Technical Report 1181

Nonverbal Communication and Aircrew Coordination in Army Aviation: Annotated Bibliography

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June 2006

United States Army Research Institute
for the Behavioral and Social Sciences

U.S. Army Research Institute for the Behavioral and Social Sciences

A Directorate of the Department of the Army Deputy Chief of Staff, G1

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REPORT DOCUMENTATION PAGE

1. REPORT DATE (dd-mm-yy) June 2006	2. REPORT TYPE Final	3. DATES COVERED (from. . . to) January 2005-April 2006
4. TITLE AND SUBTITLE: Nonverbal Communication and Aircrew Coordination in Army Aviation: Annotated Bibliography		5a. CONTRACT OR GRANT NUMBER N61339-03-C-0139 5b. PROGRAM ELEMENT NUMBER 622785
6. AUTHOR(S) Lawrence C. Katz (U.S. Army Research Institute); Gretchen Kambe, and Kurt F. Kline (Dynamics Research Corporation); Gary N. Grubb (Independent Contractor)		5c. PROJECT NUMBER A790 5d. TASK NUMBER 252 5e. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Dynamics Research Corporation 1219 Rucker Blvd. Enterprise, Alabama 36330		8. PERFORMING ORGANIZATION REPORT NUMBER KK-08-2005-A005 (U)
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Research Institute for the Behavioral & Social Sciences ATTN: DAPE-ARI-IR, (RWARU) 2511 Jefferson Davis Highway Arlington, VA 22202-3926		10. MONITOR ACRONYM ARI-RWARU 11. MONITOR REPORT NUMBER Technical Report 1181

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

Contracting Officer's Representative and Subject Matter POC: Lawrence Katz

14. ABSTRACT *(Maximum 200 words)*:

The Army's Aircrew Coordination Training (ACT) programs emphasize the importance of verbal communications between crewmembers during mission execution. While this is a critical component of effective crew coordination, little attention has been directed towards the influence of nonverbal communication on effective crew coordination. Nonverbal communication transactions occur in the cockpit, but the extent to which they supplement verbal communication and their contribution to safe mission performance remain unclear. The report documents online research materials pertaining to (but not limited to) aircrew coordination, communication classification schemas, nonverbal communication (within aviation and other applicable fields), and team training. A review of the literature was conducted with the results compiled into a database containing the relevant articles, and a categorization schema for future research in nonverbal communication in cockpit environments was recommended.

15. SUBJECT TERMS

Communication, aviation cockpit, nonverbal communication, literature review, classification schema, aircrew coordination, teamwork, rotary wing, tactical, accident reduction, aviation, crewmembers

SECURITY CLASSIFICATION OF			19. LIMITATION OF ABSTRACT	20. NUMBER OF PAGES	21. RESPONSIBLE PERSON
16. REPORT Unclassified	17. ABSTRACT Unclassified	18. THIS PAGE Unclassified	Unlimited	115	Ellen Kinzer Technical Publication Specialist (703) 602-8047

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June 2006

Army Project Number	**Personnel Performance and**
622785A790	**Training Technology**

NONVERBAL COMMUNICATION AND AIRCREW COORDINATION IN ARMY AVIATION: ANNOTATED BIBLIOGRAPHY

EXECUTIVE SUMMARY

Research Requirement:

The Army's Aircrew Coordination Training (ACT) and Aircrew Coordination Training Enhancement (ACTE) programs emphasize the importance of verbal communications between crewmembers during mission execution. While this is a critical component of effective crew coordination, little attention has been directed towards the influence of nonverbal communication on effective crew coordination. Nonverbal communication transactions occur in the cockpit, but the extent to which they supplement verbal communication and their contribution to safe mission performance remain unclear. Some Army rotary-wing aircraft employ a tandem-seating configuration that limits viewing angles between crewmembers. All Army rotary-wing aircraft operate at times with limited in-cockpit visibility resulting from night and night vision goggle (NVG) use. The resulting reductions in nonverbal communication may have an important impact on crew coordination and team performance and may require adjustments to training content and technique.

Procedure:

A review of the literature was conducted with the results compiled into a database of relevant nonverbal communication-related articles. From this review, a categorization schema for future research on nonverbal communication in rotary-wing aircraft was recommended. The report documents research materials pertaining to (but not limited to) aircrew coordination, communication classification schemas, nonverbal communication (within aviation and other applicable fields), and team training.

Findings:

The full impact of nonverbal communication on tactical rotary-wing operations is currently unknown. Extensive research on nonverbal communication and its effects on human interaction has been conducted in the areas of sociology and psychology. From the research conducted on air traffic controllers, a classification schema is identified as having potential for use with aviation crewmembers within a rotary-wing cockpit. Additionally, potential methodologies are identified and described for use in future research on the impact of nonverbal communication on aircrew coordination in rotary-wing aircraft.

Utilization and Dissemination of Findings:

This report identified a message classification schema that could be useful in conducting focused research addressing the effects of nonverbal communication on the completion of tactical missions in Army rotary-wing aircraft. The objective of this research would be to determine the level and types of nonverbal communication required in tactical rotary-wing

aircraft to provide a baseline of information to aircrew coordination trainers. This research could potentially provide aircraft accident investigators an additional category and classification schema to assist in accident investigations.

NONVERBAL COMMUNICATION AND AIRCREW COORDINATION IN ARMY AVIATION: ANNOTATED BIBLIOGRAPHY

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NONVERBAL COMMUNICATION AND AIRCREW COORDINATION IN ARMY AVIATION: ANNOTATED BIBLIOGRAPHY

Introduction

The U.S. Army Combat Readiness Center (USACRC) investigates Army aircraft accidents, and has included combat losses in their investigations. Their work continues to reveal a high incidence of crew coordination errors that contribute to loss of life and equipment. A USACRC spokesman stated that, "Eighty percent of our accidents are caused by human error and 66 percent of those can be directly linked to aircrew coordination failures" (Rosenberg, 2005). Materiel and training solutions are being sought to minimize the losses and maximize the effectiveness of Army Aviation's contributions in the Global War on Terror. Nonverbal forms of communications, such as gesturing, pointing, nodding, and shoulder tapping, comprise a method of interaction that might be related to aircrew coordination failures.

Background

The Army Research Institute for the Behavioral and Social Sciences Rotary-Wing Aviation Research Unit (ARI-RWARU) has had continual involvement in the Army's Aircrew Coordination Training program from the original conception to the current Aircrew Coordination Training Enhanced (ACTE) program, both in research and in the development of prototype training material. The USACRC, as the executive agency, along with the Directorate of Evaluation and Standardization (DES) as cadre trainers, are engaged in training the initial cadre in ACTE as one of the responses to the Secretary of Defense's requirement for a Department of Defense (DoD)-wide 50% reduction in Class A aviation accidents.

The training and its underlying research are heavily weighted to forms of verbal communication. To date, there has been almost no research into the impact of nonverbal means of communication among aircrew members in Army rotary-wing aircraft. This has hindered researchers' ability to investigate the impact of nonverbal communication on aircrew coordination. This issue has become increasingly relevant in discussions of crew coordination and flight safety. In an article in the July 2005 issue of *FlightFax*, Katz discusses nonverbal communications and asks for examples of nonverbal communication from Army aviators (Katz, 2005). These and other efforts are beginning to address the importance of nonverbal communication between crewmembers within a cockpit.

Purpose and Goals

The purpose of this research is to gather and catalog information pertaining to nonverbal communication between crewmembers in Army rotary-wing aircraft cockpits. The resulting information database and review will provide the starting point for further research into nonverbal communication as it pertains to tactical rotary-wing aircrews operating Army aircraft.

The goals of this research are:

- Establish an understanding of the issues relating to nonverbal communication in the cockpit.
- Describe types of nonverbal communications that can exist in an aviation setting.
- Provide ARI-RWARU, US Army Aviation, and other interested DoD and civilian agencies with a centralized and easily accessible store of information pertaining to nonverbal cockpit communication.
- Provide a recommended classification schema allowing for further coding and analysis of nonverbal communication as it occurs in aviation cockpits.
- Provide a list of potential research areas to focus study on the impact of nonverbal communications without repeating research.

Aircrew Coordination

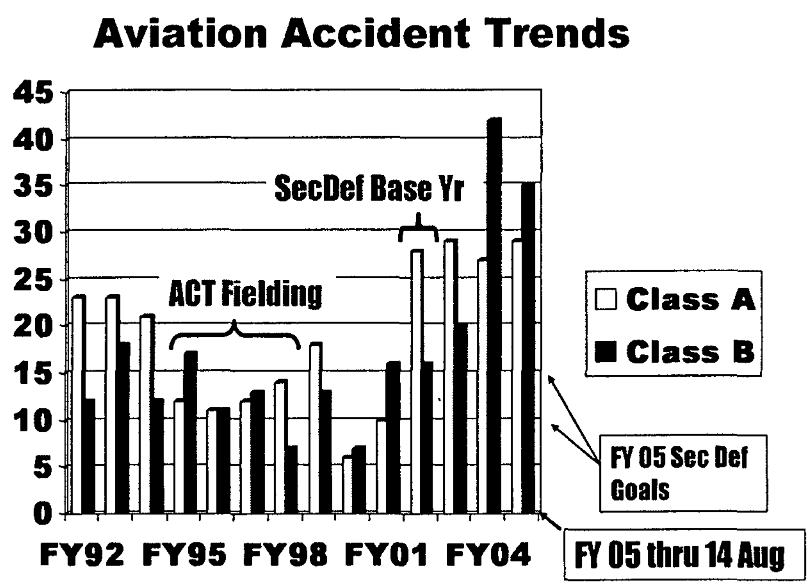
The US Army defines aircrew coordination as a set of principles, attitudes, procedures, and techniques that transforms individuals into an effective crew (Katz & Grubb, 2003). The current exportable training package contains the following definition for ACTE: "the interaction between crewmembers (communication) and actions (sequence and timing) necessary for tasks to be performed efficiently, effectively, and safely. It involves the effective utilization of all available resources; hardware, software, and liveware" (Department of the Army, 2003, p. 27).

Beginning in 1988, ARI began conducting a program of research that responded to the Army's need for better crew coordination training. This program was conducted in close cooperation with the United States Army Aviation Center (USAAVNC) and its efforts to revise its training standards to reflect increased emphasis on crew-level performance. The USAAVNC formed a Working Group in early 1990 to incorporate the results of the aircrew coordination research into revisions of the total Aircrew Training Program (Training Circular 1-210, Aircrew Training Program: Commander's Guide to the Aircrew Training Program) and Aircrew Training Manuals (ATMs) for all Army aircraft. The March 1992 revised Training Circular (TC) 1-210 introduced battle rostering and crew coordination as policies designed to improve effectiveness and safety by shifting the training emphasis from individual to crew-level performance (Department of the Army, 1992).

The new crew coordination policy, designed to standardize crew behaviors, required the development of a training course. Dynamics Research Corporation (DRC) worked closely with the USAAVNC Working Group to draft training and evaluation methods and materials for a crew coordination validation effort. During the 1992 validation test bed, Fort Campbell, KY units selected UH-60 crews who completed four missions in the visual flight simulator. The test bed demonstrated and validated the program for training and evaluating crew coordination skills. Results showed that the crews performed their missions significantly more effectively and safely after the training than before the training (Simon & Grubb, 1993). The USAAVNC subsequently implemented the Aircrew Coordination Exportable Training Package (ETP) using a trainer cadre team.

The initial ACT program was first implemented in 1993 as an ETP (Pawlik, Simon, Grubb, & Zeller, 1992). In June 1995, the requirement was established that all active duty flight crewmembers would be qualified in aircrew coordination not later than 31 May 1997 and the reserve component not later than 31 May 1998. This training was deemed to be so important that the Army redesignated Readiness Level (RL) 1 crewmembers without ACT to RL 2 until the training was completed.

Following implementation of the initial ACT program, the Army's aviation accident rate dropped dramatically. While no causal relationship can be established, commanders and aircrews alike acknowledged the benefit of the mandatory, one-time training that was received by all crewmembers within the Army. However, the accident rate steadily increased in the ensuing years (see Figure 1). The initial program did not address sustainment issues and did not package the training in a manner that would facilitate updates. Several factors are believed to have limited the attaining and maintaining of high levels of Army aircrew coordination. These include the significant personnel turbulence associated with downsizing and high operational tempo, the lowering of experience levels, and the atrophy of skills due to reduced flying hours that resulted from successive years of limited funding.



66.7% of Class A mishaps identify a lack of effective aircrew coordination
(Statement by Director of Army Safety to Congress 11 Feb 04)

Figure 1. Aviation accident trends.

In early 1998, the USAAVNC formed a special Aircrew Coordination Working Group (ACWG) to explore the increase in ACT-related accidents. The ACWG addressed the immediate problem of spatial disorientation by incorporating the issue into an overall assessment of the ACT program. Results of the ACWG effort and their ACT sustainment recommendations were noted but not acted upon due to inadequate funding (Grubb, Simon, Goddard, & Kline, 2001).

In 1999, the United States Army Safety Center (USASC) chartered the Aviation Safety Investment Strategy Team (ASIST) to define measurable accident prevention goals and identify the most important Army-wide investments needed to achieve them. Specifically, ASIST was established to reduce by 50% the rate of fatalities and serious injuries, the annual cost of aviation accidents, and the Class A-C accident rate within ten years.

The Hazard Analysis phase of ASIST identified 290 hazards across the five aircraft types analyzed. Five of the top ten hazards placed the crew of the aircraft at the center of attention. For example, “Maneuvering among obstacles in a degraded visual environment may cause an escalation in workload, increased fatigue and diminished capacity to safely maintain aircraft position, resulting in collision with ground or obstacles.” and “Hovering in close proximity to terrain in a degraded visual environment and high workload may result in loss of situational awareness, resulting in inadvertent hover drift and collision with terrain” (Hicks & Peusch, 2001, p. 129).

The ASIST study reported that by developing an ACT sustainment program, the potential for an aviation accident reduction of 6.4% or a cost reduction of 144 million dollars could be realized over a ten-year period. The study identified 249 potential controls for the 290 hazards that were defined. Number four on the list of controls was, “Develop, monitor and evaluate a Crew Coordination Sustainment Training program integrated into aviation tasks” (Hicks & Peusch, 2001, p. 132).

Communication between Crewmembers

There is a large body of research on the effects of communication on performance. The importance of communication within the aircrew is highlighted in the formal ACT program. Crew Coordination Objective (CCO) 4, *Exchange mission information*, is defined as “establishing communication using effective patterns and techniques which allow for the free flow of essential information among crewmembers and other mission elements, especially that information pertaining to the maintenance of mission situational awareness” (Department of the Army, 2003). Two of the Basic Qualities (BQ) associated with CCO 4, BQ 6, *Statements and directives clear, timely, relevant, complete and verified*; and BQ 8, *Decisions and actions communicated and acknowledged*, directly relate to the transfer of information. In addition, five of the eight associated Crew Coordination Elements (also defined in each Aircrew Training Manual) also relate to communication within the aircrew. The CCOs, BQs, and related Crew Coordination Elements stress the use of standardized terminology to avoid errors due to misunderstanding the information being related.

