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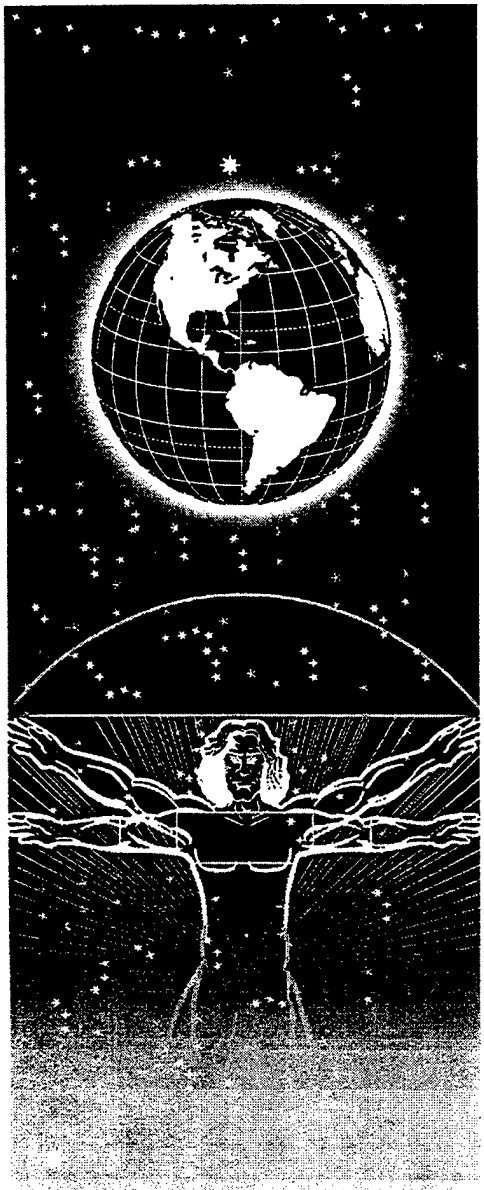

# UNITED STATES AIR FORCE RESEARCH LABORATORY

## TRANSFER OF TRAINING EFFECTIVENESS IN FLIGHT SIMULATION: 1986 TO 1997

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This report has been reviewed and is approved for publication.

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The purpose of this report was to review recent studies regarding the effectiveness of flight simulators as augmentation for "hands-on" flying training. Simulation-based training has been proposed to reduce costs, extend aircraft life, maintain flying proficiency, and provide more effective training, especially in areas difficult to train in operational aircraft. A review of the literature from 1986 to 1997 identified 67 articles, conference papers, and technical reports regarding simulator flying training and transfer. Of these, only 13 were related directly to transfer of training from the simulator to the aircraft. Studies of simulator effectiveness for training landing skills constituted a majority of the transfer studies, although a few examined other flying skills such as radial bombing accuracy and instrument and flight control. Results indicate that simulators are useful for training landing skills, bombing accuracy, and instrument and flight control. Generally, as the number of simulated sorties increases, performance improves, but this gain levels off after approximately 25 missions. Further, several studies indicate that successful transfer may not require high-fidelity simulators or whole-task training, thus reducing simulator development costs. Evaluation of this literature is difficult for many reasons. Typically, researchers fail to report sufficient detail regarding research methods, training characteristics, and simulator fidelity. In addition to these methodological concerns, there is a lack of true simulator-to-aircraft transfer studies involving complex pilot skills. This may be due to problems such as inadequate simulator design, cost, and availability, and access to simulators in operational flying units. Future directions in simulator transfer of training are discussed.

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## PREFACE

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# TRANSFER OF TRAINING EFFECTIVENESS IN FLIGHT SIMULATION: 1986 TO 1997

## INTRODUCTION

Over the past several decades, researchers have sought to determine the effectiveness of flight simulators as augmentation for "hands-on" flying training. Simulators have been proposed for use to save money, extend the life of the aircraft, maintain proficiency when not performing "hands-on" flying, and provide more effective training especially in areas difficult to train in operational aircraft (e.g., emergency procedures). The purpose of this report is to review and summarize the literature from 1986 to 1997 regarding the transfer of training from the simulator to the aircraft. Sixty-seven articles, conference papers, and technical reports regarding simulator flying training and transfer were identified. Of these, only 13 were related directly to transfer of training. For the interested reader, the Appendix contains references regarding the 54 flying training studies that were not directly related to transfer of training.

