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(6) CONTRIBUTIONS OF PLATFORM MOTION TO SIMULATOR TRAINING EFFECTIVENESS: STUDY I – BASIC CONTACT.

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A transfer-of-training design was used to evaluate the contributions of simulator training with a synergistic six-degree-of-freedom platform motion system to the acquisition of basic contact, approach and landing skills. Twenty-four Undergraduate Pilot Trainees were divided into three groups: (a) Motion, (b) No Motion, and (c) Control. The Motion and No-Motion groups received ten instructional sorties in the Advanced Simulator for Pilot Training (ASPT) on a large number of basic contact tasks ranging in complexity from Straight-and-Level to the normal Overhead Pattern and Traffic Pattern Stalls. Both groups received the same amount of training on each task. The only difference in training condition between the two groups was the presence or absence of motion cues provided by the platform system. (The G-seat was not used.) All tasks were taught using the full field-of-view

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available on the ASPT's computer-generated image visual system. The students in the Control group received the standard pre-flight training (i.e., no ASPT pretraining). Student performance during the simulator training phase was assessed by Instructor Pilot ratings of task performance and automated objective performance measures.

Two indices of transfer value were used. Short-term transfer was assessed for the Motion and No-Motion groups on the first and the fifth T-37 missions. Mission scenarios were designed to include all tasks taught during the simulator training phase. Student performance on each task was evaluated by instructor pilot ratings. Long-term measure transfer effects were provided by the task frequency data collected on selected tasks for students in all three groups on approximately their first 20 aircraft flights (through solo).

The major findings of the study are: (a) no differences in simulator performance between the Motion and No-Motion groups; (b) significant learning occurred during simulator training for both groups; (c) no difference in performance between the Motion and No-Motion groups for any of the tasks on the two special data sorties flown in the T-37; (d) no significant differences were found between the Motion and No-Motion groups in the task frequency data, although there was a trend for the Motion group to perform slightly better; (e) the two groups trained in the ASPT performed significantly better than the control group on all of the more advanced tasks. The results of this study establish the potential training value of the modern generation ground-based trainers. However, the data failed to reveal any significant or practical enhancement of training effectiveness as a result of the addition of platform motion.

PREFACE

This report represents a portion of the research program of project 1123, USAF Flying Training Development, Mr. James F. Smith, Project Scientist; task 112301, Development of Performance Measurement Techniques for Air Force Flying Training, Dr. Elizabeth L. Martin, Task Scientist.

This study was conducted by the Flying Training Division of the Air Force Human Resources Laboratory (AFSC) and supported by the 82d Flying Training Wing (ATC), Williams AFB, Arizona.

The conduct of this research would have been impossible without the assistance of Maj Robert R. Fuller and Capt John H. Fuller. These individuals were primarily responsible for the development of the automated performance measures used in this study, the collection of preliminary data in a pilot study, and the design of the syllabus used in the present study. Their technical expertise, professional attitude, and patience contributed substantially to all phases of this study.

The authors are also grateful to Capts Bruce Smith and Douglas Weyer for their efforts in the conduct of special data rides flown in the T-37. The assistance of Capt Robert McFadden in the planning and data collection phases of the study is also appreciated.

The support rendered by the members of the 82d FTW Deputy for Operational Research Staff for the simulator training of the students made this study possible.

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I. INTRODUCTION

Background

The United States Air Force is attempting to achieve a significant reduction in flying time by the early 1980s. This reduction must be accomplished without a concomitant decrease in mission readiness of the force. One of the major mechanisms by which flying time reduction can be accomplished is through greater and more effective use of aircraft flight simulators. Extensive efforts are being undertaken to examine the training effectiveness of current and future simulator facilities and programs. In many cases, current facilities will not be sufficient to support the training demands which will be made in the near future. Therefore, major additions and improvements are required. Moreover, the addition of new weapons systems into the inventory will be associated with the procurement of new synthetic flight devices.

Advances in simulation technology make available a wide variety of sophisticated systems and subsystems for combination into a training device that best meets the demands of the user. Many of the options are designed to increase the training value of a device by making it possible to implement innovative instructional and training methods. The capability for real-time automated performance measurement and feedback, adaptive training, programmed demonstrations, rapid placement of any aircraft position, and self-confrontation are examples of training-oriented features. Other options currently available to the user are designed to increase the potential for training effectiveness by increasing the fidelity (or realism) of the device. Full field-of-view visual systems of a variety of types, synergistic six-degree-of-freedom platform motion systems, G-seats, and G-suits are typical of fidelity-oriented hardware.

The user is placed in a position of deciding how many of these features are necessary for the intended use of the device. He must define the training requirements and estimate how much the various options can contribute to achieving those objectives. He must also determine the value of the expected benefits relative to the cost of the hardware capability required to yield those benefits. Unfortunately, the user is too often in the position of having to make such decisions in the absence of sufficient information.

Technological advances have proceeded too rapidly for the research community to keep ahead or even abreast of engineering developments. In an effort to bridge the gap, a research strategy is required which provides the most needed information in the quickest possible time frame. The simulator user needs several types of information to aid in the design and procurement decision-making process which should be forthcoming from the research community. Behavioral research can provide information relative to several important criteria: (a) user acceptance, (b) the feasibility of training tasks which cannot be practiced in the aircraft (e.g., some emergency situations, missile evasion techniques), and (c) training effectiveness. Evaluating the training effectiveness of a device is one of the most important types of information and is, unfortunately, one of the most time-consuming and difficult research areas. The user is interested in either a time/cost savings and/or a higher level of performance given the same time/cost.

Problem and Research Strategy

In considering the category of capabilities referred to earlier as fidelity-oriented hardware, two major option areas (in terms of cost and training potential) are motion and visual systems. The present study is one in a series concerned with assessing the training effectiveness of vestibular/kinesthetic motion cueing options such as platform, G-seat, and G-suit systems. Motion cues can be provided visually, as well as via vestibular and kinesthetic systems. For convenience, the term motion systems will refer to systems designed to provide vestibular and kinesthetic cues. The dimensions of relevance from the training research standpoint are: (a) the type of aircraft to be simulated, (b) the type of tasks to be trained, and (c) the experience level of the pilots. The most effective system may vary and interact along these dimensions. The effectiveness of the system may be a function of the presence of other motion cues provided by instruments or the external visual environment. For example, cues provided by a G-suit may have no benefit for the transition training of a less experienced pilot in a transport type of aircraft, but may be the most effective system for maintaining air combat skills of an experienced fighter pilot.

Previous research in the area of platform motion cue simulation has addressed a variety of hardware and software configurations, aircraft and trainer types, task types, and dependent measures. Findings seem to be functions of all of these variables, as well as training factors; such as, amount of practice, type of feedback, and pilot experience level. Therefore, it is difficult to synthesize the body of existing information relating motion cues to pilot performance. Much of the research has concentrated on the effects of platform motion cues on relatively simple and abstract tasks (as compared to actual flight) such as pursuit or compensatory tracking. Alternative motion cueing configurations have been shown to affect measures of pilot control inputs (Shirley & Young, 1968). The effect on error measures of state parameters is apparent on abstract tasks (Bergeron, 1970), but not as pronounced on actual flight tasks (Matheny, 1974).