Yet, the breakdown of communication among aircrew members is frequently found in USACRC accident reports as a causal factor to date. Barriers to verbal communication exist in the cockpit, such as noise and other internal and external audio communications, improper terminology, and divided attention leading to misunderstanding or misinterpreting information. The use of read back or questioning may not always be accomplished due to high workload or stress. Maintaining clear and timely verbal communications among aircrew members in operational environments continues to pose a challenge to Army aviation.

Types of Aircrew Communication

The majority of the focus of the ACT program relates to verbal communication, and includes areas such as challenge and response, read back of information, and proper use of terminology. The program includes only minor mention of nonverbal communication. Indeed, the nonverbal communication discussion is limited to written words and symbols on forms and maps and body language such as nods, gestures, and eye contact (Katz & Grubb, 2003). There is no clarification or amplification of any of the topics and facilitation of the nonverbal topics is limited to personal knowledge of the instructor.

There are Army and Joint publications that describe the use of visual signals with Army aircraft. Field Manual (FM) 21-60, Visual Signals (Department of the Army, 1987), is a primary reference for aircrew and ground support personnel during marshalling of the aircraft. Other publications are specific to areas such as shipboard operations (Department of Defense, 1997). The Federal Aviation Administration provides mandatory light signals in the Aeronautical Information Manual that allow for operation of aircraft with inoperative radios (Federal Aviation Administration, 2004). In many of these cases, the nonverbal communication is in response to or in conjunction with a verbal communication.

Anecdotal examples of nonverbal communication include:

- Visually checking for accomplishment of assigned tasks, such as the pilot on the controls visually checking to ensure the pilot not at the controls is identifying the proper switch in response to a verbal request or checklist item.
- Visually verifying the correct display is selected.
- Using a "thumbs up" or "thumbs down" in the visual scan of a crewmember as a positive or negative response.
- Slightly moving the cyclic laterally to provide reinforcement that an individual has taken control of the aircraft.
- Tapping or pointing to an aircraft flight instrument to call attention to a flight parameter such as airspeed or altitude.
- Tapping or pointing to a systems instrument to call attention to a task, such as pointing to the fuel gauge as a reminder to start or end a fuel-consumption check.

A relatively new area of nonverbal communication is the use of automated systems to display and verify information, send and receive information, and maintain situational awareness without verbal communication. This constitutes a growing body of communication between crewmembers. However, for the purpose of this research, the nonverbal communications examined will be restricted to those nonverbal communications used by the aircrew members in the cockpit of Army rotary-wing aircraft. The following operational definition is used in this literature review: Nonverbal communication (NVC) is communication without the use of spoken language and the study of communication systems that do not involve words. Nonverbal communication includes gestures, facial expressions, and body positions (known as "body language"), as well as unspoken understandings and presuppositions.

Nonverbal Communication Effects on Aircrew Coordination (Literature Review)

The Army's aircrew coordination training program relies heavily on exchanging mission information as a major objective to achieve safe mission performance. Supporting basic qualities include ensuring that statements and directives are clear, timely, relevant, complete, and verified in order to maintain situational awareness. Aircrew coordination training stresses that decisions and actions be both communicated and acknowledged. Another basic quality of effective information exchange is that aircrew members seek information and actions from each other.

For information exchange within flight crews to be effective, their words and actions, whether they are communicated intentionally or unintentionally, explicitly or implicitly, must be interpreted accurately. Team coordination training emphasizes using a professional language containing simple, unambiguous words with well-understood meaning. Considerable attention is given during training and evaluation of flight crew performance as to how well crewmembers acknowledge and verify information presented in verbal, text, and graphic form. It may be equally important to take care in correctly interpreting nonverbal messages.

In order to study the impact of nonverbal communication on crew coordination, a detailed analysis of the types of nonverbal communications that occur between crewmembers is required. Similar to the verbal communication literature, a classification schema is necessary to enable researchers to better isolate and identify the nature and impact of the nonverbal communications that occur between crewmembers. Only after a classification schema has been identified and applied to nonverbal communications can the impact of nonverbal communication on crew coordination be examined in an objective fashion. The nonverbal communications can be coded and analyzed within the framework of the classification schema in the same manner as verbal communication research is conducted.

This section describes a baseline review of aviation related (e.g., military and commercial aviation) and non-aviation related (e.g., air traffic control, medicine, power generation) nonverbal communications literature. The review is intentionally constrained to define the relevant issues and acquire knowledge concerning nonverbal communication in the cockpit environment and its effect on aircrew coordination. Additionally, the review is limited to those aspects of nonverbal communication that can be physically observed by another person. For example, physical body movement and gestures are included. Manners of speech or paralanguage aspects of verbal communications such as voice pitch, word stress, timing and pauses are excluded from this review of literature.

Method

This literature review was initiated by conducting an online search to establish a trial definition for nonverbal communication. Using the keywords nonverbal-communications-definition reduced the number of hits to two. Both sources (Hirsch, Kett, & Trefil 2002; Trenholm, 1995) provide an unambiguous description of nonverbal communications that includes elements that are consistent with the research constraints. The two search results were combined to produce the definition presented above. That is, the definition used for this literature review considered only those communications devoid of the use of spoken language, to include gestures, facial expressions, body positions, unspoken understandings and presuppositions. A parallel search of online resources was conducted to identify candidate schemas for organizing nonverbal communications topics.

Initial searches using a trial set of key words and topics (see Table 1) produced nonverbal communications literature items from a variety of sources including military manuals, books, journals, technical reports, research reports, periodicals, papers, proceedings, and training courses. Expanded searches included additional online sources and the New England Research Application Center (NERAC). NERAC search strategies ranged from the broad topic area of communications to nonverbal communications to the key words and topics. Repositories queried by NERAC included Defense Information Service (dissertation abstracts), Department of Defense (defense technical information), Energy and Engineering Indexes (monographs), Medline (research papers), National Aeronautics and Space Administration (research papers), Psychology Info (research papers), Trade and Industry News (articles), and Government Reports Announcement File (research reports). Also queried were corporate technical libraries for support, especially regarding the availability of documents identified from other sources, e.g., Defense Technical Information Center (DTIC) and interlibrary loan agreements. Researchers reviewed candidate literature items for evidence of nonverbal communications relevance and whether or not the information contributed to the emerging body of knowledge.

Table 1

Key Words and Topics

Key Words	Topics
Military aviation nonverbal communication	Definitions
Commercial aviation nonverbal communication	Schemas
Aviation-related nonverbal communication	Methodologies
	Body Movement and Gestures
	Time and Space
	Facial Displays and Eye Movement

The review and documentation process for this literature review consisted of an input worksheet and a literature review database. The input worksheet is a Microsoft Word matrix organized by topic titles. The matrix provides information areas to identify each literature item and track it through the review process. Having already developed a literature review database for the Army Research Laboratory's Battle Command Staff Proficiency Measurement System, the product was refined to support this application. The database tool was designed to store and report out information describing the nonverbal communications literature review. The tool was developed using Microsoft Access, utilizing the application's relational database environment. The user interface consists of an input form and menus for executing commands and reports. The tool can be shared on a network drive to allow for a multi-user environment. Database elements and capabilities are presented visually to the user on the input form (see Figure 2). The database tool is capable of producing and exporting to a Microsoft Word document the literature review appendix and reference reports.

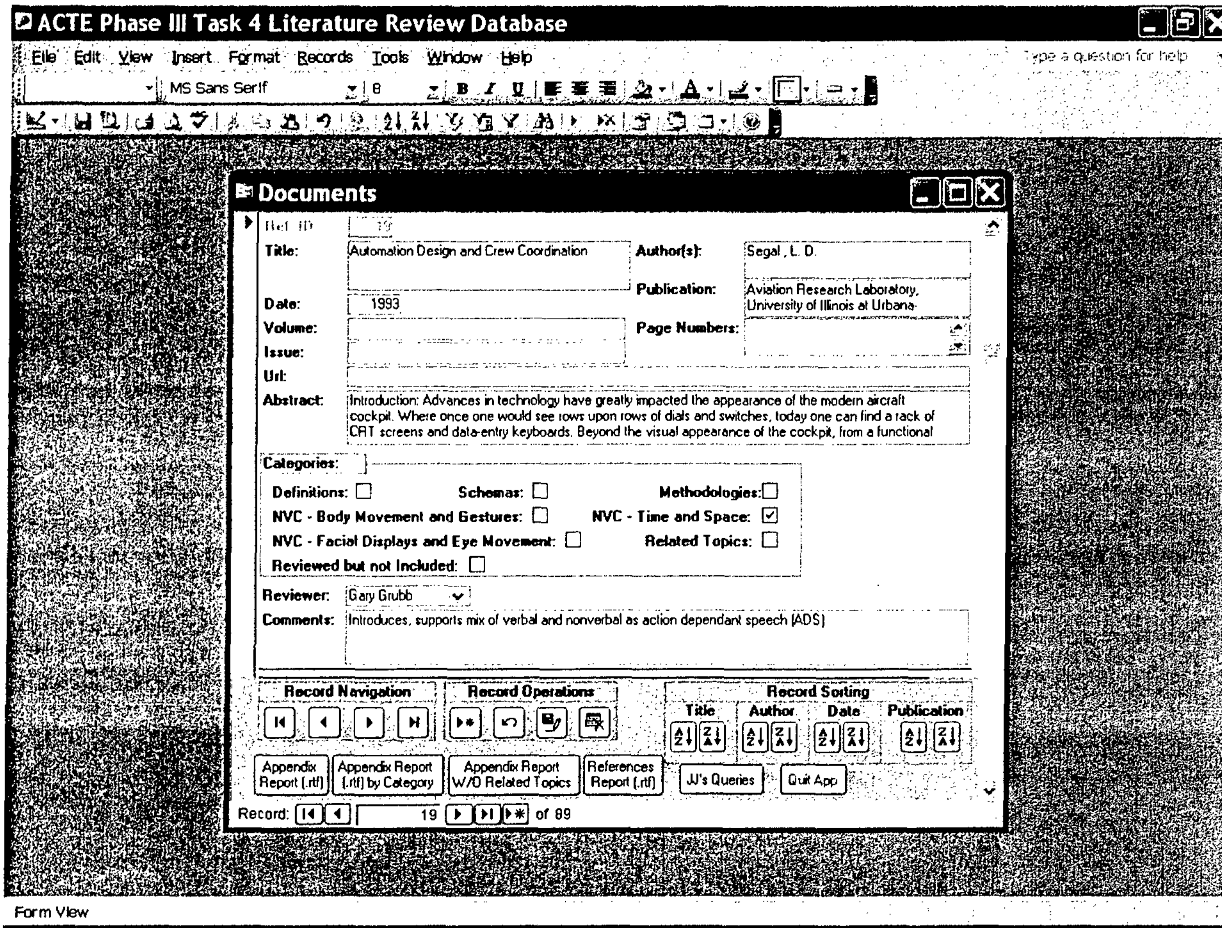


Figure 2. Nonverbal communications database tool — input form.

Focus Areas and Categorization

Guidelines for including a literature item in the review aligned directly with the constraints embodied in the definition-driven key words and topics. For example, the constraint to consider only the nonverbal communication in the cockpit environment produced a guideline to be alert for items that addressed intra-team communications. Intra-cockpit communications were defined as communication between crewmembers that share the same workspace in the aircraft cockpit (Segal, 1993). Reviewers were instructed to apply the guideline by including intra-team communication related literature and comment on whether it explicitly addressed nonverbal communications. Hence, a comments field was added to the input worksheet and the database entry form for reviewers' use.

Additionally, the expanded search identified a number of items that addressed important topics that are directly related to nonverbal communications and could have potential implications on aircrew coordination, e.g., automation, crew composition, and accident investigation. A separate category was created for related topics in both the worksheet and a corresponding field in the database tool to document these potentially relevant literature items. The key word searches identified a small number of items that were not directly related even though the title, descriptor, or abstract matched the strategy parameters. Thus, a field was added to the database tool to account for items reviewed but not included in the literature review. The intent was to provide information on nonproductive search areas and assess the effectiveness of the set of key words and topics.

The final structure is a set of categories (see Table 2) based on reviewing, assessing, and documenting the literature items generated from the searches. These categories serve to organize the assessment of the current body of nonverbal communications knowledge along with insights and implications for aircrew coordination.

Table 2

Nonverbal Communication Categories

Category	Description (Examples)
Definitions of Nonverbal Comm.	Specific to research constraints (Physical, Intra-cockpit)
Classification Schemas	Existing, directly relatable construct
Research Methodologies	Behaviors, team performance measures
Body Movement and Gestures	Physical code, observable
Time and Space	Mission-task flow
Facial Displays and Eye Movement	Facial expressions, eye behavior (Night vision devices)
Related Topics	Accident Investigation, Crew Composition, Automation
Reviewed Not Included	Face relationship to NVC but determined not relevant

Definitions of Nonverbal Communication

Scientific dictionaries provide a baseline definition of nonverbal communications, i.e., communication without the use of spoken language. Such definitions almost always include a discussion of what nonverbal communications include and sometimes how nonverbal communications differ from other forms of communication (Hirsch, Kett, & Trefil, 2002). Research definitions tend to include detailed discussion of topics like nonverbal behaviors, common nonverbal codes, and sending and receiving skills (Trenholm, 1995). Assessment of these items and others formed the basis of our operational definition of NVC and contributed to our key words and topics. Aviation-related literature defines "implicit communication" as that in which various interpretations may be derived from the information conveyed. Explicit communication is that in which the message is detailed with exact information and there is no ambiguity in interpretation (Campbell & Bagshaw, 2002).

Numerous literature items provided additional detail and reinforced one or more aspects of our operational definition. For example, several categories of human expression such as facial displays, gesture and body movement, posture and body orientation constitute active messages sent and received in ongoing interactions. Body movement and speech-related gestures are often used as a substitute for words and accompany or reinforce verbal communications (Kazdin, 2000). Recent research in the field of virtual environments emphasizes that physical gestures used to convey information or meaning require both accurate recognition and interpretation to enhance or facilitate communications (Cerney & Vance, 2005).

Classification Schemas

In the context of the current research effort, a schema is a system by which information can be grouped into common logical categories. When reviewing existing information on nonverbal communications, a variety of gestures, facial expressions, and body movements were considered. In order to determine the impact of these nonverbal communications on crew coordination, the nature and intent behind the communications need to be classified in a consistent fashion.

