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AN ANALYSIS OF AIRCREW COMMUNICATION PATTERNS AND CONTENT

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The findings reported here represent a detailed analysis of tactical rotary-wing aircrew communication patterns and content. This research is part of an extensive effort to investigate the nature of tactical aircrew coordination and to develop effective mission-oriented aircrew coordination training.

The primary objectives of this research were to answer the following questions: (1) What specific communication patterns and content are demonstrated by different helicopter crewmembers (i.e., Helicopter Aircraft Commander - HAC and Helicopter 2nd Pilot - H2P)? (2) Do tactical aircrew communication patterns and content vary as a function of the performance demands and requirements of different flight conditions (i.e., routine and non-routine)? (3) Are the communication patterns and content of more effective aircrews different from those of less effective aircrews? (4) What similarities exist between the communication patterns and content of military rotary-wing aircrews and commercial fixed-wing aircrews? and (5) Can the results of the communication analyses have an impact

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on aircrew coordination training?

In order to address these questions, a series of communication analyses were conducted using transcripts from 14 tactical rotary-wing aircrews performing mission-oriented scenarios in a motion-based simulator. The communication content was coded using a nine category classification system, in order to identify specific types of communication associated with crewmember position, flight condition, and operational performance. In addition, three types of communication patterns were investigated to determine whether communication content varied as function of the type of measurement index (i.e., frequency, rate, percentage).

In response to the five primary objectives of this investigation, the results suggest that: (1) each of the two aircraft crewmembers demonstrated specific types of communicatiion patterns and content (i.e., HACs initiated higher indices of commands, suggestions, statements of intent, and inquiries as compared to H2Ps. H2Ps initiated higher indices of observations as compared to HACs); (2) crews varied the intra-cockpit communication patterns and content depending on whether flight conditions were routine or non-routine (i.e., crews demonstrated higher indices of commands, suggestions, statements of intent, and replies during non-routine flight as compared to during routine flight); (3) specific types of crewmember communication content were related to aircrew operational performance (i.e., commands initiated by H2Ps during routine flight and inquiries initiated by HACs during non-routine flight were negatively correlated with operational performance); (4) tactical rotary-wing aircrews and commercial fixed-wing aircrews exhibited similarities with regard to the types of communication initiated by each crewmember, however, the two types of aircrews demonstrated differences with regard to how communication content varied depending on whether the flight conditions were routine or non-routine; and (5) the results of the analyses can be used to enhance the development of tactical rotary-wing aircrew coordination training.

Based on these results, it is suggested that specific attention needs to be focused on the unique communication requirements of tactical rotary-wing aircrews during routine and non-routine flight conditions. This investigation begins to provide an understanding of the nature of communication in a tactical rotary-wing cockpit. Subsequent research should analyze the communication patterns and content of tactical aircrews in other platforms or aircraft types (i.e., fixed-wing, tilt-rotor) to extend and test the generality of the current findings.

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EXECUTIVE SUMMARY

The findings reported here represent a detailed analysis of tactical rotary-wing aircrew communication patterns and content. This research is part of an extensive effort to investigate the nature of tactical aircrew coordination and to develop effective mission-oriented aircrew coordination training.

OBJECTIVES

The primary objectives of this research were to answer the following questions: (1) What specific communication patterns and content are demonstrated by different helicopter crewmembers (i.e., Helicopter Aircraft Commander - HAC and Helicopter 2nd Pilots - H2P)? (2) Do tactical aircrew communication patterns and content vary as a function of the performance demands and requirements of different flight conditions (i.e., routine and non-routine)? (3) Are the communication patterns and content of more effective aircrews different from those of less effective aircrews? (4) What similarities exist between the communication patterns and content of military rotary-wing aircrews and commercial fixed-wing aircrews? and (5) Can the results of the communication analyses have an impact on aircrew coordination training?

APPROACH

In order to address these questions, a series of communication pattern and content analyses were conducted using transcripts from 14 tactical rotary-wing aircrews performing mission-oriented scenarios in a motion-based simulator. Three types of communication patterns were investigated to determine whether communication content varied as a function of the type of measurement index (i.e., frequency, rate, percentage). The communication content was coded using a nine category classification system, in order to identify specific types of communication associated with crewmember position, flight condition, and operational performance. The communication patterns and content identified for the tactical rotary-wing aircrews were compared with results of a similar study using commercial fixed-wing aircrews (Foushee, Lauber, Baetge, & Acomb, 1986) to identify the existence of similarities between the two types of aviation settings.

RESULTS

In response to the five primary objectives of this investigation, the results suggest that: (1) each of the two aircraft crewmembers demonstrate specific types of communication patterns and content (i.e., HACs initiated higher indices of commands, suggestions, statements of intent, and inquiries as compared to H2Ps. H2Ps initiated higher indices of observations as compared to HACs); (2) crews vary the intra-cockpit communication patterns and content depending on whether the flight conditions are routine or non-routine (i.e., crews demonstrated higher indices of commands, suggestions, statements of intent, and replies during non-routine flight as compared to during routine flight); (3) specific types of crewmember communication content are related to aircrew operational performance (i.e., commands initiated by the H2Ps during routine flight and inquiries initiated by the HACs during non-routine flight were negatively correlated with operational performance); (4) tactical rotary-wing aircrews and commercial fixed-wing aircrews exhibit similarities with regard to the types of communication initiated by each crewmember, however, the two types of aircrews demonstrate differences with regard to how communication content varies depending on whether the flight conditions are routine or non-routine; and (5) the results of the analyses can be used to enhance the development of tactical rotary-wing aircrew coordination training.

CONCLUSIONS

Based on these results, it is suggested that specific attention needs to be focused on the unique communication requirements of tactical rotary-wing aircrews during routine and non-routine flight conditions. This investigation begins to provide an understanding of the nature of communication in a tactical rotary-wing cockpit. Subsequent research should analyze the communication patterns and content of tactical aircrews in other platforms or aircraft types (i.e., fixed-wing and tilt-rotor) to extend and test the generality of the current findings.

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INTRODUCTION

STATEMENT OF PROBLEM

Aviation experts estimate that over 60% of commercial aircraft accidents are attributable to human error (Billings & Reynard, 1984; Carroll & Taggart, 1986; Cooper, White & Lauber, 1979). One common type of human error involves the failure of aircrews to effectively exchange and communicate available information. For example, Billings and Reynard (1981) found that over 70% of reported aircraft incidents contained evidence of ineffective communication. Communication problems identified in the Billings and Reynard investigation included messages that were not originated; messages that were inaccurate, incomplete, ambiguous, or garbled; messages that were untimely; and messages that were misunderstood.

In an effort to provide information concerning the nature of aircrew communication and operational performance, a number of researchers have recently focused attention on the investigation of aircrew communication patterns and content (Foushee & Manos, 1981; Foushee, Lauber, Baetge, & Acomb, 1986; Jensen, 1986; Kanki, Lozito, & Foushee, 1987; Kanki, Greaud, & Irwin, 1989). It should be noted that although these studies have focused only on commercial fixed-wing aircrews, accidents due to human error are not unique to any particular type of aircraft (e.g., fixed-wing, rotary-wing) or aviation community (e.g., civilian, military). For example, Adams (1989) reported that human error was the causative factor in approximately 64% of the accidents involving helicopters. The extent of human error in Naval aviation is evidenced by reports from the Naval Safety Center. During a three year period (1985-1987), it was estimated that 162 fatalities and over $1.5 billion dollars in resources were lost because of human error (Naval Safety Center, 1987). The Naval Safety Center further 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). Although individual types of human error were not reported for the Navy, a recent analysis of Army aviation accident data (Leedom, 1990) revealed that "failure to communicate critical information" was one of the four identified causes in Army rotary-wing mishap data.

Important differences exist between tactical rotary-wing and commercial fixed-wing aircrews and aircraft, which suggest that the communication requirements of these two aviation communities are quite different and each needs to be individually investigated. One obvious difference between the aviation communities involves the maneuvering capabilities of the two types of aircraft. Helicopters possess a wider range of maneuvers and control requirements than do fixed-wing aircraft (Adams, 1989; Hart, 1988). Helicopters can virtually move in any direction, remain stationary while airborne, climb and descend vertically, operate at very low altitudes, and take off and land in almost any type of geographical terrain. 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.

A second difference between tactical rotary-wing and commercial fixed-wing communities involves the nature and purpose of the flight within the two settings. Cavanagh and Williams (1986) note that military and commercial aircrews differ on such factors as the purpose of the flight and the operational environment. Specifically, military aircrews are engaged in tactical missions and are often required to fly in hazardous or unfamiliar environments. The nature of the military mission requires that aircrews communicate mission-related, as well as, flight-oriented information. This requirement creates different communication demands in military rotary-wing aircrews. These differences suggest the need to investigate factors specifically related to the nature and function of aircrew communications in a tactical rotary-wing setting.

Despite the differences between the two aviation settings, it is possible that findings from commercial fixed-wing communication studies may be applicable to other types of aircraft and aircrews (e.g., military rotary-wing flight) given the general requirements of flight. However, since few studies have investigated the communication patterns and content in other types of aviation settings, there is no accurate way to determine what similarities and differences actually exist between the communication behaviors of tactical rotary-wing aircrews and commercial fixed-wing aircrews. The overall goal of this effort is to identify communication patterns and content that are specific to, and associated with, helicopter flight safety and tactical mission completion. The specific objectives of the current investigation are to conduct a partial replication of prior research using commercial fixed-wing aircrews (Foushee et al., 1986; Jensen, 1986; Ruffell Smith, 1979) in a military helicopter setting. The following questions were generated to guide this investigation:

(1) What specific communication patterns and content are demonstrated by tactical rotary-wing crewmembers (i.e., Helicopter Aircraft Commander - HAC, Helicopter 2nd Pilot - H2P)?

(2) Do tactical aircrew communication patterns and content vary as a function of the performance demands and requirements of different flight conditions (i.e., routine, non-routine)?

(3) Are the communication patterns and content of more effective aircrews different from those of less effective aircrews?

(4) What similarities exist between the communication patterns and content of military rotary-wing aircrews and commercial fixed-wing aircrews?

(5) Can the results of the communication analyses impact aircrew coordination training?

These questions were based on an assumption that a greater understanding of the nature of tactical aircrew communication patterns and content can be used to enhance crew coordination training effectiveness, improve certain aspects of mission performance, and increase flight safety for tactical rotary-wing aircrews. In addition, the results of this investigation will begin to provide a basis for examining the generalizability of prior commercial fixed-wing based investigations and existing commercial training programs to a tactical rotary-wing setting.

BACKGROUND

efficient exchange of information in multi-person ai. ..c cockpits is critical for effective performance and flight safety. Although instruments, manuals, and documentation provide a portion of the information needed by aircrews, oral communication between crewmembers is the most common method of information exchange (Billings & Reynard, 1981). For example, oral communications are used by aircrews in the process of organizing and planning, decision making, leading and commanding, identifying and resolving errors, and informing each other of actions being taken.

Even though oral information exchange is the prevalent means of communication between crewmembers and its breakdown has been implicated as one of the primary causes of aircraft incidents and accidents (Billings & Reynard, 1981), very little is known about the relationship between crew communication and operational performance (Dyer, 1984; Denson, 1981; Nieva, Fleishman, & Rieck, 1978). Dyer (1984) noted that little research has been devoted to examining such issues as: how team members interact with each other; how interactions vary over time; or how members interact in different situations. Helmreich, Hackman, and Foushee (1986) have commented that theoretical ideas have outreached empirical progress in the study of crew communication and task performance. Foushee and Helmreich (1988) suggested that crew communication research should include analyses involving a number of indices such as the structure, rate, and content of aircrew communication. While the current knowledge base regarding the role and nature of communication used by commercial fixed-wing aircrews is limited, it is more extensive than that available for any other aviation community. Therefore, the following review of previous research findings will concentrate almost exclusively on the results of commercial fixed-wing aircrew communication studies.

OVERVIEW

The following sections present the conceptual, literature, and research bases used to guide this investigation. Definitions of key terms related to communication patterns and content are provided and findings from related research are presented. Relevant areas of literature and research findings are reviewed to address the five questions previously presented in this paper. *Specific findings* include variations in the communication patterns and content of aircrew communication as a function of crewmember position and flight condition, as well as the relationship between operational performance and aircrew communication.

DEFINITIONS

Communication has been defined in many ways. For example, Dance (1967) identified over 95 different definitions of communication. Apparently, this plethora of definitions has developed because of the multitude of approaches and various levels of analysis which have been used to investigate the nature and process of communication. McGrath's (1984) definitions of communication and other related terms have been selected for this research because they describe the concepts specifically being addressed. According to McGrath, **interaction** occurs when two or more people do something together, and **communication** is a behavior, verbal or otherwise, used by one individual to interact with another individual. A series of communications by a set of interacting individuals can be regarded as a **communication process**.