However useful this information may be for the simulator designer interested primarily in fidelity, it has little or no direct relevance for the training program designer who needs to know the impact of motion cueing on the effectiveness of his simulation training programs. In fact, very little research has been performed investigating the incremental training effectiveness of motion simulation. In a report reviewing much of the earlier work on the effects of motion cue fidelity on pilot performance, Williges, Hopkins, and Rose (1975) conclude that the amount of fidelity required is a function of the intended use of the simulator. With respect to transfer effectiveness on instrument maneuvers, pretraining without motion has been found to be as effective as motion cue pretraining (Koonce, 1974). Thus, while motion cues have been demonstrated to affect pilot control input measures, widespread impact on transfer to inflight criterion-referenced measures has not been indicated. However, much of this earlier motion research was conducted using systems less sophisticated than those currently available. In the absence of training effectiveness research on these systems, the expectation is that the more sophisticated motion cueing systems would provide cues of higher fidelity than previously available systems, and would, therefore, lead to demonstrable training enhancement.

The problem is to assess the training effectiveness of the modern motion cueing systems along these dimensions with a research strategy meeting the criteria discussed previously (i.e., the most critical information in the shortest period of time). The research strategy adopted for this purpose is characterized as a critical dimension testing approach in which a series of short-term, single-variable studies, which compare the most costly with the least costly motion configuration for a specified point along the other dimensions. This would provide the foundation for more extensive studies, should further information be required. The studies should be designed so as to define the end points of the relevant dimensions (e.g., novice vs. experienced pilots, simple vs. complex tasks).

Training effectiveness is typically assessed by using a transfer-of-training paradigm in which preliminary training is given in at least two candidate systems, followed by a comparative performance evaluation in the criterion system. In most cases, one or more experimental treatments are compared with some standard (control) treatments. In line with the described research strategy, a motion effectiveness design would involve the selection of the cueing system to be investigated, a training task, an aircraft, and a pilot experience level. The latter factors would be held constant, while at least two levels of motion cueing would be present. In the case of a critical dimension approach, the extremes of presence vs. absence of the cues would be appropriate. The present study was designed to assess the contribution of a synergistic six-degree-of-freedom (DOF) platform motion system to the acquisition of basic contact flying skills in the T-37 aircraft. Platform motion cueing would be investigated first, since it is more costly than G-seat systems. It is well known that motion cues are not necessary for effective simulator training, since pilots have been learning to fly with the aid of fixed-base devices for years. However, the extent to which enhanced motion cues (such as those made available by a 6-DOF system) may contribute or add to the effectiveness of simulator training has not been determined.

II. METHOD

General Approach

A transfer-of-training paradigm was used to assess the contribution of six-degree-of-freedom platform motion relative to no-motion cueing on the acquisition of basic contact, takeoff, approach and landing skills. Contact flying skills; i.e., skills requiring external visual cues, were the focus of the present study, since there is little information regarding motion cue effectiveness on these tasks, particularly those requiring or utilizing a full field-of-view (FOV) visual display. The tasks chosen for investigation represent the basic transition skills which must be mastered by the beginning student in the Air Force Undergraduate Pilot Training (UPT) program. Thus, the present study represents one point of intersection of the dimensions of task type, aircraft type, motion system type, and pilot experience level which has not been previously addressed.

Two groups of UPT students received blocked training in the Advanced Simulator for Pilot Training (ASPT) on selected contact maneuvers. One group was trained without simulator motion cues. The other group received identical task training in the presence of motion cues provided by a synergistic six-DOF platform motion system. Student performance was measured periodically during ASPT training. Performance of these two groups, as well as the control group which received no ASPT training, was monitored in the T-37 for selected tasks on all pre-solo missions.

Subjects

Twelve students from UPT Class 77-02 and twelve students from Class 77-03 participated in this study. The subjects were selected from their respective classes on the basis of their previous aircraft and simulator experience. An attempt was made to select students with a minimum of previous flying experience to form homogeneous groups to whatever extent possible. For the sample selected, the source of commission was as follows: thirteen United States Air Force Academy (USAFA), eight Air Force Reserve Officer Training Corps (AFROTC), two Air National Guard (ANG), and one Officer Training School (OTS). The flying background of the sample was as follows: (a) pilot: mean of 28.8 hours with a range of 13.4 to 80 hours, (b) simulator: five students had previous simulator experience with a mean of 16 hours and a range of 1 to 50, and (c) navigator: two subjects had navigator experience of 4 and 20 hours, respectively.

Instructor Pilots

ASPT Training. Six T-37 instructor pilots (IP) from the 82nd FTW/DOR division served as instructor pilots during the ASPT training phase. Four IPs participated for each class. During the transition from Class 77-02 and 77-03, two IPs were replaced. During each class, the assignment of IPs to motion and no-motion conditions was counter-balanced.

T-37 Training. Two Air Force Human Resources Laboratory, Flying Training Division, Williams AFB, Arizona (AFHRL/FT) T-37 research IPs collected initial transfer-of-training data. Each flew two missions with each student. The assignment of IPs to students trained with motion or no-motion was counter-balanced. Due to scheduling conflicts, an additional AFHRL/FT IP was assigned to fly both sorties with one student. With the exception of the two special data sorties flown with AFHRL/FT IPs, flight line instruction was accomplished by line-assigned T-37 IPs from the 96th FTS.

Equipment

Experimental training was accomplished in the ASPT. An overview of the characteristics of the ASPT most relevant to the present study is presented in this section. Detailed descriptions of the device may be found in Hagin and Smith (1974) and Rust (1975).

ASPT is equipped with two T-37 cockpits. Each cockpit has a full FOV visual display of computer-generated images, a six-DOF synergistic platform motion system, and a sixteen panel pneumatic G-seat on the left seat (student position).

The visual display is projected through seven cathode-ray tubes (CRT). The capacity for displaying visual image detail is fixed and shared between the two ASPT cockpits. A highly detailed scene; such as, an airport requires 90% to 100% of the display capacity; thus, only 10% of the capacity would be available to the other cockpit. This amount would result in inadequate representation of a highly detailed scene but is adequate to display a generalized view from altitude such as a horizon, and surface patterns, and mountains.

The visual system uses an infinity optics display with the exit pupil located at the student's eye position. This arrangement results in the desired visual scene from the student position, but a distorted scene from the IP position. From his normal position, the IP is unable to see the visual display immediately in front of the aircraft. The scene becomes less distorted as he scans laterally. By moving his head position nearer to that of the student, the IP can increase his forward-looking view and reduce the distortion.

The ASPT platform motion system is a synergistic six-DOF system driven by six 60-inch hydraulic actuators ("legs" or "rams"). Each ram has a maximum velocity capability of 19 in/sec. The performance characteristics of the ASPT motion base are summarized in Table 1.

Table 1. **Motion Base Performance Characteristics**

Axis	Excursion	Acceleration
Forward – X	+49 in., –48 in.	±0.6 g
Lateral – Y	±48 in.	±0.6 g
Heave – Z	+39 in., –30 in.	±0.8 g
Pitch – Y	+30°, –20°	±50°/sec²
Yaw – Z	±32°	±50°/sec²
Roll – X	±22°	+50°/sec²

The platform motion system software was designed to provide translational and rotational acceleration onset cues to the student pilot position. The drive philosophy for the display of translational acceleration cues is intended to match the aircraft acceleration in magnitude and shape (provided certain boundary conditions are not exceeded). The display of rotational cues is driven by a cue-shaping philosophy which is not intended to match the aircraft onset cue. The rotational velocity rather than acceleration is used as an input. ASPT can also display some sustained acceleration cues via platform movement with a subsystem called "gravity align," which positions the platform in an attempt to substitute for a portion of the external force vector. (ASPT is also equipped with a G-seat which can display sustained acceleration cues. However, the G-seat was not used in the present study and will not be discussed.) The motion system also includes a "special effects" package which is used to display such cues as touchdown bump, runway rumble, aircraft buffet, speed brake extension, and gear-down rumble. (See Kron, 1975, for a more technical discussion of ASPTs hardware and software platform motion capabilities.)