The commercial aviation literature provided a limited number of items directly and indirectly related to schemas for nonverbal communications. Our search did identify a single Army aviation study on verbal communications, an academic paper on gesture recognition, and a book that contains insights into the development of a nonverbal communications organizing structure. Commercial aviation research into air traffic control communications provided a taxonomy of general communication categories, communication topics, and communication expression. This taxonomy supports evaluation of communications between two-person controller team members in an environment similar to aircrews (Peterson, Bailey, & Willems, 2001).

The Army aviation study applied a verbalization analysis method in which each verbalization was coded in one of eight categories (Ahroon, Gordon, Mozo, & Katz, 2000). Books identified in the search offered organizing approaches based on functions, communications models (Campbell & Bagshaw, 2002), and levels of message classification (Penman, 1980). Research papers provided insights into possible classifications for gestures (Rehfeld, Jentsch, & Rodriguez, 2004), communications topics (Costly, Johnson, & Lawson, 1989), and communication patterns in automated cockpit environments (Straus & Cooper, 1989).

Research Methodologies

Literature items addressing communications schemas and taxonomies consistently discussed the research methodologies they supported. All of the communications methodology literature we identified was commercial aviation related except the Army's research into communications effectiveness using aviator hearing protection equipment and two studies on distributed team performance. Commercial aviation methodologies used aircraft flight deck simulators and expert observers to record and evaluate aircrew communications behaviors and performance of flight mission scenarios. Cockpit communication recording was either audio only or both audio and video to support subsequent coding and analysis of communication events (Straus & Cooper, 1989). Videotaping allows for an in-depth review of intra-aircrew communications (Peterson et al., 2001). Categories of verbal communications were logged and in some studies associated overt actions taken in task performance were also logged (Costley, Johnson & Lawson, 1989). An analysis of communications protocols by NASA concluded that direct observation techniques are best to capture both verbal and nonverbal communication events (James, Sanderson, & Seidler, 1989). Literature suggested that methodologies for communications studies include quantitative measures supported by detailed video recording and expert performance evaluations (Segal, 1994).

The Coordination Index Rating for Crew Linguistic Events (CIRCLE) methodology used in the Army aircrew hearing protection study provided useful information regarding how well crewmembers communicated verbally during a simulator mission. Additionally, it was used to measure communication effects on aircrew coordination behaviors (Ahroon et al., 2000). An academic paper discussed the role of nonverbal communication in crew tasks and how actions can serve as a context for the interpretation of verbal communications (Segal, 1989). An analysis of crew factors for manned space flight described the use of written surveys to identify nonverbal communication factors, followed up by detailed questionnaires to refine categories (Wong & Lyman, 1993). The Army's studies on training and communications performance of teams working in distributed environments provided insights into the importance of face-to-face and nonverbal communications (Commarford, Kring, & Singer, 2001; Kring, Hamilton, & Singer, 2004).

Body Movement and Gestures

Gesture and body movement-related literature came mainly from commercial aviation studies of flight deck crews conducting a simulated flight. An Australian university study presented evidence that one way in which pilots develop and demonstrate to one another their shared understanding is by precisely coordinating gesture and talk. A takeoff and climb mission segment was examined by transcribing both the talk and non-talk activities, e.g., gestures, body movement, and orientation. The study concluded that analyzing more than words is necessary to explain how people interpret what they are doing and what is going on around them (Nevile, 2002). A NASA sponsored study analyzed videotape of crew actions when confronted with a dangerous fuel leak midway in the flight. Temporal analysis showed how gesture and space provided the context for interpreting speech. Gesture and speech were mutually self-supporting (Hutchins & Palen, 1997).

Time and Space

Literature addressing the time and space category of nonverbal communications focused on intra-cockpit communication and crew coordination. Research data used video and performance measures from full mission simulations conducted by two-person flight crews. One independent variable was called "action-dependent speech." Action-dependent speech was defined as "Any speech act that is so ambiguous that it cannot be understood without reference to the visual record" (p. 56). Such words get their meaning in the context of a concurrent action, i.e., the message has meaning only when both verbal and nonverbal information are combined. For example, "This light should not be red, should it?" (Segal, 1993, p. 62). Crewmembers in a two-person cockpit anticipate and look to confirm each other's interactions with aircraft displays and controls (Segal & Wickens, 1994). For example, to perform takeoff and initial climb pilots perform a number of actions in strict sequence. The talk consists mostly of prescribed callouts and responses. Precisely timed coordination of talk and hand movement is critical to effectively transfer control of engine power levers (Nevile, 2002).

Facial Displays and Eye Movement

Facial displays can be viewed and interpreted in person or by video signal as virtual face-to-face communications. Literature related to the facial displays category of nonverbal communications resides mainly in applications of videoconferencing. Research addressed the issues of field of view and fidelity necessary to provide facial expression detail (Burden, 1999). Eye movement was the subtlest of the physically observable nonverbal communications categories. Aviation related literature came from air traffic control and medical studies. Both areas of research addressed the relationship of where one's eyes are looking (Helleberg & Wickens, 2001) and for how long during the performance of collaborative tasks (Grimaud et al, 2002). Eye movement/tracking research addressed performance and communication as they relate to situation assessment and error (Fussell & Setlock, 2003).

Related Topics (Crew Composition, Automation, Accident Investigation)

Two military aviation studies and one commercial aviation study addressed the impact of crew composition on communications in the cockpit. Both the Army and Air Force military studies indicated that fixed (homogeneous) crews tend toward informal communications and commit more errors than formed (heterogeneous) aircrews (Barker, Clothier, Woody, McKinney, & Brown, 1996; Grubb, Simon, Leedom, & Zeller, 1994). The commercial aviation literature centered on the effect that automated systems have on aircrew communication patterns and generally found no overall difference as a function of crew composition (Kanki & Foushee, 1989; Straus & Cooper, 1989).

Automation and information technology for coordination and communication are rapidly replacing traditional face-to-face interactions between team members. Aircrew members often visually monitor each other's interactions with controls and displays in the cockpit and rely on nonverbal cues for task coordination and communication. There is limited research on the effects of the loss of nonverbal cues that are commonly used to transmit information in face-to-face teams (Pharmer, 2001). A review of literature on issues related to implementing adaptive automation presents a finding that some automation interfaces allow one crewmember to instruct the system without permitting the other to infer the nature of the input from observable behavior alone. This may compromise nonverbal communication, degrade situational awareness, and impede decision making, and thereby increase the possibility of errors in crew coordination and flight performance (Kaber, Riley, Tan, & Endsley, 2001).

Recent research has developed a conceptual framework for supporting awareness in a shared workspace. Teams performing collaborative tasks in real-time distributed systems obtained information that was produced by people's bodies in the workspace, from workspace artifacts, and from conversations and gestures (Gutwin & Greenberg, 2002). Research using automated weather alert transmissions revealed how information presented at different times and in different forms affects the awareness and decision-making behaviors of aircrews (Lee, 1991). Literature on pilot-automation interaction increases understanding of the attention demands placed on aircrews and the change from the traditional eye scanning behavior to individual pieces of information on the glass cockpit display (Sarter & Woods, 1995).

Aviation accident investigation literature included a National Transportation Safety Board report that points out the limits of existing flight recorders to fully document the range of flight crew actions and communications. The Safety Board recommended a cockpit image recorder to record the entire cockpit including views of each control position and actions taken by people in the cockpit (Garvey, 2000).

Implications for Aircrew Coordination

The search results reinforce the perception that nonverbal communications are only briefly mentioned in military training and evaluation. There is limited discussion of the role or importance of nonverbal communications in the Army's aircrew coordination program. Without instructional and evaluative information on nonverbal behaviors and skills, it is not possible to accurately interpret the range of communications in the cockpit. Consequences of inaccurate recognition and interpretation of nonverbal communication include potential performance errors and accidents.

An accepted schema or taxonomy for nonverbal communications is required to research and design effective training interventions and evaluation systems for the Army's aircrew coordination program. The nonverbal communications schema should address observable behaviors and be directly relatable to aircrew performance. Ideally, the behavioral constructs it addresses should have application to aircrew interfaces external to the cockpit, such as communications with Air Traffic Control.

All of the communications methodology literature, including the Army's research into communications effectiveness using aviator hearing protection equipment, used aircraft flight simulators. Meaningful communication and coordination research requires the use of expert observers to record and evaluate aircrew communications behaviors and performance of flight mission scenarios. Categories of nonverbal communications and aircrew behaviors associated with task performance should be logged for analysis. A method is needed to measure how well crewmembers communicate nonverbally during a simulator mission.

Insights and examples from the literature review of the definition-based categories of nonverbal communications, i.e., body movement and gestures, time and space, and facial displays and eye movement, are readily relatable to aircrew coordination in cockpits. Nonverbal communications training should clearly address each category with meaningful examples, e.g., "Pilots develop and demonstrate to one another their shared understanding by precisely coordinating gesture and talk;" and, "Precisely timed coordination of talk and hand movement is critical to effectively transfer control of engine power levers."

Evidence of informal procedures and nonstandard verbal communications noted by crew composition research suggests that the nonverbal communications of fixed crews may present a threat to effective crew coordination. Increasing automation and the resultant tendency of aircrews to rely more on visually monitoring each others' interactions with controls and displays in the cockpit make them more reliant on nonverbal cues for task coordination and communication. Video recording of aircrew actions and communications would enhance after action reviews and feedback on aircrew coordination behaviors.

General Literature Review Conclusions

An aviation-related taxonomy of communication and coordination used in an air traffic control study (Peterson, Bailey, & Willems, 2001) was identified that addressed intra-team communications. While the classification schema requires some modification for use with rotary-wing crewmembers internal to a cockpit, this schema provides a starting point for future research and training. The air traffic control communications taxonomy, or Controller to Controller Communication and Coordination Taxonomy (C^4T) identified during the literature review provides general communication categories, communication topics, and communication expressions that are highly relatable to aircrew coordination. This taxonomy could be adapted to support training and evaluation of aircrew nonverbal communications. (See C^4T discussion in the Classification Schemas section.)

The simulator-based methodology used during the Army's aircrew coordination training research program provides a realistic mission context in a visual flight simulator with expert observer evaluators. The use of surveys, questionnaires, and experiments to confirm nonverbal communication constructs, methods, and measures should precede full simulator missions.

The definition-based categories of nonverbal communications provide reliable input to a nonverbal communications schema. These include body movement and gestures, time and space, and facial displays and eye movement. All of these categories are readily relatable to aircrew coordination in cockpits.

Little is known concerning the potential threat to effective crew coordination and communication posed by the lack of nonverbal communication training and awareness. Many pilots report that nonverbal communications occur frequently during flight and crew coordination activities. However, there are many instances in which nonverbal communications are blocked during routine flight conditions. It is important to identify the extent to which nonverbal communications impact crew coordination and mitigate risk in situations where verbal communications are ineffective, are supplemented by nonverbal communication, are replaced by nonverbal communication, or are habitually not used. Further research on crew coordination should include the impact of nonverbal communication on risk management.

In order to research and design an effective training intervention and evaluation system for the Army's aircrew coordination program, an accepted schema or taxonomy for nonverbal communications is required. Once the various nonverbal communications that regularly occur within a cockpit have been categorized, a nonverbal communication schema should be identified and enhanced to address observable behaviors directly relatable to aircrew performance. In the following section, existing classification schemas are evaluated in terms of the theoretical communication models they support, the conceptual levels of message description they espouse, and their potential application to Army aviation.

Classification Schemas

While researchers have created a wide variety of classification schemas to encompass the types and formats of communications that occur between individuals, no research has been conducted on the impact of nonverbal communication on aircrew coordination. Of particular interest is the impact of nonverbal communication between crewmembers on aviation safety. This concern is progressively more relevant with the increase in the use of night vision goggles and tandem seating arrangements in aviation cockpits. Crewmembers' ability to visually track and interact with each other is decreased in these settings. These conditions reduce crewmembers' ability to communicate via nonverbal gestures and visual tracking of movements. The impact this has had on crew coordination and thus flight safety has yet to be formally investigated. However, informal testimonials from crewmembers have suggested that this does have a negative impact on crew coordination (Katz, 2005). Therefore, it is important to study the impact of nonverbal communication on crew coordination in order to mitigate the risks associated with blocked nonverbal communication between crewmembers.

Within the existing literature on nonverbal communication, information is available pertaining to one of three general perspectives: Theoretical, conceptual, and aviation related. While there were no classification schemas directly related to examining the impact of nonverbal communication on crew coordination among aviation crewmembers internal to the cockpit, the schemas reviewed all contribute information relevant to extending this research area in the future.

Theoretical Schema

In a chapter titled, "Theoretical Models of Communication Processes," Penman (1980) presents four interrelated communication models that can represent the complexity of communications systems in terms of their structural properties. The theoretical models are presented in a hierarchical manner such that they build on each other. The first, the *message model,* accounts for the symbolism in language (manifest or surface) as well as the symbolism in non-vocal behaviors (latent or inferential). It presents a way of conceptualizing the interrelationships between components of the message. A *punctuation model* provides a way to look at how the messages themselves are interrelated by dividing the communication sequence into transactional units with a beginning and end for analysis depending on the number of participants (dyad or triad). A system *constraints model* provides a way to look at the types of structural connections within a unit of communication. Observers' and participants' models used together provide a dual level perspective of the structures inherent in communication processes. A *rules-based model* suggests a procedure for describing regularities in terms of their function, as the final step in a structural account of ongoing communication processes.

In "Human Performance and Limitations in Aviation", Campbell and Bagshaw (2002) briefly describe components and aspects of two different models of communication. *Berlo's communication model* presents four components: source, message, channel, and receiver. The model includes elements for both the message and communication channel. *Schul von Thun's communications model* proposes four aspects or levels of a verbal message: informational, relational, appellative, and self-disclosure. Further discussion of this model notes that it is necessary to have a context, given by nonverbal cues, to properly analyze the different levels. Both communication models could potentially contribute to development of a schema for nonverbal communications in aircraft cockpits.

Conceptual Schema

Literature items identified in the search offer organizing approaches based on nonverbal communications theory and levels of message classification (Penman, 1980). Penman proposes a schema for classifying messages based on the levels of message description—manifest and latent. The schema is intended to be appropriate for classifying all behavior in a communication setting. Application examples focus on the vocal rather than non-vocal communication modes to avoid confusing an already complex situation. Each of the categories within the two levels is defined in terms of either the power or involvement dimensions of behavior. A full description of each category is provided as an appendix.

Two research papers in particular provide insight on possible classifications for gestures. In "Memory Recall for International Gestures" (Rehfeld et al., 2004), the authors review relevant research on emblem gestures and then organize a set of sixteen to research how well gestures are learned and remembered. Researchers at Iowa State University (Cerney & Vance, 2005) reviewed the cognitive, perceptual, and human factors motivations for using gestures in virtual environments. They provided a set of guidelines for gesture development and a categorization of gesture-based interaction tasks.

