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Aviation Computer Games for Crew Resource Management Training

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Crew resource management (CRM) training programs have existed for more than a decade, yet methods for providing aircrews with opportunities to practice CRM skills have been limited to role plays in class and scenarios in operational flight trainers. There are drawbacks to both training methods; role plays have few, if any, realistic environmental cues to help crews behave as they do in the cockpit, and simulator scenarios are limited by the cost and availability of the simulators. Research using inexpensive, tabletop computer-based simulations as CRM training media was conducted with military aircrews. Reactions of the crewmembers taking part in the research were very positive both in their acceptance of the system in general and as a trainer for CRM skills. This article presents this research and reports the reactions of aircrews to the tabletop simulation. In addition, a series of recommendations are provided regarding the implementation and use of this low-fidelity simulation.

For more than a dozen years, aviation organizations have been providing training in crew resource management (CRM). These programs came about in response to the emergence of human error as the leading cause of aviation accidents. CRM training emphasizes team processes and management with the goal of reducing human error accidents due to poorly functioning crews, in which communication breaks down, crew members do not back one another up, and leadership fails to adequately direct the crew.

CRM BEHAVIORAL SKILLS TRAINING

Early CRM training programs were designed primarily to change aircrew attitudes (Helmreich, 1987). Research conducted by Helmreich, Foushee, Benson, and Russini (1986) had shown that pilots considered to be superior and pilots considered

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below average differed in their attitudes as measured by the Cockpit Management Attitudes Questionnaire. Prince, Chidester, Bowers, and Cannon-Bowers (1992) noted that the vast majority of existing CRM programs assumed that changing aircrew attitudes would be sufficient CRM training and would have a direct impact on performance. However, as Fishbein and Ajzen (1975) pointed out, there is no clear research evidence that a change in attitudes alone will result in a corresponding behavioral change. Furthermore, Smith and Salas (1991) have shown that although certain training mediums (e.g., behavioral modeling) can produce a desired change in attitudes, training that includes active practice and feedback is critical to produce behavior change. Research conducted with military aircrews (Prince & Salas, 1989), and work accomplished by the National Aeronautics and Space Administration (NASA) and the University of Texas (Helmreich, Wilhelm, Kello, Taggart, & Butler, 1990) have begun identifying behaviors associated with effective crew functioning. Included are behaviors classified under leadership, decision making, communication, situation awareness, and other areas found to be important for effective resource management. CRM training programs are now beginning to move from an emphasis on changing the attitudes of aircrews to an emphasis on building behavioral skills. These behavioral skills are required to manage the resources of the entire cockpit effectively (i.e., the people as well as the equipment) and are different from the purely technical skills required to fly the aircraft (Prince, Chidester et al., 1992).

The Federal Aviation Administration (FAA) advisory circular on CRM training (FAA AC 120-51a; 1991) specifies three phases of training: awareness, practice and feedback, and recurrency. By emphasizing the behavioral basis for effective CRM (rather than the attitude or personality base), the addition of specific behavioral skill practice and feedback to CRM training has become critically important. This result also moves the emphasis on the phases of training from the awareness phase (where attitude change is targeted) to practice and feedback.

Skill practice occurs primarily either through role play or through having crews complete a realistic flight in an operational flight trainer (for an overview of selected CRM programs, see Orlady & Foushee, 1987). With role play, considerable skill is required of the facilitator to set up the situation, and considerable imagination is required of the participants to behave as if real cockpit activities are occurring while the problems built into the role play begin unfolding (Wexley & Latham, 1981). Full-mission simulator training presents a much more realistic environment to the trainees, requiring them to do most of the tasks that are necessary in the cockpit, and is a highly regarded training method (Wilhelm, Helmreich, & Gregorich, 1990). Although this training method has been well-received and is considered valuable, its application is limited due to the expense of the simulators and their use for a variety of other training and evaluation sessions that are considered more essential.

In the basic training of technical flying skills, simulators that vary in the faithfulness of their replication of the actual equipment (and thus may be purchased for far less than the full-mission simulator) allow student pilots a variety of opportunities for skill practice. Part-task trainers, for example, allow skill building

in one area before the trainee is required to accomplish the entire task. These simulators can be effective trainers (Jacobs, Prince, Hays, & Salas, 1990). Several researchers (Helmreich, Wilhelm, & Gregorich, 1988; Prince, Oser, Salas, & Shrestha, 1992; Schultz, Owens, & Harris, 1987) have suggested that CRM skills may also be trained using simulators that have less physical resemblance to the cockpit than that of the operational flight trainers presently used. Bowers, Salas, Prince, and Brannick (in press) noted that low-fidelity simulation via PC–based computer games provides an effective medium to practice and evaluate critical team behaviors and dimensions (i.e., CRM behaviors and skills).

