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THE EFFECT OF AUTOMATION ON HELICOPTER CREW COMMUNICATION: A LOW-FIDELITY INVESTIGATION

by

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This thesis was prepared under the direction of the candidate's thesis committee chair, Dr. Gerald D. Gibb, Department of Aeronautical Science, and has been approved by the members of her thesis committee. It was submitted to the Department of Aeronautical Science and was accepted in partial fulfillment of the requirements for the degree of Master of Aeronautical Science.

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Dedicated to the memory of my Uncle,
Lawrence Paul Doyle,
"Chief"
Sikorsky Aircraft.
1937-1994.

"Faretheewell my bright star,
you were a brief, brilliant miracle."
-Indigo Girls

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ABSTRACT

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Increasing levels of technology have changed the task of flying modern helicopter cockpits by allowing many crew functions to be performed automatically. This study attempted to understand the relation between automation and helicopter crew coordination. Twenty-eight helicopter pilots were assigned to two-person crews and asked to fly a simulated mission in either automated or manual conditions using a low-fidelity helicopter simulator. Communication was transcribed and coded into a nine-category content classification system by two trained raters. The inter-rater reliability was +.84. Results indicated that a higher frequency of total communications was demonstrated during manual flights. The interaction of Pilot Position by Automation Level was significant ($p<.05$) for three of the communication content categories: Observations, Suggestions, Statements of Intent. The results are discussed in terms of their implications for communications and Crew Resource Management (CRM) training for crews flying advanced technology helicopters.

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INTRODUCTION

Effective communication is paramount in an aircraft cockpit. It must occur among crew members, and it must occur so that both pilots reach a mutual level of understanding, not only of their aircraft, but of each other's responsibilities. Without this understanding, safety may be compromised.

It is becoming more evident that communication patterns and content vary with changes in the aircraft. These changes may be a cause for concern (see Wiener, 1991). In the current helicopter market there is a growing trend toward new sophisticated displays on glass cockpit screens. Flight Management Systems and Electronic Flight Instrumentation Systems are becoming available in modern helicopters, as well as in fixed-wing aircraft. It is debatable whether this complex technology effectively relates to the quick eye, hand coordination of helicopter pilots and how this technology impacts crew coordination and communication. As a matter of fact, forty reports were listed on helicopter automation and communication in the Aviation Safety Reporting System.

There is a gap in the available understanding of rotary-wing crew communication and crew resource management training available for helicopter crews. More specifically, it involves a leap of faith into a world of increasing automation without an understanding of how it impacts rotary-wing crew communication.

Statement of the Problem

There have been few studies on the behavioral changes associated with cockpit automation. However, the existing studies reveal a change in communication and workload as a consequence of automation (Foushee & Manos, 1989). Research indicates that there is a growing need to understand crew communication and to incorporate these understandings into crew resource management training. A 1992 study reports that the development of crew training specifically designed to counteract any potential negative effects of automation may be required as an interim measure in preserving and enhancing crew performance (Thornton, Brown, Bowers & Morgan, Jr.).

Bowers (1995) states that based on so little empirical data, it is difficult to describe effective crew interactions in automatic systems. It is even more difficult to describe effective crew interactions with automatic systems in rotor craft operations because of the lack of research in rotary-wing crews and their aircraft. This study will attempt to contribute to this need by expanding the investigation of automation effects on crew communication to the area of helicopters.

It is essential to avoid any assumption that fixed-wing aircrews and their aircraft impose the same type of communication requirements as rotary-wing crews. Helicopters have a number of unique capabilities that cannot be duplicated by airplanes (Helicopter Association International, 1981). "The rotary-wing aircraft's versatility, varied mission assignments, and flight-control characteristics are likely to impose a different type of communication requirement on the crew as compared to fixed-wing aircraft" (Oser, Prince, Morgan, & Simpson, 1991).

All forms of mass transportation include accidents due to human error, whether it be a car, train, airplane, or helicopter. In 1989 it was reported that human error was the causative factor in approximately 64% of the accidents involving helicopters (Alkov). Despite the decrease in the number of helicopter accidents, the causes of the accidents have been shifting more heavily toward crew involvement (Breiling, 1995). For example, in 1995, the crew was cited as a major cause in eight of the twelve accidents and in two incidents recorded by U. S. helicopters.

The Naval Safety Center also reported that aircrew error accounted for 56 of the 96 (58.3%) Naval and Marine Corps Class A helicopter flight mishaps from 1983 to 1988 (Alkov, 1989). In addition, an analysis of Army aviation accident data revealed that "failure to communicate critical information" was one of four identified causes in Army rotary-wing mishap data (Oser et al., 1991).

In spite of the trend toward the single pilot cockpit, it's likely that two-person crews will continue to flourish because of the benefit that human redundancy provides in the cockpit. Human decision-making and judgment cannot be substituted with any amount of microprocessing power. Two-person crews increase the flight experience of skill, knowledge, and judgment from which to draw from when making a decision in the cockpit.

In spite of automated functions, advanced displays and various stability and control augmentation systems, there still are not cockpit designs a single pilot can fly with the same performance and workload as two-person crews can (Hart, 1988). Many next generation helicopters reflect these design parameters of a two-person cockpit despite increases in automation, such as the Sikorsky S-92 civil and military version. Although the current fleet are mostly hybrid cockpits in which most functions remain accomplished through dedicated hardware, this will not be the case for next generation helicopters. As true glass cockpits get built, more and more coordination problems present themselves (Hamilton, 1997).

Review of the Literature

Automation and crew communication have become important topics in the human factors research community for more than a decade now. Automation of fixed-wing aircraft and crew communication appears in the literature. However, the study of helicopter automation and crew communication does not appear in the literature. For that reason, the literature review will address crew communication and helicopter automation independently before addressing both together.

Crew Communication

> Crew communication the flow of information between individual operators - serves as the coupling agent that determines the function of the operators as an ensemble (Segal, 1990).

Crew communication has been connected to the performance of crews and has also been the focus of crew resource management programs. There are two aspects of the communication process that are particularly relevant to air crew performance (Kanki, Greaud, & Irwin, 1989). First, communication is clearly a means by which crews accomplish their task through the coordination of actions by commands, statements of intent, questions. Secondly, the "how" and "when" things are communicated as opposed to the "what" can characterize some quality of the way in which crews interact with each other (Kanki, Greaud, & Irwin, 1989). Good communication is the glue that binds a crew together and is essential in two-pilot operations.

Foushee and Manos (1981) found better crew performance to be associated with more task relevant speech, commands and acknowledgments. It has been suggested that the breakdown of communication or less task relevant speech, commands, and acknowledgments among crew members is the first step leading to an accident or incident (see Foushee & Manos, 1989). This has been corroborated in several commercial aviation and helicopter accidents.

In 1983, a Sikorsky S-61 operating under British Airways Helicopters crashed into the sea while on a scheduled passenger route between Scilly and the English coastline (Manningham, 1988). Nineteen passengers and a flight attendant were killed in that accident. The official accident report blamed "the pilot's failure to detect and correct and unintentional descent while under VFR rules in poor and deceptive visibility over a calm sea" (Manningham, 1988). This was clearly a flight in which communication broke down. Crews must agree on what each will each bring to the cockpit workload, and then cooperate verbally. "During this flight there was a prime opportunity to split the work into vertical and horizontal navigation to better coordinate the flight if only the pilots had verbalized this" (Manningham, 1988).

Another major accident occurred in 1978 with the crash of United Airlines Flight 173 in Portland, Oregon. The probable cause was determined to be the failure of the captain to monitor the fuel state, and contributing causes included "the failure of the other two flight crew members either to fully comprehend the criticality of the fuel state or to successfully communicate their concern to the captain" (NTSB, 1979, p.29).

That investigation resulted in the issuance of FAA Air Carrier Operations Bulletin Number 8430.17 which provided instructions regarding resource management and interpersonal communications training for air carrier flight crews (Kanki & Palmer, 1993). Crew resource management programs have since made their way into helicopter crew training in both the military and civilian sectors.

Foushee and Manos (1981) studied crew communication in a simulated setting which provided a model for much of the communication research later carried out (Kanki & Palmer, 1993). The goal of their methodology was to provide specific characterizations of communication patterns associated with effective crew resource management principles so that pertinent training implementations could be made (Kanki & Palmer, 1993). Although crew resource management has been implemented in several helicopter training programs, it may be limited in effectiveness because it is derived from commercial aviation; and therefore based on the nature of communication of fixed-wing pilots. Helmreich states that CRM training should be customized to reflect the nature and needs of the organization (1989a).

A recent study addressed the way in which coordination problems are solved, essentially what it is that differentiates flight crews who are performing smoothly and effectively from those who are not? (Kanki, Lozito, & Foushee, 1987). It was found that crews who had recently flown together, performed better, possibly because these crews simply had increased opportunity to establish a conventional means of communicating (before they were task overloaded and time-pressured).

Much of the research on crew communication has been studied with fixed-wing crews. It may be that the lack of rotary-wing crew communication research is due to the diverse helicopter missions and functions, and cost of simulation. Also, communication research is fairly new, since the first significant studies were accomplished in the late 1970's and early 1980's.

A study conducted in 1991 by the Naval Training Systems Center, Human Factors Division, analyzed rotary-wing crew communication patterns and content.

They posed the following questions:

- what specific communication patterns and content are demonstrated by different helicopter crew members?
- do tactical air crew communication patterns and content vary as a function of the performance demands and requirements of different flight conditions?
- Third, they asked: are the communication patterns and content of more effective air crews different from those of less effective air crews?
- What similarities exist between the communication patterns and content of military rotary-wing air crews and commercial fixed-wing air crews?

A main goal of their research was to apply what they learned to Aircrew Coordination Training (ACT). (For a detailed description of results, see Technical Report 90-009/Oser et al., 1991)

The researchers of that report suggested that specific attention needs to be focused on the unique communication requirements of tactical rotary-wing air crews during routine and non-routine flight conditions (Oser et al., 1991). It was also suggested that subsequent research analyze the communication patterns and content of tactical air crews in other platforms or aircraft types (i.e., fixed-wing, tilt-rotor) to extend and test the generality of their findings. Consequently, communication research continues to evolve out of the knowledge that pilot skill and technical understanding is not sufficient.

Helicopter Automation

The first practical helicopter is generally considered to be the VS-300, designed, built and flown by Igor Sikorsky, who is the man acknowledged as the founding father of today's modern helicopters. Sikorsky's first controlled flight on September 14, 1939 provided the way for many designs to come. Despite several successful flights, it became evident that the helicopter was more difficult to fly than almost any other type of aircraft (Carey, 1986). This is due to the inherently unstable characteristics of the helicopter. It wasn't until years later with hydraulically boosted, stability augmentation systems, computer-assisted controls and autopilots that the large helicopter became easier to fly.