McGrath defines the **communication pattern** as the form or structure of a series of interactive communications or behaviors. Communication patterns entail such features as the total frequency, distribution, initiation, and reception of communication among persons, in various situations, or over time. For McGrath, the **communication content** is the type or class of information that is exchanged. The content of an interaction is coded into a taxonomy of communications and then analyzed to investigate potential relationships or to develop profiles based on variables of research interest (McGrath, 1984). Communication patterns and content can be collected using repeated measures and analyzed to identify the effect of various situations on interaction.

COMMUNICATION MODELS

A number of models have been developed by researchers to provide useful frameworks for understanding the concepts related to communication (Bales, 1950; Dance, 1967; Foushee et al., 1986; Foushee & Manos, 1981; Jensen, 1986; Kanki et al., 1987; McGrath, 1984; Schramm, 1954; Shannon & Weaver, 1949). Although the models take different approaches to the analysis of communication, they can be categorized into three general types (vis., pattern-based, content-based, integrative).

Pattern-based Communication Models

Pattern-based communication models focus on the volume, distribution, and direction of communication across group members or across time. Little emphasis is given to the content of the communication in this pattern-oriented approach to communication analysis. One of the first, and possibly most recognizable models of communication patterns, was developed by Shannon and Weaver (1949). This model described a communication system as being composed of five components: source, transmitter, channel, receiver, and destination.

The Shannon-Weaver model implied that communication follows a relatively static, linear pattern of transmission. However, not all (or even most) interactions between humans conform to this one-way pattern of communication. A number of researchers (vis., Dance, 1967; Schramm, 1954; Tubbs, 1970) continued to refine the concept of communication pattern and posited that the pattern of communication is an interactive process which changes across time and situation. Their models and concepts are important to this research because they identified the components of the communication process (i.e., source, receiver, direction), introduced the idea of evaluating communication during different segments of time, and provided justification for using multiple measures of communication patterns.

Content-based Communication Models

Content-based models of communication patterns attend primarily to the content or type of communication exchanged between interacting individuals. This approach focuses on categorizing communication according to some coding system instead of identifying the pattern of the interaction. Communication content has been evaluated using a variety of classification systems. One of the first communication content classification systems was developed by Bales (1950), and was known as the Interaction Process Analysis (IPA) system. The IPA contains twelve categories that focus on two broad (i.e., task-related, socio-emotional) classes of communication behaviors. Communications required in the performance of a task are categorized as task-related behaviors. These communications include giving and asking for suggestions, opinions, or information. Socio-emotional behaviors include all communication related to the process by which individuals get along with each other during the period of the interaction. Socio-emotional behaviors include demonstrating solidarity or antagonism, tension or tension release, and agreement or disagreement. However, since the IPA system was developed for use in any type of group setting, it is limited in its ability to provide sufficient information concerning communication related to the tactical and aviation tasks of military aircrews (Krumm & Farina, 1962).

A large number of communication content schemes followed the development of Bales' classification system. Most of these subsequent systems were designed to meet the specific needs and objectives of their developers. Dyer (1984) noted that "about as many different content analysis schemes exist as there are research studies" (p. 296). Since the focus of this research is to investigate tactical aircrew communications, the following section will summarize classification systems that were designed for and used to analyze the communication content of aircrews.

Krumm and Farina. One of the first content schemes specifically designed for analyzing aircrew communications was developed by Krumm and Farina (1962). Krumm and Farina originally attempted to use Bales' system, but found that the IPA provided insufficient information about tactical aircrew communications. In a effort to remedy this, Krumm and Farina developed a seven category classification system which focused on aircrew communications. The categories were: requests information, provides information, volunteers assistance, orders course of action, formally indicates compliance to orders, makes irrelevant remarks, and acknowledges receipt of messages.

Federman and Siegel. Federman and Siegel (1965) developed a much more complex set of categories for the analysis of military helicopter aircrew communications. Their classification system contains 28 categories (more than twice the number of categories found in either Bales' or Krumm and Farina's system). The classification system represents one of the few attempts to specifically analyze communication in a military rotary-wing setting. The major reason for the large number of categories in the Federman and Siegel classification system involves the factor analytic approach chosen by the researchers. Their factor analysis resulted in the identification of four major types of communication, which were defined as: probabilistic structure (provides information in response to requests); evaluative interchange (requests for information); hypothesis formulation (interprets past performance); and leadership control (commands).

Foushee and Associates. A more recent attempt to classify the content of aircrew communications was performed by Foushee and Manos (1981). Foushee and Manos designed a seven category classification system to specifically analyze the task-related aspects of commercial fixed-wing aircrew communication. The task-related communication categories of the Foushee and Manos classification system are: crewmember observations, commands, inquiries, response uncertainty, agreement, acknowledgments, and pushes. The Foushee and Manos (1981) categorization system was expanded by Foushee et al. (1986) to include four additional task related categories (i.e., checklist items, answers supplying information, disagreements, statements of intent). The modification of the earlier system was performed to include classifications of communications that were considered to be important to aircrew task performance but were absent in the initial version of the categorization system. Foushee and his associates used the classification systems in a number of investigations to research a variety of factors (e.g., role of crewmember fatigue and familiarity on communication; crewmember communication and performance).

Jensen. The final content system to be reviewed was developed by Jensen (1986). Jensen designed the classification system to research the communication content of commercial fixed-wing aircrews. The categories in the Jensen system include: commands, requests, suggestions, observations, acknowledgments, checklist items, answers, disagreement, and initiate-terminate. Jensen investigated the types of communication exhibited by pilots and co-pilots, as well as the content of communication in routine and non-routine flight segments.

Summary of Content-based Communication Models. Although each of the content models was developed to focus on different aspects of communication, two similarities among the content models can be identified. First, several of the models identified common types of communication content. The most commonly found categories involved requesting or providing information, commands, acknowledgments, and inquiries (Federman & Siegel, 1965; Foushee & Manos, 1981; Foushee et al., 1986; Jensen, 1986; Krumm & Farina, 1962). Although many of the categories were similar across a number of models, several important categories (i.e., statements of intent, replies) were unique to only one of the models (Foushee et al., 1986). The second commonalty across models involves the approaches used to investigate the communication content of aircrews. All of the classification systems were used to code crewmember communication during operational scenarios in aircraft simulators.

The review of the content models above provided identification of the aircrew communication categories that were selected for analysis in the current effort (vis., commands, observations, suggestions, statements of intent, inquiries, acknowledgments, replies, non-task related). The specific types of communications analyzed in this investigation were selected because of their importance to military rotary-wing aircrew performance based on findings from the literature review, subject matter expert interviews, and observation of operational rotary-wing aircrews performing mission-oriented scenarios in a simulator. A detailed description of the classification system used in this investigation is discussed in a later section of this paper.

In addition, the content model review helped to identify research approaches that have been used successfully to study the communication of aircrews. Thus, the techniques and designs provided guidance in the development of methodologies and research approaches for the current study. Specifically, they guided the development of procedures for coding communication content and the design of coder training techniques. They also supported the decision to focus on operational aircrews in simulated flight scenarios.

An Integrative Communication Model

The final type of communication model is based on an integrative approach to understanding communication. McGrath (1984) presented an integrative model which illustrates communication as an interactive process that changes across time. The model conceptually displays the relationship between the pattern and content of communication and implies that in order to fully understand the nature of communication, patterns and content need to be evaluated simultaneously instead of individually. Furthermore, the model includes the concept that communication patterns and content need to be analyzed across time. The integrative communication model established the multi-faceted approach used in the current investigation.

Although the model identifies a number of other factors, this investigation focuses on the communication patterns, content, and variations across time.

AIRCREW COMMUNICATION PATTERNS AND CONTENT

The following section will focus on the specific, although limited, findings of research which have investigated communication patterns and content in aircrews. The discussion will restate each of the five questions presented earlier in this section and provide research findings which guided the current effort. The purpose of this section is to provide an understanding of the current state of aircrew communications research. Each of the subsections describes the significant reported findings in terms of both communication patterns and content.

Communication as a Function of Crew Position

"What specific communication patterns and content are demonstrated by tactical rotary-wing crewmembers (i.e., Helicopter Aircraft Commander, Helicopter 2nd Pilot)?"

No studies were identified which specifically evaluated the communication patterns and content of individual crewmembers in a tactical rotary-wing setting. Therefore, the following section focuses on findings from communication analyses for commercial fixed-wing aircrews. Very few studies have directly investigated the communication patterns or content specific to individual crewmembers. Jensen (1986) and Foushee et al. (1986) investigated the patterns of communication for aircraft captains and first officers in a commercial fixed-wing setting, and found that first officers demonstrated significantly higher rates of communication than did the captains.

Jensen (1986) and Foushee et al. (1986) also analyzed the specific content of captain and first officer communications. The researchers found that the aircraft captains initiated more commands and inquiries than did the first officers. The study by Foushee and his associates also demonstrated that more suggestions were offered by the captains than the first officers. Kanki et al. (1987) developed profiles of aircraft captain and first officer interaction and reported that aircraft captains were more likely to initiate commands than first officers. Jensen (1986) further reported that first officers made more observations and suggestions than did the captains. Foushee et al. (1986) also found that first officers communicated higher frequencies of observations as well as more statements of intent. However, in contrast to

Jensen's findings, Foushee and his associates reported that first officers made fewer suggestions than did captains.

The results of the above research demonstrate that crewmembers (i.e., captains, first officers) exhibit differences in terms of both the communication patterns and communication content. Although the results are generally consistent across the investigations, additional research is required to determine the applicability of these results to the rotary-wing community. Thus, this research examines the pattern and content of communications as a function of crew position in rotary-wing aircrews.

Communication as a Function of Flight Requirements

"Do tactical aircrew communication patterns and content vary as a function of the performance demands and requirements of different flight conditions (i.e., routine, non-routine)?"

No research was identified which specifically evaluated the communication patterns and content of individual crewmembers in a tactical rotary-wing setting. Therefore, the following section focuses on findings from communication analyses for commercial fixed-wing aircrews. Only two investigations have directly researched the effect of different types of flight (i.e., routine versus non-routine) on communication patterns and communication content. Although most aircraft flights take place without any deviation from routine procedures, an unexpected situation will occasionally occur that requires the use of non-routine flight procedures. Jensen (1986) and Foushee et al. (1986) have investigated the communication patterns of commercial fixed-wing aircrews during routine and non-routine segments of flight. Both of these efforts found that aircrews demonstrated higher rates of communication during non-routine flight than during routine flight. Foushee and his associates and Jensen also investigated the content of communications and found that the number of commands, observations, inquiries and acknowledgments were higher during non-routine periods of flight than during routine periods of flight.

The results of these investigations are important because they suggest that commercial fixed-wing crews vary their communication in order to adapt to changes in the requirements of flight (e.g., routine, non-routine) and that the changes in interaction can be analyzed using measures of communication patterns and content. This research examined whether tactical helicopter crews made similar adjustments in communication in response to changing flight requirements.

Relationship between Communication and Performance

"Are the communication patterns and content of more effective tactical rotary-wing aircrews different from those of less effective tactical rotary-wing aircrews?"

Since only one investigation was identified which specifically analyzed the relationship between aircrew communication and tactical rotary-wing aircrew performance (i.e., Federman & Siegel, 1965), most of the research findings presented in the following section are based on fixed-wing aircrews. Most aircrew communication studies have included an assessment of the relationship between communication and operational performance. These investigations have attempted to determine whether certain communication patterns or content differ according to the effectiveness of the aircrews. Aircrew performance in these investigations was evaluated using either subjective or objective measures. The subjective measures are typically made by subject matter experts using ratings of aircrew errors or crew coordination. The objective measures are generally based on some type of flight or aircraft parameter data (e.g., altitude, course deviation, equipment settings).

Communication Patterns and Performance. In an early study of aircrew communication patterns, Krumm and Farina (1962) found a significant positive relationship between flight instructor ratings of crew performance (i.e., simulated flight checks, airborne flight checks, navigational and bombing accuracy scores from subsequent operational missions, time-to-solo) and the total amount of verbal interactions for military fixed-wing B-52 aircrews. Foushee and Manos (1981) found that there was a negative relationship between total crew communication and the frequency of operational errors for commercial fixed-wing aircrews. In a more recent study involving a different sample and flight scenario, Foushee et al. (1986) again reported a tendency for the total amount of communication to be negatively related to the frequency of operational errors. These studies clearly suggest that better aircrew performance is associated with more interaction between crewmembers. Specifically, the more effective aircrews exhibited higher frequencies of total communications during operational performance than did the less effective aircrews.