The ASPT has the capability of real-time automated measurement of the pilot's performance. Measurements can be made of pilot inputs, system outputs, and derived scores. The measurement schemes or algorithms for a given maneuver must be preprogrammed. A limited amount of this information can be displayed real-time in the cockpit via a monitor located to the right of the IP position and/or following the mission in hard copy form.

The ASPT is equipped with the capability of displaying a prerecorded demonstration of a maneuver. The information is stored on magnetic tape which enables a reproduction of the entire maneuver, including visual display, motion cues, instrument readings, rudder and throttle movements.

Two additional instructional capabilities of ASPT were utilized in the present study: problem freeze, and reinitialization. The instructor can stop and hold the system at its current position by the use of the problem freeze feature. From this position, the instructor can continue flight from the "frozen" position or return to a starting point of his choice by use of the reinitialization feature. Reinitialization allows the system to go to a designated position and configuration in a matter of seconds. These points are preprogrammed to correspond to optimal starting positions for most maneuvers, including cross-country positions, in the T-37 training program. The main utility of the freeze feature is in its instructional value whereas the reinitialization is a timesaving feature which also allows for tighter experimental control over student practice.

The advanced instructor operator console (AIOS) is equipped with a vector general monitor which has a spatial display option. This option can follow the flight path of the simulated aircraft which can be rotated around the x, y, or z axis. This image can be temporarily stored and displayed following the mission for use in the debriefing.

Procedure

Subject Assignment. The subjects were randomly assigned to one of three treatment conditions: (a) no-motion (NM), (b) 6-DOF motion (M), or (c) control (C). A total of 24 subjects participated with 8 subjects per group. The study was conducted with two consecutive UPT classes (77-02 and 77-03). One-half of each group was comprised of students from each class.

Pretraining. All subjects were given the Williams AFB Runway 30L Left Programmed Text (Smith, Waters, & Edwards, 1975) one week prior to entering the flight line.

IP Training. All ASPT instructors were given verbal and written briefings on the experimental procedure and the use of ASPT and the pertinent instructional features. In addition, the six ASPT instructors rehearsed each ASPT scenario with a practice student. This procedure familiarized them with the scenarios, the operating procedures, and allowed them to tailor their instructional techniques to the restrictions of the study syllabus.

ASPT Training. Subjects assigned to the M and NM groups received 10 training sorties in ASPT beginning on the 11th day of academic training. All sorties were completed prior to the first T-37 mission (B1701). The instructional content of the ASPT sorties was identical for both groups (with the only difference being whether the platform motion system was operative or not). Thus, all subjects in the motion condition received all sorties in the presence of motion cues, while the subjects in the no-motion condition received the same sortie content but with no platform motion. The G-seat was inoperative throughout the study. All training was accomplished under full FOV conditions. Cockpit assignment was alternated daily.

Mission Content. The content of each sortie was specified in terms of the order of maneuver instruction and the number of repetitions per maneuver. The number of trials per maneuver was determined by reference to T-37 task frequency information (Brown & Rust, 1975), data on other trainer skill acquisition rates (Woodruff & Smith, 1974), a preliminary ASPT study, and pilot opinion if no other data were available. It was intended that the number of trials would be sufficient to enable the average student to attain at least a minimum level of proficiency. The 10 ASPT sorties were divided into three categories: (a) basic airwork, (b) pattern work, and (c) mission profiles. A summary of the total number of task repetitions and the content of each mission is found in Appendix A.

a. *Basic Airwork.* There were two missions covering basic contact maneuvers. Both missions were approximately 1.3 hours in length and were accomplished using 10% of the visual capacity. Instructions on these missions were given on the following maneuvers: (a) Straight-and-Level, (b) Airspeed Changes, (c) Constant Airspeed Climbs and Descents, (d) 30° Bank Turns, (e) Turns to Headings, (f) Airspeed Changes while Turning to a Heading, (g) 45° Bank Turns, (h) 60° Bank Turns, (i) Tech Order Climb, (j) Configuration Change, (k) 30° Bank Descending Left Turn, and (l) Slow Flight.

b. *Pattern Work.* There were a total of four pattern missions ranging in length from .8 to 1.5 hours. These missions alternated daily with the mission profile sorties. Instruction on these missions covered (a) Takeoffs and Traffic Exits, (b) Straight-in Approach and Landing, (c) 360° normal Overhead Traffic Pattern and subcomponents, and (d) Touch-and-Go's. All pattern work missions used 90% of the visual capacity.

c. *Mission Profile.* Four ASPT sorties were constructed in a mission profile scenario beginning with a Takeoff and ending with a Landing. These missions alternated daily with the pattern missions ranging in length from 0.75 to 1.3 hours. All of the tasks practiced in the basic and the pattern missions were instructed further in these sorties. In addition, Power-On Stalls and Traffic Pattern Stalls were instructed during these sorties. In the no-motion condition, IPs gave stall cues by manually shaking the stick. In the motion condition, the stall cues were delivered with motion platform buffet.

Performance Measurement. Periodically throughout the 10 ASPT sorties, the students' performance was measured by the automated performance measurement feature on ASPT. The maneuvers and measures computed for each maneuver are presented in Appendix B. Each time the student's performance was measured, the IP also rated the performance on a 12-point scale with the following characteristics: 1 to 3 representing an unsatisfactory performance; 4 to 6 representing a fair level; 7 to 9 reflecting a good level; 10 to 12 representing an excellent performance. The criteria for unsatisfactory, fair, good, and excellent are specified in the Air Training Command (ATC) training syllabus (July 1975). The categories correspond approximately to unsafe, minimum safety, proficient, and superior. These ratings were given immediately following the maneuver over an intercom system and were not available to the student. The portion of the measurement algorithms containing derived scores in the format of time on tolerance and procedural errors was made available to the student immediately following the mission.

Instructional Control. A fixed trial procedure was used according to which the number of trials for each maneuver on each mission was specified. If a maneuver was prematurely terminated at the discretion of the instructor, the attempted trial was considered a complete trial. However, if a maneuver was interrupted due to a system failure, the trial was repeated. An observer was located at each conventional instructor operator console to monitor mission content. For the trials using the automated performance measurement system (APM), the instructor was not allowed to give any instructions. He was allowed to debrief the student's performance following the maneuver. In addition to instructions given in the ASPT, each mission was preceded and followed by a debriefing ranging from .25 to .50 hour in length. Other than these restrictions, no attempt was made to specify or control the individual style of instruction.

T-37 Training and Evaluation

Two separate procedures were used in an attempt to assess the transfer of the motion/no-motion pretraining in ASPT. Special data ride scenarios were designed to cover all maneuvers taught in ASPT. In addition, task frequency data were collected on selected maneuvers on all subjects up to the solo phase of T-37 training. Data collection forms are presented in Appendix C.

Data Rides. All students trained in ASPT were given two special (i.e., syllabus deviations) data rides in the T-37. The scenario of each mission was the same and designed to include all maneuvers practiced in ASPT. The data rides were given on the first (B1701) and fifth (B1801) normally occurring T-37 sorties. All missions were flown by AFHRL/FT research instructor pilots. With the one exception noted earlier, IP assignment was counter-balanced by treatment conditions. The IPs were told to instruct as little as possible while the student was actually performing the maneuvers. They were to assign grades on the 12-point rating scale discussed above for each maneuver performed. The IPs were given pretraining in ASPT on the mission scenario and grading requirements.