The most basic type of helicopter automation is stability and control augmentation (Hart, 1988). This permits a pilot to stabilize a helicopter in an established trim condition as flight conditions or tasks require. For example, in high speed flight, turn coordination and speed, altitude, and altitude-hold are necessary to permit pilots to perform other duties (Hart, 1988). During low-speed flight, sensors are required to detect small deviations in speed, position, heading, and altitude to provide a stabilized hover without continuous pilot inputs (Prouty, 1986b). Control augmentation is essential in low-visibility, nap of the earth operations conducted with helmet-mounted displays (Aiken, 1984). Recently, the focus of technology has moved from automating these inner-loop control tasks to outer-loop, higher-order tasks (Hart, 1988).

Advanced controls and cockpit displays have taken shape in modern day helicopters. Multi-function displays are replacing the traditional single-purpose instruments. Weather, flight path and terrain information can be exhibited on one display. Consequently, the number of individual displays in advanced cockpit designs are significantly reduced in comparison to the number of instruments and displays (in past helicopters) (Hart, 1988). Helicopter automation has reached a pivotal point in development, because of receiving great attention from the human factors community. Bob Spaulding, an engineering test pilot with Sikorsky on the S-92 program, states, "The point we've reached in cockpit design today, is that we're relatively happy with the data processing speed, the software, and the quality of the displays. Now we have to confront the man-machine relationship head-on" (Harvey, 1993).

From a human factors viewpoint, the implications of cockpit automation are an unsettled topic. Technology has allowed automation of functions once performed by humans to computers. High-speed processing and increased data throughout is allowing helicopter avionics developers to tailor next-generation equipment to mission needs more closely than ever before. (Harvey, 1993). Despite the reduction of certain human errors, it appears that automation may set the stage for new types of errors, such as failures in programming or mode awareness (see Wiener, 1991).

Human factors considerations, presentation of displays, and cleaner cockpit arrangements of switches all are on the verge of receiving much greater attention than previously provided by helicopter avionics designers (Harvey, 1993). Developing helicopters include automated functions to "reduce workload," however it's questionable whether automation is being added randomly, without a broad understanding of the consequences. "Automation for the sake of automation" is not reason enough to utilize this technology. Hamilton (1997) states that over-automation can lead to the pilot not being aware of what the helicopter is doing, what his limitations are, and leave him helpless when the automation fails.

Helicopter automation will continue to evolve. According to Sandra G. Hart, considerable research is still needed to define the role pilots should play, and to determine where computer aiding, automation, and "expert" systems can provide the most benefit (1988). Along with these technological advances comes a removal of the pilot further from the actual manipulation of the aircraft. This evolution is illustrated in Figure 1. "As automation levels increase, the crew is less able to understand and control the automation with the result that workload increases and awareness drops" (Hamilton, 1997). With these technological advances that remove the pilots further from direct control of the aircraft, crew resource management training will become more important than ever.

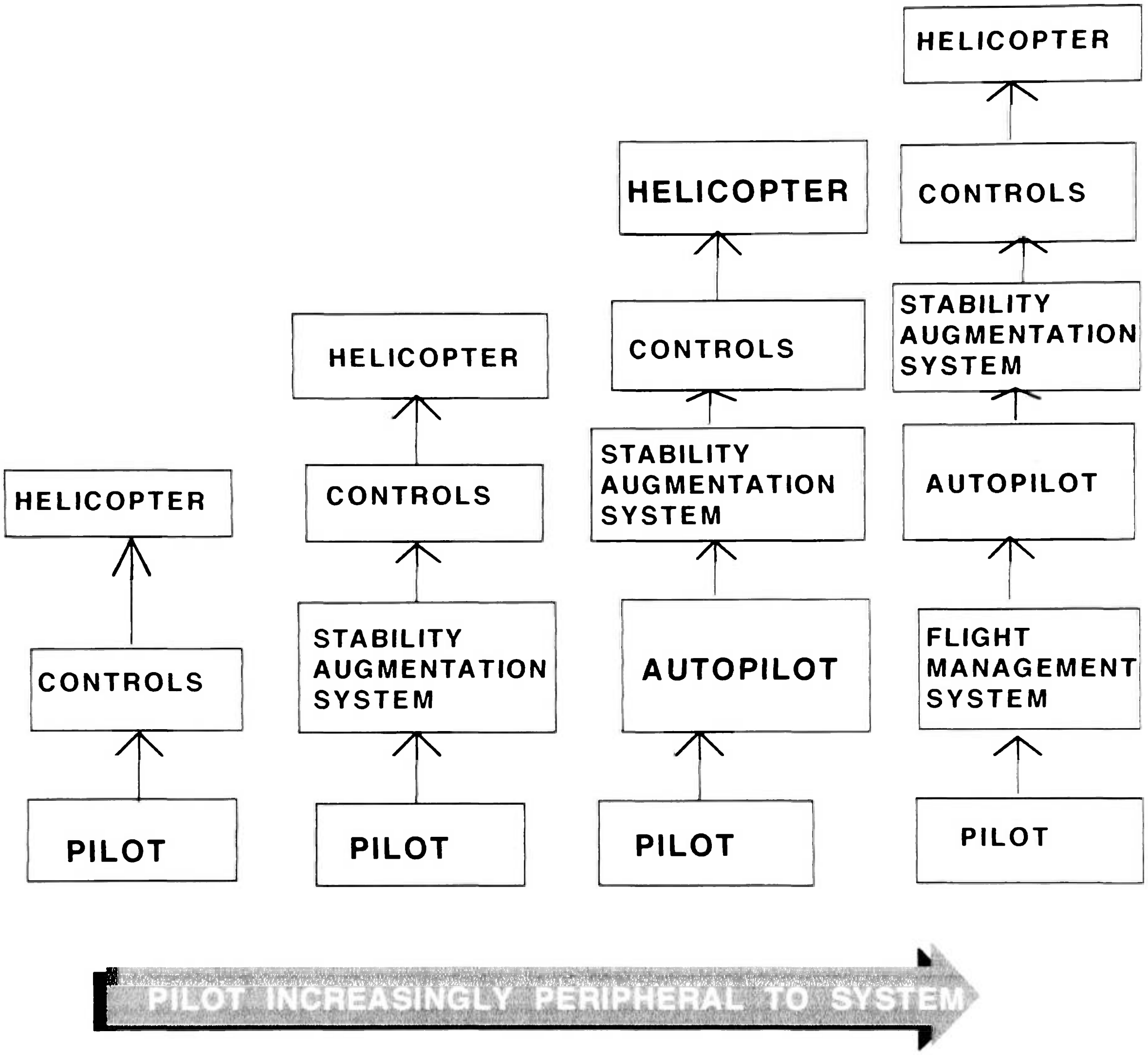

Figure 1. Increasing Complexity of Helicopter Automation (adapted from Billings, 1991b, p.10 "Toward a Human-Centered Aircraft Automation Philosophy." NASA-Ames Research Center.)

Automation and Aircrew Communication

In the last fifteen years because of the increase in automated flight-decks, research has begun to address the effect of automation on crew communication. Recent studies of crew communication in modern "all glass" cockpits support the argument that changes in the design of displays and controls result in significant changes in cockpit communication (Costley, Johnson, & Lawson, 1989).

Earl Wiener and other researchers were the first to raise the concern that cockpit automation may not lead to an improvement in crew coordination. In fact crew communication and coordination may gain more importance in automated systems (Jentsch & Bowers, 1996). Wiener (1984) stated that "the insertion of automatic devices into man-machine systems inevitably raises questions . . . which probably apply to helicopters as well as transport aircraft. He identified the psychosocial aspects of automation as an important research area.

Only two studies have been conducted that collected data during actual airline operations. In 1989, a study was conducted in which communication rates were compared in three aircraft with increasing levels of automation, the B737-200, B737-300, and B757 (Costley et al., 1989). It was found that significantly fewer questions were asked in the highly automated B757 cockpit. Night operations also produced a lower rate of communication among crews in the B757. (The results were based on total communication as opposed to communication interactions between the pilots). The researchers concluded that there is a trend toward lower inter-pilot communication as the degree of cockpit automation increases (Costley et al., 1989).

Lyall (1992) investigated the effects of mixed-fleet flying on pilot performance by collecting data during jump-seat observations on the B737-200 and B737-300. The results indicated that pilots flying mixed trips (flew both the B737-200 and the more automated B737-300) generally engaged in more flight-relevant talking between them than did pilots flying pure trips, (flew only the B737-200 or B737-300 over three days). No significant differences in flight-relevant talking were found when simply comparing the two aircraft types (Lyall, 1990).

Wiener (1991) investigated the effects of automation on crew coordination and communication by comparing the performance of crews flying the DC-9 and the MD-88 aircraft. It was found that the more automated MD-88 imposed greater workload. Wiener theorized (1989) that the roles and responsibilities of crew members change when automation is introduced into the aviation task.

In 1993, a succeeding analysis showed that crew members in the MD-88 aircraft (highly automated) demonstrated significantly more frequent communications with more questions being asked in the MD-88 (Veinott & Irwin). Researchers concluded that automatic systems seem to result in a shift in workload rather than a decrease.

Segal (1993) addressed the connection between automation design and group dynamics. The data utilized in this study were video and crew performance measures recorded in 1990 at NASA Ames' Advanced Concept Flight Simulator. The study found that a reduction in the overall speech among crew members occurred in the automated cockpit.

Simulator studies have collected data on automation and crew communication as well. Researchers concluded that it is possible to create manipulations of automation in low fidelity simulations which possess sufficient psychological fidelity to allow useful research, if care is taken in developing the experimental scenario (Bowers, Jentsch, & Salas, 1995).

A 1992 study which utilized a low-fidelity simulation concluded that automation appeared to require reallocation of the crew coordination behaviors (Thornton et al., 1992).

A subsequent study by Bowers extended the investigation of automation effects to general aviation. He tested subjects with a low-fidelity tabletop system used to simulate a Cessna 210 aircraft (1995). The communication between the crew members were analyzed. The results suggested that the incorporation of the automated system is associated with changes in the communication patterns initiated by each of the crew-members (Bowers, 1995). Essentially, the nature of communication varies with changes in the demands of the task.

No studies were found in the literature that addressed the impact of automation on rotary-wing crew communication.

Statement of the Hypothesis

The research evidence suggests that there may be a change in crew communication on the automated versus standard flight deck. It is hypothesized that there will be significant differences between the communication amount and content of the pilots in the automated and manual scenarios under varying conditions of workload. More specifically, it is hypothesized that there will be a significant decrease in communication amount and content in the automated scenarios. This hypothesis is based upon consistent findings in the fixed-wing literature which point to an underlying model of the "need" to communicate being lower in the context of automation, or perhaps automation masks the "need" to communicate. This study could support a null hypothesis, in which case, communication content and amount remained the same in both the automated and manual scenarios under varying conditions of workload. This study could support a second null hypothesis in which communication amount and content increases in the manual scenario's under varying conditions of workload.