Communication Content and Performance. Although the total frequency of aircrew communication has been found to be related to effective aircrew performance, further analyses of communication has led to the identification of specific communication content that is also related to aircrew performance. The remainder of this section describes the relationships between operational performance and each of the nine content categories analyzed in this investigation.

<u>Commands</u> - Krumm and Farina (1962) and Federman and Siegel (1965) found positive relationships between operational crew performance and the frequency of crewmember's use of commands about tactical courses of action. In addition, Foushee and Manos (1981) found that the number of commands issued were negatively correlated to operational errors. The results of these studies suggest that crewmember commands are associated with aircrew performance.

<u>Observations</u> - Krumm and Farina (1962) found a positive relationship between observational aircrew communications and operational performance (i.e., bombing and navigational accuracy during a simulated tactical mission). Lanzetta and Roby (1960) also found that the frequency of volunteered information regarding observations was positively related to performance. In more recent investigations involving commercial fixed-wing air rews, Foushee and Manos (1981) and Foushee et al. (1986) found that crewmember observations were negatively related with systems operational errors. These results clearly suggest that crewmember observations are related to aircrew performance.

<u>Suggestions</u> - Krumm and Farina (1962) found a direct positive relationship between operational crew performance and the frequency of crewmembers' use of suggestions. Foushee et al. (1986) demonstrated results similar to those found in the Krumm and Farina study (i.e., better performance was positively related to higher frequency of suggestions by the crewmembers). The findings of these investigations indicate that aircrews which actively make task-related suggestions perform better than crews which do not frequently make suggestions.

<u>Inquiries</u> - Foushee et al. (1986) found that crews with fewer errors demonstrated higher frequencies of inquiries. Foushee and his associates theorized that this positive relationship existed because inquiries were used by one crewmember to involve the crew and to obtain needed information from other crewmembers. This, in turn, enhanced the quality of a particular decision or action. Federman and Siegel (1965) also found that better tactical performance was related to more frequent use of messages involving requests for information and data.

In contrast, Lanzetta and Roby (1960) found that the number of requests for information was negatively related to performance. Lanzetta and Roby (1960) and Jensen (1986) posited that inquiries are representative of ineffective crew performance, indicating that one crewmember does not have information that the task requires.

The results of these investigations suggest that inquiries might be related to both more, and less, effective crew performance. It is clear that on the one hand, inquiries might be indicative of an effort to enhance crew coordination, whereas on the other hand, inquiries might suggest that a crewmember is unable to perform the assigned task effectively. Further research is needed to investigate this relationship and to establish a better understanding of the nature of inquiries in crew communication.

Acknowledgments - Foushee and Manos (1981) found that acknowledgments were negatively related to operational crew errors. In a later study, Foushee et al. (1986) found that high-error crews demonstrated lower frequencies of acknowledgments as compared to low-error crews. Kanki and Foushee (1989) found that acknowledgments were prevalent in low-error crews and that the frequency of acknowledgments was positively related to statements of intent, commands, and observations in these crews. These investigations suggest that crews which actively acknowledge the receipt of specific types of information from each other make fewer operational errors.

Replies - Only one research effort was identified that specifically investigated the relationship between replies and aircrew performance. Kanki, Lozito, and Foushee (1987) reported that low-error crews more consistently used replies in response to a command, question, or observation initiated by another crewmember. In comparison, high-error crews demonstrated little consistency with regard to the use of replies in response to a communication. Although the Kanki et al. (1987) study indirectly evaluated the role of replies in aircrew performance, additional research is needed to directly test the relationship between replies and performance.

Summary - The previous investigations have identified several types of communication content that have consistently been positively related to aircrew performance (e.g., commands, observations, suggestions, acknowledgments); one type of communication content that has demonstrated varied relationships with performance (e.g., inquiries); and two types of communication content that may be related to performance (e.g., statements of intent, replies). The findings, however, are based on a small number of investigations. More research specifically focused on communication content is clearly needed. This research provided such an investigation of tactical rotary-wing aircrew communication. Specifically, it examined whether helicopter aircrew communication patterns and content are related to operational performance.

<u>Tactical Rotary-wing and Commercial Fixed-wing Communication Comparison</u>

"What similarities exist between the communication patterns and content of military rotary-wing aircrews and commercial fixed-wing aircrews?"

No investigations were identified which directly or indirectly compared the communication patterns and content found in tactical rotary-wing aircrews with that found in commercial fixed-wing aircrews. Even though researchers have noted that rotary-wing aircraft are capable of different types of flight profiles as compared to fixed-wing aircraft (Adams, 1989; Hart, 1988) and that the nature of the tactical aircrew mission is different from the purpose of the commercial aircrew mission (i.e., Cavanagh & Williams, 1986), detailed analyses of rotary-wing aircre communication are largely non-existent. This gap in the literature could lead to incorrect assumptions about the nature of tactical rotary-wing communications if procedural or training decisions are based solely on the results of commercial fixed-wing investigations.

An indirect method of investigating the similarities found between fixed-wing and rotary-wing aircrew communication patterns and content was performed as part of this research. The results of the communication analyses conducted in this investigation were compared with the results from a communication content analysis of commercial fixed-wing aircrews (i.e., Foushee et al., 1986) to determine if similarities exist in the communications of the two sample groups. The two investigations that were compared are methodologically similar to each other in terms of the types of classification systems (i.e., pattern, content), coding techniques, realistic mission-oriented scenarios, motion-based simulators, data analysis procedures, and statistical procedures.

METHOD

The following sections describe the acquisition of the data, identify the major characteristics of the sample group, and outline the procedures and techniques used to develop the experimental database. The methodological approaches employed in the analyses of data in the current research are then discussed.

DATA ACQUISITION

The data for this research were acquired as part of an extensive investigation of aircrew coordination by researchers at the Naval Training System Center, Orlando, FL, in cooperation with Aviation Safety Officers and instructional staff at a military airbase located on the east coast of the U.S. The overall project included the design of four mission-oriented scenarios for use in the evaluation and training of aircrew coordination. The scenarios were structured to realistically portray different mission requirements and situations. The scenarios presented the crews with different tactical missions which included scripted routine and non-routine flight segments. Operational aircrews were then videotaped (using an infrared camera and VHS-format videotape recorder) performing one of the scenarios in a motion-based simulator. The simulator is a high-fidelity, full-mission capable replica of one version of the helicopter flown by the aircrews. In addition, the simulator has a six degrees of freedom motion-base and provides crewmembers with computer-generated views of the external environment. It should be noted that the simulator displayed a full field of view for only the crewmember seated in the right seat of the cockpit (i.e., Helicopter Aircraft Commander).

Prior to performing the simulated mission, the crews received an abbreviated version of a typical mission and pre-flight brief, simplified mission-oriented documentation (e.g., radio frequencies, route of flight, checkpoint names), a map of the planned mission area, the current and predicted weather conditions along the flight route, and a notebook listing recent maintenance performed on the simulated aircraft (vis., aircraft discrepancy book - ADB). Although the crews were informed as to the objectives of the mission, they were not informed of the specific situations they would encounter during the scenario. A total of 24 pilot and copilot crews (48 crewmembers) were assigned to perform one of four scenarios. Videotaped recordings for fourteen of the crews, all performing the same scenario, provided the data to be analyzed in the current research.

Experimental Scenario

Two different segments from the scenario under investigation were selected for detailed communication pattern and content analyses. The first segment is representative of a routine mission where most of the flight occurs without incident. During this segment the crew under observation flies their aircraft behind a lead aircraft along a flight route consisting of four checkpoints. The segment begins when the aircraft passes the first checkpoint and ends when the aircraft reaches the fourth checkpoint. This portion of the scenario proceeds exactly according to the pre-flight brief provided to the crew, with the exception of a minor equipment malfunction involving an unreliable attitude gyro. The malfunction had repeatedly been documented in the ADB maintenance log reviewed by the crew during the pre-flight brief. The malfunction is easily identifiable and the crew does not have to perform extensive procedures to correct the situation.

The second segment contains a portion of the scenario during which the crew is confronted with two unpredictable, non-routine, problem-solving situations. During this segment the crew is no longer flying in formation and is, therefore, responsible for its own navigation. The segment begins when the crew encounters a rapid degradation of the weather conditions along the flight route. The weather conditions presented to the crew up to this point have been very good and were as briefed prior to beginning the scenario. The crew is suddenly confronted with a change of weather from conditions where the pilot has clear visibility of the ground and airspace around the aircraft (i.e., Visual Meteorological Conditions) to a condition where the pilot has either limited or no visibility outside the aircraft (i.e., Instrument Meteorological Conditions).

This change in weather requires the crews to make important decisions and perform certain operational procedures based on the results of those decisions. The crew must decide whether it is safe to continue flying or if other actions are required. The change in weather conditions requires the crews to implement flight procedures that are used when visibility is poor. These flight procedures (i.e., Instrument Flight Rules) require that crews maintain a minimum safe altitude to avoid possible obstacles and contact different controlling agencies (i.e., air traffic control).

The crew also must decide whether to check the weather conditions at the final landing field or whether to investigate weather conditions at alternate locations. If weather conditions at an airfield are below published minimums, an aircraft can not land at that particular location. Although weather at the scheduled airfield is within allowable limits, crews are trained to determine whether any alternative landing sites are available in case the weather at the scheduled airfield deteriorates. Alternate landing sites are in the immediate area, but the weather at these locations is below allowable limits. Therefore, all crews must land at the predetermined and scheduled airfield.

In the scenario, a short time after the weather conditions deteriorate, the crew experiences an unpredictable, non-routine malfunction of an aircraft engine control device. This situation requires the crew to make important decisions and perform appropriate operational procedures. The first decision a crew must make involves determining if the aircraft is still flyable. Although the control device malfunction does affect the performance of the aircraft, the aircraft can still be flown safely. The crew then needs to diagnose the specific aircraft system failure, determine what appropriate procedures should be applied to the situation, and perform those procedures accurately. In addition, the crew must decide whether to communicate to an air traffic control agency that they are experiencing problems and are possibly in need of assistance, or that they are declaring an emergency. This second flight segment ends when the crewmembers have completed their interactions concerning the two problem-solving non-routine situations.

Each of the crews communicated information orally during both scenario segments (i.e., routine and non-routine) and these communications were the focus of this investigation. It should be noted that the actual videotape segments used in the current effort varied in duration because of differences in the way that each crew performed the scenario. The mean duration of the routine videotape segments was 14.79 minutes (SD = 1.71, Range = 10.61 minutes to 17.65 minutes), whereas the mean duration of the non-routine videotapes segments was 12.77 minutes (SD = 3.23, Range = 7.76 minutes to 18.72 minutes). The set of routine videotape segments was significantly longer in duration than was the set of non-routine videotape segments [$\underline{t}(26) = 2.07$, $\underline{p} < .05$]. These differences in the duration of the videotaped segments required that the data in this investigation be analyzed in terms of both frequency and rate of communication.

SUBJECTS

Each of the fourteen crews were composed of a Helicopter Aircraft Commander (i.e., pilot), Helicopter 2nd Pilot (i.e., co-pilot), and crew chief. The Helicopter Aircraft Commander (HAC) had the responsibility for the simulated mission and the final authority on all decisions made by the crew. The Helicopter 2nd Pilot (H2P) was responsible for performing duties as assigned by the HAC. The HACs and H2Ps were selected from helicopter training squadrons and operational units.

Demographic information was available for 12 of the 14 crews. A summary of the demographic information is presented in Table 1. The HACs were significantly older [$t(22) = 2.80$, $p<.05$], had longer service tenures [$t(22) = 2.55$, $p<.05$], and more total flying hours [$t(22) = 4.43$, $p<.05$], as compared to H2Ps. These differences were expected because the designation of HAC is given only to pilots who have reached the level of expertise necessary to command a helicopter. Although both pilots flying on any flight may be qualified to perform as a HAC, only one of the pilots in a given aircraft is officially the aircraft commander during a particular mission. Two of the H2Ps in the experimental scenarios had been HACs during previous operational missions.

Table 1
Crewmember Demographics

Crewmember Position	Age (Years)	Service Tenure (Months)	Total Flying Time (Hours)
HACs			
Mean	31.92	106.92	1622.50
SD	5.92	63.51	900.67
Min	26.00	30.00	794.00
Max	47.00	253.00	3530.00
H2Ps			
Mean	26.83	54.33	415.25
SD	2.12	32.82	281.65
Min	24.00	27.00	110.00
Max	31.00	120.00	1050.00

The crew chief, who had responsibility for mechanical and electrical maintenance was role-played by the simulator instructor in the research scenario. The simulator instructor also role-played a variety of other individuals, including Air Traffic Control and pilots in other aircraft. The instructor roles were scripted and remained relatively consistent across all of the crews. The communications initiated to or by the simulator operator were not included in the subsequent analyses.