Aviation-related Schema

Commercial aviation research into air traffic control communications provides a taxonomy of general communication categories, communication topics, and communication expression. This C^4T supports evaluation of communications between two-person controller team members in an environment similar to aircrews (Peterson et al., 2001). The taxonomy divides communication expression into the categories of verbal, nonverbal, and both, i.e., containing components of both verbal and nonverbal expression. Initial field testing and experiments suggest the taxonomy is useful to support both training and evaluation of intra-team communications.

Selection of a Taxonomy

In order to investigate the impact of nonverbal communications on aircrew coordination a classification schema needs to be identified that can be applied to aircrew communications internal to the cockpit. The classification schema used to support this type of research needs to accommodate both the type of communications that occur between crewmembers and the format of the communications. For example, not all communications between crewmembers in an aviation cockpit are verbal. Some are nonverbal and some are "mixed," a combination of verbal and nonverbal communications. Further, communications are expressed in a variety of formats. Communications can take the form of a request, command, question, response, or statement. The schema should be supported by a clearly established taxonomy.

Research conducted by the Federal Aviation Administration (FAA) on controller-to-controller communications (Peterson et al., 2001) included the development of a classification schema and supporting taxonomy that can be applied to crewmembers within a cockpit (see Figure 3). Communications between and among air traffic controllers (ATC) share several properties with the communications between crewmembers. For example, the type, format and topic of communications overlap between these groups.

The taxonomy captures communications in three general categories of topic, format, and expression—all categories are highly related to aircrews in a cockpit environment. The *communication topic* category contains 13 topics such as traffic, altitude, and route that account for the majority of air traffic control communications. Definitions and examples for each topic are brief and precise. Aircrew coordination parallels are readily apparent. The second category is *grammatical format* and consists of five subcategories including question, answer, statement, command, and command answer. Similar grammatical forms specific to Army aircrews are available in Army manuals and research reports. Three subcategories of *communication expression* address verbal, nonverbal, and both verbal and nonverbal communications. Nonverbal communications considers mainly physical gestures such as head nodding, thumbs up, etc. Explicit recognition of nonverbal communications in this taxonomy provides a distinct point for development of more descriptive subcategories based on insights from this literature review.

The Controller-to-Controller Communication and Coordination Taxonomy (C^4T) provides the best application of knowledge concerning theoretical and conceptual communications schemas that is relatable to developing a nonverbal communications classification schema for aircrew coordination. This candidate taxonomy affords the opportunity to incorporate, in particular, the latent levels of communication into a practical classification schema for researching nonverbal communication in aircrew coordination.

Table 3

Recommended Classification Schemas and Levels of Classification for Messages

Recommended classification schemas	**Levels of classification for messages**
Communication Topic (definitions specific to "speaker" group)	 Manifest
1. Approval	1. Exchange
2. Handoff	2. Advise
3. Point-out	3. Support
4. Traffic	4. Agree
5. Altitude	5. Concede
6. Route	6. Request
7. Speed	7. Avoid
8. Weather	8. Disagree
9. Frequency	9. Aggress
10. Flow Messages	10. Offer
11. Flight Strips	
12. Equipment	Latent
13. Aircraft ID	1. Offer
	2. Seek
Grammatical Formats	3. Abstain
1. Question	4. Resist
2. Answer	5. Control
3. Statement	6. Initiate
4. Command	7. Share
5. Command Answer	8. Collaborate
	9. Oblige
Communication Expression	10. Cling
1. Verbal	11. Submit
2. Nonverbal	12. Relinquish
3. Both	13. Remove
	14. Evade
	15. Counter
	16. Reject

Potential Methodologies

No previous research has been conducted to address the impact of nonverbal communication on aircrew coordination. The focus of such a research initiative would be to conduct a preliminary investigation on the types, functions, and effects of nonverbal communication on aircrew coordination. The following section addresses research methodologies found in the literature that may be applicable to this effort.

Review

Most of the communications methodology literature identified was commercial aviation related. The few exceptions included the Army's research into communications effectiveness using aviator hearing protection equipment and two studies on distributed team performance. Commercial aviation methodologies used aircraft flight deck simulators and expert observers to record and evaluate aircrew communications behaviors and performance of flight mission scenarios. Cockpit communication recording was either audio only or both audio and video to support subsequent coding and analysis of communication events (Straus & Cooper, 1989). Videotaping allows for an in-depth review of intra-aircrew communications (Peterson et al., 2001). In all coordination and communications methodologies, the categories of verbal communications were logged and in some studies associated overt actions taken in task performance were also logged (Costley et al., 1989). A review of literature items concluded that direct observation techniques were best to capture both verbal and nonverbal communication events (James et al., 1989). The most cited literature items suggest that methodologies for communications studies include quantitative measures supported by detailed video recording and expert performance evaluations (Segal, 1994).

The Coordination Index Rating for Crew Linguistic Events (CIRCLE) methodology used in the Army aircrew hearing protection study provides useful information regarding how well crewmembers communicated verbally during a simulator mission. Additionally, it was used to measure communication effect on aircrew coordination behaviors (Ahroon et al., 2000). A related academic paper discussed the role of nonverbal communication in crew tasks and how actions can serve as a context for the interpretation of verbal communications (Segal, 1989). An analysis of crew factors for manned space flight described the use of written surveys to identify nonverbal communication factors followed up by detailed questionnaires to refine categories (Wong & Lyman, 1993). The methodology used in the Army's study on training and communications performance of teams working in distributed environments provides insights into the importance of face-to-face and nonverbal communications (Commarford et al., 2001; Kring et al., 2004).

All of the communications methodology literature including the Army's research into communications effectiveness using aviator hearing protection equipment used aircraft flight simulators. Meaningful communication and coordination research requires the use of expert observers to record and evaluate aircrew communications behaviors and performance of flight mission scenarios. Categories of nonverbal communications and aircrew behaviors associated with task performance actions should be logged for analysis.

Selection of a Methodology

The methodology to support a preliminary investigation of the impact of nonverbal communication on aircrew coordination should establish some initial data on three issues: 1) the types of nonverbal communications that occur between crewmembers during mission execution, 2) the frequency with which nonverbal communications occur, and 3) how nonverbal communications affect aircrew coordination.

An accepted schema or taxonomy for nonverbal communications is required in order to research and design effective training interventions and evaluation systems for the Army's aircrew coordination program. The nonverbal communications schema should address observable behaviors and be directly relatable to aircrew performance. Behavioral constructs should have application to aircrew interfaces with other than the cockpit crewmembers, i.e., mission crewmembers, other members of the mission package, and external resources and control agencies.

A simulation-based methodology is recommended to evaluate the effects of nonverbal communication on aircrew coordination. Crew coordination behaviors would be the focus for evaluation during this research for two purposes: 1) to determine the degree of crew coordination that occurred during mission execution; and 2) to determine the extent to which nonverbal communications are used during crew coordination behaviors. It is hypothesized that less coordinated crews will display fewer nonverbal communications during mission execution. Additionally, it is possible that mission execution will be compromised more when nonverbal communication is obstructed for crews that demonstrate high levels of crew coordination than those that do not. Additionally, nonverbal communications may be utilized to support verbal coordination behaviors performed during mission execution, or in lieu of verbal communications. It is important to track the extent to which nonverbal communications are used during crew coordination to better assess the degree to which situations that compromise nonverbal communication (such as night systems operations and tandem aircraft crew configurations) might negatively impact crew coordination and mission execution.

To investigate the effects of nonverbal communication on aircrew coordination, aircrews would be asked to participate in two visual flight simulator periods for observation and data collection. During one simulator period aircrews would be observed during mission execution where nonverbal and verbal communication is able to proceed naturally ("Open Cockpit"). This would provide a baseline measure of the frequency and nature of nonverbal communications as it occurs during mission execution. A second simulator period would include a visual barrier that would partially obstruct crewmembers' view of each other, hindering nonverbal communication ("Closed Cockpit"). Comparing aspects of crew coordination across these two conditions would provide the opportunity to determine the degree to which nonverbal communications affect aircrew coordination during mission execution. To increase the likelihood of capturing nonverbal communications, the aircrews selected for participation would be expected to be familiar with each other and have logged previous flight/simulation hours together. Evidence supports the supposition that increased familiarity between crewmembers increases the frequency and type of nonverbal communications likely to occur (Grubb et al., 1994).

Several measures could be used during this research endeavor. Video and audio-captures allow for analysis of the frequencies and categorization of the types of verbal and nonverbal communications that occur during crew coordination. The ACTE Behavioral Anchored Rating System (BARS) provides the ability to determine whether the nonverbal communications that occur during mission execution actually affect crew coordination. Observer Evaluator Worksheets would allow measurement of performance parameters, and structured interviews could be used to supplement these measures with subjective feedback.

Conclusion

Summary

Nonverbal communication is communication without the use of spoken language and the study of communication systems that do not involve words. Nonverbal communication includes gestures, facial expressions, and body positions (known as "body language"), as well as unspoken understandings and presuppositions, and cultural and environmental conditions that may affect any encounter between people. Nonverbal communication provides for emphasis or enhancement of verbal communications in its simplest forms and at the extreme can completely alter the meaning of verbal communications. Additionally, nonverbal communications may occur in lieu of verbal communication. As Army aviation continues to expand operations at night and utilize complex glass cockpits and tandem seating, the effects of nonverbal communication on crew coordination will need to be understood. Research on the impact of obstructing nonverbal communication between crewmembers will need to be conducted in conjunction with the investigation into the effect of nonverbal communication on crew coordination. In this way the means by which nonverbal communications enhance or affect mission safety can be established. So far, very little is known about the impact of nonverbal communication on aircrew coordination. In particular, research on nonverbal communication within rotary-wing tactical aviation is extremely limited.

The full impact of nonverbal communication on tactical rotary-wing operations is currently unknown. Extensive research on nonverbal communication and its effects on human interaction have been conducted in the areas of sociology and psychology. Crew coordination and its verbal component continue to be cited as a factor in aviation accidents. The impact of nonverbal communication in aviation accidents is unmeasured. The need to conduct further research, based on a pre-determined schema, into the effects of nonverbal communication within the aviation industry exists. Research in this area will support cockpit design, operational training, and tactical deployment of modern rotary-wing aircraft. For example, if research indicates that nonverbal communication has little or no effect on tactical rotary-wing operations then aircraft designers would be free from current design limitations that provide for line of sight with other crewmembers.

Recommendations for Future Research

ARI should conduct focused research on the effects of nonverbal communication on the conduct of tactical missions in Army rotary-wing aircraft. The objective of this research would be to determine the level of nonverbal communication currently ongoing in rotary-wing operations and the effect of reducing or eliminating the nonverbal communication on mission success. This baseline of information will provide aircraft designers, aviation trainers, and accident investigators with a known effect of nonverbal communication on mission safety and task performance in tactical rotary-wing aircraft. This baseline could assist in the design and modification of aircraft, training products, operational tactics, techniques, and procedures. In addition, this research could provide the aviation accident investigator with additional investigative tools and knowledge.

Acronyms

ACT	–	Army Aircrew Coordination Training
ACTE	–	Army Aircrew Coordination Training Enhancement
ACWG	–	Aircrew Coordination Working Group
ARI	–	Army Research Institute for the Behavioral and Social Sciences
ARI-RWARU	–	ARI Rotary-Wing Aviation Research Unit
ARNG	–	Army National Guard
ASIST	–	Aviation Safety Investment Strategy Team
ATC	–	Air Traffic Controllers
ATM	–	Aircrew Training Manual
BARS	–	Behavioral Anchored Rating System
BQ	–	Basic Qualities
C^4T	–	Controller to Controller Communication and Coordination Taxonomy
CIRCLE	–	Coordination Index Rating for Crew Linguistic Events
CCO	–	Crew Coordination Objective
DES	–	Directorate of Evaluation and Standardization
DoD	–	Department of Defense
DRC	–	Dynamics Research Corporation
DTIC	–	Defense Technical Information Center
ETP	–	Exportable Training Package
FAA	–	Federal Aviation Administration
FM	–	Field Manual
NASA	–	National Aeronautics and Space Administration
NERAC	–	New England Research Application Center
NVC	–	Nonverbal Communication
NVD	–	Night Vision Device
NVG	–	Night Vision Goggle
RL	–	Readiness Level
SOP	–	Standard Operating Procedure
TC	–	Training Circular
USAAVNC	–	United States Army Aviation Center
USACRC	–	United States Army Combat Readiness Center
USASC	–	United States Army Safety Center

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Appendix A

Nonverbal Communication Literature by Category

This appendix provides a summary sheet for each literature item considered in the baseline review of aviation related (e.g., military and commercial aviation) and non-aviation related (e.g., medicine, power generation) nonverbal communications literature.

Summary sheet contents provide the standard title-author reference details and abstract. Included are comments indicating how the literature item relates to the nonverbal communications body of knowledge as it applies to aircrew coordination in Army aviation cockpits. Comments are provided for every literature item that is cited in the report as directly relevant to the research effort. Comments provided for literature items not cited in the report indicate how the literature is related and supports one or more aspects of nonverbal communications. Some literature items with face relationship communication titles and/or abstracts intentionally do not have comments posted as content review disclosed little or no relevance.

Summary sheets are organized by key words and topics derived from the operating definition of nonverbal communications: nonverbal communication (NVC) is communication without the use of spoken language and the study of communication systems that do not involve words. Nonverbal communication includes gestures, facial expressions, and body positions (known as "body language"), as well as unspoken understandings and presuppositions, and cultural and environmental conditions that may affect any encounter between people.

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Note: MS Access NVC database tool with literature item entries provided separately.

Definitions

Title:	Science Information about Nonverbal Communication
Author:	Hirsch, Jr. E.D., Kett, J. F., & Trefil, J.
Date	2002
Publication:	The New Dictionary of Cultural Literacy, Third Edition
Volume:	
Issue:	
Page Numbers:	
Abstract:	Communication without the use of spoken language. Nonverbal communication includes gestures, facial expressions, and body positions (known collectively as "body language"), as well as unspoken understandings and presuppositions, and cultural and environmental conditions that may affect any encounter between.
Comments:	Baseline definition of nonverbal communication from a science perspective. (Cited item)

Title:	The Shaker is the Taker
Author:	Katz, L.
Date	2005
Publication:	FlightFax
Volume:	33
Issue:	(7) July
Page Numbers:	9
Abstract:	Army Research Institute is currently conducting research to explore the impact of limited nonverbal communication on aircrew coordination.
Comments:	Provides definition of nonverbal communications as--Nonverbal communications include any interactions in which a message is sent or received without using written or spoken words; e.g., prodding, pointing, tapping, gesturing, etc. Article alerts aviation leaders and Soldiers of research effort and solicits their input and support. (Cited item)

Title:	Encyclopedia of Psychology
Author:	Kazdin, A. D.
Date	2000
Publication:	Oxford University Press
Volume:	(5)
Issue:	
Page Numbers:	
Abstract:	Nonverbal communication subsumes several categories of human expressiveness such a facial displays (including eye contact and gaze behavior), gesture and body movement, posture and body orientation, touch, human spacing and territorial behavior, and vocal and paralinguistic behavior. Some explications also include physical attractiveness and other physical attributes, odor, and features such as hair, clothing, and adornment. These latter aspects, however, are less frequently included under the nonverbal communication rubric since they are more static than messages sent.
Comments:	Supports the operational definition of nonverbal communications established by the review team. (Cited item)

Title: Thinking through Communication: An Introduction to the Study of Communication. 3rd edition.