METHOD

This study explored the effects of automation on crew communication in an S-76 low-fidelity desktop simulated helicopter. Two derivatives of the aircraft were simulated: the automated S-76B helicopter versus the non-automated S-76B helicopter.

Subjects

Subjects were drawn from Embry-Riddle Aeronautical University's student population and were also sought from helicopter flight schools in the local and extended Florida area.

Pilots were randomly assigned to two-person crews. A change in crew occurred if pilots had previously flown together as a crew. All subjects held a minimum of a current private pilot helicopter rating.

Each of the fourteen crews were composed of a pilot and co-pilot. The pilot had the responsibility of flying the mission and was given the responsibility for all final decisions made by the crew. The pilot was in command of the aircraft. The copilot was responsible for maintaining air traffic control communications, copying clearances, accomplished checklist items and other tasks as directed by the pilot. The copilot was responsible for programming the radios, autopilot (if necessary), and instruments. All of this was accomplished through pointing and clicking on the appropriate instrument with the mouse, and utilizing a keyboard.

Demographic information was available for all the crews, and is summarized in Table 1.

Table 1 Crew member Demographics

CREW POSITION	AGE (Years)	TOTAL HELICOPTER FLYING TIME (HOURS)
Pilots		
Mean	42.28	2977.92
SD	11.78	870.00
Min	23.00	95.00
Max	60.00	10000.00
Copilots		
Mean	35.28	794.78
SD	10.60	993.34
Min	23.00	125.00
Max	60.00	4000.00

Out of a total twenty-eight subjects, two were female. Eight out of the twenty-eight subjects were previously Army helicopter pilots. Three of the total subjects were active airline pilots. All but two of the subjects were instrument rated, and six of the total subjects had Air Transport Pilot ratings. Only three subjects had experience flying highly automated (EFIS & FMS) helicopters (Sikorsky 76C+). A total of four subjects had experience flying a highly automated Level D Helicopter simulator. These simulators included the S-76C, AH-64, and AH-1. Two of the subjects had previously flown offshore oil support.

Instrument

A low-fidelity desktop simulator was used to simulate a Sikorsky S-76B. The hardware consisted of one CPU, two computer monitors, three headsets, a mouse, a cyclic(joystick), collective, and a video camera and recorder. The monitors were connected to a video splitter, allowing both to run off the same CPU. The joystick was used as the cyclic, and a collective was integrated. This particular collective was obtained from FlightLink and was compatible with the software. A partitioner to divide the pilot and copilot was installed in between subjects. The purpose for the partitioner was "to create interdependence in the two-person crews" (Bowers, Salas, Prince & Brannick, 1992). Essentially, the task is divided so that each crew member has specific responsibilities as well as overlapping functions (Bowers et al., 1992). The pilot flew the simulated program and made input to the computer with a joystick acting as the cyclic and a collective that was mounted to the floor. The copilot made input to the simulated program via a keyboard and mouse. Responsibilities of the copilot included changing frequencies and instrument settings, screen views, as well as the setting of the autopilot.

The instrument set up for this research was based upon a low-fidelity paradigm used to study teams outlined by Bowers, Salas, Prince, and Brannick (1992). This model is outlined in Figure 2.

The simulation software that was used for this research was X-Plane/X-Rotor by Laminar Research. This software was chosen because of it's helicopter cockpit software and allowed the experimenter to alter the cockpit from manual to automated and manipulate weather changes.

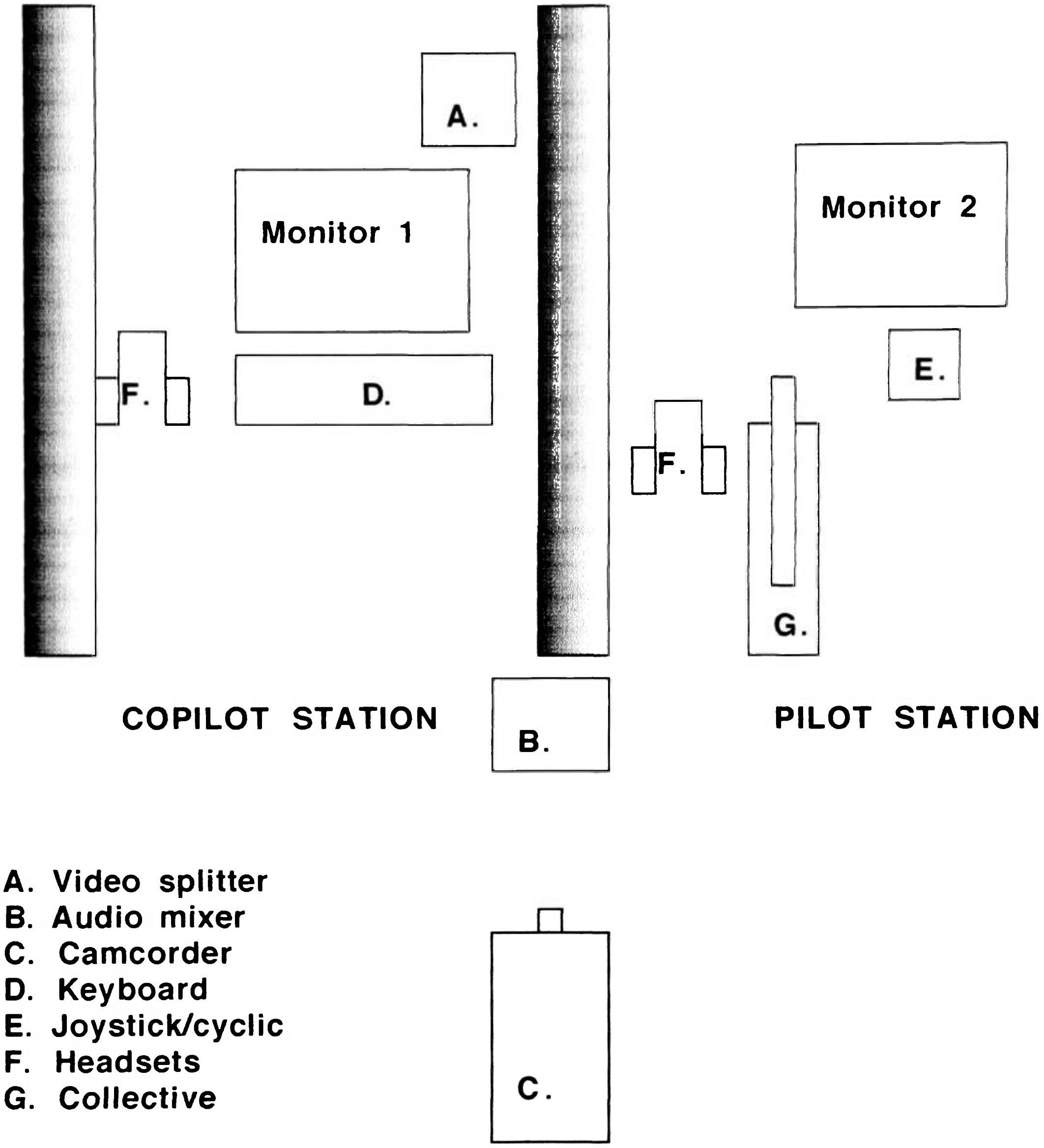

Figure 2. Schematic illustration of the low-fidelity simulation research paradigm.
(from Bowers, Salas, Prince & Brannick, 1992).

Design

The design and procedure for this study will parallel the procedures conducted by Bowers in 1995, while conducting a study entitled "Impact of Automation on Air crew Communication and Decision-Making Performance." In that study pilots were assigned to two-person crews and asked to fly a simulated mission in either automated (autopilot engaged) or manual conditions using a low-fidelity desktop simulator.

In this study seven crews were assigned to the automated condition in which they were instructed to fly as much of the scenario as possible with the simulator's autopilot engaged. The autopilot consists of directional GPS integration, altitude and vertical speed hold. Seven crews were also assigned to the manual condition in which they were instructed <u>not</u> to use the autopilot function.

Experimental Scenario

Each crew flew a scenario designed specifically for this research project. The scenario was one which began as a VFR flight and degraded into a high workload IFR flight. All subjects received the same script for the experiment.

Each crew was instructed that their mission involved flying from a departure airport (Daytona Beach -DAB) to land at a second airport(MCO-Orlando Executive). When subjects stated that they were ready to begin, they were given a clearance. The study began at that point.

The scenario involved a period of increased workload while enroute. The scenario started as a marginal VFR approach which degraded into an IFR approach as crews approached their destination airport. Weather was pre-programmed before the experiment to meet VFR conditions with weather slowly deteriorating into the flight.

The scenario began when the crew encountered a deteriorating weather condition along the route. Crews were informed of this initially through a call to listen to the ATIS in which they heard the following: "Executive Information Juliet, 1 Hundred Zooloo Weather, Measured Ceiling 2300 overcast, visibility 3, temperature 59, dewpoint 54, Winds 360 at 32, arriving and departing runway 25, advise on initial contact you have Juliet." The weather conditions up to this point had been very good. The ATIS call is the first step in a deteriorating weather condition. At this point, crews must decided weather to continue on, change their approach, return to departure airport, or decide if other actions are needed. The second step in the deteriorating weather condition is revealed to the crew after they contact Orlando approach in which they are told: "Sikorsky 8375Tango, weather deteriorating in approach area, wind 050 at 32, runway 7 in use, contact tower on 118.7." At this point, the crew must decide whether it is safe to continue flying and what other actions are required by them. The change in weather conditions requires the crews to utilize Instrument Flight Rules. And the high winds are a significant factor that act to deter the crew and provide significant information for them to consider as a helicopter crew. Crews must also decide at this point whether to check weather at alternate airports. Fuel remaining also becomes a more significant factor at this point in the scenario. The third step in the degradation of the weather is the call from the Airport Tower informing crew that "8375Tango, Orlando Executive closed due to convective weather and windshear in the area, proceed to alternate airport." This is a high workload task requiring crews to locate alternate airport(s), tune the VOR, locate frequencies, re-program autopilot, check maps/approaches, etc... Crews must also decide whether to communicate to the air traffic control agency.

Each of the crews communicated information orally during scenarios. It is important to note that the actual videotape segments varied in length because of the choices and different ways in which crews performed the flight. These differences in the duration of videotapes required that a twenty-five minute "chunk" be taken from each scenario for analyses.