Task Frequency. The student's line assigned instructors were asked to fill in task frequency cards on every T-37 mission prior to solo (C2402). The card was constructed so they circled either U, F, G, or E for each repetition of the maneuver on that mission. Task frequency data were collected on the following maneuvers: Takeoff, Straight-In Approach, Landing, Overhead Pattern and Landing; Slow Flight; Power-On Stall; and Traffic Pattern Stall. In addition, the IP was asked to indicate (by circling the appropriate option) whether the student experienced any airsickness (passive or active) and whether he was safe for solo.

III. RESULTS

ASPT Training

All students completed the 10 ASPT mission profiles. Most weekday missions were separated by 24-hour intervals, although occasional system failures resulted in 48-hour intervals. The students' performance in ASPT was evaluated on eleven maneuvers on designated trials using instructor judgments as well as the automated performance measurement system. Due to system malfunctions, not all automated performance measurements were accomplished on the designated trial. In this event, the IP conducted the trial as a measurement trial (i.e., no instruction) and performed the subjective rating of the performance as outlined in the mission scenario. On occasion, a total system failure occurred following a measurement trial, resulting in a data loss. The values for missing data were estimated using the least-squares technique described in Kirk (1968). Algorithm programming errors of certain parameters (e.g., airspeed on Straight-and-Level) resulted in unusable data. These parameters were omitted from data analysis.

From the information contained in the APM system, measures of system output with respect to maneuver criteria (in terms of root mean square) were selected for subsequent analysis. These parameters are listed in Appendix B. The RMS values on the objective measures were logarithmically transformed, normalized to a T distribution, and subsequently combined to form an equally-weighted total score. All analyses were split-plot ANOVAS (motion vs. no-motion as the between-subject factor and trials as the repeated measure) with the degrees of freedom adjusted accordingly for the estimated data points. The IP ratings were also analyzed using a split-plot ANOVA. Thus, two ANOVAS (APM scores and IP ratings) were performed on each of the eleven measured tasks. Appendix B presents the descriptive statistics and results of the data analysis.

There were no significant differences between the motion and no-motion conditions for any of the maneuvers using either the automated performance measures or the IP ratings. A reliable trials effect was found for most maneuvers using both the automated performance measures and the IP ratings. Only two maneuvers, Turns to Headings and Steep Turns, did not result in a significant change for either type of measurement. A reliable trials effect was observed for the automated performance measures but not for the IP ratings for the Slow Flight and Straight-and-Level tasks.

In most cases, the significant trials effects were the result of improvement (decreased RMS and increased IP rating), primarily from the first to second analyzed trials. However, the effect observed for the Constant Airspeed Descent reflects a decrement in performance on the middle measurement trial for the IP measurments and an improvement on the last measurement trial for the RMS error values.

A reliable motion x trials interaction effect was found for only one maneuver, the Constant Airspeed Climb. This effect was observed for the APM scores but not for the IP ratings. The significant interaction was due to the larger RMS error values for the motion condition on the first measured trial. The difference between the conditions was eliminated by the next measurement.

T-37 Training Transfer Evaluations

Two sources of transfer information were utilized in this study: (a) performance on two specially designed T-37 aircraft sorties for the ASPT trained groups, and (b) performance on selected tasks during the normal pre-solo T-37 Undergraduate Pilot Training (UPT) syllabus sorties for the ASPT and Control groups.

Special Data Rides. All 16 students trained in the ASPT received the two T-37 data rides on the first and fifth aircraft sorties. Due to the constraints of local operating procedures, equipment conditions, and weather factors, not all items in the scenario were accomplished for all students on each ride. Due to scheduling requirements, one student was assigned to fly the two sorties with an additional instructor pilot. With this exception, two instructor pilots performed the measurements on these rides and each was assigned one motion and one no-motion student.

The 29 items in the scenarios were collapsed into sixteen separate tasks for data analyses. Although the data card has only one item for the Overhead Pattern, IPs were required to separately evaluate the Pitchout, Downwind, Final Turn, Final Approach and Landing, and record these on the back of the form. In this manner each student was measured on each task. In the event that a score was still missing for one of the trials, the value was estimated by the least-squares technique described in Kirk (1968). Sixteen split-plot ANOVAs were performed on these data with degrees of freedom adjusted accordingly for estimated data. The mean performance ratings and associated statistical tests are presented in Appendix D.

The results of these analyses may be summarized as follows. There were no significant differences between the motion and no-motion conditions either as a main effect or as a trials x treatment interaction effect. There was a reliable trials effect on nine of the 16 maneuvers. The following tasks did not show a reliable trials effect: Straight-and-Level, Airspeed Change, Constant Airspeed Climb and Descent, Configuration Change, Touch-and-Go, Power-On Stall, and the Overhead Pattern. The observed trials effects were the result of improved performance on the second data ride (the student's fifth aircraft sortie).

Task Frequency Data. Task frequency data were collected on all students in the motion and control groups to the solo flight. The data for one student in the no-motion group was discarded due to irregularities in the data recording procedures. Summary statistics and subsequent analyses are presented in Appendix E.

The mean overall score per student per maneuver was computed by assigning numerical values (1, 2, 3, 4) to the assigned grades (U, F, G, E). This technique results in one score per maneuver per student and controls for the unequal number of repetitions per maneuver across the students. One-factor ANOVAs and *a priori* "t" test comparisons were performed. The *a priori* "t" test comparisons were between motion vs no motion, and the ASPT-trained groups combined vs the control group. The F ratios, *a priori* "t" tests and descriptive statistics are presented in Table E3.

The F ratios revealed reliable group differences on Takeoff, Straight-In Approach, Overhead Pattern and Landing and Slow Flight, but not on the Power-On Stall, Traffic Pattern Stall Series, or the Landing from the Straight-In Approach. The *a priori* "t" tests did not reveal any reliable differences between the motion and no-motion groups, whereas the performance of the ASPT trained groups combined was superior to the control groups across all maneuvers.

IV. DISCUSSION

This study was designed to assess the relative contributions of a synergistic six-DOF platform-motion cueing system to the acquisition of basic contact flying skills in a primary jet trainer. It was apparent that under the conditions of this study, the presence of motion cues did not have a significant impact on performance in the ASPT or the T-37. For the tasks measured in ASPT, there were no reliable main effects due to the motion variable on either the automated scores or the IP ratings. In general, the differences between the means of the two conditions were extremely small in magnitude and not consistent in direction. For the automated measures, there was only one case, the Constant Airspeed Climb, in which the mean of the motion condition was reliably different than that for the no-motion condition. This was due to a reliable motion trials interaction in which the motion condition resulted in poorer performance on the first measured trial. There were a few tasks in which the difference between the means of the two conditions reflected a beneficial effect of motion: Turns to Headings, Takeoff, and Straight-In Approach. These differences, however, were small in magnitude and not statistically significant, and, thus, should not be overemphasized.

The measures of skill transfer to the aircraft were ratings provided by T-37 instructor pilots. There were essentially two indices of transfer effects: (a) short-term, initial-transfer measures, and (b) long-term measures. It was originally anticipated that the difference between the motion and no-motion conditions, if any, would be most evident as a short-term effect, and that the difference would tend to "washout" with more training.

The initial transfer evaluation was designed to assess the short-term effects of the motion and no-motion pretraining on all of the tasks trained in the ASPT. This information was collected on the first and fifth aircraft sorties. The instructor pilots who flew these missions with the students had received extensive checkout in ASPT on the use of the 12-point rating scale and the desired content of the two data collection missions. The results revealed virtually no mean differences between the motion and no-motion conditions on these rides.