The majority of investigations examining the viability of using computer games to train CRM skills has been conducted with college students (Baker, Cannon-Bowers, Salas, & Spector, 1992; Brannick, Roach, & Salas, 1991; Lassiter, Vaughn, Smaltz, Morgan, & Salas, 1990; Smith & Salas, 1991). For example, Stout, Cannon-Bowers, Salas, and Morgan (1990) investigated the use of a computer game called GUNSHIP™–THE ATTACK HELICOPTER SIMULATION (Hollis, Tavares, & Meier, 1986) to elicit CRM behaviors, as well as to determine the extent to which the quality of these behaviors related to performance on the task. An analysis of the relationship of coordination ratings for the pilot and copilot separately, and of the overall crew rating with objective task performance, showed each of the coordination variables to be correlated with mission performance. These results provided preliminary evidence for the viability of such approaches for eliciting critical CRM skills.

Although computer games may be effective for eliciting CRM-type behaviors in college student populations, a major question remains: whether this level of simulation is acceptable to aviators as a CRM training method. Therefore, the purpose of this investigation was to address the issue of acceptability by collecting aviator reactions to a tabletop training system designed to augment the training of CRM skills. Kirkpatrick (1976) suggested that such reactions are a critical element of training evaluation.

SYSTEM INVESTIGATION

The training system employed consisted of off-the-shelf software and a PC–based hardware system. The software used in this investigation was a computer game designed for a single player. The hardware was a desktop computer, three monitors, a video splitter, and control yokes. An important addition to the hardware and the software were the scenarios created for the research effort. The NASA *Guidelines for the Development of Line-Oriented Flight Training* (Lauber & Foushee, 1981) were used for initial guidance. Furthermore, the scenarios were purposely designed to present opportunities to demonstrate and evaluate the critical crew-coordination skill behaviors for military aircrews identified by Prince and Salas (1989).

Participants

The tabletop system was evaluated by 112 male military aviators who each flew two different scenarios as crews of two. Of the 112 participants, 36 were instructor-pilots

and 46 were students learning to fly their first multiengine aircraft. The remaining 30 participants consisted of senior military aviators presently assigned to staff positions. Twenty-two of the participants had previously received CRM training.

Tabletop Aircrew Coordination Training System

The simulation software packages used for this research were Microsoft Flight Simulator 4.0B (Artwick, 1989), SubLOGIC Scenery Disk 7 (Woodley, 1987), and Microsoft Flight Simulator Aircraft and Scenery Designer (Bruce Artwick Organization, Ltd., 1990). The software packages provided (a) the simulated aircraft instruments, controls, and aerodynamic models; (b) a database representing major airports in the southeast region of the United States; and (c) the capability to modify the flight characteristics of the aircraft in the Flight Simulator 4.0B software and to add scenery to the SubLOGIC Scenery Disk 7.

The simulation hardware configuration consisted of an IBM-compatible 286 PC, three EGA monitors, a standard PC keyboard, and yokes. The monitors were connected via a series of image splitters so that the simulation could be viewed simultaneously on the three monitors. Two of the monitors were placed side by side to emulate the left and right crewmember positions. The third monitor was located behind the crewmember positions for the scenario facilitator. A keyboard was utilized to operate the aircraft's landing gear, landing lights, flaps, navigational aids, and throttle. The keyboard was placed between the left and right seats to allow either of the crewmembers access. The subjects activated the aircraft brakes and manipulated the pitch and roll of the aircraft using control yokes. Although both subjects could operate the system with their yoke, only one yoke was active at any given time. Control could be changed through the use of a switch box.

A VHS-format camcorder recorded the video portion of the simulation from the facilitator's monitor. The audio portion of the simulation was recorded through headsets connected to the camcorder by a series of intercom boxes. This enabled crewmembers to communicate with each other as well as with the scenario facilitator, who played the roles of air traffic control, aircraft passengers, and external agencies. Two scenarios were designed to provide opportunities for the crew to demonstrate coordination behaviors (Prince & Salas, 1989). Each of the scenarios was scripted to ensure consistent presentation of the material. Radio calls as well as various altitude and heading changes were given to the crews throughout the scenarios.