Procedures

Before the scenario, subjects completed a background/demographic information form. Subjects were randomly assigned to the position of Pilot or Copilot-pilot and were allowed to perform practice scenarios that involved familiarizing themselves with the simulator. Crews were randomly assigned to flight condition (manual or automated). Subjects assigned to the automated scenario were given training on the use of the autopilot and were instructed to use the autopilot as much as possible during the experiments. Subjects in the manual scenario were instructed <u>not</u> to use the autopilot feature. After the practice scenario, subjects were given a short scenario to fly in which they were required to meet a standard baseline of performance. After training criteria were met, subjects were given a short break. Upon their return, subjects were given time to flight plan and conduct a "pretakeoff briefing" before the experiment began. All the charts, sectionals, and approach plates that subjects needed were supplied for them. Subjects were instructed to inform the experimenter when the pretakeoff briefing was complete. When subjects were ready, they were given a clearance and the experiment began at that time. After the experiment subjects were debriefed by the experimenter.

Training Criteria

Initially subjects were allowed to "play" around with the simulator to familiarize themselves with it as well as to adjust the seat height to match their body position comfortably with the collective and cyclic. Subjects were given training and instruction on the desktop simulator and software. After the training, subjects were instructed to fly a short twenty-minute scenario in which they were required to meet certain training standards such as holding heading plus/minus 10 degrees, holding altitude plus/minus 100feet. The training criteria for the copilot consisted of demonstrating knowledge of how to operate the radios: Com1 and Nav2 and autopilot. The co-pilot was also required to meet the criteria of using the keyboard for certain functions such as changing the view if the Pilot Flying commanded him/her to do so: "forward 30 degrees", "downward 50 degrees", "backward view", etc... For example, to change screen downward 50 degrees, keyboard function F5 accomplished this. These training criteria was set forth to insure steady state performance from subjects as opposed to being somewhere on the learning curve.

Data Collection

The scenarios were monitored. Audio and video tape provided the primary means of data capture by recording all verbal transactions that occured between crew members.

Communication Coding and Coder Training

Communication content was coded by three trained raters. Raters received training designed to familiarize them with the categories and to facilitate reliability. The coder training was based on the technique utilized by Bowers, Deaton, Oser, Prince, & Kolb (1995).

Coder training included:

- a brief overview of the project
- an overview of the coding form
- an overview of the two scenarios
- an explanation of the definitions and examples of the nine target behaviors (SEE TABLE 2)
- practice coding sessions
- a discussion on how to handle the ambiguous communications.

Communication Categories

Communication content of the participants were coded using a nine-category coding system, and was adapted from (Oser et al, 1991). SEE TABLE 2. The categories were based on the findings of previous aircrew communication literature (Oser et al, 1991). The categories were: commands, observations, suggestions, statements of intent, inquiries, acknowledgments, replies, non-task related, and uncodable communications.

<u>Commands</u> - Commands are specific assignment(s) of responsibility by one group member to another (Foushee & Helmreich, 1988). Although the pilot or co-pilot can issue commands, it is typically the pilot in command of the aircraft that initiates commands. "Commands serve as a means to communicate information related to the division of labor and delegation of duties"(Oser, et al. 1991). Commands are also used to communicate information about the specific task to be accomplished, its timing, and relative priority compared to other tasks (Jensen, 1986). Foushee et al. (1986) points out that commands appear to have a coordinating effect on crew

performance because of their strong influence on subordinate crewmember actions.

Observations - Observations are remarks made by crewmembers aimed at orienting others to some aspect of flight status such as references to instruments or navigation (Foushee & Manos, 1981). This type of verbalization provides information about what a crewmember has seen, heard, perceived and is characteristic of their awareness of some aspect of flight status. Oser et. al. (1991) note that crewmembers often communicate what is taking place internal and external to the aircraft and that the observations verbalized provide input for the crewmembers to act upon.

Suggestions - Suggestions are recommendations for a specific course of action (Foushee, Lauber, Baetge, & Acomb, 1986) or the introduction of an idea for consideration from one crewmember to another (Jensen, 1986). Suggestions involve a recommendation or an idea put forth by one crewmember to the other about a flight topic (Oser, et al., 1991).

Statements of Intent Statements of intent are announcements of intended actions, present or future, by the speaker (Foushee et al., 1986). These types of communication occur prior to the crew performing a duty and include tasks or specific actions such as navigational, tactical or procedural (Oser et al., 1991). Statements of intent keep other crewmembers informed about actions that either the speaker or crew is about to undertake (Jensen, 1986). Foushee et al. (1986) suggested that statements of intent reflect the amount of overall coordination between crewmembers.

Inquiries Inquiries are requests for information in regards to some aspect of flight status (Foushee & Manos, 1981) or for assistance on a particular task (Jensen, 1986). Communication of these type are information seeking behaviors designed to elicit assistance from others and are generally in the form of a question (Oser et al., 1991). Inquiries are used by crewmembers to formally request inputs from each other and obtain needed information about a task (Oser et al., 1991).

<u>Acknowledgments</u> - Acknowledgments are recognitions of a given communication (Foushee & Manos, 1981). They provide an indication that a prior speech act was heard, but do not supply any additional information or evaluative response (Foushee et al., 1986). Typical acknowledgments are "yeah," "okay," or "roger." These types of communication are important because they are informative in nature and let the other crewmember know that his/her communication was received. Acknowledgments tend to reinforce the interaction process (Foushee et al. 1986).

<u>Replies</u> - Replies are statements used to respond to an inquiry, suggestion, or other communication that involves more information than a simple acknowledgment (Kanki et al., 1987). Replies provide more information than a simple acknowledgment. Also, replies may provide an indication to the sender of a message that information has been properly understood or accurately received (Oser et al., 1991).

<u>Non-task related</u> These types of communication are unrelated to the flight task at hand. These behaviors include all socio-emotional communications exhibited between crewmembers (Oser et al., 1991). Non-task related communications include incidents of embarrassment, tension release, humor, frustration, etc. (Oser et al., 1991). Non-task related communications accounted for a very small percentage of the total communications in this investigation.

<u>Uncodable</u> "These communications include interactions that can not be classified, either because no accurate category exists or because they are unintelligible" (Oser et al., 1991). Less than 6.9% of all the communications in

this study were uncodable. Uncodable communications result from a crewmember mumbling or malfunctioning radio equipment or two crewmembers trying to talk at the same time. Oser et al. (1991) notes that the presence of uncodable communication may be suggestive of difficulties that exist in the interaction process between crewmembers.

Each of these categories was analyzed separately. The communication content results were used as dependent variables to explore how the content of communication was affected by crewmember position and type of flight: manual or autopilot.

TABLE 2
COMMUNICATION CATEGORIES, DEFINITIONS, AND EXAMPLES

(Bowers, Deaton, Oser, Prince, & Kolb, 1995)

Category	**Definition**	**Examples**
Commands (CMD)	Specific assignments of responsibility by one group member to another.	"I need timing there please" "You need to come a little bit to the right here."
Observations (OBS)	Remarks made by crewmembers aimed at orienting others to some aspect of flight status, such as references to instruments, environment or navigation.	"Altitude looks good." "And I got you at about 100 feet prior." "We're starting to go in and out of the clouds here."
Suggestions (SUG)	Recommendations for a specific course of action or the introduction of an idea for consideration from one crewmember to another.	"I don't think this is gonna get us there......." "And you might want to let ATC know that we're heading back."
Statements of Intent (SOI)	Announcements of intended actions, present or future, by the speaker.	"Okay, I'm coming right." "I'm gonna change us to operations."
Inquiries (INQ)	Requests for information regarding some aspect of flight status.	"What supply are we picking up next?" "When do we call?"
Acknowledgments (ACK)	Statements that are u sed to reply to an inquiry, observation, or other communication that only indicates that a communication was received.	"You say 13?" (OBS) "Roger." (ACK) "Lewis is next?" (INQ) "Yeah" (ACK)
Replies (REP)	Statements used to respond to an inquiry, suggestion, or other communication that involves more information than a simple acknowledgment.	"What's our ETA?" (INQ) "11:47:34" (REP) "Slow down your airspeed." (CMD) "Slowing down to 80knots." (REP)
Nontask related (NTR)	Any speech acts referring to something other than the present task.	"I'm not comfortable here." "Good call Joe, you read my mind."
Uncodable (UNC)	Any speech acts that are unintelligible or unclassifiable with respect to the present coding scheme.	". . . " ". . . right" "The cards there."

ANALYSIS

Video tapes were randomized when played back for analysis coding so as to conceal the flight condition (automated or manual) to the raters. The transcripts were categorized using a nine category coding system adapted from Oser et al. (1991). The communication content of the subjects' speech were transcribed onto coding forms. Raters were given the task of categorizing speech acts into one of nine categories: commands, observations, suggestions, statements of intent, inquiries, acknowledgments, replies, non-task related, and uncodable communications. The data from the coding sessions indicated that raters could perform this task with acceptable levels of agreement (the average inter-rater r was .84).

The hypotheses of how crew communication content is affected by pilot position and automation level was examined using a Multivariate Analyses of Variance (MANOVA). A MANOVA was selected because multiple dependent variables (i.e., nine communication content categories) were assessed. Advantages to using MANOVA instead of multiple one or two-way variance (ANOVA) is that MANOVA can reveal differences not shown in a series of individual ANOVAs and MANOVA can provide increased protection against Type-1 errors (Oser, et al. 1991).

The MANOVA focused on assessing changes in the frequency of the communication content measures (i.e., dependent variables) as a function of crew member position (i.e., pilot, copilot) and flight level (i.e.,manual, automated).

Results

The results of this research are discussed in two sections. The first section provides the results of descriptive analyses (i.e., totals, means, standard deviations) performed for the communication patterns. The descriptive analyses provide a preliminary examination of the general nature of helicopter crew communication.

The second section of the results investigates how communication content is affected by pilot position (pilot vs. copilot) and flight requirement (manual vs. automated). These results emphasize the relationship between communication and automation level. The results of this analysis identify specific types of communication content that are associated with the flight type: manual or automated.

Descriptive Analyses

Frequency-based Communication Content

Using the nine category classification system, a total of 3012 transcript lines were coded for the fourteen crews (mean=253 lines/crew). The means and standard deviations for the frequencies of communication content during manual and automated flight scenarios are presented in Tables 2 and 3. Preliminary analyses indicated that a higher frequency of total communications was demonstrated during manual flights (1771 lines in manual vs. 1241 in automated). The mean frequency of communications during the manual and automated flights were 126.5 (manual) and 88.6 (automated).