Author: Trenholm, S.

Date Publication: 1995

Volume: Chapter 5

Issue:

Page Numbers:

Abstract: Chapter 5: Encoding Messages/Nonverbal Communication. Goal: To appreciate the extent to which nonverbal behaviors convey messages; to identify common nonverbal codes and explore ways to use them more effectively during communication. Nonverbal communication is the study of communication systems that do not involve words. It is not easy to define nonverbal communication. Experts disagree about whether to count unintended actions as nonverbal communication. In this book, nonverbal communication is regarded as occurring whenever stimuli other than words create meaning in either a sender's or a receiver's mind. Given such a broad definition, we must keep in mind that nonverbal stimuli are often outside a sender's awareness. It is important to take care in interpreting nonverbal messages. To increase interpretive accuracy, we should check the communication context cues to meaning. Comparing nonverbal acts to baseline behaviors will increase interpretive accuracy. If unsure, we should ask for verbal feedback. As a system of communication, nonverbal communication is unique. It has several defining characteristics. It may be unintentional, may often combine multiple codes, is relatively universal, (although nonverbal acts can be conventionalized), and it conveys certain kinds of messages particularly well. It is immediate, continuous, and natural. Nonverbal communication is often used to make initial judgments when direct verbal questioning would be inappropriate. It gives us information about our relationships with others, particularly in regard to status, liking, and responsiveness. Nonverbal messages are particularly appropriate for conveying emotion. Nonverbal communication often accompanies and supplements verbal messages by repeating, contradicting, substituting for, complementing, accenting, and regulating them. Nonverbal communication consists of several codes working in concert. Body movement and gesture, part of the kinesic code, are important sources of information. Emblems act like words and they have direct verbal translations. Illustrators are gestures that accompany speech and add meaning to it. Regulators maintain the back and forth flow of talk in an interaction by acting as social traffic signals. Affect displays convey emotional meaning. Posture and gesture often tell us how a person feels. When people lie, body movements can give them away. Adaptors are unnoticed gestures or movement we use to calm ourselves in moments of stress. Facial displays, including eye movement, are also part of nonverbal

communication, as the face is a powerful source of nonverbal information. Facial displays are partly innate and partly learned. People learn to use facial expressions to intensify or de-intensify feelings and to neutralize or mask other emotions. We follow cultural, professional, and personal display rules as we learn to manage our faces. The eyes, long associated with mystic power, are important sources of information. Eye behavior serves to maintain social position. The eyes are good indicators of emotion. Eye contact signals our willingness to relate to one another. Eye behavior is associated (often falsely) with character traits. Paralanguage, the way we say something rather than what we say, is another nonverbal code. Paralanguage is usually divided into three parts, each of which convey meaning. Vocal qualities are characteristics of the voice like pitch. Vocalizations are special sounds like groans or sighs. . Vocal segregates are pauses, fillers, and other hesitation phenomena. Although the judgments we make on the basis of voice are not necessarily accurate, we think they are. Silence is an overlooked aspect of paralanguage that carries meaning. Time, or chronemics, and space, or proxemics, also convey messages. The values we attach to and the way we use time provide useful information about us. People have different psychological orientations to the present and the future. People are also controlled by biological clocks. Cultures also differ in the meanings they attach to time. The way we use space is called proxemics. We mark and defend four kinds of territories, public, home, interaction and body, and these territories can be encroached through contamination, violation, and invasion. The ways we arrange home and public territories affect the amount, flow, and kind of interaction that occur in these territories. Each of us varies in our attitudes to personal space, how close we prefer to be to other people. The extreme of personal closeness is touch.

Comments: This document supports the operating definition of Nonverbal Communication used for this study. It provides a definitional basis for the selected categories of nonverbal communications, i.e., body movement and gestures, time and space, and facial displays and eye movement. (Cited item) All cultures regulate and forbid certain kinds of touch. Touch defines relationships, communicates social status, and satisfies emotional needs. All cultures favor certain body types and create stereotypes about the characteristics attached to them. People can be classed according to somatypes. North American cultural norms value men who are muscular and women who are slender. Dress fulfills several functions: comfort protection, modesty, and cultural display. The objects or artifacts we display also send messages. Our possessions are closely linked with our sense of self. Elements in the design of built environments give off additional messages. Size, shape, texture, linear perspective, lighting, color, temperature, noise, and sensory stimulation are important environmental factors.

Schemas

Title:	Human Performance and Limitations in Aviation: Third edition
Author:	Campbell, R. D., & Bagshaw, M.
Date	2002
Publication:	Malden, MA: Blackwell Science Ltd
Volume:	
Issue:	
Page Numbers:	
Abstract:	Human error continues to be a major cause of aviation accidents. Experts agree that a better understanding of the factors affecting human capabilities and limitations whether physical or psychological will help reduce pilot error and improve safety standards. This new training manual covers the physiological aspects of aviation medicine and provides a readable introduction to aviation psychology. A knowledge and understanding of this aspect of flying helps reduce risks and motivates pilots to maintain personal fitness, which is essential for pilot well being. Written by pilots for pilots, the book avoids excessive medical jargon and makes the material of real practical use for all who fly. The information covered is suitable not only for private pilots, but also for commercial aviators. The book takes into account the most recent changes in the newly revised European JAR pilot training syllabus, but is based on an international PPL syllabus to appeal to aviators around the globe.
Comments:	Provides brief description of schema-related components and aspects of two different communications models. Emphasizes the distinction between explicit and implicit communication to include the importance of accurate interpretation. Also supports the operating definition of nonverbal communication established by the research team. (Cited item)

Title:	Gesture Recognition in Virtual Environments: A Review and Framework for Future Development
Author:	Cerney, M. M., & Vance, J. M.
Date	2005
Publication:	Ames, Iowa: Human Computer Interaction Program and Department of Mechanical Engineering
Volume:	
Issue:	(ISU-HCI-2005-01)
Page Numbers:	
Abstract:	Gesture recognition has the potential to be a natural and powerful tool in virtual environments, supporting efficient and intuitive interaction between the human and the computer. A review of the cognitive, perceptual, and human factors motivations for the use of gesture in virtual environments is provided. A set of guidelines for gesture development and a categorization of gesture-based interaction tasks are formulated for practitioners.
Comments:	Provides a set of guidelines for gesture development and categorization of gesture-based interaction tasks. Also supports the operational definition of nonverbal communications and provides input to methods for evaluating gestures in nonverbal interactions. (Cited item)

Title:	Nonverbal Communication: Studies and Applications (Fourth Edition)
Author:	Hickson, III, M. L., Stacks, D. W., and Moore, N.
Date	2004
Publication:	Los Angeles, CA: Roxbury Publishing Company
Volume:	(ISBN: 1-891487-20-5)
Issue:	
Page Numbers:	
Abstract:	The text offers complete coverage of the field's basic subcodes: Haptics (touch); Proxemics (space); Physical appearance; Kinesics (human body movement); Oculesics (face and eye); Vocalics (paralanguage); Olfactics (scent and smell); and Chronemics (time usage). An ever-popular feature is the chapter on research methodology. Students will better understand what they are learning if they become aware of the processes scholars follow in developing theories. The authors conclude their text with a chapter on the future of nonverbal communication--what we know about the field, its practical implications, and where the discipline appears to be heading.

Title:	Communication Processes and Relationships
Author:	Penman, R.
Date	1980
Publication:	London: Academic Press.
Volume:	
Issue:	
Page Numbers:	
Abstract:	The dual emphasis on theory and method is reflected in the structure of the book. The first half is concerned primarily with theory integration and development and the latter half with the theory in practice. As a means of demonstrating practical applications, the author presents descriptions of the conversations of a sample of marital-type dyads. However, in order to make the second half of the book more readable, the author minimizes technical matters, except where necessary.
Comments:	Provides an organizing approach based on nonverbal communications theory and levels of message classification. (Cited item)

Title:	Controller-to-Controller Communication and Coordination Taxonomy(C4T)
Author:	Peterson, L. M., Bailey, L. L., & Willems, B. F.
Date	2001
Publication:	Washington, DC: Office of Aerospace Medicine
Volume:	
Issue:	
Page Numbers:	
Abstract:	While previous research in the air traffic control (ATC) communications area has generally concentrated on controller-pilot communications, this program of research focuses on controller-to-controller communications. At the Air Route Traffic Control Center (ARTCC), teams of two controllers, R-side and D-side, are required to communicate on a continuing basis to coordinate the duties of their sector. As modernization of the ATC system progresses, questions arise concerning the effects these changes will have on intra-enroute sector team (EST) communications. In anticipation of technology changes, the Federal Aviation Administration commissioned a series of studies investigating intra-EST communication. This initial study details the design and subsequent field-testing of the Controller-to-Controller Communication and Coordination Taxonomy (C4T). The taxonomy is designed to capture the following general communication categories: Topic, Format (grammatical form), and Expression. The final taxonomy resulting from this research contains 12 ATC topics (i.e., Traffic, Altitude, etc.). Communication Grammatical Format contained 5 subcategories: Question, Answer, Statement, Command, and Command Answer. Communication Expression consisted of 3 subcategories: Verbal, Nonverbal or a combination of Verbal and Nonverbal, referred to as Both. A field study at an ARTCC was conducted with subject-matter experts coding intra-EST communications using the taxonomy described. Field observations were made at 18 different sectors between the hours of 07:00 and 019:00 based on moderate to high traffic levels. Descriptive statistics detail the results of the taxonomy's use in a field setting. Testing and further refinement of the taxonomy allows its use in both field and controlled experimental settings. Provides a tool for training individuals to code C4T communications, and enables the establishment of a C4T baseline to investigate changes in communication patterns as modernization continues in the enroute ATC environment.
Comments:	Provides insight into key elements of nonverbal communications operational definition and includes a taxonomy of general communications categories, topics, and expression means. Supports methodologies using video recording of simulator missions. (Cited item)

Title:	Memory Recall for International Gestures
Author:	Rehfeld, S. A., Jentsch, F. G., & Rodriguez, T. N.
Date	2004
Publication:	Proceedings of the Human Factors and Ergonomics Society 48th Annual Meeting, USA
Volume:	
Issue:	
Page Numbers:	2604-2607
Abstract:	The current project reviewed relevant research in the area of emblem gestures and created an electronic library of gestures that incorporates established population norms by culture and region. In order to present this information to assist learning and remembering the information, four displays were used (text only, text with gender-neutral and expression neutral image, text with contextually relevant image, or text with detailed image of gesture) with 16 gestures (eight with the same meaning across countries, eight with different meanings). Accuracy was measured for the first set of 32 questions (learning) and the second set of 32 questions (transfer of knowledge to novel stimuli). Results showed a clear benefit for gestures with the same meaning across cultures. In addition, use of the detailed image produced significantly higher accuracy than textual information alone.
Comments:	Author reviews emblem gestures and organizes a set of sixteen to support research regarding how well gestures are learned and remembered. (Cited item)

Title:	Crew Structure, Automation and Communication - Interaction of Social And Technological Factors on Complex Systems Performance [Electronic version]
Author:	Straus, S. & Cooper, R.
Date	1989
Publication:	Proceedings of the Human Factors Society 33rd Annual Meeting: Santa Monica, CA
Volume:	
Issue:	
Page Numbers:	783-787
Abstract:	The effects of automation and task group social structure on group communication and performance are analyzed in a simulated flight experiment. The interaction of technological and social factors is studied through micro communication analysis of crew interaction during the flight simulation mission. Based on the analysis of recorded transcripts, no overall difference is found in communication patterns as a function of crew composition. However, the results indicate that heterogeneous crews tend to exchange a higher ratio of task relevant to task irrelevant statements compared to homogeneous crews. This interaction corresponds to performance data that show enhanced performance for heterogeneous crews in the automated condition. It is suggested that group structure and interaction may contribute to the observed performance differences. (V.T.)
Comments:	Identifies three groups of communications patterns used in analysis of recorded simulator missions. Also addresses crew composition aspects of intra-cockpit communications. (Cited item)

Methodologies

Title:	Communications Effectiveness When using the Communications Earplug or Expandable-Foam Earplug with the HGU-56/P Aviator
Author:	Ahroon, W. A., Gordon, E., Mozo, B. T., & Katz, L. C.
Date	2000
Publication:	Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory
Volume:	
Issue:	(USAARL Report No. 2000-27)
Page Numbers:	
Abstract:	The ability of rotary-wing aircrew to utilize cockpit communications to successfully coordinate missions is impaired by the high noise inherent in the aviation environment and by hearing protection strategies designed to protect the aviators from noise-induced hearing loss. The use of the communication earplug in place of an expandable-foam earplug when using double-protection (sound-attenuating helmet and earplugs) significantly reduces the number of events classified by the Coordination Index Rating for Crew Linguistic Events (CIRCLE) measurement technique in the sub-code associated with pilots requesting that a communication be repeated. The sub-codes associated with missed transmissions (i.e., repeated verbalizations caused by an assumed missed transmission) and improper responses (where the response was inappropriate to the message received) did not show statistical significance. However, the relatively low frequency of occurrence of these sub-codes may limit the application of these two sub-coded behaviors.
Comments:	CIRCLE is a sequential analysis system employed at USAARL for quantifying cockpit communications as coded pairs of events (Katz, Fraser, & Wagner, 1998a). Each verbalization is labeled as one of eight verbalization types and operates as a response to the previous utterance and a stimulus for ensuing verbalizations. CIRCLE is a system that codes all verbalizations as well as a lack of expected verbalizations between pilot and copilot. The codes that CIRCLE employs are Command, Question, Observation, Self-report, Acknowledgement, Reply, Zero response, and Dysfluency. Subcodes within each of these major codes are possible. Also supports nonverbal communications schema development. (Cited item)