Scenarios for the Tabletop System

Before taking part in the scenarios, crews completed a demographics form and then were given 15 min of practice on the tabletop system. Following this practice, en-route low-altitude airway maps and approach plates, briefing materials, and checklists (pre-takeoff, takeoff, climb, approach, and landing) were given to the crews. At this time, the scenario facilitator briefed the crew on necessary information (e.g., the primary mission, communication/emergency procedures, weather, and navigational and flight plans). Crews were then given the opportunity to plan and prebrief each mission.

Scenario 1. For the first scenario, the mission was to transport two military passengers from Orlando, Florida (MCO) to Daytona Beach, Florida (DAB). The planning skills of the crews were observed in their preflight brief as well as at times in the scenario when it was necessary to change plans. The flight progressed as briefed until the crew approached DAB, where they were informed that the airport had closed due to a power failure in the tower. Decision-making skills of the crew were observed as the crew considered the extenuating factors to decide their course of action (e.g., return to MCO, proceed to an alternate, select another airport). In light of the circumstances, their best option was to continue on to their filed alternative, Ormond Beach, Florida (OMN). If a crew chose a destination other than OMN, the scenario facilitator, following a script as air traffic controller, redirected them to OMN. Shortly after stating their intention to land at OMN, the crew lost the capability to transmit external communications. In order to regain communications, the crew had to follow standard operating procedure and switch back to the previous frequency. No further incidents were included. Each part of the scenario was designed both to be realistic and to elicit specific skills. Communications skills were observed throughout the scenario.

Scenario 2. In the second scenario, the crew's mission was to transport two military passengers from St. Augustine, Florida (SGJ) to Malcolm McKinnon Airport (SSI) in Brunswick, Georgia. Approximately three fourths of the way through the scenario, one of the passengers began to complain of chest pains. The crew had to decide what to do and where to go next (e.g., declare an emergency, increase airspeed, or locate the nearest medical facilities). This instance provided an opportunity to observe the decision making and flexibility of the crews. In the event that a crew did not decide to go to the closest airport with medical facilities (Jacksonville International Airport, Jacksonville, Florida; JAX), they were eventually guided there by the facilitator acting as the appropriate external agency. On their final approach into JAX, prior to being cleared for landing, the crew was informed that there was an aircraft on the runway experiencing problems. The crew was required to execute a missed approach and was cleared to land on an alternate runway.

Both scenarios were realistic for the type of aircraft that the students and instructors flew. Each scenario offered multiple opportunities for the crews to use the behaviors that had been identified as necessary for effective performance.

Scenario Sessions

All crews flew both scenarios. Following the completion of both scenarios, the participants filled out a short reaction form. The form consisted of six statements: "Felt prepared for what I needed to do," "Had difficulty navigating," "Would like to fly more tabletop missions," "Overall, I think this system could be used for CRM training," "Overall, I feel the game provided a good way of learning CRM concepts," and "Overall, I feel the missions demonstrated the importance of CRM." Participants

rated each statement on a 5-point scale ranging from *strongly disagree* (1) to *strongly agree* (5). These reactions were collected as the initial step in the evaluation of this training technique.

Aviator Reactions to a Tabletop Trainer for CRM

Aviator reactions were examined at four levels: (a) reactions of the total sample (N = 112), (b) reactions of the instructor-pilots only (n = 36), (c) reactions of the student pilots only (n = 46), and (d) reactions of those pilots who had previously attended CRM training (n = 22). All of these data were converted to percentage scores so that comparisons could be made across the various subgroups.

Total sample reactions are only reported for the first three items on the reaction form. These items provide an indication of how comfortable pilots felt while flying the tabletop system. Overall, 74.1% of the aviators agreed or strongly agreed that they felt prepared for the scenarios, 74.1% disagreed or strongly disagreed that they had trouble navigating, and 75.9% agreed or strongly agreed that they would like to fly more scenarios on the system.