Observations were the most frequently coded communications initiated by both crew members during manual and automated flights. Observations accounted for 24.4% of the total communications during manual flights and

26.5% of the total communications during automated flights. In comparison, the initiation of suggestions were the least frequently coded type of communication during the manual flights, accounting for only 5.4% of the total communications in manual flights. The initiation of non-task related communications were the least frequently coded type of communication during the automated flights, accounting for only 1.4% of the total communications, respectively.

Table 3
Means and Standard Deviations (SD) For Frequencies of Communication Content By Crew members During Manual Flight.

Pilots	CMD	OBS	SUG	SOI	INQ	ACK	REP	NTR	UNC
Freq.	232	185	50	63	95	109	61	125	5
Mean	31.71	26.42	6.71	9.00	13.57	15.57	8.71	15.28	.7143
SD	13.32	8.81	2.43	3.74	5.62	7.76	4.02	9.48	1.49
CPs									
Freq.	21	248	47	84	90	192	99	56	9
Mean	3.00	35.42	6.71	12.57	12.85	27.42	14.14	7.85	1.28
SD	1.63	9.64	2.28	3.40	2.26	5.79	3.48	2.96	1.79
Crew									
Freq.	253	433	97	147	185	301	160	181	14
Mean	17.35	30.92	6.71	10.78	13.21	21.50	11.42	11.57	1.00
SD	17.46	10.02	2.26	3.90	4.13	9.01	4.58	7.77	1.61

Table 4
Means and Standard Deviations (SD) For Frequencies of Communication Content By Crew members During Automated Flights.

Pilots	CMD	OBS	SUG	SOI	INQ	ACK	REP	NTR	UNC
Freq.	171	179	55	82	59	72	59	12	2
Mean	24.42	25.57	7.85	11.71	8.42	10.28	8.42	1.71	.2857
SD	7.63	9.67	3.07	3.54	4.11	4.30	1.90	.9512	.4880
CPs									
Freq.	3	150	22	59	59	135	114	6	2
Mean	.4286	21.42	3.14	8.42	8.42	19.28	16.28	.8571	.2857
SD	.5345	4.07	2.67	2.07	2.99	7.15	2.05	.8997	.4880
Crew									
Freq.	174	329	77	141	118	207	173	18	4
Mean	12.42	23.5	5.50	10.07	8.42	14.78	12.35	1.28	.2857
SD	13.49	7.44	3.69	3.26	3.45	7.35	4.49	.9945	.4688

Note. CMD=Commands; OBS=Observations; SUG=Suggestions; SOI=Statements of Intent; INQ=Inquiries; ACK=Acknowledgments; REP=Replies; NTR=Non-task related; UNC=Uncodable.

Frequency-Based Communication Analyses

This section of the results focuses on identifying the effects of crew member position and automation level on communication amount and content. A Multivariate Analyses of Variance (MANOVA) was performed to analyze the frequency data for each of the nine content categories. Multivariate tests yielded a significant effect among the nine categories, in terms of both main effects and their interaction. Through the use of Wilks' Lambda criterion for the data analysis, the content categories were found to be significantly affected by crew position [F (9,16) = 19.178, $p<.05$], automation level [F, 9,16) = 9.842, $p<.05$], and their interaction [F (9,16) = 3.037, p,.05].

Based on the significant results of the MANOVA, a series of univariate ANOVAs was performed to identify the specific dependent variables (i.e., communication content categories) that were affected by the independent variables (i.e., crew position, automation level) or their interaction. The results of the univariate ANOVAs are presented in Table 4.

The univariate ANOVAs yielded significant main effects for the crew member position variable on five of the communication content categories (i.e., commands, suggestions, acknowledgments, replies, non-task related) and for the automation level variable on four of the communication content categories (i.e., observations, inquiries, acknowledgments, non-task related).

In addition, three position-by-automation level interactions were found to be significant (i.e., observations, suggestions, statements of intent).

Commands

The main effect for automation was not significant, nor was the interaction of pilot position X automation level. However, the main effect for pilot position was significant, F (1,27), = 81.452, p<.05. The mean command response rate for the pilots was 28.07, whereas the mean for the copilots was 1.71. Figure 3 illustrates the main effect for pilot position on command responses.

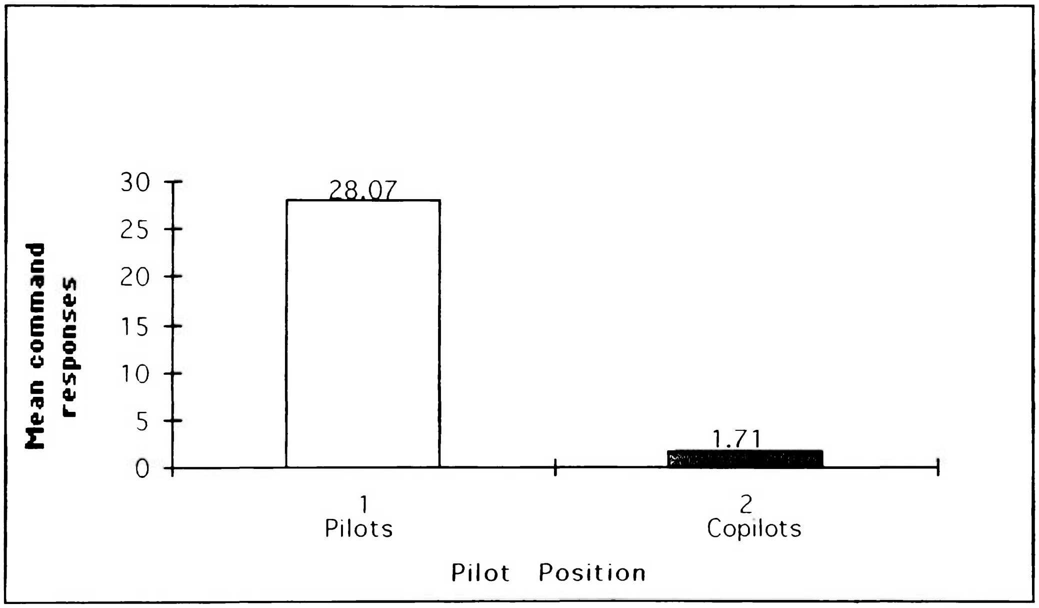

Figure 3. Average command responses as a function of pilot position.

Observations

The main effect for automation was significant, F (1,27) = 5.50, p<.05. The mean for the manual condition was 30.92, whereas the mean for the automated condition was 23.50.

Observation responses were produced .2444 (or 24.4%) of the time in the manual mode and .3083 (or 30.8%) of the time in the automated mode.

The Pilot Position X Level of Automation interaction was significant, F (1, 27) = 4.306, p<.05. Figure 4 shows the Observation response rate as function of pilot position and level of automation. Essentially, figure 4 displays that the mean for pilots in the manual condition was 26.42, whereas the mean Observations for pilots in the automated condition was 25.57. The mean Observations for copilots in the manual condition was 35.42, as compared to a mean of 21.42 for copilots in the automated condition.

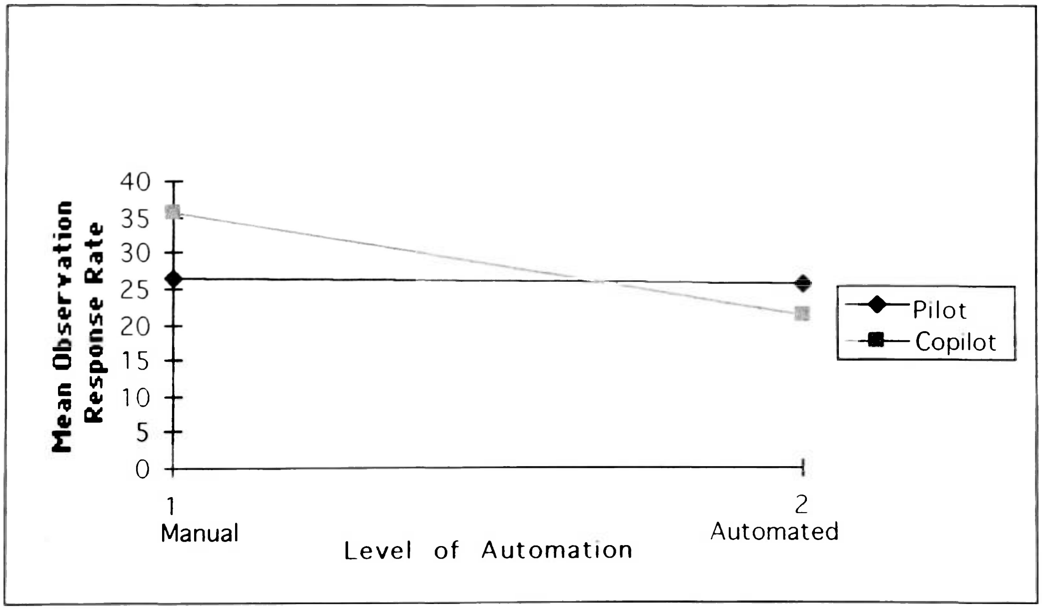

Figure 4. Observation rate as a function of pilot position and automation level.

Suggestions

The main effect for automation was not significant. However, the main effect for pilot position was significant, F (1,27) = 5.604, p<.05. The mean suggestion response rate for pilots was 7.28 as compared to a mean of 4.92 for copilots.

The interaction of Pilot Position X Automation level was significant, F, (1,27) = 5.604, p<.05. The mean number of Suggestions for the pilots in the manual condition was 6.71 and the mean for the automated condition was 7.85. In addition, the mean number of Suggestions for copilots in the manual condition was 6.71 with a decrease to a mean of 3.14 in the automated condition. Suggestion response rate as a function of pilot position and level of automation is displayed in Figure 5.

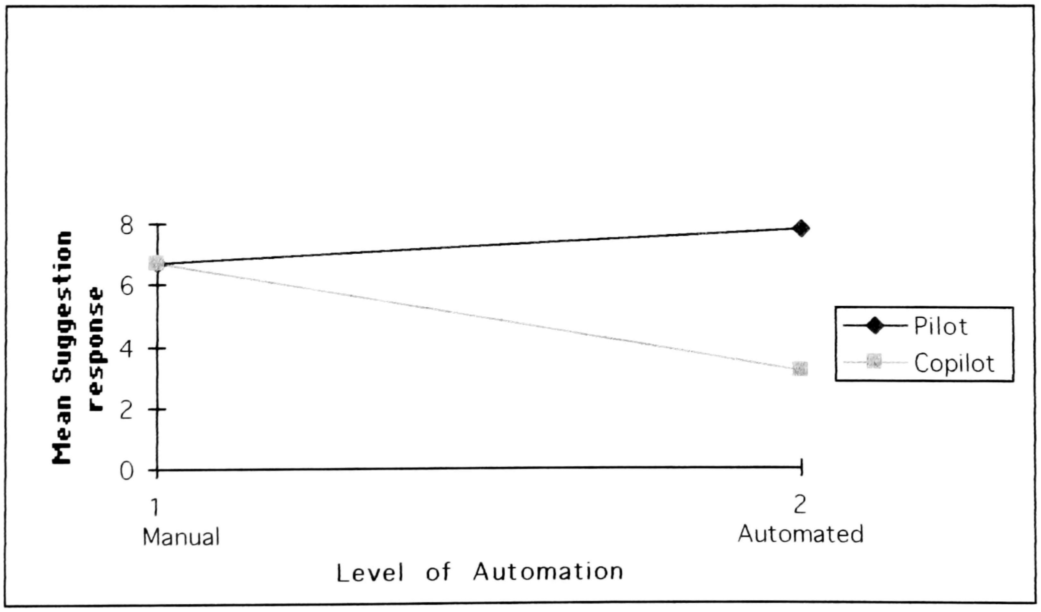

Figure 5. Suggestion response rate as a function of pilot position and automation level.