The second transfer measure was task frequency information provided by the students' flight line instructors through the solo phase of the T-37 training. Of the twenty some tasks trained in ASPT, eight of the more advanced tasks were selected for this aspect of the transfer evaluation. Instruction on some of these tasks normally would not begin until after the second special data rides discussed above. (Instruction of the Takeoff and Straight-In Approach starts on the first flight.) Again, there were no reliable differences between the motion and no-motion groups on these scores. Unlike the results of the two special data rides, there was a trend for the motion group to perform slightly better than the no-motion group on these tasks with the exception of the Takeoff and the Landing from the Overhead Pattern. However, all the differences were small in magnitude and were not statistically significant.

Thus, the motion variable did not have significant beneficial training value in either the simulator training phase or the aircraft training phase. There are several experimental design factors which may have contributed to these findings and merit mention. First, the sample size was small (8 per group). Virtually any variable can be shown to be significantly related to another variable given a large enough sample size. Sizes can be made sufficiently large by employing a within-subject design with large number of observations per subject. In this manner, the actual number of subjects required can be smaller than that employed in this study. This type of design is often used in simulator-only studies of the motion factor. However, the hypothesis being investigated demanded a between-group design and logistics dictated a small sample size.

The between- and with-subject variability was high, which is commonly observed in investigations of initial skill acquisition. In addition, there were uncontrolled factors which acted to increase variance (e.g., varying times between sorties, flightline IP changes, weather conditions). The variance combined with small sample sizes reduces the power of any statistical significance test. It should be noted that the ASPT vs flightline groups comparison revealed significant differences in spite of the high variance, suggesting that the sensitivity of the test was satisfactory in this case.

The dependent measures were criterion-referenced as opposed to control input derivations. Criterion-referenced measures are the most appropriate type for the questions being asked (i.e., training value), but they may not be the most sensitive to motion-cue manipulations (Irish, Grunzke, Gray, & Waters, 1977; Matheny, 1974). For the issue addressed in the present context, however, motion-cue manipulations are not considered to be important unless they influence the pilot's ability to fly the aircraft or acquire the task-relevant skills.

All simulator training was given under full field-of-view conditions, and all of the tasks were trained as contact tasks. Skillful performance required attention to cues displayed in the external visual scene with intermittent attention to the instrument panel. The only tasks containing motion cues which were also training-relevant cues were the Stalls where the motion cue indicates stall onset or entry into a secondary stall. In the motion condition, stall onset was signalled by platform buffet (a cue produced by the special effects package not requiring the synergistic system) whereas the stick was shaken manually by the IP in the no-motion condition. It could be argued that the motion cue functions primarily as an alerting cue not requiring a six-DOF motion system for adequate cue display. The aircraft performance of the two groups reveals slightly better performance for the motion-trained group. However, the difference was not greater than other motion-favored performances and was not statistically reliable. The main point is that, with the exception of the stalls, motion cues were not training-relevant cues for the tasks covered in this study. One could argue that motion cues were, for the most part, incidental cues. Typically, the magnitude of transfer effects expected from incidental cues is small compared to that from primary cues. There is not a great deal of motion cueing involved in the tasks in the sense that the amount and/or the magnitude of actual aircraft cueing in these tasks is relatively small.

The subjects were student pilots with no previous jet flying experience. Theoretically, motion cues acquire meaning (i.e., have information value) as a function of experience. At an early point in training, the student may not have an expectation of what motion cues are associated with given control inputs. In such cases, motion cues may function as undifferentiated noise rather than as meaningful signals.

For whatever reason(s), motion cueing was not a potent training variable. An issue secondary to the motion question, but perhaps a more important issue, concerns the overall training effectiveness observed. The primary source of information on this issue comes from the comparisons of overall performance of the experimental groups with the control group. No precise information can be derived from the special data rides, since the control group did not receive these rides. However, the overall level of performance on these rides is higher than one would expect for a novice pilot. As expected, the highest levels of performance were observed on the basic airwork tasks (e.g., Turns, Climbs, Rate Changes). Generally, performance was judged to be in the good to excellent range on these tasks. The least effective transfer was on the Overhead Pattern which is clearly the most difficult of the tasks trained. However, even on the Overhead Pattern, most of the students were able to accomplish the task on the first ride in the aircraft.

On all the more advanced tasks monitored through the solo phase of the training program, the performance of the experimental group was superior to that of the control groups. The most effective training appeared to be for the Takeoff and Slow-Flight tasks with Overhead Pattern at an intermediate level. Unfortunately, it was not possible to arrive at a valid trials-to-proficiency measure, but inspection of the raw data revealed that the majority of the transfer value was in elevating performance at the initial state and mid-state of training. It is worth noting that five weeks had passed between the ASPT training and normal syllabus training on the stalls. Even with this considerable time interval, the performance of the experimental groups was superior to that of the control group.

When considering the overall effectiveness of the ASPT training, the reader should be reminded that there were several factors which probably acted to decrease the maximum training value that could have been achieved in a less restrained more operational training environment. (a) All ASPT trained students received a fixed amount of practice on each task. A more effective training syllabus should be sufficiently flexible so that the amount of practice could be matched with the individual student's proficiency levels. This would insure that the student receives sufficient practice for him to achieve criterion level proficiency at the completion of ASPT training. (b) A large number of tasks were instructed within a relatively short period of time. Normally, this instruction would be more evenly distributed allowing for a higher level of mastery and skill consolidation of each task. (c) Many of the tasks were beyond the level of a normal beginning student, thereby not optimizing the match between instructional content and the student's cognitive and psychomotor skill levels. (d) Time did not permit instruction on some of the auxiliary tasks which the student would encounter in flight (e.g. radio calls and use of checklist). These factors increased task load and probably degraded overall performance. (e) More effective transfer probably could have been attained on the runway environment tasks with the inclusion of environmental factors such as crosswind training. Clearly, extensive training optimization research needs to be conducted prior to establishing the limits of productive simulator training. The results of the present study are promising with respect to the training potential of the new generation of ground-based trainers. However, the data failed to demonstrate any enhancement of training effectiveness as a result of the addition of platform motion.

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APPENDIX A: ASPT TRAINING SYLLABUS DESCRIPTION

Table A1. **ASPT Training Task Summary**

Task	# Repetition
Basic Airwork	
Straight & Level	9
Airspeed Changes	10
Constant Airspeed Climbs and Descents	10
30° Turns	2
Turns to Headings	9
Airspeed Changes, Turn to Heading	12
45° Turns	2
60° Turns	16
Configuration Change	4
Slow Flight	10
Pattern Work	
Takeoff	12
Traffic Exit	6
Overhead Pattern Enabling Tasks	
Pitch-Out at Altitude	8
30° Descending Left Turns	6
Initial	2
Initial + Pitchout	6
Downwind	2
Initial, Pitchout, Downwind	2
Final Turn	4
Final Turn + Landing	4
Overhead Pattern	29
Mission Work	
Tech Order Climb	2
Departure	5
Letdown	5
Recovery	2
Power-On Stalls	24
Traffic Pattern Stall Series at Altitude	6