The other three items on the reaction form addressed aviators' perceptions of the viability of using the tabletop training system for CRM training. Figures 1, 2, and 3 present these data and are broken down into total sample reactions, instructor-pilot reactions, student pilot reactions, and reactions of those aviators who had previously attended CRM training. Examination of Figures 1, 2, and 3 indicates that, for the total sample and across all the subgroups, more than 90% of the aviators agreed or strongly agreed that the tabletop system could be used for CRM-skills training.

CONCLUSION

Computer games have the capacity to engage the player, are inexpensive, and are readily available. These three qualities suggest possible value as a training medium, even though existing aviation game software has not been designed specifically for training or crew interactions. Reactions of pilots participating in this research indicated that the use of computer games with carefully designed scenarios can be an acceptable means of training CRM skills. Aircrews seemed to appreciate the training value of the system and became engaged in its scenarios. Acceptance was found by aviators of all experience levels.

There are two issues of immediate concern for the use of this system: the generalizability of the system to other aviation communities and the comparability of the system with operational-flight trainers. Some preliminary data that address these issues were collected from a group of military helicopter pilots. The hardware used was as described above (except for the use of joysticks instead of yokes) and the software program used was an off-the-shelf helicopter simulation, GUNSHIP (Hollis et al., 1986). Twelve crews consisting of pilot and copilot flew two similar

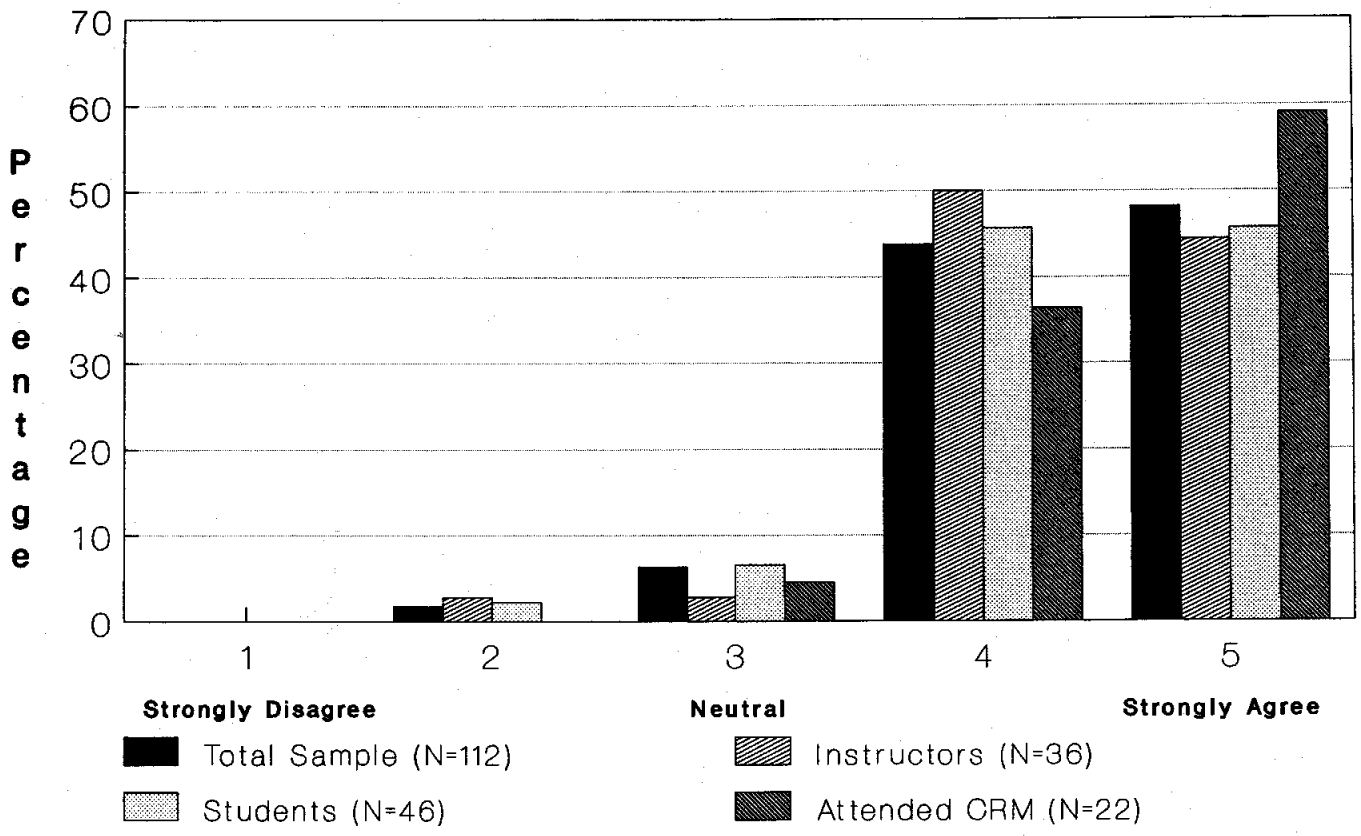

FIGURE 1 Distribution of responses to Item 4: "Overall, I think this system could be used for CRM training."