Statements of Intent

The main effect for automation was not significant, nor was the main effect for pilot position. The interaction of Pilot Position X Level of Automation was significant, F (1,27) = 7.749, p<.05. Figure 6 shows the "Statements of Intent" response rate as a function of pilot position and level of automation. The mean number of "Statements of Intent" issued by pilots in the manual condition was 9.00 as compared to 11.71 mean statements of intent issued by pilots in the automated condition. The mean number of Statements of Intent issued by copilots in the manual condition was 12.57 and 8.42 in the automated condition.

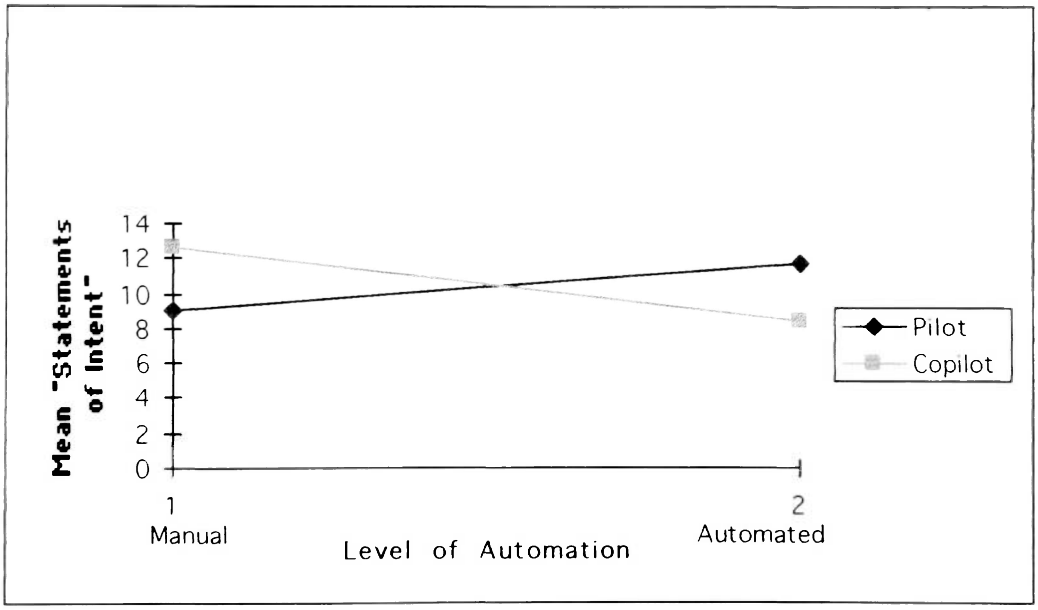

Figure 6. Statements of Intent as a function of pilot position and automation level.

Inquiries

The main effect for automation was significant, F (1,27) = 10.233, p<.05. The mean for the manual condition was 13.2143, whereas the mean for the automated condition was 8.4286. Figure 7 illustrates the main effect for automation. The main effect for pilot position was not significant, nor was the interaction of pilot position by automation level.

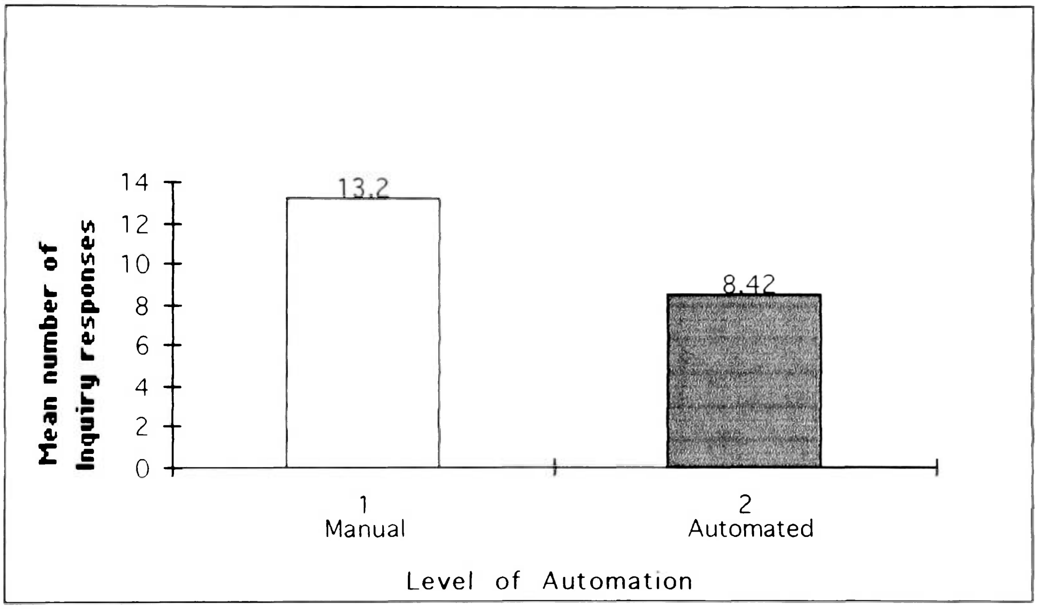

Figure 7. Inquiry response rate as a function of automation level.

Acknowledgments

The main effect for automation was significant, F (1,27) = 7.710, p<.05. The mean for the manual condition was 21.50, as compared to the mean for the automated condition which was 14.78.

In addition, the main effect for pilot position was significant, F (1,27) = 18.600, p<.05. The mean for the Pilots in the manual condition was 15.57, whereas the mean for the pilots in the automated condition were 10.28. The mean for the Copilots in the manual condition were 27.42, whereas the mean for the Copilots in the automated condition were 19.28. The interaction of pilot position and level of automation was not significant. Figure 8 illustrates these main effects.

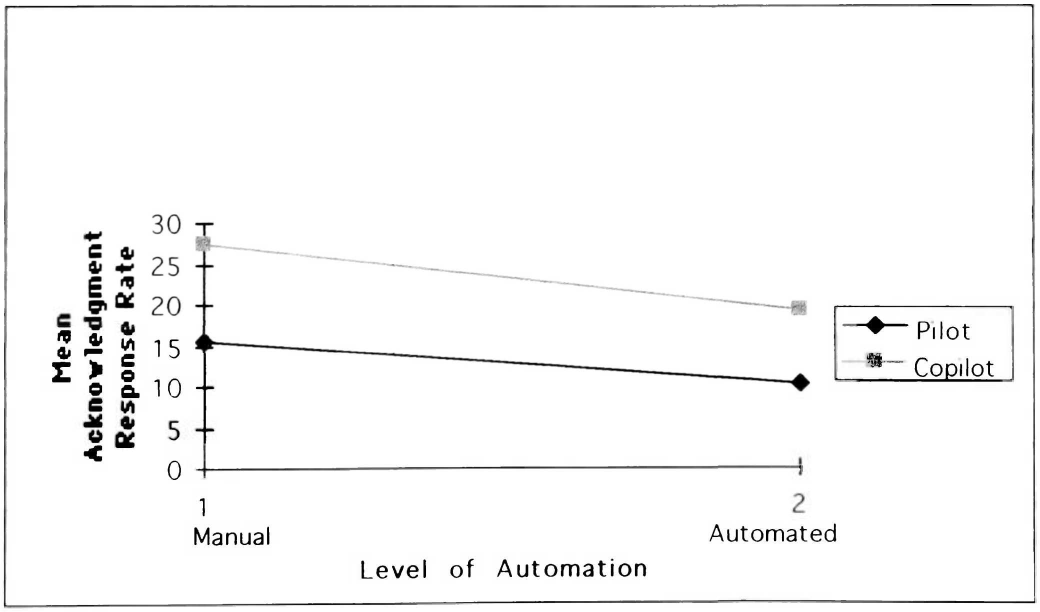

Figure 8. Acknowledgment response rate as a function of pilot position and automation level.

Replies

The main effect for automation was not significant, nor was the Interaction between Pilot Position and Level of Automation. Yet, the main effect for pilot position was significant, F(1,27) = 34.09, p<.05. The mean reply response rate for pilots in the manual condition were 8.71, as compared to a mean reply response rate of 8.42 in the automated condition. The mean reply response rate for the copilots in the manual condition was 14.14, whereas the mean for the copilots in the automated condition was 16.28. Figure 9 illustrates the percentage of the response "replies" for pilot position and automation level. For example, in the manual condition, 6.5% of pilots' total speech acts were replies as compared to 8.5% in the automated condition. For copilots, 11.7% of their total speech acts consisted of replies, as compared to 20% in the automated condition.

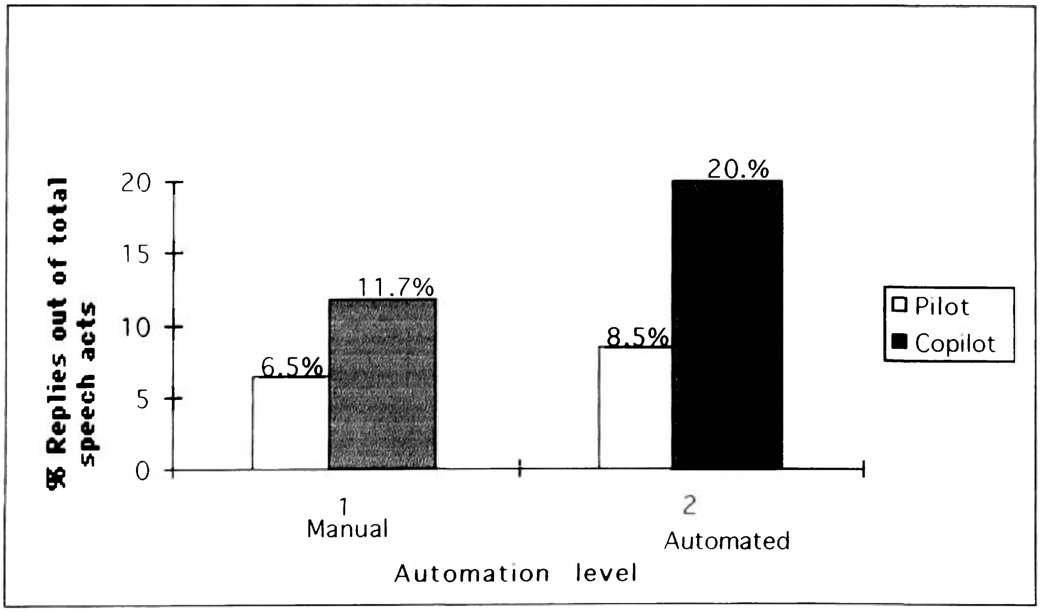

Figure 9. Reply response rate
as a function of pilot position and automation level

Non-task related

The main effect for automation level was significant, F (1,27) = 29.49, p<.05. The mean number of non-task related speech acts was 11.57 in the manual condition, versus a mean response rate of 1.28 in the automated condition.