## TRANSFER OF TRAINING STUDIES

### *Early Studies: 1957 to 1986*

Hays, Jacobs, Prince, and Salas (1992) reviewed the pilot training literature from 1957 to 1986. Their initial survey included 247 journal articles, book chapters, and technical reports regarding training effectiveness. Of these, only 26 studies included information sufficient to be included in a meta-analysis regarding transfer of training in a flight simulator to operational aircraft equipment. Of the 26 studies, 19 involved jet aircraft and 7 involved helicopters. The meta-analysis revealed several trends that were not readily apparent from the individual studies. First, simulators consistently led to improved training effectiveness for jet pilots relative to training in the aircraft only. However, this was not true for helicopter pilots. Second, motion cueing was not found to add to training effectiveness for jet pilots and, in some instances, may have led to less-effective training. Motion cueing was not examined for helicopter pilots due to the small number of studies. Finally, training effectiveness was strongly influenced by the amount and type of training given and by the type of task trained. For instance, simulators were more effective for training takeoff, approach to landing, and landing than they were for the combination of all pilot tasks.

### *Recent Studies: 1987 to 1997*

Since the mid-1980s, several studies have examined transfer and/or quasi-transfer of training of flying skills (Lintern & Garrison, 1992; Lintern, Roscoe, Koonce, & Segal, 1990; Lintern, Roscoe, & Sivier, 1990; Lintern, Sheppard, Parker, Yates, & Nolan, 1989; Lintern, Taylor, Koonce, Kaiser, & Morrison, 1997; Lintern, Thomley-Yates, Nelson, & Roscoe, 1987; Pfeiffer, Horey, & Butrimas, 1991; Taylor, Lintern, & Koonce, 1993; Westra, et al., 1986; Wightman & Sistrunk, 1987). Although simulators have been used to train several aspects of

flying (e.g., takeoff, landing, instruments, control), by far, the most frequently investigated use of simulators was for training landing skills.

*Landing Skills*. Consistent with meta-analytic results found in Hays et al. (1992), several subsequent studies have shown simulators to be effective for training landing skills. Westra et al. (1986) examined the effects of simulator design features on the training effectiveness of the skill required for landing on aircraft carriers. They compared night (i.e., low detail) versus daytime (i.e., high detail) scenes crossed with wide versus narrow field of view. Pilots received 20, 40, or 60 simulator trials. Results indicated that neither scene detail nor field of view influenced effectiveness of transfer from the simulator to the aircraft. However, pilots receiving 40 or 60 simulator trials exhibited better landing skills than those who received only 20 trials.

Lintern and his colleagues have conducted several studies investigating the effects of the amount of simulator time, scene detail, crosswind, field of view, display orientation, augmented feedback, and bank control. For example, Lintern, Roscoe, Koonce, and Segal (1990) examined transfer of landing skills from a flight simulator to an aircraft in early flight training. One group of beginning flight students was given two sessions of practice of landing skills in a simulator before starting landing practice in the aircraft. A control group was given no practice in the simulator prior to practice in the aircraft. Results indicated that the experimental group required 1.5 fewer pre-solo flying hours than the control group. This reduction in flying hours, whether military or civilian, could lead to considerable savings.

Several follow-on studies were conducted to examine the effects of different simulator attributes on the transfer of landing skills. Lintern, Roscoe, and Sivier (1990) investigated effect of scene detail (pictorial vs. symbolic), display orientation (outside in or inside out), bank control order (first order or zero order), crosswind (present or absent), command guidance (constant, adaptive, or no augmentation), and flight path prediction (constant, adaptive, or no augmentation) on transfer of landing skill in the simulator. The final criterion was a "conventional inside out pictorial contact display, normal simulator control dynamics, and a 5-knot crosswind" (p. 299). They found that pictorial displays were more effective than symbolic displays and normal bank control order was better than reduced control for producing transfer.

Lintern and Garrison (1992) examined transfer effects of scene detail (high pictorial, low pictorial, or symbolic) and level of crosswind (zero, moderate, or high) on landing performance in a simulator. Participants were assigned to one of nine training conditions. The final performance criterion consisted of a high pictorial, moderate crosswind, simulation. Neither scene detail (high vs. low pictorial) nor level of crosswind had a significant effect on transfer. Consistent with Lintern, Roscoe, and Sivier (1990), pictorial displays led to better transfer than symbolic displays.