Table A2. **ASPT Mission Scenarios**

Mission 1		Task	Repetition
Basic Airwork	1.	Straight-and-Level	2
	2.	Airspeed Decrease	1
	3.	Airspeed Increase	1
	4.	Constant Airspeed Climb	1
	5.	Constant Airspeed Descent	1
	6.	Turn-Left (30^{o} Bank)	1
	7.	Turn-Right (30^{o} Bank)	1
	8.	Turns to Headings - Left	2
	9.	Turns to Headings - Right	2
	10.	Performance Measurement	
		a. Straight-and-Level	1
		b. Airspeed Decrease	1
		c. Airspeed Increase	1
		d. Constant Airspeed Climb	1
		e. Constant Airspeed Descent	1
		f. Turn to Heading	1
	11.	Airspeed Increase, Right Turn to heading	2
	12.	Airspeed Decrease, Left Turn to heading	2
	13.	Airspeed Increase, Left Turn to heading	2
	14.	Airspeed Decrease, Right Turn to heading	2
	15.	45^{o} Bank Turn - Right	1
	16.	45^{o} Bank Turn - Left	1
Mission 2		**Task**	**Repetition**
Basic Airwork	1.	Straight-and-Level	2
	2.	Tech Order Climb & Level-Off	2
	3.	60^{o} Bank Turn - Left (160K)	2
	4.	60^{o} Bank Turn - Right (160K)	2
	5.	60^{o} Bank Turn - Left (200K)	2
	6.	60^{o} Bank Turn - Right (200K)	2
	7.	Letdown	2
	8.	Configuration Change	4
	9.	30^{o} Bank Descending Turn - Left	4
	10.	Slow Flight	4

Table A2. (*Continued*)

Mission 2 (Cont'd)		Task	Repetition
	11.	Performance Measurement	
		a. Straight-and-Level	1
		b. 60^{o} Bank Turn - Left (160K)	1
		c. 60^{o} Bank Turn - Right (160K)	1
		d. Slow Flight	1
Mission 3		**Task**	**Repetition**
Pattern Work 1	1.	Takeoff/Automated Demonstration	1
	2.	Takeoff	2
	3.	Performance Measurement	
		a. Takeoff	1
	4.	Takeoff	2
	5.	Straight-In Approach/Automated Demonstration	1
	6.	Straight-In Approach	2
	7.	Performance Measurement	
		a. Straight-In Approach	1
	8.	Straight-In Approach	8
Mission 4		**Task**	**Repetition**
Mission Profile 1	1.	Takeoff	1
	2.	Traffic Exit	1
	3.	Departure	2
	4.	Straight-and-Level	1
	5.	Airspeed Increase	1
	6.	Airspeed Decrease	1
	7.	Constant Airspeed Climb	1
	8.	Constant Airspeed Descent	1
	9.	Turn to Heading - Left	1
	10.	Turn to Heading - Right	1
	11.	30^{o} Bank Descending Turn - Left	2
	12.	Airspeed Increase, Turn to Hdg-Right	1
	13.	Airspeed Decrease, Turn to Hdg-Left	1
	14.	Airspeed Increase, Turn to Hdg-Left	1
	15.	Airspeed Decrease, Turn to Hdg-Right	1
	16.	60^{o} Bank Turn - Left (200K)	2
	17.	60^{o} Bank Turn - Right (200K)	2

Table A2. (*Continued*)

Mission 4 (Cont'd)	Task	Repetition
	18. Pitch-Out at Altitude	4
	19. Power-On Stall, Straight	4
	20. Power-On Stall, Left	2
	21. Power-On Stall, Right	2
	22. Letdown	2
	23. Straight-In Approach	1
Mission 5	**Task**	**Repetition**
Pattern Work 2	1. Takeoff and Traffic Exit	2
	2. Performance Measurement	
	a. Takeoff	1
	3. Straight-In Approach	4
	4. Performance Measurement	
	a. Straight-In Approach	1
	5. Straight-In Approach & Touch-&-Go	2
	6. Overhead Pattern/Automated Demonstration	1
	7. Initial	2
	8. Initial and Pitch-Out	4
Mission 6	**Task**	**Repetition**
	1. Takekoff and Traffic Exit	1
	2. Departure	1
	3. Slow Flight	2
	4. Power-on Stall, Straight	4
	5. Power-on Stall, Right	2
	6. Power-on Stall, Left	2
	7. Performance Measurement	
	a. Straight-and-Level	1
	b. Airspeed Increase	1
	c. Airspeed Decrease	1
	d. Constant Airspeed Climb	1
	e. Constant Airspeed Descent	1
	f. Turn to Heading	1
	g. 60° Bank Turn - Left (160K)	1
	h. Slow Flight	1

Table A2. (*Continued*)

Mission 6 (Cont'd)	Task	Repetition
	8. Pitch-Out at Altitude	4
	9. Letdown	1
	10. Performance Measurement	
	a. Straight-In Approach	1
Mission 7	**Task**	**Repetition**
Pattern Work 3	1. Initial and Pitch-Out	2
	2. Downwind	2
	3. Initial, Pitch-Out, & Downwind	2
	4. Final Turn	4
	5. Final Turn and Landing	4
	6. Overhead Pattern	3
	7. Performance Measurement Overhead Pattern	1
	8. Overhead Pattern	5
	9. Performance Measurement Overhead Pattern	1
Mission 8	**Task**	**Repetition**
Mission Profile 3	1. Performance Measurement	
	a. Takeoff	1
	2. Traffic Exit	1
	3. Departure	1
	4. Slow Flight	1
	5. Power-On Stall, Straight	2
	6. Power-On Stall, Left	1
	7. Power-On Stall, Right	1
	8. Traffic Pattern Stall Series	4
	9. Recovery	1
	10. Performance Measurement	
	a. Straight-In Approach	1

Table A2. (*Continued*)

Mission 9	Task	Repetition
Pattern Work 4	1. Overhead Pattern	3
	2. Performance Measurement	
	a. Overhead Pattern	1
	3. Overhead Pattern	5
	4. Overhead Pattern & Touch-&-Go	5
	5. Performance Measurement	
	a. Overhead Pattern	1
	6. Overhead Pattern (Solo)	2
	7. Performance Pattern	
	a. Overhead Pattern (Solo)	1
Mission 10	**Task**	**Repetition**
Mission Profile 4	1. Performance Measurement	
	a. Takeoff	1
	2. Traffic Exit	2
	3. Departure	1
	4. Traffic Pattern Stall Series	2
	5. Power-On Stall, Straight	2
	6. Power-On Stall, Left	1
	7. Power-On Stall, Right	1
	8. Performance Measurement	
	a. Straight-and-Level	1
	b. Airspeed Increase	1
	c. Airspeed Decrease	1
	d. Constant Airspeed Climb	1
	e. Constant Airspeed Descent	1
	f. Turn to Heading	1
	g. 60° Bank Turn - Left (160K)	1
	h. Slow Flight	1
	9. Recovery	1
	10. Overhead Pattern	1

APPENDIX B: SUMMARY DATA FOR ASPT PERFORMANCE EVALUATIONS

Table B1. **Automated Performance Measurement Parameters**

Task	Paremeters
Straight-and-Level	Altitude, Heading
Turn-to-Heading	Altitude, Airspeed, Heading
Steep Turns (60^{o})	Altitude, Airspeed, Bank
Constant Airspeed Climb/Descent	Altitude, Airspeed, Heading
Airspeed Decrease/Increase	Altitude, Airspeed, Heading
Slow Flight	Altitude, Airspeed, Inclinometer
Takeoff	Altitude, Heading, Climb-Out Attitude
Straight-In Approach	Final: Altitude, Centerline Deviation Airspeed; Glidepath: Centerline Deviation on Glidepath, Airspeed on Glidepath
Overhead Pattern	Pitch-Out: Altitude, Bank; Downwing: Altitude; Final Turn: Altitude, Bank Airspeed; Final: Glidepath, Centerline Deviation, Airspeed