The main effect for pilot position was also significant, F (1,27) = 4.785, p<.05. The mean number of non-task related responses for the pilots flying in the manual condition was 15.28, as compared to a mean of 1.71 in the automated condition. Also, the mean number of non-task related responses for the copilots-pilots in the manual condition was 7.85, as compared to a mean of .85 in the automated condition. Figure 10 illustrates the mean number of non-task related responses as a function of pilot position and automation level.

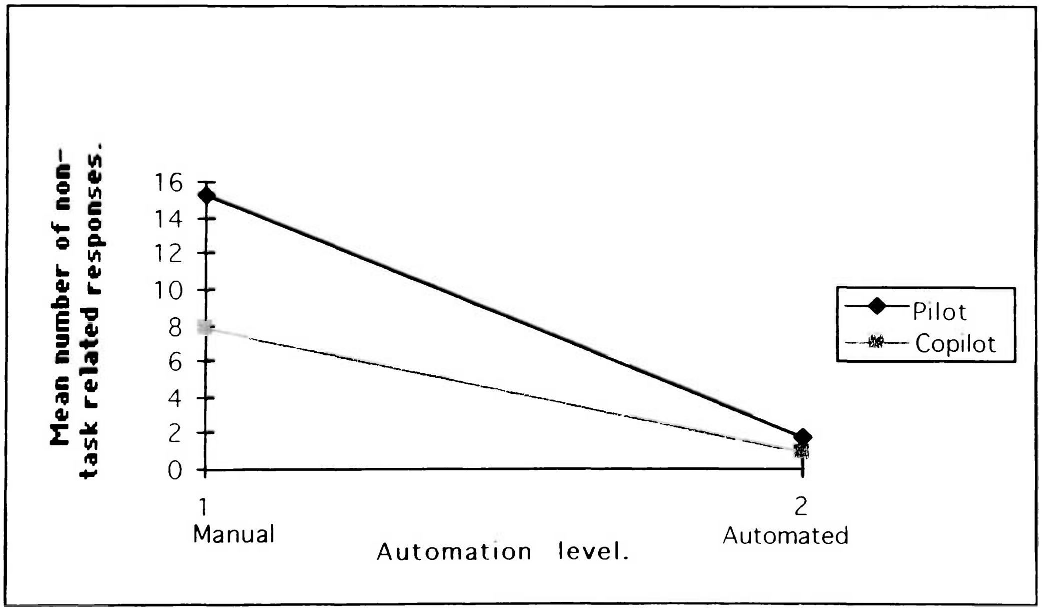

Figure 10. Non-task related responses as a function of pilot position and automation level.

Uncodable

None of the effects were significant.

CONCLUSIONS

The purpose of this investigation was to clarify the relationship between cockpit automation and helicopter crew communication. This study was designed based on previous research carried out with fixed-wing crews, but it was restructured to address helicopter crew issues. The conclusions that are presented here thus refer to the helicopter environment. However, some conclusions do parallel situations already recognized by research in this area with fixed-wing crews, therefore highlighting that some effects of automation are not unique to a specific flight platform.

Overall, crews in the automated condition exhibited far less communication behaviors than crews in the manual conditions. The results suggest that the introduction of automation reduces the amount of cockpit crew communication used by crews. Another explanation for the decrease in overall communication in the automated conditions is that the automation "masks" the need to communicate.

Automation Level, Pilot Position Interactions

Observations

The primary task of the pilot was to provide control inputs to the simulator to sustain the flight requirement. In the automated scenario, this task was changed to a monitoring of the controls and system. The results of the analyses showed that pilots exhibited higher rates of Observations in the manual conditions than did pilots in the automated conditions. This finding is somewhat surprising as the removal of the physical task of flying would increase the need for pilots to provide observations during automated conditions. The only explanation for the increased rates of observations on the part of the pilots in the manual must be due to other task requirements. A likely explanation is that although the copilot has taken over the task requirement of flying (essentially by programming and having control over the autopilot), the shift in workload has not occurred in a mutual way. That is, the pilot has not taken over the traditional monitoring and observing role in the automated scenario from the copilot. The pilot is still concerned with other tasks in the automated condition and does not willingly move into an observer role, or realize that his/her copilot is making fewer observations.

The results of the analyses also indicated that pilots exhibited higher rates of Observations during automated conditions than did their copilots in the automated conditions indicating the shift in roles with the copilot becoming more active with the programming of the autopilot in flight and therefore less time to devote to observation. The introduction of automation changed the copilots role to that of a programmer of the autopilot. Essentially, it appears the copilots using an automated cockpit had less time to monitor and scan for traffic, with more "heads down" time with the programming of the autopilot (this is expressed in the decreased number of observations in the automated condition).

The results also show that copilots exhibited higher rates of Observations in the manual conditions than copilots in the automated conditions. This is not surprising as the task of the copilots in the manual is one of an observer of flight status (as the pilot does most of the work in the physical task of flying). Again, it appears from the results that the copilot role changed from one of a observer in the manual condition to one of a programmer in the automated condition. Hence, the copilots' communication is indicative of the switch in roles. These results validate Wiener's theory (1989) that the roles and responsibilities of the crew members change when automation is introduced into an aviation task.

Suggestions

The results of the analyses indicated that pilots exhibited a higher rate of suggestions as compared to copilots during automated conditions. These results suggest that the incorporation of automation into the system relieves the pilot of the task of flying, thereby freeing up his/her resources and allowing more attention to be focused on decision-making and future courses of action(as indicated by the increased number of suggestions in the automated conditions).

The role of the copilot as a "communicator of suggestions" was greater in the manual conditions as compared to copilots in the automated conditions. This indicates the shift in workload. Essentially, the copilots' workload became higher in the automated conditions as he/she had the responsibility of programming the autopilot in addition to traditional responsibilities. It appears that the copilot has less resources to lend to the decision-making task, as indicated by the decrease in suggestions under automation.

Again, these results validate Wiener's (1989) hypothesis that roles and responsibilities of crew members change when automation is introduced into the aviation task. In essence, the nature of communication varies with changes in the demands of the task itself.

Statements of Intent

The results of the analyses indicated that pilots initiated higher rates of statements of intent in the automated condition than did pilots in the manual condition. This finding is somewhat surprising because the need for pilots to make control inputs and therefore the need to inform their copilots of their intended actions should be reduced with the introduction of the automated system. Hence, it is reasonable to assume that the increased rate of statements of intent initiated by pilots in the automated conditions must be due to other task requirements. One likely explanation is that the pilots in the automated flight were stating more of their intended actions (going over their approaches, what they will do, etc...) to keep themselves in the loop of flying and their copilots informed. This could be observed in the videotapes of the automated conditions where the pilots exhibited almost a "nervous chatter" of intended actions as a result of the hands off (which is unusual for helo. pilots), autopilot flying. Their role became more of a manager and planner as a result of the removal of the physical task of flying. The increased statements of intent in the automated conditions were composed of more future intended actions rather than present actions initiated. For example, in one crew, the pilot began to review his intended approach with his copilot once the autopilot was engaged. Several communications were initiated between the crew, most of which were composed of statement of intent by the pilot such as: "We'll do the 18right, and our decision height will be 540 feet...upon station passage we'll do a right turn, etc..."

OVERALL CONCLUSIONS

The results of the analyses indicated that the roles (as indicated by the rates of observations, suggestions and statements of intent) for each of the crew members were different as a function of whether the crew was performing in the automated or manual conditions. The roles shift as a function of the task demand (Bowers et. al., 1995). Overall, pilots exhibited far less communication in the automated conditions. However, the pilots role as a communicator of observations, suggestions and statements of intent was greater in the automated conditions than the manual. The results suggest that the incorporation of automation is associated with changes in the communication amount and content initiated by each of the crew members. In other words, the verbalization demands placed on pilots and copilots differ as a result of automation.

In summary, the above results have led the researcher to accept the initial hypothesis and conclude that, within the helicopter environment, crew communication and therefore, crew coordination is influenced by automation under varying conditions of workload.

RECOMMENDATIONS

This investigation provided an initial understanding of how automation influences the unique communication patterns and characteristics of helicopter pilots. Based on the findings, the following recommendations are proposed:

1. A low-fidelity research paradigm was utilized for this study. Therefore, the first recommendation is to study the effects of automation in a full-motion simulator, with a LOFT type scenario to obtain a more realistic, high fidelity environment.
2. Only one experimental scenario was utilized in this study. It would be beneficial to repeat this study design with different scenarios. For example, the ASRS (Aviation Safety Reporting System) frequently cited incidents that occurred in congested cities. It would be beneficial to understand how different terrain's affect the use of automation. To illustrate, many of the former Army helicopter pilots in this study considered automation a benefit to long-range missions such as offshore oil support and Coast Guard operations, and a hazard to other types of helicopter flying, such as in congested cities or short flights.
3. This study made no distinction between military and civilian trained helicopter pilots. Military pilots receive some form of ACT (Aircrew Coordination Training) and were very cognizant of crew coordination in this study, whereas most of the civilian helicopter pilots had little or no CRM training. Although this allowed for a good representative sample of

commercial helicopter pilots flying today, it would be beneficial to study the effects of automation on crew coordination in a military setting as well as in the commercial (civilian) helicopter market. Essentially, the use of automated systems is driven by mission requirements in the military. It would be beneficial to understand the result of this technology on crew coordination with the goal of implementing the findings into Aircrew Coordination Training for crews flying highly advanced helicopters.

4. To the researcher's knowledge, automation effects on crew coordination are not taken into account in Helicopter CRM (Crew Resource Management) training programs. This might call for a unique program or an addition to CRM programs to address this issue.