Title:	Investigating Communication As A Possible Mediator Of Team Performance In Distributed Environments
Author:	Commarford, P. M., Kring, J. P., & Singer, M. J.
Date	2001
Publication:	Proceeding Human Factors and Ergonomics Society 45th Annual Meeting, USA
Volume:	
Issue:	
Page Numbers:	1939-1942
Abstract:	The U.S. Army Research Institute (ARI) is investigating the use of virtual environment (VE) technologies to train personnel in distributed simulations. As part of this endeavor, ARI compared the communication activities of two team types as they completed a series of missions in a common VE. Local teams were comprised of two members situated in the same physical location, whereas distributed team members were separated geographically and had no opportunity for face-to-face communication. Following the first 7 (of 8 total) missions, communications were recorded as each team completed an after action review of their performance. Analyses of the amount and type of communication acts revealed no significant differences between local and distributed teams, even though significant performance differences were found for these team types during the VE missions. Results suggest that nonverbal communication likely mediated the relationship between networking condition and team performance.
Comments:	Methodology used in Army study on training and communication performance of teams working in distributed environments. Provides insights into importance of face-to-face and nonverbal communications. (Cited item)

Title:	A Comparison of Cockpit Communication B737-B757
Author:	Costley, J., Johnson, D., & Lawson, D.
Date	1989
Publication:	Proceedings of the Fifth International Symposium on Aviation Psychology, Columbus: The Ohio State University
Volume:	
Issue:	
Page Numbers:	413-418
Abstract:	Concern has been expressed for some time that the coming of automated (EFIS) flight decks might well change the nature or the pattern of communication and activity of flight deck crews, and that any changes might detract from the alertness of pilots and therefore from the level of safe operation of new-generation aircraft crewed by new-generation pilots. If there is evidence of such changes there will undoubtedly be a need for guidance in respect of Flight Deck Management training for future generations of pilots. Interaction Trainers Limited, in cooperation with Air Europe, has undertaken a research study of inter-pilot communication on the flight decks of three types or marques of aircraft and this paper presents preliminary results. The aircraft concerned were the 737-200, with a conventionally instrumented flight deck, the 737-300, with 'glass' flight instrumentation, and the 757 with full 'glass' cockpit. Communication behavior was observed and manually recorded by an observer present on the flight deck throughout each flight from pre-start to post-shutdown.
Comments:	Expert observers manually recorded inter-pilot communication behaviors. Data were logged into fifteen elements organized by four communications categories for analysis. Also supports development of nonverbal communications schema. (Cited item)

Title:	C3 Generic Workstation: Performance Metrics and Applications
Author:	Eddy, D. R.
Date	1988 (May 1, 1988)
Publication:	Mental-State Estimation, NASA Langley Research Center
Volume:	
Issue:	19880501
Page Numbers:	pp. 381-384
Abstract:	The large number of integrated dependent measures available on a command, control, and communications (C3) generic workstation under development are described. In this system, embedded communications tasks manipulate workload to assess the effects of performance-enhancing drugs (sleep aids and decongestants), work/rest cycles, biocybernetics, and decision support systems on performance. Task performance accuracy and latency were event coded for correlation with other measures of voice stress and physiological functioning. Sessions were videotaped to score non-verbal communications. Physiological recordings included spectral analysis of EEG, ECG, vagal tone, and EOG. Subjective measurements included SWAT, fatigue, POMS and specialized self-report scales. Performance assessment algorithms were also developed, including those used with small teams. This system provides a tool for integrating and synchronizing behavioral and psychophysiological measures in a complex decision-making environment.

Title:	SHAPA: An interactive software tool for protocol analysis applied to aircrew communications and workload
Author:	James, J. M., Sanderson, P. M., & Seidler, K. S.
Date	1989
Publication:	Proceeding of the Third Annual Workshop on Space Operations Automation and Robotics, Lyndon B. Johnson Space Center, USA
Volume:	
Issue:	(SEE N90-25503 19-59)
Page Numbers:	347-352
Abstract:	As modern transport environments become increasingly complex, issues such as crew communication, interaction with automation, and workload management have become crucial. Much research is being focused on holistic aspects of social and cognitive behavior, such as the strategies used to handle workload, the flow of information, the scheduling of tasks, and the verbal and non-verbal interactions between crewmembers. Traditional laboratory performance measures no longer sufficiently meet the needs of researchers addressing these issues. However observational techniques are better equipped to capture the type of data needed and to build models of the requisite level of sophistication. Presented here is SHAPA, an interactive software tool for performing both verbal and non-verbal protocol analysis. It has been developed with the idea of affording the researchers the closest possible degree of engagement with protocol data. The researcher can configure SHAPA to encode protocols using any theoretical framework or encoding vocabulary that is desired. SHAPA allows protocol analysis to be performed at any level of analysis, and it supplies a wide variety of tools for data aggregation and manipulation. The output generated by SHAPA can be used alone or in combination with other performance variables to get a rich picture of the influences on sequences of verbal or nonverbal behavior.
Comments:	Reinforces importance of direct observation to evaluate communications interactions. (Cited item)

Title:	Implications of Team Communication Training for Distributed Team Performance in an Immersive Virtual Environment
Author:	Kring, J. P., Hamilton, R. M., & Singer, M. J.
Date	2004
Publication:	Proceeding of the Human Factors and Ergonomics Society 48th Annual Meeting, USA
Volume:	
Issue:	
Page Numbers:	2647-2651
Abstract:	Distributed immersive virtual environments (VEs) allow geographically separate individuals to train together in a common setting, yet research suggests that the absence of face-to-face (FTF) contact may degrade distributed team performance by negatively affecting communication-dependent team functions. This study tested whether brief team communication training (TCT) could reduce this distributed team disadvantage by imparting skills to compensate for the lack of FTF contact. Two-person teams completed a series of VE missions under local (same physical location) or distributed (different locations) conditions with half of each team type receiving TCT. Results indicated all local teams outperformed distributed teams overall, but there were no observable benefits of TCT for team performance. Explanations focus on the brevity and administration approach of the TCT as well as how cognitive overload may have negated any beneficial aspects of TCT.
Comments:	Methods included physical separation of team members (local and distant) and introduced communications training as approach to compensate for lack of face-to-face interactions. (Cited item)

Title:	Differences In Cockpit Communication
Author:	Segal, L. D.
Date	1989
Publication:	International Symposium on Aviation Psychology 5th, Columbus, OH Apr. 17-20, 1989, Proceedings
Volume:	2
Issue:	
Page Numbers:	576-581
Abstract:	The purpose of this theoretical paper is to identify and call attention to effects of cockpit spatial layout on crew communication and subsequent task performance. The paper discusses the general role of nonverbal communication in crew tasks, how workspace spatial layout affects behavior, how semantics can emerge from behavior within a specified context, and how actions can serve as a context for the interpretation of verbal communication. Examples are initially taken from general crew task scenarios, and later focus on specific aircraft cockpit interactions. It is suggested that human factors include the effects of cockpit spatial layout on crew communication in their research effort, aiming to apply the results to cockpit designs and crew training programs.
Comments:	Discusses the role of nonverbal communications in how actions can serve as a context for the interpretation of verbal communications in methodologies. Also supports the time and space category of nonverbal communications. (Cited item)

Title:	Validation of Crew Coordination Training and Evaluation Methods for Army Aviation
Author:	Simon, R., & Grubb, G.
Date	1993
Publication:	Wilmington, MA: Dynamics Research Corporation
Volume:	
Issue:	(E-785U)
Page Numbers:	
Abstract:	At the request of the U.S. Army Aviation Center (USAAVNC), the Army Research Institute Aviation Research and Development Activity (ARIARDA) developed field exportable training and evaluation materials for aircrew coordination. A testbed of the materials was implemented with the cooperation of the 101st Aviation Brigade. Sixteen aircrews participated. Using a UH-60 flight simulator, aircrews were evaluated while executing a comprehensive tactical mission. Evaluation data were collected before and after aircrew coordination training was provided. Evaluation measures included attitude, behavior, task performance, and mission performance. Results showed that 1) the training had positive effects on all of the measures, and 2) the measures are sensitive to changes in performance. The impact on safety of flight was also assessed. The report concludes with recommendations and suggested areas for future research.
Comments:	Methodology includes use of flight simulator missions, audio and video recording of communications interactions, and expert observation of aircrew coordination behaviors. (Cited item)

Title:	Team Performance in Distributed Virtual Environments
Author:	Singer, M. J., Grant, S. C., Commarford, P. M., Kring, J. P., & Zavod, M.
Date	2001
Publication:	Orlando, FL: US Army Research Institute for the Behavioral and Social Sciences (Simulator Systems Research Unit)
Volume:	
Issue:	(ARI Tech Report No. 1118; ADA 396489)
Page Numbers:	
Abstract:	The U.S. Army is using virtual simulations for mission planning, training, rehearsal, and concept development. Virtual environment (VE) technology can provide simulated real world activities for dismounted Soldiers. One issue in the use of distributed simulations is whether team members learn, perform, and transfer their skills in distributed situations in the same ways as individuals in local situations. In this experiment, local and distributed teams completed a series of mission rehearsals in a VE over two days. Eighteen, two-person teams of college students performed synthetic tasks representative of tasks performed by police, emergency response, and military teams. All participants were trained to criterion in a VE before being assigned to a team. Biographical information and subjective self-report questionnaires were administered before, during, and after training and mission sessions. Local teams interacted face-to-face between mission rehearsal sessions, while distributed teams only interacted by phone during the after action review session following each mission. Local teams performed significantly better than distributed teams on several collective task measures over the repeated missions. Simulator sickness and presence during the mission rehearsals were also investigated.
Comments:	Methodology uses mission simulators with two-person teams executing a discrete portion of an overall mission.

Title: Crew Structure, Automation and Communication: Interaction of Social and Technological Factors on Complex Systems Performance

Author: Straus, Suang, Cooper, & Russells

Date 1989

Publication: Institute of Aviation, Aviation Research Laboratory
University of Illinois at Urbana Champaign
Savory, Illinois

Volume:

Issue:

Page Numbers:

Abstract: The effects of automation and task group social structure on group communication and performance are analyzed in a simulated flight experiment. The interaction of technological and social factors is studied through micro communication analysis of crew interaction during the flight simulation mission. Based on the analysis of recorded transcripts, no overall difference is found in communication patterns as a function of crew composition. However, the results indicate that heterogeneous crews tend to exchange a higher ratio of task relevant to task irrelevant statements compared to homogeneous crews. This interaction corresponds to performance data that show enhanced performance for heterogeneous crews in the automated condition. It is suggested that group structure and interaction may contribute to the observed performance differences.

Comments: Methodology includes use of flight simulator missions, audio and video recording of communications interactions, and expert observation of aircrew coordination behaviors. (Cited item)

Title:	Analysis Of Multicultural Crew Factors For International Manned Spaceflight Missions
Author:	Wong, C. K., & Lyman, J.
Date	1993
Publication:	CSERIAC Gateway
Volume:	54-03b
Issue:	
Page Numbers:	1641
Abstract:	The objective of this study was to provide manned spaceflight personnel from the world's space agencies with information on how key cultural and interpersonal communication factors can impact multicultural crew operations and interaction. American, Canadian, European, and Japanese manned spaceflight personnel and officials participated in this study as research collaborators and/or subjects. A two-phased procedure was used to identify key multicultural factors and assess their potential effect on international manned spaceflight crews. In Phase 1, they conducted a literature review, interviews with retired and active astronauts, and administration of written surveys to identify 14 multicultural factors: language, nonverbal communication styles, task- and relationship-oriented behavior, patience and tolerance, assertiveness, decision making processes, interpersonal interest, respect for other cultures, personal hygiene and cleanliness norms, gender roles/norms/stereotypes, conflict management and resolution, trust in people, sense of humor, and crew-machine interfaces. In Phase2, a detailed questionnaire was developed and administered to American, Canadian, European, and Japanese manned spaceflight personnel contacts to assess cultural differences and similarities on these 14 factors. The questionnaire grouped the 14 multicultural factors into four sections: language, cultural flexibility and personal space, management styles, and crew-machine interface design. The questionnaires revealed that the four cultural groups have both similar and different attitudes regarding the following areas: (1) verbal communication styles (e.g., slang, profanity, accents, idioms, formal versus informal language), (2) discussion topics (e.g., humor, sex, religion, politics, emotions and personal feelings), (3) cultural norms for work ethics, social behavior, and traditional practices, (4) personal hygiene and cleanliness norms, (5) cultural norms for proxemic and haptic behavior, (6) gender roles in operational settings, (7) management styles and approaches to conflict resolution in different types of situations, and (8) movement stereotypes and color conceptual compatibility for crew-machine interfaces. A conceptual multicultural education and training program for international manned spaceflight crews is proposed and briefly described.
Comments:	Describes the use of written surveys to identify nonverbal communications factors with questionnaires to refine initial categories. (Cited item)

NVC - Body Movement and Gestures

Title:	Constructing Meaning from Space, Gesture, and Speech
Author:	Hutchins, E., & Palen, L.
Date	1997
Publication:	http://hci.ucsd.edu/lab/hci_papers/EH1997-1.pdf
Volume:	
Issue:	
Page Numbers:	
Abstract:	Face-to-face communication in the workplace is often conceived of as consisting mainly of spoken language. Although spoken language is clearly a very important medium for the creation of representations, in complex work settings, it is one of several such media. Gestures and the space inhabited by speakers and listeners are normally thought of as providing context for the interpretation of speech. This chapter shows how space, gesture, and speech are all combined in the construction of complex multi-layered representations in which no single layer is complete or coherent by itself. They examine a brief explanation given by one worker to two others, focusing on the coordination among the spatial organization of specialized artifacts, the positioning of gestures with respect to those artifacts, and the words that are spoken.
Comments:	Temporal analysis of simulator mission showed how gesture and space provide context for interpreting speech. (Cited item)

Title:	Gesture In The Airline Cockpit: Allocating Control Of The Power Levers During Takeoff
Author:	Nevile, M.
Date	2002
Publication:	Paper presented at the First International Conference on Gesture, University of Texas at Austin, USA, June.
Volume:	
Issue:	
Page Numbers:	
Abstract:	This paper explores the role of gesture in the routine work of airline pilots. The airline cockpit is an information rich environment (Hutchins 1995), with an almost bewildering array of displays, buttons, switches, lights and levers. This paper uses video data of airline pilots at work during a regular passenger flight, along with detailed transcriptions of the pilots' talk and non-talk activities. The paper draws on insights and practices of ethno-methodology and conversation analysis to examine gesture and processes of talk-in-interaction as the pilots collaborate together to accomplish a routine but critical action for a takeoff: allocating 'control' of the engine power (thrust) levers. To have control of the power levers is to have the responsibility, indeed the right, to touch them and to move them to alter engine power. The paper explores how pilots develop and demonstrate to one another their situated and moment-to-moment understandings of which pilot has control of the power levers, and exactly when they have this control. The pilots are shown to coordinate with precision a range of available resources, including talk, visual monitoring of displays, and physical contact with the levers. Such coordination is one way that pilots both orient to and enact relevant cockpit roles as Captain or First Officer, and as Pilot-flying or Pilot-not-flying.
Comments:	Supports NVC Time & Space & Methodologies. Suggests that analyzing more than words is necessary to explore how people interpret their interactions. (Cited item)