Table B2. **Descriptive Statistics for ASPT Performance Evaluations**

Maneuver		APM Scores Trial 1	2	3	4	5	IP Ratings Trial 1	2	3	4	5
Straight & Level	M	59.51	48.23	45.59	43.63		8.08	9.63	9.53	10.13	
	NM	53.04	50.06	48.86	51.09		8.86	9.00	8.98	8.25	
Airspeed Increase	M	57.54	46.04	45.65			6.08	8.15	7.88		
	NM	57.92	46.06	46.79			5.31	8.31	7.81		
Airspeed Decrease	M	56.90	48.13	44.55			6.84	7.59	8.88		
	NM	58.09	46.17	46.16			4.84	7.82	8.25		
CAS Climb	M	59.88	46.93	44.45			6.86	7.72	9.13		
	NM	52.29	50.93	45.52			7.36	7.87	8.50		
CAS Descent	M	53.26	50.89	44.46			6.99	6.42	8.13		
	NM	51.60	52.01	47.77			7.62	5.39	6.88		
Turn-to Heading	M	48.81	49.00	48.59			7.76	7.19	7.63		
	NM	49.69	56.30	47.60			8.14	5.90	7.25		
Steep Turn	M	51.91	48.88	47.26	50.74		5.57	6.43	5.70	4.25	
	NM	53.79	48.38	49.69	49.36		5.50	6.13	5.55	5.75	
Slow Flight	M	54.00	46.74	47.98			7.56	6.17	6.13		
	NM	53.92	50.50	46.86			6.39	6.03	5.76		
Takeoff	M	49.48	49.39	47.92	46.17		5.23	6.88	6.25	6.98	
	NM	53.21	51.59	56.77	45.46		5.75	6.63	4.88	7.25	
Strat-in Approach	M	49.96	44.81	49.77	50.75		4.10	7.13	5.95	6.75	
	NM	53.29	45.78	53.80	51.84		4.78	7.49	5.03	5.13	
Overhead Pattern	M	55.21	49.25	48.93	47.07	48.61	3.00	3.59	4.88	5.88	6.01
	NM	53.47	49.44	51.03	47.61	49.36	3.38	5.00	6.00	6.56	6.00

Table B3. **Analysis of Variance Summary for ASPT Performance Evaluations**

Maneuver	APM Scores			IP Ratings		
	Motion	Trials	Trials x Motion	Motion	Trials	Trials x Motion
Straight & Level	1	4.94*	2.31	1.23	1.42	2.66
Airspeed Increase	1	25.79**	1	1	12.20**	1
Airspeed Decrease	1	18.96**	1	2.45	10.32**	1.69
CAS Climb	1	26.15**	7.50**	1	4.43*	1
CAS Descent	1	3.76*	1	1	7.28**	2.54
Turn-to-Heading	1	2.07	1.74	1	3.27	1.31
Steep Turn	1	2.00	1	1	1.42	1
Slow Flight	1	9.37**	1.28	1	1.77	1
Takeoff	1.37	4.03*	1.93	1	3.75*	1
Strat-in Approach	2.75	8.60**	1	1	8.28**	1.71
Overhead Pattern	1	7.93**	1	1	16.25**	1

*p < .05.
**p < .01.

MANEUVER GRADE CARD

STUDENT	DATE	FLIGHT
INSTRUCTOR	MISSION	

U			F			G			E		
1	2	3	4	5	6	7	8	9	10	11	12

MANEUVER	REPETITIONS I	II
1. TAKEOFF		
2. TRAFFIC EXIT		
3. DEPARTURE		
4. STRAIGHT AND LEVEL		
5. CAS CLIMB		
6. CAS DESCENT		
7. AIRSPEED INCREASE		
8. AIRSPEED DECREASE		
9. TRN TO HDG (R)		
10. TRN TO HDG (L)		
11. A/S INC. + TRN TO HDG (R)		
12. A/S DEC. + TRN TO HDG (L)		

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Figure C1. **Special data ride evaluation form.**

MANEUVER GRADE CARD		
STUDENT	DATE	FLIGHT
INSTRUCTOR	MISSION	

U			F			G			E		
1	2	3	4	5	6	7	8	9	10	11	12

MANEUVER	REPETITIONS I	II
13. 45° TURN R		
14. 45° TURN L		
15. 60° TURN (R)		
16. 60° TURN (L)		
17. CONFIGURATION CHANGE		
18. TPS SERIES		
19. SLOW FLIGHT		
20. PWR ON STALLS		
21. LETDOWN		
22. STRAIGHT-IN		
23. TOUCH & GO		
24. OVERHEAD PATTERN		
AIRSICK	YES	NO
PASSIVE ACTIVE		

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Figure C1. (*Continued*)

INSTRUCTOR________________ DATE____________________

STUDENT___________________ MISSION_________________

NOTE: Use syllabus grading standards, disregard maneuver item file: call them as you see them.

TAKEOFF

1.	H.P.	W	U	F	G	E
2.	H.P.	W	U	F	G	E
3.	H.P.	W	U	F	G	E
4.	H.P.	W	U	F	G	E
5.	H.P.	W	U	F	G	E
6.	H.P.	W	U	F	G	E
7.	H.P.	W	U	F	G	E

STRAIGHT-IN APPROACH							LANDING			
1.	H.P.	W	U	F	G	E	U	F	G	E
2.	H.P.	W	U	F	G	E	U	F	G	E
3.	H.P.	W	U	F	G	E	U	F	G	E
4.	H.P.	W	U	F	G	E	U	F	G	E
5.	H.P.	W	U	F	G	E	U	F	G	E

OVERHEAD PATTERN							LANDING			
1.	H.P.	W	U	F	G	E	U	F	G	E
2.	H.P.	W	U	F	G	E	U	F	G	E
3.	H.P.	W	U	F	G	E	U	F	G	E
4.	H.P.	W	U	F	G	E	U	F	G	E
5.	H.P.	W	U	F	G	E	U	F	G	E
6.	H.P.	W	U	F	G	E	U	F	G	E
7.	H.P.	W	U	F	G	E	U	F	G	E

Figure C2. **Task frequency data form.**

SLOW FLIGHT

1.	U	F	G	E
2.	U	F	G	E
3.	U	F	G	E
4.	U	F	G	E

TRAFFIC PATTERN STALL SERIES

1.	U	F	G	E
2.	U	F	G	E
3.	U	F	G	E
4.	U	F	G	E

POWER ON STALLS

1.	U	F	G	E
2.	U	F	G	E
3.	U	F	G	E
4.	U	F	G	E

AIRSICK:	PASSIVE	YES	NO
	ACTIVE	YES	NO

SAFE FOR SOLO: YES NO

Figure C2. (*Continued*)

APPENDIX D: SPECIAL DATA RIDE SUMMARY

Table D1. **Descriptive Statistics for T-37 Special Data Rides**

Maneuver	Motion						No Motion					
	1st Sortie			2nd Sortie			1st Sortie			2nd Sortie		
	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N
Straight-and-Level	10.25	1.83	8	10.87	1.24	8	9.50	2.00	8	11.12	1.45	8
Airspeed Increase	9.12	1.80	8	10.57	.97	7	9.00	3.16	8	10.00	1.41	5
Airspeed Decrease	9.25	2.12	8	10.25	1.48	8	8.85	2.11	7	10.12	1.95	8
Constant Airspeed Climb	9.16	1.16	6	10.20	1.09	5	9.00	1.54	6	10.00	1.54	6
Constant Airspeed Descent	8.62	1.76	8	9.00	1.77	8	9.37	1.30	8	9.75	1.38	8
Turn-to-Heading (Right)	7.87	2.29	8	9.42	1.98	8	8.12	2.16	8	9.50	1.19	8
Turn-to-Heading (Left)	7.50	2.50	8	8.00	1.85	8	6.87	2.23	8	8.50	1.77	8
45^{0} Turn (Right)	6.57	2.87	7	8.50	1.85	8	7.62	2.13	8	9.50	2.00	8
45^{0} Turn (Left)	6.71	2.36	7	8.87	1.64	8	6.50	1.69	8	8.62	1.30	8
60^{0} Turn (Right)	5.28	3.03	7	5.50	2.56	8	4.14	1.77	8	6.12	2.85	8
60^{0} Turn (Left)	7.12	2.16	8	8.75	1.83	8	6.12	2.85	8	8.37	1.59	8
Configuration Change	6.57	2.07	6	9.87	1.12	8	7.00	1.67	6	7.12	3.09	8
Slow Flight	7.68	2.86	8	9.75	1.66	8	7.62	3.11	8	9.50	2.72	8