DATABASE DEVELOPMENT PROCEDURES

The following section will outline the procedures used to classify the crewmember communications and to develop the database for the analyses in this investigation. The interactions between the HAC and H2P were transcribed from the videotapes so that each separate communication appeared on a different line of the transcript. Each of the transcript lines were then coded by trained raters using a nine-category content classification system.

Communication Coding and Coder Training

Following procedures of Foushee and his associates (Foushee & Manos, 1981; Foushee et al., 1986; Kanki et al., 1987; Kanki et al., 1989), the communication patterns and content were coded for each of the fifteen scenario transcripts. Two raters were trained prior to the start of the coding process in order to increase the reliability of the communication coding. The rater training program included: (a) a brief explanation of the purpose of the study, (b) an overview of the coding forms and scenario transcripts, (c) a practice coding session using a transcript not included in the data set to be analyzed, and (d) a discussion of correct and incorrect coding by the coders during the practice session. The coder training technique was based on a program outlined by Barlow and Hersen (1984).

Inter-rater reliability was calculated using a point-by-point evaluation technique to determine whether the coders were consistently coding the communication content and patterns (Hopkins & Herman, 1977). The point-by-point reliability procedure is based on the level of agreement across each instance of behavior instead of being based upon the total frequency of behaviors. The point-by-point inter-rater reliability established in the Foushee et al. (1986) research (i.e., 71% coder agreement after the completion of coder training) was used as the minimum acceptable point-to-point rater reliability for the current research.

Actual coding of the research transcripts in this investigation began after a satisfactory reliability (i.e., 80% point-to-point coder agreement) was achieved through training and the resolution of any difficulties in the coding process. Each of the research transcripts was randomly assigned for coding by one of the two raters. This procedure has been used to investigate aircrew communication pattern and content by a number of other researchers (Jensen, 1986; Foushee & Manos, 1981; Foushee et al., 1986).

Coding Variables

Communication Content. The communication content of the aircrew interactions were coded using a nine category coding system. The categories were based on the findings of previous aircrew communication literature, interviews with subject matter experts, and behavioral observation of operational aircrews. The nine categories were: commands, observations, suggestions, statements of intent, inquiries, acknowledgments, replies, non-task related, and uncodable communications.

Commands - Commands are specific assignment(s) of responsibility by one group member to another (Foushee et al., 1986). This type of communication is typically used by the pilot in command of the aircraft. Although either the pilot or co-pilot can issue commands, they are typically initiated by the senior pilot or aircraft commander. Commands serve as a means to communicate information related to the division of labor and delegation of duties. 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) noted 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 communication provides information about what a crewmember has seen, noticed, or perceived. Crewmembers often communicate what is taking place internal and external to the aircraft. This information provides input for the crewmembers to act upon. In addition, observations can ensure that equipment cross-checking and monitoring is taking place (Foushee et al., 1986). Lanzetta and Roby (1960) hypothesized that volunteering information about observations is indicative of effective coordination, since aircrew performance requires that the crewmembers maintain an awareness of the current flight status.

Suggestions - Suggestions are recommendations for a specific course of action (Foushee et al., 1986) or the introduction of an idea for consideration (Jensen, 1986) from one crewmember to another. This type of communication involves statements that allow crewmembers to put forward their opinions about a topic or decision. They are not directive in nature. However, suggestions often lead to an action being taken if the suggestion is accepted by the crew. Foushee et al. (1986) noted that suggestions made by the pilot are a "softer" way of providing directions as compared with commands. Suggestions can also be viewed as statements aimed at prompting other crewmembers to agree or disagree to the actions currently being taken or to provide input into a decision currently under consideration.

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 task. Statements of intent include tasks or specific actions (e.g., navigational, tactical, procedural) that the crew is about to perform. 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. Crew statements of intent are similar to commands, but they are generally informative instead of directive in nature.

Inquiries - Inquiries are requests for information regarding some aspect of flight status (Foushee & Manos, 1981) or for assistance on a particular task (Jensen, 1986). These types of communication are information seeking behaviors designed to elicit assistance from others and are generally in the form of a question. Inquiries are used by crewmembers to formally request inputs from each other and obtain needed information about a task. This type of communication has been theorized to be indicative of either effective (Federman & Siegel, 1965; Foushee et al., 1986) or ineffective (Jensen, 1986; Lanzetta & Roby, 1960) aircrew performance.

Acknowledgments - 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). These communications are used by crewmembers to inform each other that a particular communication was received. Acknowledgments are initiated in response to previous communication and typically take the form of short utterances (e.g., yeah, okay). Foushee et al. (1986) noted that acknowledgments tend to reinforce the interaction process. Although simple acknowledgments suggest to the sender that a communication was received, they do not provide any indication as to whether the information was accurately transferred or properly understood.

Replies - 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). In many cases a crewmember's reply will begin with an acknowledgment, which is followed by the initiation of some other type of communication (e.g., command, observation, inquiry). Replies may provide an indication to the sender of a message that information has been properly understood or accurately received. In addition, this type of communication may contain a more detailed response to the communications that preceded it, as compared to simple acknowledgments.

Non-task related - These behaviors include all socio-emotional communications exhibited between crewmembers. Previous research (Foushee & Manos, 1981; Foushee et al., 1986; Jensen, 1986; Krumm & Farina, 1962) has suggested that non-task related communications constitute a small percentage of the total interactions demonstrated by aircrews in simulated scenarios. Non-task related communications include incidents of embarrassment, tension release, humor, frustration, etc. Although non-task related communications were coded as part of the current investigation, specific analyses of the various types of non-task related communication were not conducted.

Uncodable - These communications include interactions that can not be classified, either because no accurate category exists or because they are unintelligible. Although most communications could be classified into one of the previous categories, the quality of communication exchange in the cockpit can be degraded for a number of reasons including: aircraft noise, malfunctioning communication equipment, external chatter on the radio channels, or more than one crewmember trying to talk at the same time. The presence of uncodable communication may be suggestive of difficulties that exist in the interaction process between crewmembers.

Each of the individual categories was analyzed separately. The results of the communication classification and analysis was used as an independent variable to test whether specific communication content was related to operational ratings for the crews. In addition, the communication content results were also used as dependent variables to explore how the content of communication was affected by crewmember position and performance demands of routine and non-routine segments of flight.

Communication Pattern. The communication pattern for each content category and for each crew was assessed using three different measures: the frequency of communications, the rate of communications, and the frequency of communications initiated by each crewmember relative to the other crewmember. These measures were obtained for each of the fourteen crews by crew position and by flight segment. The frequency of communications was obtained by counting the number of lines in the transcript for a given condition (i.e., crew, crewmember, flight requirement, content). The rate of communication was calculated by dividing the frequency of communications observed for a given condition (i.e., crew, crewmember, flight requirement, content) by the amount of time required to complete that particular scenario segment.

The final pattern measure was based on the frequency of specific types of communications (i.e., the content categories) initiated by one of the crewmembers relative to the initiation of the same type of communication by the other crewmember. A ratio of the frequencies (vis., Crewmember Interaction Ratio) was calculated to investigate the nature of the relationship of initiated communications for crewmembers with respect to each other. The Crewmember Interaction Ratio (CIR) was calculated by dividing the number of pilot-initiated communications for a given content category by the number of copilot-initiated communications. For example, if a total of 23 commands were demonstrated by a crew during non-routine flight requirements, where 21 (or 91.3%) of the commands were initiated by the pilot and the remaining 2 (or 8.7%) were initiated by the copilot, the CIR would be 21/2 = 10.50. This CIR value indicates that pilots initiated more than ten times the number of commands as compared to the co-pilots during non-routine flight. CIR values equal to or approximately equal to 1.00 indicate that each of the crewmembers initiated an approximately equal number of communications (i.e., two-way communication), whereas as CIRs that are greater or less than a 1.00 suggest that a type of communication was not demonstrated in equal proportions across the crewmembers (i.e., one-way communication). CIRs could only be calculated for those types of communication where both crewmembers demonstrated at least one incident of the communication type. Otherwise the CIRs would be either 0.0/1.00 = 0.0 or 1.00/0.0 = an indeterminant.

The three pattern measures (i.e., frequency, rate, CIR) of communication were used to investigate the previously described conditions (i.e., crewmember position, flight requirement, content categories). The results of the communication pattern analyses served as a dependent variable to explore whether the pattern of communication content is affected by crewmember position and different flight requirements. In addition, the results of the communication pattern analyses also served as an independent variable to test whether specific communication patterns were related to operational ratings.

Aircrew Performance. The operational ratings were obtained from a subject matter expert for each of the two videotape segments. The rating was a subjective evaluation of the operational performance of the crewmembers. This rating was provided by a military helicopter instructor pilot with several thousand hours of experience in flying, training, and evaluating pilots in the specific aircraft being used in the simulation. The rater was asked to observe the scenario videotapes and then rate the operational performance of the two flight segments (i.e., routine, non-routine) for each of the crews. The operational rating was scored on a seven-point Likert-type scale. The scale points were defined as follows: 1 = unacceptable; 2 = least acceptable; 3 = slightly less than acceptable; 4 = acceptable; 5 = slightly more than acceptable; 6 = most acceptable; 7 = optimally acceptable.

Acceptable performance was defined as the level of expertise an **average** crew performing this scenario would have demonstrated. The two operational crew ratings were used to test the relationship between performance and communication content during routine and non-routine flight requirements.

STATISTICAL APPROACH

Database Descriptives

Descriptive statistics for the data will be presented to provide an understanding of the general nature of the aircrew communications. Frequencies, means, standard deviations, and intercorrelations for the nine communication content categories were calculated for each of the communication pattern measures. These descriptives are reported by overall totals, crewmember position, and flight requirement.

Analyses of Communication by Different Crewmembers and Different Flight Segments

The hypotheses dealing with how aircrew communication content is affected by crewmember position and different flight requirements were tested using three separate Multivariate Analyses of Variance (MANOVA). One MANOVA was performed for each of the communication pattern types (i.e., frequency, rate, CIR). MANOVA was selected because multiple dependent variables (i.e., nine communication content classifications) were assessed. One advantage to using MANOVA instead of a simple analysis of variance (ANOVA) is that MANOVA can reveal differences not shown in series of individual ANOVAs. For example, MANOVA results in a multivariate test for each effect in the design and indicates whether there is a significant effect for all independent variables simultaneously (Spector, 1981). In addition, MANOVA can provide increased protection against Type-1 errors (Tabachnick & Fidell, 1983).

The first MANOVA focused on discovering changes in the frequency of the communication content measures (i.e., dependent variables) as a function of crewmember position (i.e., pilot versus co-pilot) and flight requirements (i.e., routine, non-routine). The second MANOVA analyzed how the rate of the nine communication categories (i.e., dependent variables) are affected as a function of the two crewmember positions and the two types of flight segments. The third MANOVA investigated the ratio of communications initiated for each of the content categories as a function of crewmember position and flight requirements.

Significant communication pattern MANOVAs were investigated further to identify the types of communication content specifically affected by crewmember position and flight requirement. Further analysis of the communication patterns was conducted by performing univariate F-tests for each of the communication categories. This analysis included evaluating the main effects and interactions for the communication categories. Significant interactions were investigated using Tukey post-hoc analysis techniques.

Analyses of Communication and Performance

The relationship between aircrew performance and communication was tested using a series of bivariate correlations. The frequency-based communication pattern measure for each of the content categories was individually correlated with the aircrew performance scores to determine the degree of association between the pattern measures and operational performance. The content measures that significantly correlate with the performance measures are discussed in detail. The communication content measures were individually correlated with performance measures, and also with each other to determine the amount of inter-category correlation.

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RESULTS

OVERVIEW

The results of this investigation are discussed in three sections. In each case, the sections focus on addressing the objectives of the current effort: (a) identification of Helicopter Aircraft Commander and Helicopter 2nd Pilot communication patterns and content; (b) identification of crewmember communication patterns during routine and non-routine flight conditions of a mission-oriented scenario; (c) investigating the relationship between communication and operational aircrew performance; (d) conducting an informal comparison between tactical rotary-wing aircrew communication and commercial fixed-wing aircrew communication; and (e) providing input to the development of a tactical aircrew coordination training program.

The first section provides the results of descriptive analyses (i.e., totals, means, standard deviations - SD) performed for the three communication patterns (vis., frequency, rate, CIR). In addition, intercorrelations between the frequencies of the nine communication categories are reported for crewmember position and flight requirement. This analysis was conducted for only one of the communication patterns (e.g., frequency) because: (1) the other communication patterns were generated from the frequency data and; (2) the frequency correlations lend themselves most readily to discussion of the results. The descriptive analyses provide an exploratory investigation of the general nature of aircrew communication patterns.