NVC - Time and Space

Title:	Automation Design and Crew Coordination
Author:	Segal , L. D.
Date	1993
Publication:	Moffett Field, CA: Aviation Research Laboratory
Volume:	
Issue:	
Page Numbers:	578-583
Abstract:	Introduction: Advances in technology have greatly impacted the appearance of the modern aircraft cockpit. Where once one would see rows upon rows of dials and switches, today one can find a rack of CRT screens and data-entry keyboards. Beyond the visual appearance of the cockpit, from a functional point of view, the introduction of automation has greatly altered the demands on the pilots and the dynamics of aircrew task performance. Unfortunately, the rapid pace of introduction of computer-based devices into the cockpit has outstripped the ability of designers, pilots, and operators to formulate an overall strategy for their use and implementation (Wiener, 1988). While engineers and designers continue to implement the latest technological innovations in the cockpit – claiming higher reliability and decreased workload – a large percentage of aircraft accidents are still attributed to human error: for air carriers, about two thirds of all accidents are attributable to the cockpit crew; for general aviation, the rates are even more disproportionate, with almost 9 out of 10 accidents attributable to human causes (Nagel, 1988). While these figures may accurately reflect the apparent cause of an accident, it is important to remember that, rather than being the main instigators of accidents, operators tend to be the inheritors of system defects created by poor design, incorrect installation, faulty maintenance and bad management decisions (Reason, 1990). This paper looks at some of the variables that need to be considered if we are to eliminate at least one of these inheritances – poor design. Specifically, this paper describes the first part of a comprehensive study aimed at identifying the effects of automation on crew coordination.
Comments:	Introduces and discusses the mix of verbal and nonverbal as action dependent speech (ADS). Also provides definitional basis for intra-cockpit communication. (Cited item)

Title:	Actions speak louder than words: How pilots use nonverbal information for crew communications
Author:	Segal, L. D.
Date	1994
Publication:	Proceedings of the International Symposium on Aviation Psychology, 5th Annual Meeting, USA
Volume:	
Issue:	
Page Numbers:	21-25
Abstract:	How does the design of an aircraft cockpit affect crew communication? The research described hereunder aimed at identifying aspects of design that play a critical role in task coordination, yet have heretofore been ignored. It is proposed that crewmembers coordinate the performance of tasks using visual, nonverbal, information that emerges from the interactions between individual pilots and the aircraft's systems. Twenty-four airline pilots participated in a high-fidelity simulator experiment that compared the impact of three different types of interface on crew communication and coordination. Measurement included detailed video recording, and quantitative and expert performance evaluations. The data suggest that pilots visually monitor each other's performance of tasks, that visual monitoring is affected by the design of the interface, and that pilots rely on such nonverbal information for communication and coordination. The discussion looks at implications of these data to the design of workstations and cockpits.
Comments:	Methodology includes use of flight simulator missions, audio and video recording of communications interactions, and expert observation of aircrew coordination behaviors. (Cited item)

Title: Effects of Checklist Interface on Non-Verbal Cockpit Communications
Author: Segal, L. D., and Wickens, C.
Date 1994
Publication: University of Illinois at Urbana-Champaign
Volume: 55-09B
Issue:
Page Numbers:

Abstract:

The investigation described hereunder looked at the effects of the spatial layout and functionality of cockpit displays and controls on crew communication Specifically, the study focused on the intra-cockpit crew interaction--and subsequent task performance--of airline pilots flying different configurations of a new electronic checklist, designed and tested in a high-fidelity simulator at NASA-Ames Research Center (ARC). The first part of this proposal establishes the theoretical background for the assumptions underlying the research, suggesting that in the context of the interaction between a multi-operator crew and a machine, the design and configuration of the interface will affect interactions between the individual operators and the machine, and subsequently, the interaction between operators. In view of the latest trends in cockpit interface design and flight-deck technology--in particular, the centralization of displays and controls--the theoretical introduction identifies certain problems associated with these modern designs, and suggests specific design issues to which the expected results could be applied. A detailed research program and methodology is outlined, and the results are described and discussed. Overall, differences in cockpit design were shown to impact the activity within the cockpit, including interactions between pilots and aircraft and the cooperative interactions between pilots. The research--which was performed on site at NASA ARC--served as the basis for Leon Segal's doctoral dissertation; Dr. Barbara Kanki served as his technical monitor and chief collaborator for NASA ARC and Prof. Chris Wickens as academic advisor. This research was supported by NASA-Ames University Consortium grant NCA 2-616.

Comments: Investigates crewmember interactions when using automated checklists to include timing and movement to confirm crewmember actions with aircraft controls and displays. (Cited item)

NVC - Facial Displays and Eye Movement

Title:	Coming Into Focus. (Lucent's MMCX Desktop Videoconferencing Server; Microsoft's Netmeeting)(Product Information) (Abstract) [Electronic Version].
Author:	Burden, K.
Date	1999
Publication:	Journal of Computerworld
Volume:	
Issue:	
Page Numbers:	
Abstract:	Production of Joint Strike Fighter requires face-to-face collaboration. Lockheed Martin Tactical Aircraft Systems in Fort Worth, Texas, wants everyone involved in the production of its new Joint Strike Fighter working as if they were side-by-side. Actually, its testing methodology requires it. Lockheed uses the Fagen inspection program, which involves four people conducting formalized walk-throughs designed to detect defects in software and its documentation as early as possible. But because the Fagen system calls for the players to be face-to-face so that facial expressions and body language can be recorded, Lockheed had to create a virtual enterprise for its geographically dispersed team members. "Nonverbal communication is critical to this inspection process," says Wynn Jones, engineering specialist. "Things like raising an eyebrow when you don't understand something -- that gets lost in conference calls." Lockheed chose the MMCX desktop videoconferencing server from Lucent Technologies Inc. in Murray Hill, N.J., for many reasons: foremost for its application sharing, which is handled through Microsoft Corp.'s NetMeeting. With it, team members can work together in shared applications, passing documents back and forth while talking in full duplex mode. The system connects Lockheed's Fort Worth campus with its divisions in Marietta, Ga., and Palmdale, Calif., and will soon connect to British Aerospace in the U.K. Image size and quality were also priorities, because it was important for workers to clearly see facial expressions. But Lockheed needed to decide how far back from broadcast quality would be acceptable, because the 30 frame/sec. needed for real-time video wasn't possible on its 10Base-T network. "We found that a frame rate about half that of real time was acceptable for us," Jones says. But Lockheed is upgrading its network to a Category 5 cabling. Although 15 frame/sec. is workable, Lockheed wants it to be better.
Comments:	Provides insights into field of view and fidelity issues associated with facial expression details. (Cited item)

Title:	Using Eye-Tracking Techniques to Study Collaboration on Physical Tasks: Implications for Medical Research
Author:	Fussell, S. R., & Setlock, L. D.
Date	2003
Publication:	Unpublished manuscript, Carnegie Mellon University
Volume:	
Issue:	
Page Numbers:	
Abstract:	This paper discusses eye-tracking as a technique to study collaborative physical tasks—tasks in which two or more people work together to perform actions on concrete objects in the three-dimensional world. For example, a surgical team might collaborate to treat a patient. They first consider the use of eye tracking as people perform their tasks. They review studies applying eye-tracking to individual performance of physical tasks and interpersonal communication, then present a study on gaze in a collaborative construction task. Next, they consider eye tracking as an independent measure—a factor that is manipulated in studies of remote collaboration on physical tasks. They discuss how the use of eye-tracking can be used to assess the importance of gaze awareness information for collaboration and present results of a study using this technique. They end by considering limitations and theoretical issues regarding eye-tracking as a research tool for collaborative physical tasks.
Comments:	Importance of gaze awareness as it relates to situation assessment and error. Unpublished manuscript, Carnegie Mellon University. (Cited item)

Title:	Delegation Of Spacing Tasks From Controllers To Flight Crew: Impact On Controller Monitoring Tasks
Author:	Grimaud, I., Hoffman, E., Pellegrin, A., Rodet, L., Rognin, L., & Zeghal, K.
Date	2002
Publication:	Proceedings of the Air Traffic Management for Commercial and Military Systems, USA
Volume:	1
Issue:	
Page Numbers:	2B31-2B39
Abstract:	The impact of introducing procedures on active control (communication and instructions) and on monitoring task was discussed. Air traffic controller activity combines the issuing of instructions with continuous visual assessment of the situation. Visual scanning is a systematic and continuous effort to acquire all the necessary visual information in order to build and maintain a complete awareness of activities and situations which may affect the controllers.
Comments:	Addresses how long air traffic controller remains focused on a single area during performance of a collaborative task. Impacts situational awareness-assessment and decision making. (Cited item)

Title:	Auditory Vs. Visual Data Link: Relative Effectiveness
Author:	Helleberg, J., & Wickens, C. D.
Date	2001
Publication:	Proceedings of the Human Factors Ergonomics Society 45th Annual Meeting, USA
Volume:	
Issue:	
Page Numbers:	35-39
Abstract:	Pilots flew a GA simulator based on ATC-instructed maneuvers, while scanning outside for traffic. Various length ATC instructions were delivered through a textual, voice, or redundant data link format. Pilots read back the instructions, then complied with the maneuver. Visual scanning was measured. Results indicated the visual display provided greatest accuracy of communications read back and least disruption of traffic monitoring and flight-path tracking. The voice-only condition was most disruptive, partially because the pilot's eyes were drawn into the cockpit longer while note taking, compared to the two visual text displays. The redundant display never supported better performance than the visual display. This cost resulted partially because arrival of the discrete auditory communications disrupted flight-path performance. Pilots allocated about 60% of visual attention to the instrument panel, and communications accuracy was degraded by longer ATC instructions. Results are interpreted referencing mechanisms of attention, working memory, and the pilot's task priority hierarchy.
Comments:	Visual scanning and eye location during simulator mission. (Cited item)

Title:	Aircrew Decision-Making Behavior In Hazardous Weather Avoidance
Author:	Lee, A.T.
Date	1991
Publication:	http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?CMD=Display&DB=pubmed
Volume:	
Issue:	
Page Numbers:	
Abstract:	In-flight encounters with hazardous weather represent one of the most significant safety issues in civil aviation operations. Aircrew judgment is often cited as the probable cause of incidents and accidents involving weather, although lack of information is also a factor. The present study examines how information, presented at different times and in different forms, affects the awareness and decision-making behavior of aircrews in a flight simulation study of a recent microburst/wind shear incident. In order to examine the influence of enhanced information transfer on aircrew behavior, intracrew communications and approach-to-land decisions were evaluated with conventional ATC communications and with automated cockpit alerting and display of weather information. Results of the study revealed that aircrews provided only with conventional ATC transmissions of weather information had difficulty discriminating conditions conducive to microburst events from less hazardous wind shear events. Improved situation awareness for microburst events was found when ground-based convective weather information was provided in real time to aircrews. Avoidance decision-making was found to be less efficient with conventional ATC alert transmissions when compared to the performance of crews provided with a visual display of microburst events. The importance of information transfer on aircrew situation awareness and decision-making in hazardous weather avoidance is discussed.
Comments:	Automation related article shows how information presented at different times and in different forms affects behaviors of aircrews.

Related Topics

Title:	Crew Resource Management: A Simulator Study Comparing Fixed Versus Formed Aircrews [Electronic version]
Author:	Barker J.M., Clothier C. C., Woody J. R., McKinney, Jr., E. H., & Brown, J. L.
Date	1996
Publication:	USAAhttp://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=pubmed&dopt=Abstract &listuids=8929198&query_hl=2
Volume:	January
Issue:	
Page Numbers:	
Abstract:	Most airline and military transport planes are flown by crews that have been teamed together for a short amount of time before disbanding and becoming part of a different crew (formed crew concept). Some military operations use a fixed crew concept, pairing crewmembers together for an indefinite period. This research investigated the effect of crew formation policy on aircrew performance during missions in U.S. Air Force KC-135 (tanker) simulators. METHOD: The performance of fixed aircrews is compared to formed aircrews flying the same simulator mission scenario, which included an in-flight emergency. Cockpit resource management (CRM) behavioral data and error data were collected by trained observers for 17 crews (9 fixed and 8 formed). RESULTS: The results show that fixed crews committed more minor errors (4.4 per mission) than formed crews (2.6 per mission), t (14) = 2.32, p = 0.036. No differences were found concerning major errors or CRM behavioral indicators. CONCLUSIONS: The results suggest the possibility of a "familiarity decline," where aircrew performance declines when crewmembers become too familiar with each other and may affect flight safety.
Comments:	Crew Composition related study suggests presence of a familiarity decline in performance of fixed crews compared to formed crews during simulator missions. (Cited item)

Title:	A Macroergonomic Approach to Distributed Team Performance
Author:	Cuevas, H., Fiore, S., Salas, E., & Bowers, C.
Date	2002
Publication:	Proceedings of the 46th Annual Meeting of the Human Factors and Ergonomics Society, Santa Monica, CA: HFES.
Volume:	
Issue:	
Page Numbers:	1335-1339
Abstract:	With the structure of teams in organizations increasing in complexity to include both co-located and distributed team members, explicit linkages between theory and practice are critically needed to mitigate the negative effects that computer-mediated interaction may have on distributed team performance. Following a macroergonomic approach, this paper focuses on describing how theories from organizational psychology can address some of the challenges faced by this small, but growing, subset of teams. Specifically, theories in motivation, group dynamics, and decision-making can be applied to offer practical guidelines to foster the development of positive team attitudes (e.g., cohesion, trust) and behaviors (e.g., goal-setting, self-regulation), and successful decision-making performance in distributed teams.
Comments:	Team performance related paper introduces the concept of team opacity as the phenomenon whereby distribution decreases awareness of team member actions and may thus alter their interactions.