Lintern et al. (1997) investigated effects of scene detail (low or moderate), visual augmented guidance (off, constant, or adaptive), and number of landing training trials (0, 24, 48, or 72) in the simulator on transfer to the aircraft. Those in the zero landing trials group received instrument training, but no visual display. The performance criterion was the number of attempted landings prior to solo in the operational aircraft. They reported that students who

trained using low detail had better transfer compared to those using moderate detail. Further, augmented guidance enhanced transfer for low detail scenes but degraded transfer for high detail scenes.

In summary, simulators were shown to be useful for training landing skills. As the number of simulated sorties increased, performance increased, but this gain appeared to level off after approximately 25 missions. Field of view, as well as the presence or absence of crosswinds, had no significant effect on transfer. The results concerning scene detail are unclear. In some instances, greater detail led to better performance, while in other instances, it did not.

*Radial Bombing Accuracy.* While a majority of the research has centered on landing skill acquisition, a few studies have been conducted to determine the feasibility of training bombing missions in the simulator. For example, Lintern et al. (1987) manipulated scene content and augmented feedback in a quasi-transfer training study of air-to-ground attack skills. Participants received training using one of three scene detail levels. Final performance was based on simulated bombing missions in the simulator. They found that dive pitch error was reduced as scene detail increased. In addition, augmented feedback aided inexperienced pilots with dive pitch control and more experienced pilots with longitudinal bombing error.

Lintern et al. (1989) examined the influence of scene detail, field of view, and number of simulator trials on performance in an air-to-ground mission (i.e., radial bombing accuracy). As with Westra et al (1986), scene detail and field of view had no significant effect on performance. However, bombing accuracy improved as a result of simulator training. Lintern et al. noted that no additional improvement in bombing accuracy was achieved after 24 simulator sorties.

*Instrument and Flight Control.* Simulators are often used for training instrument and contact flight in beginning training. Pfeiffer et al. (1991) evaluated transfer of simulated instrument training to instrument and contact flight for a limited set of maneuvers involving turn and speed change. Participants completed eight simulator flights followed by two aircraft flights. Simulator and aircraft performance measures consisted of deviations from assigned airspeed, attitude, and heading. Results indicated positive transfer from the simulator to the aircraft. A test of the validity of simulator performance for predicting actual flight performance showed mean performance in the simulator to be strongly related to both instrument ($r = .98$) and contact ($r = .95$) flight.

Goettl (1995) used a backward quasi-transfer technique to determine transfer effects of part-task training to complex flight control tasks. Participants were assigned to one of three training groups. The first group received whole-task training, the second received part-task training concentrating on the critical task components, and the third group received part-task training on the noncritical task components. Final performance was measured in the simulator using four slalom courses (i.e., two easy and two difficult courses), where participants had to fly through "gates in the sky." The groups who received part-task training on the critical components and the group who received whole-task training did not differ in performance, while those who received non-critical part-task training performed significantly worse.

Both studies suggest that simulators provide an effective means to train instrument procedures and flight control. The results suggest that in order to produce transfer to the aircraft it may be necessary to train only the critical components of the task rather than the whole task. This has implications for simulator design and the development of simulator training syllabi.

## PROBLEM AREAS

Evaluation of the transfer of training literature is difficult for many reasons. Typically, researchers fail to report sufficient detail regarding research methods (e.g., assignment of participants to control and experimental groups, reasons for loss of participants, methods used to estimate interrater agreement), training characteristics (e.g., general training features, instructor variables, student variables, training program), and simulator fidelity characteristics (Hays et al., 1990). These problems have not been resolved in the last ten years. For example, Jorna, Van Kleef, and de Boer (1992) noted that the mission requirements often are not well understood, making it difficult to design an adequate training syllabus for the simulator and identify a measure of performance. According to Taylor et al. (1993), the development and implementation of design principles to facilitate maximization of training transfer and cost effectiveness have not been well established.

In addition to these methodological concerns, this literature suffers from the lack of true simulator-to-aircraft transfer studies involving complex pilot skills. This may be due to a number of reasons including inadequate simulator design, cost, and availability and access to simulators in operational flying units.

## FUTURE DIRECTIONS

Recent developments in technology have led to advances in simulator design. For example, faster, more powerful computers make it possible to link several simulators together to create a virtual multiship environment. Pilots are now able to fly four-ship sorties against multiple adversaries in near real time. In addition, the simulator visual systems have improved in that more realistic terrain mapping is now possible.

Given the current status of simulator design, it is now possible to investigate a wide range of flying skills in both novice and experienced pilots. Future studies will be able to address issues such as complex skill acquisition and group performance involving multiship scenarios.

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