The second section of the results investigates how communication content is affected by crewmember position and different flight requirements. The purpose of this analysis was to determine whether communication patterns and content vary as a function of whether the HAC or H2P is speaking, or depending on whether the crew is experiencing routine or non-routine flight requirements. In addition, an analysis was performed to identify whether specific crewmember communication changes as a function of the type of flight requirement.

The third portion of the results section emphasizes the relationship between communication and operational crew performance. Two operational ratings (i.e., routine, non-routine) of the crews made by a subject matter expert were correlated with the frequency of the nine communication content categories observed during routine and non-routine flight requirements. The results of this analysis identifies specific types of communication content that are associated with the operational performance of the crews.

DESCRIPTIVE ANALYSES

Frequency-based Communication Pattern

Using the nine category classification system, a total of 4431 transcript lines were coded for the 14 crews ($\bar{X}$ = 317 lines/crew, SD = 78.08). The means and standard deviations for the frequencies of communication content during routine and non-routine flight requirements are presented in Tables 2 and 3, respectively. Preliminary analyses indicated that a higher frequency of total communications was demonstrated during non-routine flight requirements than during routine flight requirements ($t(26) = 2.35$, $p<.01$). The mean frequency of communications during the non-routine and routine flight requirements were 179.00 (SD = 49.37) and 137.50 (SD = 43.93), respectively. There was no significant difference in the frequency of total communications between the crewmembers (e.g., HACs vs. H2Ps). Observations were the most frequently coded communications initiated by both crewmembers during routine and non-routine flight requirements. Observations accounted for 40.9% of the total communications during routine flight requirements and 32.0% of the communications during nonroutine flight. In comparison, the initiation of non-task related communications were the least frequently coded type of communication during both types of flight requirements accounting for only 1.6% and 1.0% of the total communications in routine and non-routine flight, respectively.

Crewmembers did not provide a response (i.e., replies and acknowledgments) to every communication that was initiated. The ratio of initiated to response communications was approximately 2:1 in both routine and non-routine flight requirements. This indicates that only half of the communications initiated by one crewmember are actually responded to by the other crewmember.

Crews demonstrated a tendency to use a higher percentage of replies (i.e., responses providing more information than simple acknowledgments) as compared to acknowledgments when responding to each other during both routine and non-routine flight requirements. Replies accounted for 21.2% and 22.9% of the total communications during routine and non-routine flight requirements, respectively. In comparison, acknowledgments

Table 2

Means and Standard Deviations (SD) For Frequencies Of Communication Content By Crewmembers During Routine Flight Requirements

	Communication Content Categories									
Crewmember	CMD	OBS	SUG	SOI	INQ	ACK	REP	NTR	UNC	TOT
HACs										
Frequency	63	269	46	50	98	151	182	20	56	935
Mean/HAC	4.50	19.21	3.29	3.57	7.00	10.79	13.00	1.43	4.00	66.79
SD	4.39	11.61	2.37	2.06	3.96	5.12	6.35	2.77	3.09	
H2Ps										
Frequency	8	519	38	31	34	75	227	10	48	990
Mean/H2P	0.57	37.07	2.71	2.21	2.43	5.36	16.21	0.71	3.43	70.71
SD	0.76	14.68	2.40	1.89	2.03	4.67	5.88	1.44	3.13	
Crew (HAC+H2P)										
Frequency	71	788	84	81	132	226	409	30	104	1925
Mean/Crew	5.07	56.29	6.00	5.79	9.43	16.14	29.21	2.14	7.43	137.50
SD	2.58	12.95	2.39	3.95	3.00	4.90	6.11	2.11	3.11	

Note. CMD = Commands; OBS = Observations; SUG = Suggestions; SOI = Statements of Intent; INQ = Inquiries; ACK = Acknowledgments; REP = Replies; NTR = Non-task Related; UNC = Uncodable; TOT = Total; HAC = Helicopter Aircraft Commander; H2P = Helicopter 2nd Pilot.

Table 3

Means and Standard Deviations (SD) for Frequencies of Communication Content by Crewmembers During Non-routine Flight Requirements

	Communication Content Categories									
Crewmember	CMD	OBS	SUG	SOI	INQ	ACK	REP	NTR	UNC	TOT
HACs										
Frequency	190	386	88	148	88	82	300	9	97	1388
Mean/HAC	13.57	27.57	6.29	10.57	6.29	5.86	21.43	0.64	6.93	99.14
SD	7.31	11.00	3.29	4.83	4.12	4.61	8.22	1.15	4.60	
H2Ps										
Frequency	19	417	58	65	50	164	273	7	65	1118
Mean/H2P	1.35	29.79	4.14	4.64	3.57	11.71	19.50	0.50	4.64	79.86
SD	1.22	18.37	3.94	3.67	2.24	7.63	5.71	0.94	3.00	
Total (HAC+H2P)										
Frequency	209	803	146	213	138	246	573	16	162	2506
Mean/Crew	14.93	57.36	10.43	15.21	9.86	17.57	40.93	1.14	11.57	179.00
SD	4.27	14.69	7.23	8.50	3.18	6.12	6.97	1.05	3.80	

Note. CMD = Commands; OBS = Observations; SUG = Suggestions; SOI = Statements of Intent; INQ = Inquiries; ACK = Acknowledgments; REP = Replies; NTR = Non-task Related; UNC = Uncodable; TOT = Total; HAC = Helicopter Aircraft Commander; H2P = Helicopter 2nd Pilot.

accounted for 11.7% and 9.8% of the communications during routine and non-routine flight requirements, respectively. It is interesting to note that uncodable communications accounted for 5.4% of the total communications during routine and 6.6% during non-routine flight requirements. Based on the coders' responses, it was impossible to determine whether the uncodable statements were due to the communications being unintelligible or because no appropriate category existed.

Rate-based Communication Pattern

The means and standard deviations for the rates of communication content during routine and non-routine flight requirements are presented in Tables 4 and 5, respectively. Crews, on the average, demonstrated 9.30 communications per minute (HACs = 4.52 per minute; H2Ps = 4.78 per minute) during routine flight requirements and 14.02 communications per minute (HACs = 7.76 per minute; H2Ps = 6.25 per minute) during non-routine flight requirements.

Tables 4 and 5 provide an indication of how often specific types of communication were exhibited by the crew as a whole or by either of the crewmembers individually. For example, on the average, crews provided almost four observations every minute during routine flight conditions and more than four observations per minute during non-routine flight conditions. More crewmember observations were communicated per minute than were any other type of communication.

Crewmember observations had the highest rate of the nine communication content categories for both HACs and H2Ps during both routine and non-routine flight requirements. HACs demonstrated more than one observation per minute during routine flight requirements and more than 2 observations per minute during non-routine flight requirements. In comparison, H2Ps demonstrated more than 2 observations per minute during both types of flight requirement.

On the average, HACs during routine flight conditions issued one command approximately every three minutes, whereas during non-routine flight conditions HACs issued more than one command every minute. H2Ps, on the average, issued one command or less every ten minutes during both routine and non-routine flight. Both crewmembers, on the average, initiated only one or less than one non-task related statement every ten minutes during the experimental scenario.

Table 4

Means and Standard Deviations (SD) for Rates of Communication Content by Crewmember during Routine Flight Requirements

Crewmember	Communication Content Categories									
	CMD	OBS	SUG	SOI	INQ	ACK	REP	NTR	UNC	TOT
HACs										
Mean/HAC	4.50	19.21	3.29	3.57	7.00	10.79	13.00	1.43	4.00	66.79
Rate[a]	0.30	1.30	0.22	0.24	0.47	0.73	0.88	0.10	0.27	4.52
SD	0.31	0.80	0.18	0.14	0.26	0.33	0.43	0.19	0.21	
H2Ps										
Mean/H2P	0.57	37.07	2.71	2.21	2.43	5.36	16.21	0.71	3.43	70.71
Rate[a]	0.04	2.50	0.19	0.16	0.16	0.36	1.10	0.05	0.23	4.78
SD	0.05	0.91	0.17	0.14	0.12	0.31	0.38	0.09	0.20	
Total (HAC+H2P)										
Mean/Crew	5.07	56.28	6.00	5.78	9.43	16.15	29.21	2.14	7.43	137.50
Rate[a]	0.34	3.81	0.41	0.39	0.64	1.09	1.97	0.14	0.50	9.30
SD	0.18	0.86	0.18	0.15	0.19	0.32	0.41	0.14	0.21	

Note. CMD = Commands; OBS = Observations; SUG = Suggestions; SOI = Statements of Intent; INQ = Inquiries; ACK = Acknowledgments; REP = Replies; NTR = Non-task Related; UNC = Uncodable; TOT = Total; HAC = Helicopter Aircraft Commander; H2P = Helicopter 2nd Pilot.

[a]Mean per crewmember divided by average time for segment.

Table 5

Means and Standard Deviations (SD) for Rates of Communication Content by Crewmember during Non-routine Flight Requirements

Crewmember	CMD	OBS	SUG	SOI	INQ	ACK	REP	NTR	UNC	TOT
HACs										
Mean/HAC	13.57	27.57	6.29	10.57	6.29	5.86	21.43	0.64	6.93	99.14
Rate[a]	1.06	2.16	0.49	0.83	0.40	0.46	1.68	0.05	0.54	7.76
SD	0.64	0.82	0.23	0.36	0.32	0.38	0.44	0.11	0.32	
H2Ps										
Mean/H2P	1.35	29.79	4.14	4.64	3.57	11.71	19.50	0.50	4.64	79.86
Rate[a]	0.11	2.33	0.32	0.36	0.28	0.92	1.53	0.04	0.36	6.25
SD	0.11	1.24	0.26	0.28	0.18	0.53	0.40	0.11	0.27	
Total (HAC+H2P)										
Mean/Crew	14.92	57.36	10.43	15.21	9.86	17.57	40.93	1.14	11.57	179.00
Rate[a]	1.17	4.49	0.82	1.19	0.77	1.38	3.21	0.09	0.91	14.02
SD	0.38	1.03	0.25	0.32	0.25	0.46	0.42	0.11	0.30	

Communication Content Categories: CMD through TOT.

Note. CMD = Commands; OBS = Observations; SUG = Suggestions; SOI = Statements of Intent; INQ = Inquiries; ACK = Acknowledgments; REP = Replies; NTR = Non-task Related; UNC = Uncodable; TOT = Total; HAC = Helicopter Aircraft Commander; H2P = Helicopter 2nd Pilot.

[a]Mean per crewmember divided by average time for segment.

Crewmember Initiation Ratio-based Communication Pattern

The frequencies and percentages of communications initiated by each of the crewmembers for the nine communication content categories are presented for the routine and non-routine flight requirements in Tables 6 and 7, respectively. H2Ps demonstrated a higher frequency, and thus higher percentage, of total communications during routine flight requirements, whereas the HACs demonstrated a higher frequency and percentage of total communications during non-routine flight.

The results of the CIR analysis are also presented in Tables 6 and 7. The CIR values were calculated by dividing the number of HAC-initiated communications for a given content category by the number of H2P-initiated communications for the same content category. None of the CIR values were equal to 1.00, and only two of the CIR values were between the range of 0.90 and 1.10 (e.g., observations and replies during non-routine flight). These two communication categories were initiated at approximately equal proportions by both crewmembers, while the remaining seven categories were initiated by a larger proportion by one of the two crewmembers.

The largest CIR values identified for either routine or non-routine flight were calculated for commands. These data indicate that HACs initiated nearly 90% of all commands (eight to ten times as many as the H2P). HACs, on the average, initiated a higher proportion of communications for seven of the categories during both routine and non-routine flight requirements as compared to H2Ps. H2Ps initiated higher proportions of observations and replies as compared to HACs during routine flight, and higher proportions of observations and acknowledgments as compared to HACs during non-routine flight requirements.

The CIR values for only two of the communication content categories changed direction as a function of the type of flight requirements. This indicates that certain types of communication were primarily initiated by only one of the crewmembers regardless of the flight condition. HACs, in contrast to H2Ps, initiated higher proportions of acknowledgments during routine flight but lower proportions during non-routine flight. H2Ps, in contrast to HACs, demonstrated higher proportions of replies during routine flight but a lower proportion during non-routine flight requirements.