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APPENDIX A. DEMOGRAPHIC SHEET

HELICOPTER STUDY

MINIMUM REQUIREMENTS ARE A PRIVATE PILOT - HELICOPTER LICENSE.

1. <u>Helicopter</u> pilot Certificates and Experience:

___private ___commercial ___instrument ___instructor
___ATP

other (please explain): ____________________

Flight Time Total: ____________________

Last 90 days: ____________________

2. Were you trained as a helicopter pilot in the military? __no __yes
If yes, what helicopter(s) are you certified in? ____________________

____

____

3. Do you have any experience flying a highly automated helicopter(s)? (automated = EFIS and FMS) ___no ___yes
(If yes, please elaborate on type of helicopter and automated systems): ____________________

____

____

____

EXPERIMENT WILL CONSIST OF FLYING A SIMULATED HELICOPTER SCENARIO IN A TWO-PERSON CREW. A DESKTOP SIMULATOR WILL BE USED TO SIMULATE A SIKORSKY S-76B HELICOPTER. THE EXPERIMENT SHOULD TAKE APPROXIMATELY 1 HOUR TO COMPLETE.

Name (Print): ____________________
Phone: ____________________
E-mail: ____________________
Primary language: ____________________
Date of Birth: ____________________

APPENDIX B. CREW CONCEPT BRIEFING - PILOT

CREW CONCEPT BRIEFING

PILOT

You have been randomly assigned to the position of **PILOT.** **Responsibilities include making control inputs into the simulator with respect to the course and altitude, airspeed, etc... For the purposes of this study this also means that you are the PIC. Pilot in Command is responsible for the conduct and safety of the flight. PIC designates pilot flying and copilot duties.**

APPENDIX C. CREW CONCEPT BRIEFING - COPILOT

CREW CONCEPT BRIEFING

COPILOT

You have been randomly assigned to the position of **COPILOT.**

Copilot maintains ATC communications, copies clearances, accomplishes checklists and other tasks as directed by the Pilot (PIC).

Through the use of a keyboard and mouse, the instruments, radio settings, and autopilot functions can be manipulated.

APPENDIX D. ASSIGNED MISSION SHEET FOR MANUAL CONDITION

ASSIGNEDMISSION

YOUR MISSION IS TO FLY FROM DAYTONA BEACH AIRPORT (DAB) TO ORLANDO EXECUTIVE AIRPORT (ORL).

Do not use the Autopilot function to fly the scenario.

Your alternate landing airports are:
Orlando Sanford (SFB)

All the charts, sectionals, and approach plates that you need will be supplied for you.

You will now have fifteen minutes (or more if needed) to conduct a preflight briefing as a crew:
-review departure procedures (route and altitude)
-review required callouts
-ask your crewmember if there are any questions.

PLEASE INFORM THE EXPERIMENTER WHEN YOU ARE FINISHED WITH THE PREFLIGHT BRIEFING.

APPENDIX E. ASSIGNED MISSION SHEET FOR AUTOMATED CONDITION

ASSIGNED MISSION

YOUR MISSION IS TO FLY FROM DAYTONA BEACH AIRPORT (DAB) TO ORLANDO EXECUTIVE AIRPORT (ORL).

Fly as much of the scenario as possible with the simulator's Autopilot engaged.

Your alternate landing airports are:
Orlando Sanford (SFB)

All the charts, sectionals, and approach plates that you need will be supplied for you.

You will now have fifteen minutes (or more if needed) to conduct a preflight briefing as a crew:
-review departure procedures (route and altitude)
-review required callouts
-ask your crewmember if there are any questions.

PLEASE INFORM THE EXPERIMENTER WHEN YOU ARE FINISHED WITH THE PREFLIGHT BRIEFING.

APPENDIX F. MANUAL DEPARTURE CHECKLIST

DEPARTURE CHECKLIST

Pilot flying calls for checklist items and copilot "reads back" item as action is completed. Pilot flying must complete departure checklist.

1. **SEAT............ADJUST (Both)**
2. **FUEL............CHECK (Copilot)**
3. **TRIM............CENTERED (Pilot)**
4. **ATIS (120.5)............COPIED (Copilot)**
5. **ALTIMETER............SET (Copilot)**
6. **CLEARANCE (119.3)............RECEIVED (Copilot)**
7. **NAVs............SET (Copilot)**
8. **HEADING AND COURSE BUG............SET (Copilot)**
9. **DME............SET (Copilot)**
10. **TRANSPONDER............SET (Copilot)**
11. **DEPARTURE BRIEFING............COMPLETE (Pilot)**
12. **COM TO TWR. (120.7)............SET (Copilot)**
13. **REQUEST TAKEOFF............COMPLETE (Copilot)**

(Begin flight by clicking yellow "paused" button.)

APPENDIX G. AUTOMATED DEPARTURE CHECKLIST

DEPARTURE CHECKLIST

Pilot flying calls for checklist items and copilot "reads back" item as action is completed. Pilot flying must complete departure checklist.

1. SEAT	ADJUST (Both)
2. FUEL	CHECK (Copilot)
3. TRIM	CENTERED (Pilot)
4. ATIS (120.5)	COPIED (Copilot)
5. ALTIMETER	SET (Copilot)
6. CLEARANCE (119.3)	RECEIVED (Copilot)
7. NAVs	SET (Copilot)
8. HEADING AND COURSE BUG	SET (Copilot)
9. DME	SET (Copilot)
10. TRANSPONDER	SET (Copilot)
11. DEPARTURE BRIEFING	COMPLETE (Pilot)
12. COM TO TWR. (120.7)	SET (Copilot)
13. REQUEST TAKEOFF	COMPLETE (Copilot)
14. PROGRAM AUTOPILOT	CHECK (Copilot)

(Begin flight by clicking yellow "paused" button.)

APPENDIX H. AIR TRAFFIC CONTROL SCRIPT

ATC SCRIPT

ATC calls are listed in order of first, second, etc...

1. ATIS DAYTONA (120.05) : "Daytona Beach International -InformationXRay Zero Hundred Zooloo Weather. Sky clear, visibility 5, Temp. 59, Dewpoint 0. Wind 050 at 6. Altimeter 29.92. Arriving and departing runway 7 left. Advise on initial contact you have X-ray."

2. ATC CLEARANCE OUT OF DAYTONA: "8375Tango you are cleared as filed, maintain at or below 1500 initially, expect higher after that. Departure will be on 123.9. Squawk 4244. Advise when ready to takeoff."

3. TAKEOFF CLEARANCE: "8375Tango cleared for takeoff runway 7 left."

4. ONE MINUTE AFTER DEPARTURE: "8375Tango contact departure on 123.9."

5. DEPARTURE: "8375Tango, Radar Contact, climb to 2000 approved, proceed on course to Orlando Executive."

6. ON COURSE, SEVEN MINUTES INTO SCENARIO: "8375Tango turn left 20 degrees for traffic avoidance."

7. ON COURSE, TWELVE MINUTES INTO SCENARIO: "8375Tango, Proceed on course."

8. ORLANDO EXECUTIVE ATIS (127.25) : "Executive Information Juliet. 1 Hundred Zooloo weather, Measured ceiling 2300 overcast. Visibility 3. Temperature 59.
Dewpoint 54. Wind 360 at 32. Arriving and Departing runway 25. Advise on initial contact you have Juliet."

9. APPROACH CALL(124.8) : "8375Tango weather deteriorating in approach area, wind 050 at 32, runway 7 in use, contact tower on 118.7."

10. TOWER CALL (118.7) : "8375Tango, Orlando Executive closed due to convective weather and windshear in the area, proceed to alternate airport."

11. ATIS FOR SANFORD ALTERNATE: "Orlando Sanford, Information November. Measured ceiling 3000, visibility 4 miles, temp. 59, dewpoint 56, wind 350 at 15. Altimeter 29.92. Arriving and departing runway 9 left. Advise on initial contact you have November."

APPENDIX I. KEY COMMAND INSTRUCTIONS FOR COPILOT IN MANUAL CONDITION

KEY COMMAND INSTRUCTIONS - COPILOT/MANUAL

Operating the system can be accomplised in two ways: (1) By pointing and clicking with the mouse, or (2) Using the keyboard command equivalents listed below:

(By depressing the key function on the left, the instrument on the right is manipulated). For example, press the "y" key and the heading bug turns left. Press the "u" key and the heading bug turns right.

y	u	Heading bug
n	m	Adjust OBS

Views:

Listed below are the keyboard command equivalents for views in the view menu. For example, pressing the "S" key results in the screen view shifting down 4 degrees.

W	Forward
Z	Backwards
S	Down 4 degrees
X	Down 8 degrees
F	Above 10 degrees
R	Above 40 degrees
Q	Left
E	Right
Shift +	Full screen without HUD
Shift -	Full screen with HUD
=	Zoom In
-	Zoom Out

APPENDIX J. KEY COMMAND INSTRUCTIONS FOR COPILOT IN AUTOMATED CONDITION

KEY COMMAND INSTRUCTIONS - COPILOT/AUTOMATED

Operating the system can be accomplised in two ways: (1) By pointing and clicking with the mouse, or (2) Using the keyboard command equivalents listed below:
(By depressing the key function on the left, the instrument on the right is manipulated). For example, press the "y" key and the heading bug turns left. Press the "u" key and the heading bug turns right.

y	u	Heading bug
n	m	Adjust OBS

Autopilot commands:

Shift + 1	Autopilot Disconnect
Shift + 4	Autopilot Heading
Shift + 5	Autopilot Nav Course 1
Shift + 6	Autopilot Nav Course 2
Shift + 7	Autopilot Altitude Hold
Shift + 8	Autopilot Glide Slope 2

Views:

Listed below are the keyboard command equivalents for views in the view menu. For example, pressing the "S" key results in the screen view shifting down 4 degrees.

W	Forward
Z	Backwards
S	Down 4 degrees
X	Down 8 degrees
F	Above 10 degrees
R	Above 40 degrees
Q	Left
E	Right
Shift +	Full screen without HUD
Shift -	Full screen with HUD
=	Zoom In
-	Zoom Out

APPENDIX K. CODING FORM

ID#
ID#

PILOT
COPILOT
ATC

TRANSCRIPT LINES	COMMANDS	OBSERVATIONS	SUGGESTIONS	STATEMENTS OF INTENT	INQUIRIES	ACKNOWLEDGMENTS	REPLIES	NONTASK RELATED	UNCODABLE

ID#
ID#

PILOT
COPILOT
ATC

TRANSCRIPT LINES	COMMANDS	OBSERVATIONS	SUGGESTIONS	STATEMENTS OF INTENT	INQUIRIES	ACKNOWLEDGMENTS	REPLIES	NONTASK RELATED	UNCODABLE