Table D1. *(Continued)*

Maneuver	Motion						No Motion					
	1st Sortie			2nd Sortie			1st Sortie			2nd Sortie		
	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N
Takeoff	5.00	2.09	6	7.25	1.83	8	5.60	2.19	5	7.37	2.97	8
Traffic Exit	5.50	2.25	6	7.25	1.48	8	5.62	1.92	8	6.75	1.83	8
Departure	6.18	.92	8	7.87	1.80	8	5.28	1.38	7	7.75	2.05	8
Power-On Stall (Straight)	6.25	1.38	8	7.00	2.23	7	7.11	1.69	8	7.00	1.06	8
Power-On Stall (Turn)	6.12	2.10	8	7.42	1.90	7	6.87	2.35	8	6.87	1.12	8
Traffic Pattern Stall (Pitchout)	3.25	1.83	8	8.12	3.04	8	2.50	1.76	7	5.12	1.82	8
Traffic Pattern Stall (Nose Low)	4.87	2.79	8	5.87	3.35	8	3.66	2.33	6	4.50	1.60	8
Traffic Pattern Stall (Nose High)	4.12	1.12	8	6.62	2.38	8	3.83	1.50	6	5.37	1.50	8
Traffic Pattern Stall (Landing)	5.33	1.96	6	6.25	2.12	8	4.50	2.25	6	5.37	1.50	8
Touch-and Go	4.70	1.98	5	5.56	1.34	8	5.00	2.21	6	6.18	1.79	8
Straight-In (Approach)	6.14	1.95	7	7.81	1.60	8	5.92	1.89	7	7.57	1.56	7
Straight-In (Flare/Landing)	2.60	.54	5	3.71	1.97	7	2.25	.50	4	4.33	1.03	6
Overhead Pattern (Pitchout)	4.75	2.20	8	5.31	2.06	8	4.50	2.81	6	5.18	1.77	8

Table D1. (*Continued*)

Maneuver	Motion						No Motion					
	1st Sortie			2nd Sortie			1st Sortie			2nd Sortie		
	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N	$\bar{X}$	S.D.	N
Overhead Pattern (Downwind)	4.81	1.75	8	4.62	1.68	8	4.50	2.94	6	4.81	2.12	8
Overhead Pattern (Final Turn)	4.50	2.16	7	5.31	1.25	8	2.70	1.30	5	4.31	.84	8
Overhead Pattern (Final)	4.91	1.88	6	5.25	.92	8	3.16	1.16	6	4.68	2.12	7
Overhead Pattern (Landing)	3.07	1.09	7	3.12	1.24	8	2.12	.25	4	3.58	1.35	6

Table D2. **Analysis of Variance Summary for T-37 Special Data Rides**

Maneuver	Motion	Trials	Trials x Motion
Straight-and-Level	1	11.01**	2.18
Airspeed Changes	1	3.87	3.13
CAS Climb/Descent	1	1.15	1
Turn-to-Heading	1	16.32**	1
45° Turns	1	20.60**	1
60° Turns	1	6.29*	1
Configuration Change	1.19	3.30	4.75
Slow Flight	1	10.97**	1
Traffic Exit	1	4.91*	1
Departure	1	17.21**	1
Takeoff	1	11.40**	1
Touch-and-Go	1	1.87	1
Straight-in Approach/Landing	1	14.92**	2.56
Overhead Pattern	1	1.30	1
Power-On Stalls	1	1.63	2.32
Traffic Pattern Stalls	3.18	18.53**	1.11

*$p < .05$.
**$p < .01$.

APPENDIX E: TASK FREQUENCY DATA SUMMARY

***Table E1.* Descriptive Statistics for Total Number of Repetitions**

Maneuver	Mean	S.D.
Takeoff	19.00	1.47
Straight-In Approach	24.34	3.66
Landing (Straight-In Approach)	23.17	4.31
Overhead Pattern	56.78	13.31
Landing (OVH Pattern)	51.13	9.76
Slow Flight	6.34	2.18
Traffic Pattern Stall Series	6.86	2.30
Power-On Stalls	7.17	3.31

Table E2. **Destribution of Task Frequency Data**

Takeoff	Control	No Motion	Motion
Total N	147.0	140.0	150.0
% U	29.3	15.0	13.5
% F	33.3	25.0	31.9
% G	34.7	48.6	54.6
% E	2.7	11.4	0.0
Straight-In Approach	**Control**	**No Motion**	**Motion**
Total N	209.0	167.0	185.0
% U	42.6	23.9	20.5
% F	34.5	42.5	36.8
% G	21.1	31.1	39.5
% E	1.9	2.4	3.2
Landing (Straight-In)	**Control**	**No Motion**	**Motion**
Total N	199.0	158.0	175.0
% U	60.3	41.1	39.4
% F	30.2	43.0	37.1
% G	8.5	15.2	21.1
% E	1.0	0.6	2.3

Table E2 (*Continued*)

	Overhead Pattern		
	Control	No Motion	Motion
Total N	410.0	439.0	438.0
% U	54.9	34.9	29.2
% F	28.3	31.9	41.6
% G	15.9	28.7	27.4
% E	0.98	4.6	1.8
	Landing (Overhead Pattern)		
	Control	No Motion	Motion
Total N	377.0	418.0	380.0
% U	31.3	17.0	22.6
% F	52.0	43.3	47.1
% G	16.2	37.6	28.4
% E	0.5	2.2	1.8
	Slow Flight		
	Control	No Motion	Motion
Total N	38.0	55.0	54.0
% U	39.5	14.6	3.7
% F	47.4	29.1	38.9
% G	10.5	43.7	38.9
% E	2.6	12.7	18.5

Table E2 (*Continued*)

	Power-On Stalls		
	Control	No Motion	Motion
Total N	39.0	51.0	75.0
% U	48.7	21.6	16.0
% F	33.3	43.1	49.3
% G	18.0	31.4	32.0
% E	0.0	3.9	2.7

	Traffic Pattern Stalls		
	Control	No Motion	Motion
Total N	41.0	54.0	63.0
% U	65.9	40.7	19.1
% F	22.0	31.5	52.3
% G	12.2	14.8	25.4
% E	0.0	13.0	3.2

Table E3. **Task Frequency Data Summary and Analysis**

Maneuver	Mean IP Ratings			Statistical Comparisons		
	Motion	No-Motion	Control	F-Ratio	t(M vs MN)	t(M/NM vs Con)
Takeoff	2.50	2.58	2.11	9.12**	.67	4.22**
Straight-In Approach	2.23	2.10	1.83	3.66*	.91	2.58*
Straight-In Landing	1.84	1.72	1.51	3.28	.75	2.43*
Overhead Pattern	2.01	1.98	1.61	5.09*	.18	3.26**
Overhead Landing	2.08	2.25	1.86	3.77*	1.01	2.48*
Slow Flight	2.72	2.53	1.79	8.92	.76	4.18**
Power-On Stall	2.20	2.15	1.75	2.70	.36	2.36*
Traffic Pattern Stall	2.09	1.91	1.43	3.38	.60	2.54*

*P < .05.
**P < .01.

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