Table 6

Means and Standard Deviations (SD) for Percentages of Communication Content and CIR Values by Crewmembers during Routine Flight Requirements

	Communication Content Categories									
Crewmember	CMD	OBS	SUG	SOI	INQ	ACK	REP	NTR	UNC	TOT
HACs										
Frequency	63	269	46	50	98	151	182	20	56	935
% of total[a]	88.73	34.14	54.76	61.73	74.24	66.81	44.50	66.67	53.85	48.57
H2Ps										
Frequency	8	519	38	31	34	75	227	10	48	990
% of total[b]	11.27	65.86	45.24	38.27	25.76	33.19	55.50	33.33	46.15	51.43
Crew Frequency (HAC+H2P)	71	788	84	81	132	226	409	30	104	1925
CIR[c] (HAC/H2P)	7.88	0.52	1.21	1.61	2.88	2.01	0.80	2.00	1.17	0.94

Note. CMD = Commands; OBS = Observations; SUG = Suggestions; SOI = Statements of Intent; INQ = Inquiries; ACK = Acknowledgments; REP = Replies; NTR = Non-task Related; UNC = Uncodable; TOT = Total; HAC = Helicopter Aircraft Commander; H2P = Helicopter 2nd Pilot.

[a]Percentage of communications for a given category by HAC.
[b]Percentage of communications for a given category by H2P.
[c]Crewmember Interaction Ratio calculated by dividing frequency of communications for the HAC by the frequency of communications for the H2P.

Table 7

Means and Standard Deviations (SD) for Percentages of Communication Content and CIR Values by Crewmembers during Non-routine Flight Requirements

Crewmember	Communication Content Categories									
	CMD	OBS	SUG	SOI	INQ	ACK	REP	NTR	UNC	TOT
HACs										
Frequency	190	386	88	148	88	82	300	9	97	1388
% of total[a]	90.90	48.07	60.27	69.48	63.77	33.33	52.36	56.25	59.88	55.39
H2Ps										
Frequency	19	417	58	65	50	164	273	7	65	1118
% of total[b]	9.10	51.93	39.73	30.52	36.23	66.67	47.64	43.75	40.12	44.61
Crew Frequency (HAC+H2P)	209	803	146	213	138	246	573	16	162	2506
CIR[c] (HAC/H2P)	10.00	0.93	1.52	2.28	1.76	0.50	1.10	1.29	1.49	1.24

Note. CMD = Commands; OBS = Observations; SUG = Suggestions; SOI = Statements of Intent; INQ = Inquiries; ACK = Acknowledgments; REP = Replies; NTR = Non-task Related; UNC = Uncodable; TOT = Total; HAC = Helicopter Aircraft Commander; H2P = Helicopter 2nd Pilot.

[a] Percentage of communications for a given category by HAC.
[b] Percentage of communications for a given category by H2P.
[c] Crewmember Interaction Ratio calculated by dividing frequency of communications for the HAC by the frequency of communications for the H2P.

Summary of Descriptive Analyses

The descriptive analyses provided preliminary information with regard to the first two objectives of this investigation (i.e., identifying specific communication patterns and content as a function of crewmember position and flight condition). Although the results are interesting, they primarily served as needed input for more detailed analyses. Additional statistical procedures had to be performed prior to fully addressing the two objectives and, thus, drawing any detailed conclusions about the nature of tactical rotary-wing aircrew communication. The results of the more detailed statistical analyses of the data are reported in a later section.

CORRELATIONAL ANALYSES OF COMMUNICATION CONTENT CATEGORIES

Correlations were performed for the frequencies of all of the communication content categories by crewmember position and flight requirement. The correlation matrix resulted in 648 pairings of variables, but the following discussion focuses only on specific relationships relevant to the current investigation. First, the correlations between the nine content categories were identified for HACs and H2Ps during routine and non-routine flight requirements. Significant correlations for HACs and H2Ps during routine and non-routine flight segments are presented in Table 8. This analysis was performed to determine the relationship between specific types of communication content for a given crewmember during specific flight conditions. The significant correlations suggest the existence of meaningful relationships between specific communication categories. The number of significant relationships also provides some indication of the complexity and framework of crewmember communication content.

The intercorrelations of the communication content categories yielded 7 and 14 pairs of significant relationships for the crews, during routine and non-routine flight, respectively. The results of the intercorrelations suggest that the initiation of certain types of communication content appear to have been associated with the initiation of other types of content. For example, during routine flight, HACs who initiated high frequencies of commands also demonstrated high frequencies of inquiries and non-task related statements.

HACs and H2Ps each demonstrated different patterns of significant correlations, with only one pair of categories correlating significantly for both HACs and H2Ps during non-routine flight (i.e., observations x replies). This indicates that HACs and H2Ps structured their communications in different ways. Crewmember observations was the only communication

Table 8

Summary of Significant Correlations for HACs and H2Ps During Routine Flight and Non-routine Flight

Crewmember	Correlation	r*
	Routine Flight	
<u>HACs</u>		
Commands	Commands X Inquiries	0.47
	Commands X Non-task Related	0.67
Observations	Observations X Statements of Intent	0.63
<u>H2Ps</u>		
Observations	Observations X Replies	0.55
Suggestions	Suggestions X Inquiries	-0.48
	Suggestions X Replies	0.59
Inquiries	Inquiries X Acknowledgments	0.62
	Non-routine Flight	
<u>HACs</u>		
Commands	Commands X Observations	0.62
	Commands X Statements of Intent	0.58
Observations	Observations X Statements of Intent	0.75
	Observations X Replies	0.71
	Observations X Non-task Related	-0.62
Suggestions	Suggestions X Replies	0.59
	Suggestions X Non-task Related	-0.48
Statements of Intent	Statements of Intent X Inquiries	0.47
	Statements of Intent X Replies	0.63
	Statements of Intent X Non-task Related	-0.53
Inquiries	Inquiries X Replies	0.53
Non-task Related	Non-task Related X Replies	-0.57
<u>H2Ps</u>		
Observations	Observations X Suggestions	0.66
	Observations X Replies	0.81

*$p<.05$

category which produced significant correlations with other categories for each crewmember in both flight segments. This suggests that observations played a central role in the initiation of other types of communication.

The intercorrelations provided an indication of the way crewmember communication content and structure changed during different flight requirements. For example, during routine flight, only three significant correlations were found between the various types of communication content used by the HAC. However, twelve significant correlations were identified during non-routine flight. This indicated that the structuring of HAC communication became more complex when the HAC was performing in non-routine situations.

The intercorrelations also provided information about the way that specific relationships between individual content categories change during routine and non-routine flight requirements. For example, during routine flight, high frequencies of HAC commands were related to high frequencies of inquiries and non-task related statements. However, in non-routine flight, high frequencies of HAC commands were related to high frequencies of observations and statements of intent. Only one of the HAC correlations (i.e., observations X statements of intent) and one of the H2P correlations (i.e., observations X replies) were significant during both the routine and non-routine flight conditions. These two relationships appeared to remain stable regardless of the flight condition.

During routine flight, non-task related statements initiated by the HACs were positively correlated with commands. In comparison, non-task related statements initiated by the HACs during non-routine flight conditions were negatively correlated with other types of communication content (i.e., observations, suggestions, statements of intent). The use of replies to respond to communications was significantly correlated with more types of communication content than was the use of acknowledgments. This indicated that replies were more integrated with other types of communication than were acknowledgments.

The next communication content correlation investigated the relationship between the frequency of communications, for a given category, during different flight requirements to determine if frequencies of specific communications in one flight condition were correlated with frequencies of the same type of communication during the other flight condition. The results of these analyses indicated that, for HACs, the frequencies of commands, observations, and statements of intent during routine and non-routine flight were significantly correlated (r = 0.68, 0.56, and 0.57, respectively). In comparison, for H2Ps, the frequencies of statements of intent, acknowledgments, and non-task related communications during routine and non-routine flight were significantly correlated (r = 0.51, 0.57, and 0.63, respectively).

The final inter-category correlations to be discussed involved identifying relationships between crewmember communications within a given flight condition. Significant correlations are presented in Table 9. These correlations indicated the existence of relationships between specific HAC and H2P communication categories and provide a preliminary understanding of how crewmembers communicated with each other. Although the specific order of occurrence of communications can not be inferred from simple bivariate correlations, some indication of order is implied by the fact that, by definition, responses to communications followed the initiation of some prior communication.

During routine flight, H2P commands (vis., specific assignment of responsibility) were associated with HAC observations and statements of intent. In comparison, HAC commands during non-routine flight were associated with H2P suggestions and acknowledgments. HAC commands were only related to H2P communications during non-routine flight, but were not significantly correlated to any type of co-pilot communication during routine flight.

Observations made by the HACs were associated with acknowledgments from the H2Ps in both routine and non-routine flight. In comparison, observations made by the H2Ps were related to HAC replies and acknowledgments during routine flight, but only with HAC replies during non-routine flight. In addition, observations made by the H2Ps were also associated with HAC suggestions and inquiries in routine and non-routine flight requirements, respectively.

Suggestions made by the H2Ps in routine flight were associated with HAC inquiries, whereas suggestions made by the HAC in non-routine flight were associated with H2P statements of intent. These results indicate that certain types of HAC and H2P communication content were related, and that significant associations between HAC and H2P communication varied depending on whether the flight requirements were routine or non-routine.

The frequency of HAC inquiries, during both flight conditions, was significantly correlated with H2P replies. The frequency of HAC commands, observations, suggestions, and statements of intent were significantly correlated with H2P acknowledgments during non-routine flight. This suggests that H2Ps responded differently to different types of communication initiated by the HACs. Simple responses to some communications

Table 9

Summary of Significant Correlations Between Crewmembers During Routine and Non-routine Flight

Communication Category	Correlation HACs X H2Ps	r*
	Routine Flight	
Commands	Observations X Commands	0.48
	Statements of Intent X Commands	0.56
Observations	Observations X Acknowledgments	0.75
	Suggestions X Observations	-0.47
	Acknowledgments X Observations	0.59
	Replies X Observations	0.48
Suggestions	Inquiries X Suggestions	0.51
Inquiries	Inquiries X Replies	0.87
Acknowledgments	Acknowledgments X Replies[a]	0.55
	Acknowledgments X Replies[b]	0.60
Replies	Replies X Replies	0.79
	Non-routine Flight	
Commands	Commands X Suggestions	-0.51
	Commands X Acknowledgments	0.58
Observations	Observations X Acknowledgments	0.85
	Inquiries X Observations	0.55
	Replies X Observations	0.46
Suggestions	Suggestions X Statements of Intent	0.50
	Suggestions X Acknowledgments	0.50
Statements of Intent	Statements of Intent X Acknowledgments	0.68
Inquiries	Inquiries X Replies	0.71
Acknowledgments	Acknowledgments X Replies	0.57
	Acknowledgments X Non-task Related	-0.63

[a]HAC acknowledgments were correlated with H2P replies only.
[b]H2P replies were correlated with HAC acknowledgments only.

*$p < .05$.

may have been appropriate, whereas detailed responses may have been required for other communications.

HAC acknowledgments and H2P replies were significantly correlated in both routine and non-routine flight conditions. HAC and H2P replies were also significantly related in routine flight conditions. These results indicate that the type of response one crewmember used was associated with the type of response the other crewmember used.

Summary of Correlational Analyses

The correlational analyses provided important information with regard to the first two objectives of this investigation (i.e., identifying specific communication patterns and content as a function of crewmember position and flight condition). Specifically, meaningful relationships existed between specific communication patterns at two levels (i.e., individual crewmember, crew interaction). The correlational analyses provided an indication of the structure and complexity of tactical rotary-wing aircrew communications.

Significant relationships between categories of communication for a given crewmember in a specific type of flight were identified. Certain types of communication content were associated with other types of communication content for a given cremwmember. These relationships were different for each of the crewmember positions. Significant relationships between the initiation of a given type of communication for the two flight conditions were also found. Finally, significant relationships between specific HAC and H2P communication categories were identified. The correlational analyses provided a preliminary understanding of how crewmembers individually communicated and how crewmembers communicated with each other.

THE EFFECT OF CREWMEMBER POSITION AND FLIGHT REQUIREMENT ON COMMUNICATION CONTENT

This section of the results focuses on identifying the effects of crewmember position and flight requirement on patterns of communication content. A series of analyses (i.e., MANOVAs, univariate ANOVAs, and post-hoc analyses of significant interactions) were performed for each of the three communication patterns. The following discussion is divided into three sections: the results from the frequency-based communication pattern analysis, the results from the rate-based communication pattern analysis, and the results from the CIR-based communication pattern analysis. Each section presents the results of the MANOVAs, univariate ANOVAs, and post-hoc analyses for a given communication pattern.

Frequency-Based Communication Analyses

A repeated measures 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. With the use of Hotellings' trace criterion (cf. Tabachnick & Fidell, 1983) for the data analysis, the content categories were found to be significantly affected by crew position [F (9,18) = 11.49, p<.001], flight requirement [F (9,18) = 21.80, p<.001], and their interaction [F(9,18) = 6.16, p<.001].

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) which were affected by the independent variables (i.e., crewmember position, flight requirement) or their interaction. The results of the frequency-based univariate ANOVAs are presented in Table 10.