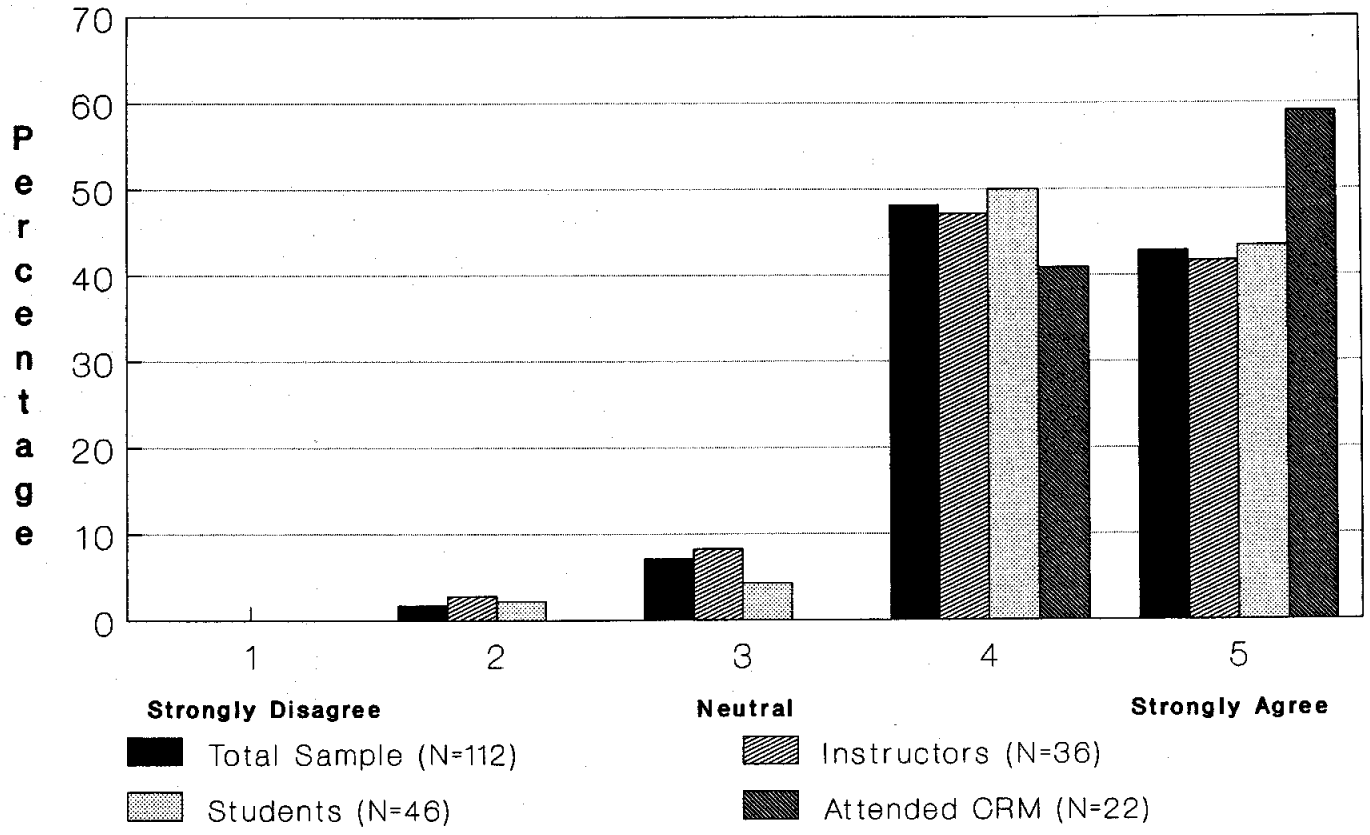

FIGURE 2 Distribution of responses to Item 5: "Overall, I feel the game provided a good way of learning CRM concepts."

