHER
   4. PERFECT PILOTS
   5. NO WIND
   6. SET UP TWO OR THREE AIRCRAFT
      a. TALK PARTICIPANTS THROUGH ACTION
      b. RUN THROUGH ALL COMMANDS

B. WALK THROUGH ADDITIONAL PRACTICE SESSIONS

   1. THIS CONTINUES FOR ONE HOUR
   2. INCREASE DIFFICULTY EACH DEMONSTRATION

      a. STOP AND RE-START AS NECESSARY
      b. ANSWER QUESTIONS AS NECESSARY

C. GIVE TEN MINUTE BREAK

D. HAVE STUDENTS PRACTICE FREE-FORM FOR 45 MINUTES

   1. ANSWER QUESTIONS
   2. DEMONSTRATE INDIVIDUALLY
   3. MAKE SURE ALL BENEFIT FROM THE QUESTION/ANSWER

E. GIVE TEN MINUTE BREAK

1. SET STUDENTS UP IN MIAMI SCENARIO
2. SET UP PARAMETERS AS FOLLOWS

   a. USE SAME NAME
   b. CONTROL SECTOR-MIAMI
   c. SIMULATION-NEW
   d. 10 AIRCRAFT OVER 45 MINUTES
   e. WEATHER-IFR
   f. PILOTS-PERFECT
   g. WIND-NO FACTOR (DEFAULT)

3. HAVE STUDENTS ALL START TOGETHER
4. ANSWER NO QUESTIONS

   a. "CHEAT SHEET" WILL BE ON THE BOARD
   b. TELL THEM HOW TO GET INFORMATION ONLY

5. AFTER 45 MINUTES

   a. HAVE EVERYBODY STOP
   b. HAVE EVERYBODY PUSH ALT/S TO SAVE DATA

F. GIVE TEN MINUTE BREAK

1. GATHER GROUPS TOGETHER
2. GIVE EVERYBODY POST-TEST ANSWER SHEET
3. ADMINISTER TEST
4. 30 MINUTE TIME LIMIT

G. COLLECT MATERIALS

1. THANK EVERYBODY
2. DISMISS

VITA

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Candidate for the Degree of

Doctor of Education

Thesis: A STUDY OF THE RELATIONSHIP BETWEEN PRACTICE IN THE USE OF A RADAR SIMULATION GAME AND ABILITY TO NEGOTIATE SPATIAL ORIENTATION PROBLEMS

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