The univariate ANOVAs yielded significant main effects for the crewmember position variable on four of the communication content categories (i.e., commands, observations, statements of intent, inquiries) and for the flight requirement variable on five of the communication content categories (i.e., commands, suggestions, statements of intent, replies, uncodable). The frequencies of commands, statements of intent, and inquires were higher for HACs, while the frequency of observations was higher for H2Ps. The frequency of commands, suggestions, statements of intent, replies, and uncodable statements were higher during non-routine flight requirements than during routine flight requirements.

In addition, four significant position-by-flight requirement interactions were also found (i.e., commands, observations, statements of intent, acknowledgments). Tukey post-hoc analyses were performed on the means of the independent variables for the significant interactions to identify the joint effect of the independent variables over and above their individual effects. The results of the frequency-based communication analysis are summarized in Table 11. The variables, with their respective means, are given for the significant main effects and interactions. The bold-face variables and means in the cells represent the crewmember position or flight condition with the highest mean for a given content category. The information in the interaction column provides a brief description of the

Table 10

Frequency-based Univariate ANOVA
Tests of Crewmember Position, Flight Requirement,
And Their Interaction

IV	DV	Univariate F
Crewmember Position	Commands	30.68*
	Observations	6.66*
	Suggestions	2.50
	Statements of Intent	11.76*
	Inquiries	14.07*
	Acknowledgments	0.01
	Replies	0.10
	Non-task Related	0.69
	Uncodable	1.92
Flight Requirement	Commands	44.07*
	Observations	0.02
	Suggestions	8.05*
	Statements of Intent	47.67*
	Inquiries	0.08
	Acknowledgments	0.35
	Replies	15.15*
	Non-task Related	1.56
	Uncodable	6.09*
Crewmember Position X Flight Requirement Interaction	Commands	31.14*
	Observations	4.44*
	Suggestions	1.01
	Statements of Intent	11.21*
	Inquiries	1.57
	Acknowledgments	21.82*
	Replies	2.92
	Non-task Related	0.51
	Uncodable	1.04

*$p<.05$; df = 1/26.

Table 11

Summary of Results of the Frequency-based Univariate ANOVAS
(Identification of Significantly Higher Means)

Communication Category	Crewmember Position (Mean)	Flight Requirement (Mean)	Interaction (Mean)
Commands	**HAC (9.04)** H2P (0.96)	**NR (7.47)** R (2.54)	**HAC higher mean during NR (13.57)** than R (4.50), no difference for H2P
Observations	**H2P (33.43)** HAC (23.39)		**H2P higher mean (37.07)** than HAC (19.21) during R only, no difference during NR
Suggestions		**NR (5.22)** R (3.05)	
Statements of Intent	**HAC (6.97)** H2P (3.43)	**NR (7.61)** R (2.89)	**HAC higher mean (10.57) during NR** than R (3.57), no difference for CP
Inquiries	**HAC (6.65)** H2P (3.00)		
Acknowledgments			**HAC higher mean** (10.79) than H2P (5.36) during routine, **H2P higher mean** (11.71) than HAC during non-routine (5.86)
Replies		**NR (20.47)** R (14.61)	
Non-task Related			
Uncodable		**NR (5.79)** R (3.72)	

Note. HAC = Helicopter Aircraft Commander; H2P = Helicopter 2nd Pilot; R = Routine flight requirements; NR = Non-routine flight requirements; **Boldface** = significantly higher mean.

significant interactions found between the crewmember position and flight requirement variables.

Rate-Based Communication Analyses

A repeated measures MANOVA was performed to analyze the rate 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 interactions. With the use of Hotellings' trace criterion for the data analysis (cf. Tabachnick & Fidell, 1983), the content categories were found to be significantly affected by crew position [F (9,18) = 11.15, p<.001], flight requirement [F (9,18) = 26.87, p<.001], and their interaction [F(9,18) = 6.03, p<.001].

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) which were affected by the independent variables (i.e., crewmember position and flight requirement) or by the independent variables' interaction. The results of the rate-based univariate ANOVAs are presented in Table 12.

The univariate ANOVAs yielded *significant* main effects for the crewmember position variable on four of the communication content categories (i.e., commands, observations, statements of intent, inquiries) and for the flight requirement variable on five of the communication content categories (i.e., commands, suggestions, statements of intent, replies, uncodable). The rates of commands, statements of intent, and inquires were higher for HACs, while the rates of observations was higher for H2Ps. The rates of commands, suggestions, statements of intent, replies, and uncodable statements were higher during non-routine flight requirements than during routine flight requirements.

In addition, four significant position by flight requirement interactions were also found (i.e., commands, observations, statements of intent, acknowledgments). Tukey post-hoc analyses were performed on the means of the independent variables for the significant interactions to identify the joint effect of the independent variables over and above their individual effects. The results of the rate-based communication analysis are summarized in Table 13. The variables, with their respective means, are given for the significant main effects and interactions. The bold-face variables and means in the cells represent the crewmember position or flight condition with the highest mean for a given content category. The information in the interaction column provides a brief description of the significant interactions found between the crewmember position and flight requirement variables.

Table 12

Rate-based Univariate ANOVA
Tests of Crewmember Position, Flight Requirement, and Their Interaction

IV	DV	Univariate F
Crewmember Position	Commands	26.72*
	Observations	5.89*
	Suggestions	2.87
	Statements of Intent	12.38*
	Inquiries	14.49*
	Acknowledgments	0.08
	Replies	0.21
	Non-task Related	0.67
	Uncodable	1.48
Flight Requirement	Commands	58.05*
	Observations	2.23
	Suggestions	13.33*
	Statements of Intent	59.60*
	Inquiries	2.45
	Acknowledgments	2.85
	Replies	50.61*
	Non-task Related	0.29
	Uncodable	14.49*
Crewmember Position X Flight Requirement Interaction	Commands	39.69*
	Observations	5.07*
	Suggestions	1.28
	Statements of Intent	12.90*
	Inquiries	0.81
	Acknowledgments	22.33*
	Replies	3.41
	Non-task Related	0.43
	Uncodable	1.06

*$p<.05$; df = 1/26

Table 13

Summary of Results of the Rate-based Univariate ANOVAS
(Identification of Significantly Higher Means)

Communication Category	Crewmember Position (Mean)	Flight Requirement (Mean)	Interaction (Mean)
Commands	**HAC (0.72)** H2P (0.26)	**NR (0.63)** R (0.17)	**HAC higher mean during NR (1.13)** than R (0.30), no difference for H2P
Observations	**H2P (2.41)** HAC (1.77)		**H2P higher mean (2.41)** than HAC (1.77) during R only, no difference during NR
Suggestions		**NR (0.41)** R (0.21)	
Statements of Intent	**HAC (0.55)** H2P (0.27)	**NR (0.61)** R (0.21)	**HAC higher mean (0.84)** during NR than R (0.37), no difference for CP
Inquiries	**HAC (0.49)** H2P (0.23)		
Acknowledgments			**HAC higher mean** (0.73) than H2P (0.36) during routine, H2P higher mean (0.91) than HAC during non-routine (0.44)
Replies		**NR (1.62)** R (0.99)	
Non-task Related			
Uncodable		**NR (0.92)** R (0.25)	

Note. HAC = Helicopter Aircraft Commanders; H2P = Helicopter 2nd Pilots; R = Routine flight requirements; NR = Non-routine flight requirements; **Boldface** = significantly higher mean.

Crewmember Initiation Ratio (CIR)-Based Communication Analyses

A repeated measures MANOVA was performed to analyze the CIR measure for each of the nine content categories. Multivariate tests yielded a significant effect for the crewmember position variable but not for the flight requirement variable. With the use of Hotellings' trace criterion for the data analysis (cf. Tabachnick & Fidell, 1983), the content categories were found to be significantly affected by crew position variable [F (9,18) = 37.50, p<.001]. Although only one of the independent variables demonstrated a significant main effect with the dependent variables (i.e., communication content categories), the interaction between the two independent variables was significant [F (9,18) = 6.89, p<.001].

Based on the significant results of the MANOVA, a series of univariate ANOVAs were performed to identify the specific dependent variables which were affected by the crewmember position and to test for the interaction of the independent variables. The results of the CIR-based univariate ANOVAs are presented in Table 14.

The univariate ANOVAs yielded significant main effects for the crewmember position variable on seven of the communication content categories (i.e., commands, observations, suggestions, statements of intent, inquiries, replies, uncodable). The CIR-based measure for commands, suggestions, statements of intent, inquiries and uncodable statements was higher for HACs, while the CIR-based measure for observations and replies was higher for H2Ps. Since none of the main effects for flight requirements were significant, no further analyses on the means for the condition variable were performed.

Four significant position-by-flight requirement interactions were found (i.e., observations, inquiries, acknowledgments, and replies). Tukey post-hoc analyses were performed on the means of the independent variables for the significant interactions to identify the specific joint effects of the independent variables in combination, over and above their individual effects. The results of the CIR-based communication analysis are summarized in Table 15. The variables, with their respective means, are given for the significant main effects and interactions. The bold-face variables and means in the cells represent the crewmember position with the highest mean for a given content category. The information in the interaction column provides a brief description of the significant interactions found between the crewmember position and flight requirement variables.

Table 14

Crewmember Initiation Ratio-based Univariate ANOVA Tests of Crewmember Position, Flight Requirement, and Their Interaction

IV	DV	Univariate F
Crewmember Position	Commands	67.89*
	Observations	13.21*
	Suggestions	8.43*
	Statements of Intent	18.30*
	Inquiries	20.77*
	Acknowledgments	1.46
	Replies	6.45*
	Non-task Related	0.71
	Uncodable	7.27*
Flight Requirement[a]		
Crewmember Position X Flight Requirement Interaction	Commands	3.81
	Observations	14.94*
	Suggestions	0.00
	Statements of Intent	4.12
	Inquiries	9.13*
	Acknowledgments	56.05*
	Replies	19.88*
	Non-task Related	0.00
	Uncodable	0.00

[a]MANOVA main effect for the flight requirement variable was not significant, therefore no further univariate ANOVAs were conducted.

*p =<.05; df = 1/26

Table 15

Summary of Results of the
Crewmember Initiation Ratio-based Univariate ANOVAS
(Identification of Significantly Higher Means)

Communication Category	Crewmember Position (Mean)	Flight Requirement[a]	Interaction (Mean)
Commands	**HAC (0.81)** H2P (0.16)		
Observations	**H2P (0.58)** HAC (0.42)		**H2P higher mean** (0.66) than HAC (0.34) during R only, no difference during NR
Suggestions	**HAC (0.61)** H2P (0.39)		
Statements of Intent	**HAC (0.65)** H2P (0.32)		
Inquiries	**HAC (0.66)** H2P (0.34)		**HAC higher mean** (0.75) than H2P (0.25) during R only, no difference during NR
Acknowledgments			**HAC higher mean** (0.72) than H2P (0.64) during routine, **H2P higher mean** (0.64) than HAC during non-routine (0.28)
Replies	**H2P (0.52)** HAC (0.48)		**H2P higher mean** (0.57) than HAC (0.43) during R only, no difference during NR
Non-task Related			
Uncodable	**HAC (0.56)** H2P (0.41)		

[a]Insignificant MANOVA main effect, no univariate ANOVAs were performed. HAC = Helicopter Aircraft Commander; H2P = Helicopter 2nd Pilot; R = Routine flight requirements; NR = Non-routine flight requirements; **Boldface** = significantly higher mean.

Summary of MANOVA and ANOVA Analyses

The MANOVA and ANOVA analyses complete the presentation of results that address the first two objectives of this investigation (i.e., identifying specific communication patterns and content as a function of crewmember position and flight condition). Table 16 presents a summary of the ANOVAs for the communication pattern and content analyses. The results of the analyses indicate that the frequency and rate indices of communication content yielded identical significant results. The CIR-based pattern analyses provided identical main effect results as compared to the frequency and rate pattern indices, as well as several additional significant results unique to the CIR-based measure.

Communication content was found to vary as a function of crewmember position and flight condition. Specific communication content profiles for HACs and H2Ps were identified which are representative of the tasks that the crewmembers perform. For example, H2Ps demonstrated higher communication pattern indices for observations than did HACs. This result indicates that the role of H2Ps in the tactical rotary-wing cockpit is to monitor and initiate task-related communications about the status of equipment, weather, etc. to the HAC. In comparison, the HACs demonstrated a more complex communication content than did the H2Ps. HACs initiated higher communication pattern indices for commands, statements of intent, inquiries, and replies as compared with the H2Ps.