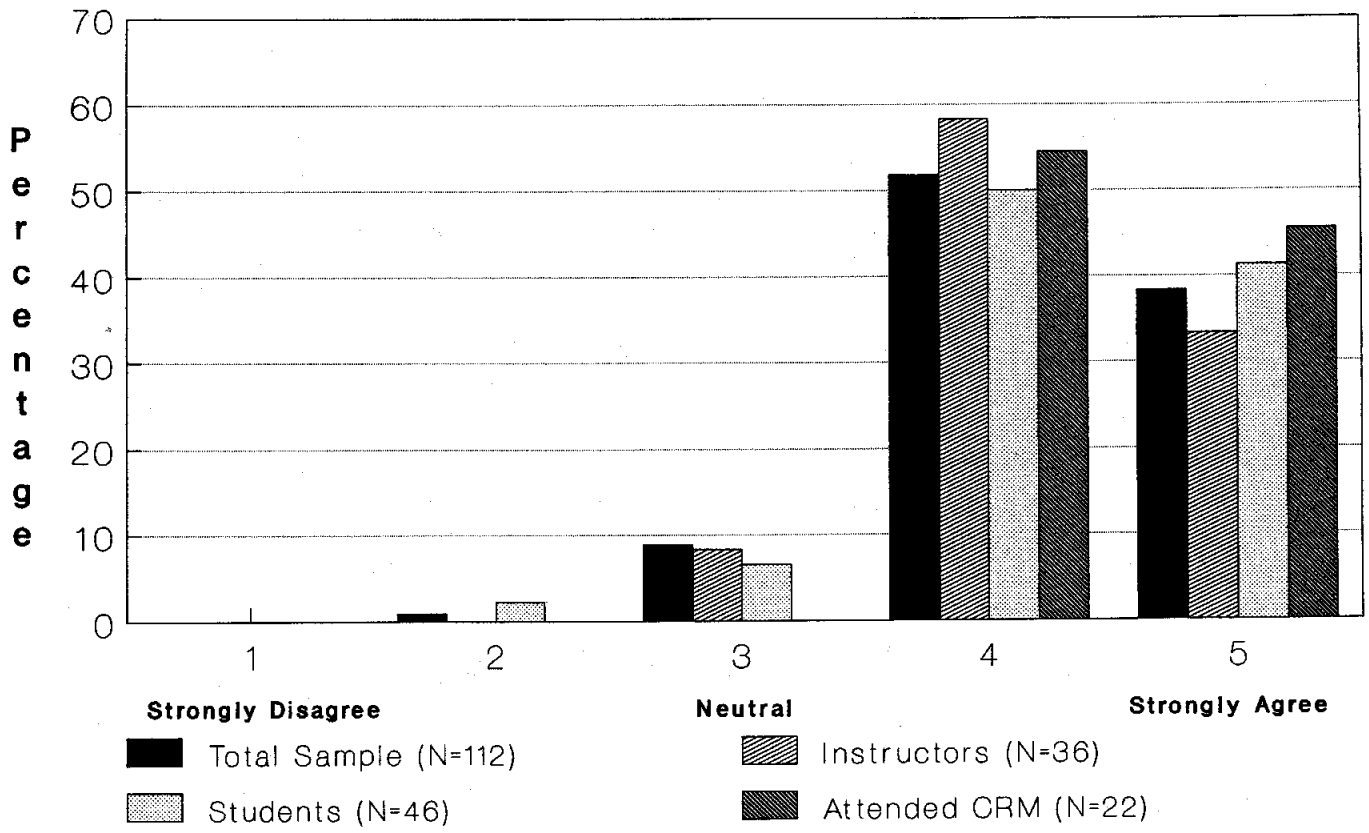

FIGURE 3 Distribution of responses to Item 6: "Overall, I feel the missions demonstrated the importance of CRM."

mission scenarios, one on the tabletop system and the other in an operational flight trainer with visuals and a 6°-of-freedom motion system. Reactions of the subjects to the two scenarios were collected. Their responses were positive and were similar for the two different simulators. The helicopter pilots indicated that training on the tabletop system was acceptable, appropriate for training CRM skills, and challenging. Nonetheless, given the small number of aircrews, these data should only be considered preliminary, and future research must continue to address the issue of simulator comparability. Specifically, such research needs to focus on the generalizability of CRM skills across various levels of simulator fidelity.