Communication content was also found to vary depending on the type of flight condition. The frequency and rate pattern indices for the content categories of commands, suggestions, statements of intent, and replies were higher during non-routine flight than during routine flight. This indicated that tactical rotary-wing aircrews changed the structure of certain types of communication depending on the nature of the flight condition (i.e., routine, non-routine).

OPERATIONAL PERFORMANCE AND COMMUNICATION CONTENT

The operational ratings of crew performance for a given flight requirement (i.e., routine, non-routine) were correlated with the frequencies of the content categories and total communications demonstrated during that flight requirement. This analysis was performed to identify the existence of relationships between communication and operational performance. The mean operational rating for the crews during the routine flight requirements was 3.92 on a seven-point scale (SD = 0.65, Range = 3.00 to 5.00), whereas the mean operational rating for the crews

Table 16

Summary of ANOVAS for Communication Pattern and Content Analyses

Communication Category	Crewmember Position	Flight Requirement	Interaction
Commands	F(HAC), P(HAC) CIR(HAC)	F(NR), R(NR)	F, R
Observations	F(H2P), P(H2P) CIR(H2P)		F, R, CIR
Suggestions	CIR(HAC)	F(NR), R(NR)	
Statements of Intent	F(HAC), R(HAC) CIR(HAC)	F(NR), R(NR)	F, R
Inquiries	F(HAC), R(HAC) CIR(HAC)		CIR
Acknowledgments			F, R, CIR
Replies	CIR(H2P)	F(NR), R(NR)	CIR
Non-task Related			
Uncodable	CIR(HAC)	F(NR), R(NR)	

Note. F = Frequency-based pattern; R = Rate-based pattern; CIR = Crewmember interaction ratio-based pattern; (HAC) = Helicopter Aircraft Commander mean significantly higher than H2P mean; (H2P) = Helicopter 2nd Pilot mean significantly higher than HAC mean; (NR) = Non-routine flight requirement mean significantly higher than routine flight requirement mean.

during non-routine flight requirements was 3.96 on a seven-point scale (SD = 1.19, Range = 2.00 to 6.00).

A significant negative correlation was found between the operational rating for crews during routine flight and the frequency of commands issued by the H2P ($\underline{r}$ = -0.60). A significant negative correlation was also found between operational rating for crews during non-routine flight and the frequency of inquiries initiated by the HAC ($\underline{r}$ = - 0.47). No other significant correlations were found, including the correlation between the operational ratings for the crews during routine flight and non-routine flight requirements. The results of the communication content and operational performance analyses address the third objective of the current effort (i.e., investigating the relationship between communication and operational performance). Even though specific types of communication content were found to be significantly related to operational performance (i.e., H2P commands during routine flight, HAC inquiries during non-routine flight), most types of communication content were not significantly related to operational performance.

COMMUNICATION CONTENT SIMILARITIES BETWEEN TACTICAL ROTARY-WING *AIRCREWS AND COMMERCIAL FIXED-WING AIRCREWS*

The fourth objective of the current investigation was to compare the pattern and content of communications for military rotary-wing aircrews with that of civilian fixed-wing aircrews. For this comparison, the results of a communication content analysis study conducted by Foushee et al. (1986) were compared to the results obtained in the current research. Since the Foushee investigation used a frequency-based pattern measure, only the results of the frequency-based pattern analyses from the current research were used in the comparison. The results of the current effort and the Foushee et al. (1986) research similarly found significant crewmember position main effects for the communication categories of commands, observations, inquiries, and statements of intent. In addition, the direction of the main effects for the commands, observations, and inquiries categories were identical for the two samples. The aircraft commander (i.e., captain, HAC) initiated more commands and inquiries, whereas the second pilot in the cockpit (i.e., first officer, H2P) initiated more observations.

Only one of the flight condition variable main effects was found to be similarly significant for the current efforts and the Foushee et al. (1986) investigation (i.e., more commands were initiated by the crews during non-routine flight than during routine flight). In addition, only one interaction between the crewmember position and flight requirement variables was found to be similarly significant for both of the investigations (i.e., aircraft commanders initiated more commands during non-routine situations than during routine situations).

These results suggest that the communication patterns and content for tactical rotary-wing aircrews and commercial fixed-wing aircrews are more similar with respect to the effect of crewmember position than with respect to the effect of flight condition. This indicates that the crewmembers in both types of aircraft initiate similar types of communication. This is probably a function of the task duties of each crewmember. For example, aircraft commanders are ultimately responsible for the conduct and safety of the flight, whereas the second pilots in the cockpit are responsible for monitoring equipment and backing up the aircraft commander.

THE IMPACT OF COMMUNICATION ANALYSES ON AIRCREW COORDINATION TRAINING

The final objective of this investigation was to determine whether the communication analyses can have an impact on tactical aircrew coordination training. The results gleaned from the detailed communication analyses discussed previously provide important input for the development of aircrew coordination training specifically focused on the unique characteristics of tactical rotary-wing aircrews. The specific implications of the results will be described in the discussion section of this report.

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DISCUSSION

As stated in the introduction of this report, the purpose of this research was to identify communication patterns and content that are specific to, and associated with, helicopter flight safety and tactical mission completion. This section of the report focuses on the findings that appear to contribute most to the understanding of tactical rotary-wing aircrew communication. Specifically, this discussion summarizes the findings relevant to the original research questions, posits potential implications of the investigation results, and presents future research areas.

SUMMARY OF FINDINGS

This section addresses each of the questions posed in the introduction of this report:

(1) What specific communication patterns and content are demonstrated by tactical rotary-wing crewmembers (i.e., HACs, H2Ps)?

Based on the correlational and multivariate analyses, specific communication patterns and content were identified for each of the crewmembers (see Table 16). HACs demonstrated a more complex set of communication behaviors than did H2Ps. HACs demonstrated higher pattern measures for commands, statements of intent, and inquiries than did H2Ps. These results suggest that HACs' communication is characterized by specific assignment of responsibility, announcements of intended actions, and requests for information regarding some aspect of flight status. It appears that HAC communication focuses on gathering data, making resource management decisions, and keeping the other crewmembers aware of ongoing and future maneuvers and actions.

H2Ps demonstrated higher pattern measures for observations than did HACs. This indicates that H2P communication is characterized by providing information about some aspect of flight status (e.g., instruments, environment, navigation). This suggests that H2Ps are primarily responsible for initiating communications about the status of the flight.

(2) Do tactical aircrew communication patterns and content vary as a function of the performance demands and requirement of different flight conditions (i.e., routine, non-routine)?

Based on the results of the correlational and multivariate analyses, specific communication patterns and content were identified for rotary-wing crews during routine and non-routine flight conditions (see Table 16). Crews demonstrated higher patterns of commands, suggestions, statements of intent, and replies during non-routine flight as compared to routine flight. These results suggest that crews change the way they communicate as a function of the flight condition. Non-routine flight was characterized by higher indices of specific assignments of responsibility, recommendations for specific courses of action, announcements of intended actions, and responses providing information. It appears that communication during non-routine flight is used to organize the effort and actions of the crew to perform during abnormal flight conditions. Crew communication patterns of observations, inquiries, acknowledgments and non-task related statements did not vary as a function of flight condition. This suggests that certain types of communication remain stable regardless of the condition of the flight.

(3) Are the communication patterns and content of more effective aircrews different from those of less effective aircrews?

Based on the bivariate correlational analysis, two types of communication content were significantly related to operational crew performance (i.e., commands initiated by H2Ps during routine flight and inquiries initiated by HACs during non-routine flight were negatively correlated with operational performance). Although these results were promising, the small sample and restricted range of the operational ratings could have hindered the ability to identify more types of communication associated with operational crew performance. These results demonstrated that it is possible to identify the existence of communication related to more, and less, effective aircrews. However, more research needs to be conducted to enhance the current results.

(4) What similarities exist between the communication patterns and content of military rotary-wing aircrews and commercial fixed-wing aircrews?

The results of this rotary-wing aircrew communication investigation were compared with the results of a similar study conducted by Foushee et al. (1986) which investigated the communication content of commercial fixed-wing aircrews. The results of the comparison for the two investigations identified a number of similarities in the way that specific crewmembers in each sample communicated with the other crewmember. This suggests that the content of the crewmember communication is related to the normal division of duties inside the cockpit.

While one crewmember is responsible for flying the aircraft, the other crewmember is actively monitoring the status of the flight. Since this division of duties is similar in both tactical rotary-wing and commercial fixed-wing settings, it is reasonable that the comparison between samples for individual crewmember communication would have yielded similar results.

In contrast, the two investigations demonstrated few similarities as to changes in communication content during routine and non-routine flight. This suggests that the types of communication exchanged during non-routine flight by tactical rotary-wing aircrews is different from the type of communication exchanged by commercial fixed-wing aircrews. The content of crew communications during varying flight conditions may have been different for the two samples because of differences in the maneuverability of the aircraft types or because of the differences the nature of the flight (i.e., military versus civilian).

These findings indicated that the results of prior communication analysis research was more similar to the results of the current effort with respect to how crewmembers communicate based on their respective positions and specific operational duties than with how crewmember communication changes as a function of flight requirements. The results suggest that additional research is needed to more fully understand changes in tactical rotary-wing aircrew communication as a function of flight condition.

(5) Can the results of the communication analyses have an impact on aircrew coordination training?

The results of the current investigation suggest that communication analyses can have an impact on the development of aircrew coordination training. The results of this research begin to describe tactical aircrew communication patterns and content. Tactical aircrew communication varies as a function of crewmember position and flight conditions. That is, the type of communication initiated by each crewmember position is unique, and crews change communication as a function of flight condition.

The results of the communication analyses provided detailed information about the content and structure of aircrew communication, the effect of changing flight conditions on aircrew communication, and the relationship between communication and overall operational performance. This information is important for understanding the nature of aircrew communication and for the identification of potential candidates for specific training. The results of the communication analysis can also be used to identify larger elements (i.e., dimensions of aircrew coordination) relevant to tactical aircrew performance. It appears that crews engaged in communication behaviors that were reflective of dimensions such as adaptability and flexibility, situational awareness, and leadership. The communication patterns and content identified in the current investigation can provide behavioral descriptions of specific behavioral skills that comprise aircrew coordination dimensions. These skills can then be evaluated and assessed by instructors to provide specific behaviorally-based feedback to tactical aircrews.

Even though few specific content categories actually correlated with the operational ratings, it should be noted that all of the aircrews in the sample successfully completed the mission-oriented scenario. Thus, the communication patterns and content identified in this research provide an indication of successful tactical aircrew communication. The results further suggest that overall crew performance is more than simply a function of the patterns and content of communication.

IMPLICATIONS AND FUTURE RESEARCH

This investigation produced a series of interesting and important results which are specific to the communication patterns and content of tactical rotary-wing aircrews. Although most of the previous research of aircrew communication has been conducted in a commercial fixed-wing setting, this investigation begins to provide a framework to focus on addressing the unique communication requirements and characteristics of military helicopter aircrews. Based on the findings reported here, preliminary inputs can be made towards the development of mission-oriented aircrew coordination training. For example, the results could lead to: the design of communication training aimed at training aircrews to adapt their communication to the flight condition; the development of assessment devices to provide instructors with a tool to provide specific feedback about the use of communication during training exercises; or the establishment of procedures which outline the optimal ways for crews to communicate.

One advantage of this investigation was the setting in which it was conducted. Although the use of simulated scenarios did provide a unique opportunity to observe and record tactical aircrew communication and performance, some constraints (i.e., low number of available aircrews, non-random selection of aircrews, full-visual displays for the right-seat only) did exist. The use of simulated scenarios and detailed communication analyses to investigate aircrew communication was not unique to this research. However, the use of multivariate analyses of variance techniques, multiple pattern measures and comparisons between fixed-wing and rotary-wing aircrews were unique to the current investigation.

The detailed communication analysis conducted in this research represented a microscopic approach to understanding the nature of tactical aircrew communication. Although important information was gleaned from the analysis, the communication transcription and coding processes were tedious and time consuming. Different methods of measuring and assessing aircrew communication must be developed to reduce the time required to obtain the information needed for analysis. Methods could include either the use of electronic transcribing devices or a dimension-based analysis, such as used in an assessment center. Specific communication behaviors identified in this investigation could be used to develop a detailed description of tactical aircrew communication.

CONCLUSIONS

The ultimate goal of the tactical rotary-wing aircrew communication analysis is to enhance the design of future training systems by providing: (a) a greater understanding of the interaction and performance process variables that contribute to the improvement of crew performance, and (b) a sound basis for the development of interventions that will enhance training in a variety of crew training systems.

The findings of this effort begin to provide detailed behavioral information about tactical rotary-wing aircrew communication. The information can be used to aid in the development of crew training interventions. Although the results are encouraging, additional tactical aircrew research is clearly needed to understand more fully the complex interactions involved in tactical aircrew performance.

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