Wilhelm (1991) reported reactions of airline crews to full-mission simulator scenarios and noted that aircrews rated the realism of the scenarios very highly. Although the crews in the research reported here were not asked to respond to a specific question about realism, a short interview was conducted following the scenarios. A review of these data showed that participants characteristically commented about the realism of both scenarios, when realism was measured based on the type of problem presented, on calls of controlling agencies, on flight progress, and on the behavior that the scenario elicited. Furthermore, it was observed that perceived realism did not vary as a function of aviation experience.

RECOMMENDATIONS

The results of this research have led to a series of recommendations for the use of computer games to supplement CRM-skills training. We have broken these recommendations into three general categories: (a) hardware and software, (b) CRM scenarios, and (c) implementation.

Hardware and Software

Hardware and software are critical elements of computer-based CRM-skills training. To date, most computer-based research (see, e.g., Baker et al., 1992; Bowers et al., in press; Brannick et al., 1991; Stout et al., 1990) has employed similar hardware configurations and several different software programs. Based on these efforts and the present research, we recommend that the following issues be considered:

1. *Select a computer system and software that meets the training needs of the aircrew population.* Although computer and software technology have advanced over the years, PC–based systems may never completely model the performance of the actual aircraft. Some software programs can be used with a variety of computer hardware (i.e., DOS systems with 286, 386, or 486 processors). The more powerful processors provide smoother flight and may be important to the type of aircraft modeled. Therefore, it is recommended that the system selected

meet the requirements of the software employed and that the software meet the requirements of the scenarios to be developed.

2. *Incorporate all relevant peripherals.* Headsets, sound boards, and control yokes are valuable additions that increase participant motivation. Furthermore, maps, approach plates, checklists, and navigation aids also enhance perceived realism.

3. *Provide a system to record CRM behaviors.* In the present investigation, a VHS camcorder was used to record the scenario and the aircrew communications from a separate computer monitor. This information is vital for providing aircrews feedback on their CRM skills.

CRM Scenarios

Skill-based CRM scenarios are the driving force in PC–based CRM training. A comprehensively designed scenario can have a significant impact on perceived realism when conducting computer-based CRM training. Prince, Oser, et al. (1992) outlined a number of key points for the development of CRM scenarios for both full-mission and PC–based simulators. Although Prince, Oser, et al. provided considerable detail on these points, we feel that several of these guidelines deserve additional emphasis here:

1. *Develop scenarios that focus specifically on CRM skills and require minimal technical expertise.* PC–based systems and software are unlikely to model accurately the aircraft displays and systems, thereby limiting the degree to which technical flight skills can accurately be assessed. For this reason, it is important to identify the limitations of the system employed and to construct scenarios accordingly.

2. *Develop scenarios as comprehensively as possible from preflight brief to debrief.* Such scenarios should enhance realism when using computer games and result in increased participant motivation.

3. *Design scenarios to model actual missions and the problems that they might present so that CRM skills required by the scenarios will be relevant.* A review of the typical missions conducted provides a foundation on which to begin scenario development. Furthermore, inclusion of subject-matter experts in the development and review of scenarios should ensure that scenarios are realistic.

Implementation

Computer-based CRM-skills training must be carefully implemented in the training curriculum to ensure success. As such, we propose two recommendations for implementing PC–based CRM-skills training:

1. *Use PC–based simulation on its own only when full-motion simulators are unavailable.* Computer games may be used most effectively as additional training to CRM scenarios in the full-mission trainer. The current results with PC–based programs are promising, but further research is necessary to determine how much

training transfers to the cockpit when such systems are used. Until that research is done, we do not recommend computer games as an adequate substitute for trainers with higher levels of physical fidelity.

2. *Target low-fidelity simulation to supplement CRM training, especially in terms of skill practice and feedback.* A number of short scenarios could be incorporated throughout CRM training, and a final scenario could be incorporated at the end of training. The critical element here is to provide participants with some mechanism to practice and receive feedback on CRM skills.

SUMMARY

The potential training value of this type of simulation is promising, with its low cost and easy availability. Experiments conducted with both fixed- and rotary-wing aviators and with two different off-the-shelf programs indicate that these systems can be acceptable to aviators. Research with such systems needs to be continued to determine the full range of capabilities and limitations of this approach to CRM-skills training.

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