Title:	Joint Tactics, Techniques, and Procedures for Shipboard Helicopter Operations
Author:	Department of Defense
Date	1997
Publication:	Fort Monroe, VA: Joint Warfighting Center
Volume:	
Issue:	(Joint Publication 3-04.1)
Page Numbers:	
Abstract:	Joint Service doctrinal publication incorporates joint and Service tactics, techniques, and procedures into a single-source publication and provides the guidance and procedures necessary to plan, coordinate, and conduct joint shipboard helicopter operations from US Navy and US Coast Guard ships.
Comments:	Army doctrine related manual provides codes and signals appendices related to gestures and nonverbal communications category. (Cited item)

Title:	Field Manual 21-60, Visual Signals
Author:	Department of the Army
Date	1987
Publication:	Washington, D.C; Headquarters,
Volume:	
Issue:	
Page Numbers:	
Abstract:	Army doctrine on visual signals including arm-and-hand, flag, pyrotechnic, panel, mirrors, and strobes.
Comments:	Army manual covers general subject area related to nonverbal communications, especially as arm-and-hand signals as gestures. (Cited item)

Title:	Aircrew Coordination Qualification Course
Author:	Department of the Army
Date	2003
Publication:	Fort Rucker, AL: United States Army Aviation Center
Volume:	March
Issue:	File No. 4634
Page Numbers:	
Abstract:	Army Aircrew Coordination Training Program
Comments:	Provides a formal definition of aircrew coordination and includes three talking points specific to nonverbal communications, i.e., signals, words and symbols, and body language. (Cited item)

Title:	Effects Of Cockpit Display Of Traffic Information On Visual Attention And Eye Movements In The General Aviation Cockpit
Author:	Duley, J. A.
Date	2001
Publication:	Dissertation Abstracts International: Section B: The Sciences & Engineering
Volume:	62
Issue:	(2-B)
Page Numbers:	1122
Abstract:	A General Aviation pilot must perform primary flight tasks of aviate, navigate, and communicate while attending to information regarding collision avoidance. A cockpit display of traffic information (CDTI) has been previously proposed as a form of automation to assist in the latter task. The present study assessed the impact of a CDTI on the performance of a pilot's primary flight tasks. The Multi-Attribute Task Battery (MAT) was used as the primary task. The University students' multi-task performance, and visual sampling strategies with and without the CDTI were assessed. The addition of the CDTI task to the MAT task performance induced a scanning strategy change resulting in improved task performance. There appears to have been a shift from a data acquisition strategy to one emphasizing the frequent sampling of all task displays. However the engine thrust maintenance sub-task was negatively impacted by the addition of the CDTI task. It appears that the overall task demands of the MAT and CDTI together created interference with the memory demands of this sub-task leading to longer periods of time away from the optimal thrust. The effects of expertise on these abilities and strategies were investigated in a second experiment with University students and GA pilots. Expertise played a role in their strategies such that the students who had more MAT experience determined their attention strategy based on the ratio of intruders to total number of CDTI events. In contrast, the number of CDTI events appears to have driven the sampling strategies of the other participants (pilots and a second group of students) who had less experience with the MAT. The results of both experiments indicate the need for the training of an efficient information acquisition strategy particularly when a new display is added to a set of primary task displays. While the CDTI did not negatively affect overall primary task performance, it did alter the attentional strategies of the participants which was beneficial under the data-limited conditions of the first experiment but detrimental under the increased CDTI event rate of the second experiment.
Comments:	Related topic – Automation

Title:	Aeronautical Information Manual, Official Guide to Basic Flight Information and ATC Procedures
Author:	Federal Aviation Administration
Date	2004
Publication:	Washington, D.C: Headquarters
Volume:	
Issue:	
Page Numbers:	
Abstract:	Official guide to basic flight information and ATC procedures.
Comments:	Traffic control light and hand signals relate to gestures and nonverbal communications category. (Cited item)

Title:	Safety Recommendation
Author:	Garvey, J.
Date	2000
Publication:	Washington, DC: National Transportation Safety Board
Volume:	
Issue:	(A-00-30 and -31)
Page Numbers:	
Abstract:	In this letter, the National Transportation Safety Board recommends that the Federal Aviation Administration (FAA) take actions to address safety issues concerning the current lack of cockpit imagery and the location of flight recorder circuit breakers. These recommendations were prompted by the lack of valuable cockpit information during the investigations of several aircraft incidents and accidents, including USAir flight 105 on September 8, 1989, ValuJet flight 592 on May 11, 1996, Silk Air flight 85 on December 19, 1997, Swissair flight 111 on September 2, 1998, and Egypt Air flight 990 on October 31, 1999. This letter summarizes the Safety Board's rationale for issuing the recommendations.
Comments:	Accident Investigation related Safety Recommendation suggests installation of cockpit image recorders to record the views of each control position and actions taken by crewmembers. (Cited item)

Title: Review of Current Aircrew Coordination Training Program and Master Plan for Program Enhancement: Aircrew Coordination Training Master Plan

Author: Grubb, G., Simon, R., Goddard, J., Kline, K.

Date 2001

Publication: Wilmington, MA: Dynamics Research Corporation

Volume:

Issue: (A-515693)

Page Numbers:

Abstract: This report presents the results of reviewing the training and evaluation of aircrew and team coordination aspects of the Army's current Aircrew Coordination Training (ACT) program to develop a master plan of continuous improvement. Research source materials included policies, training courseware, evaluation guides, research papers and reports, and assessment summaries of operational trend data. Information was developed from interviews with team coordination subject matter experts and published information across the Department of Defense military services, commercial carriers, and academia. Interviews, reviews, and information results focused on ACT policy, training, evaluation and risk management, and future plans and research. The results of the review led to the conclusion that the Army's ACT program effectiveness has greatly declined since 1995 due to limited funding and that it requires revitalization and enhancement. Because Army aviation reorganization and modernization initiatives impact all units and components, it is now more important than ever to develop an integrated strategy of corrective actions. The report includes a recommended Master Plan for ACT Enhancement in the form of a proactive, multi-phased course of continuous improvement to maximize Army aviation modernization investments and complement leadership training initiatives.

Comments: Team training related Contractor Report provides historical background and provides a strategic program plan for the Army's Aircrew Coordination Training Program. (Cited item)

Title:	Effect of Crew Composition on AH-64 Attack Helicopter Mission Performance and Flight Safety
Author:	Grubb, G., Simon, R., Leedom, D., & Zeller, J.
Date	1994
Publication:	Wilmington, MA: Dynamics Research Corporation
Volume:	
Issue:	(E-1534U)
Page Numbers:	
Abstract:	This report presents the results of evaluating battle rostering (pairing crewmembers on a long-term basis) by comparing AH-64 attack helicopter crews when flying in a battle-rostered and mixed crew composition. Participants in the experiment were AH-64 attack helicopter standardization instructor pilots, and 12 battle-rostered aircrews consisting of a pilot and copilot gunner. All participants received training in the Army's Aircrew Coordination Exportable Training Package as a prerequisite for the experiment. Participating aircrews conducted two missions in a battle-rostered crew and two missions in a mixed crew. Discussion and analysis of crew performance are presented as measures of behavior, task performance, mission performance, and participant exit interview comments. The study concludes that minimal evidence exists to show that battle rostering provides meaningful improvements in the mission performance or flight safety of crew coordination-trained aircrews. Battle rostering drawbacks include overconfidence and increased reliance on implicit communications and coordination. The report recommends implementing actions to improve mission effectiveness and flight safety and follow on research to better understand and capitalize on the strengths of crew and team coordination.
Comments:	Report findings support the perception that battle-rostering fosters implicitness, which can lead to informality and complacency. Battle-rostered crews rated their crew coordination style as more implicit than mixed crews. Both objective and subjective data collected during the study identified the following operational drawbacks associated with battle-rostering--overconfidence, informal and nonstandard procedures, and implicit coordination behaviors. (Cited item)

Title:	A Descriptive Framework of Workspace Awareness for Real-Time Groupware [Electronic version].
Author:	Gutwin, C., & Greenberg, S.
Date	2002
Publication:	Computer Supported Cooperative Work, Netherlands: Kluwer Academic Publishers
Volume:	11
Issue:	3
Page Numbers:	411-446
Abstract:	Supporting awareness of others is an idea that holds promise for improving the usability of real-time distributed groupware. However, there is little principled information available about awareness that can be used by groupware designers. In this article, the authors develop a descriptive theory of awareness for the purpose of aiding groupware design, focusing on one kind of group awareness called workspace awareness. They focus on how small groups perform generation and execution tasks in medium-sized shared workspaces – tasks where group members frequently shift between individual and shared activities during the work session. They have built a three-part framework that examines the concept of workspace awareness and that helps designers understand the concept for purposes of designing awareness support in groupware. The framework sets out elements of knowledge that make up workspace awareness, perceptual mechanisms used to maintain awareness, and the ways that people use workspace awareness in collaboration. The framework also organizes previous research on awareness and extends it to provide designers with a vocabulary and a set of ground rules for analyzing work situations, for comparing awareness devices, and for explaining evaluation results. The basic structure of the theory can be used to describe other kinds of awareness that are important to the usability of groupware.
Comments:	Automation related publication indirectly addresses time and space aspects of nonverbal communications called workspace awareness. Teams performing collaborative tasks obtain information that is produced by team members' bodies in the workspace, workspace artifacts, and conversations and gestures. (Cited item)

Title:	Field Manual 3-04.564, Shipboard and Overwater Operations
Author:	Headquarters, United States Army Aviation Center: Fort Rucker, Alabama
Date Publication:	2005
Volume:	
Issue:	
Page Numbers:	
Abstract:	Army doctrine on shipboard and overwater operations includes detailed appendices on aircraft handling, arming, and safing signals.
Comments:	Signals appendices relate to nonverbal communications gestures category.

Title:	Army Safety Investment Strategy Team (ASIST) Translating Aviation Accident Information to Hazards and Controls
Author:	Hicks, J., & Peusch, I.
Date	2001
Publication:	Proceedings of the 19th International System Safety Conference, USA
Volume:	
Issue:	
Page Numbers:	
Abstract:	As part of a risk management campaign to enhance readiness and protect the capability of the force, the US Army leadership directed an Aviation Safety Investment Strategy Team (ASIST) to chart a path toward breakthrough gains in aviation safety. The ASIST Team was chartered to define measurable accident prevention goals and identify the most important Army-wide investments needed to achieve them. The means to achieve the Army goals will be the integration of accident prevention and risk management requirements into the Aviation planning, programming, and budgeting system. The team has completed an in-depth analysis of accident experience involving all force-modernized aircraft during the last 5 years. Currently, the team is prioritizing and validating requirements in various areas of doctrine, training, leader development, organization, materiel, and Soldier performance.
Comments:	Provides a comprehensive review of Army aviation accidents over a five-year period concluding that aircrew coordination training represents a high payoff, low cost solution (control) that addresses a range of threats (hazards). (Cited item)

Title:	On the Design of Adaptive Automation for Complex Systems [Electronic version].
Author:	Kaber, D. B., Riley, J. M., Tan, K. W., & Endsley, M. R.
Date	2001
Publication:	International Journal of Cognitive Ergonomics
Volume:	5
Issue:	(1)
Page Numbers:	37-57
Abstract:	This article presents a constrained review of human factors issues relevant to adaptive automation (AA), including designing complex system interfaces to support AA, facilitating human–computer interaction and crew interactions in adaptive system operations, and considering workload associated with AA management in the design of human roles in adaptive systems. Unfortunately, these issues have received limited attention in earlier reviews of AA. This work is aimed at supporting a general theory of human-centered automation advocating humans as active information processors in complex system control loops to support situation awareness and effective performance. The review demonstrates the need for research into user-centered design of dynamic displays in adaptive systems. It also points to the need for discretion in designing transparent interfaces to facilitate human awareness of modes of automated systems. Finally, the review identifies the need to consider critical human–human interactions in designing adaptive systems. This work describes important branches of a developing framework of AA research and contributes to the general theory of human-centered automation.
Comments:	Automation related article provides an excellent review of literature on issues in the implementation of adaptive automation. Addresses nonverbal communication, situational awareness, and decision-making. (Cited item)
Key References:	Bowers, C. A., Oser, R. L., Salas, E., & Cannon-Bowers, J. A. (1996). Team performance in automated systems. In R. Parasuraman & M. Mouloua (Eds.), Automation and human performance: Theory and applications (pp.243–263). Mahwah, NJ: Lawrence Erlbaum Associates, Inc. Costley, J., Johnson, D., & Lawson, D. (1989). A comparison of cockpit communication B737–B757. In Proceedings of the Fifth International Symposium on Aviation Psychology (pp. 413–418). Columbus: The Ohio State University. Sarter, N. B., & Woods, D. D. (1995). How in the world did we ever get into that mode? Mode error and awareness in supervisory control. Human Factors, 37, 5–19. Sarter, N. B. (1995). "Knowing when to look where": Attention allocation on advanced automated flight decks. In Proceedings of the Eighth International Symposium on Aviation Psychology (Vol. 1, pp. 239–242). Columbus: The Ohio State University.

Straus, S. G., & Cooper, R. S. (1989). Crew structure, automation and communication: Interaction of social and technological factors on complex systems performance. In Proceedings of the Human Factors Society 33rd annual meeting (pp. 783–787). Santa Monica, CA: Human Factors Society.

Title: Communication As Group Process Media Of Aircrew Performance

Author: Kanki, B. G., & Foushee, H. C.

Date 1989

Publication: http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=pubmed&dopt=Abstract&list_uids=2730482&query_hl=2

Volume:

Issue:

Page Numbers:

Abstract: This study of group process was motivated by a high-fidelity flight simulator project in which aircrew performance was found to be better when the crew had recently flown together. Considering recent operating experience as a group-level input factor, aspects of the communication process between crewmembers (Captain and First Officer), were explored as a possible mediator to performance. Communication patterns were defined by a speech act typology adapted for the flight deck setting and distinguished crews that had previously flown together (FT) from those that had not flown together (NFT). A more open communication channel with respect to information exchange and validation and greater First Officer participation in task-related topics was shown by FT crews while NFT crews engaged in more non-task discourse, a speech mode less structured by roles and probably serving a more interpersonal function. Relationships between the speech categories themselves, representing linguistic and role-related interdependencies provide guidelines for interpreting the primary findings.

Comments: Crew Composition related study explored communication patterns and differences between crews that had previously flown together from those that had not. (Cited item)

Title:	Enhancing U.S. Army Aircrew Coordination Training.
Author:	Katz, L. C., & Grubb, G.
Date	2003
Publication:	Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences
Volume:	
Issue:	(Special Report #56)
Page Numbers:	

Abstract:

This special report describes objectives and outcomes of ongoing team training research and development (R&D) under the guidance of the U.S. Army Research Institute for the Behavioral and Social Sciences, Rotary-Wing Aviation Research Unit (ARI-RWARU) at Fort Rucker, Alabama. The Aircrew Coordination Training Enhancement (ACTE) program is an applied research project that employs experience, innovation, and technology to address the operational issue, "Can interactive multimedia courseware using web-based distribution provide the realism and relevance necessary for effective behavior-based team training and evaluation?" The goal of the ACT Enhancement effort is to make available a web-delivered, interactive aircrew coordination training system that provides Army aircrews with the knowledge and skill-sets needed to increase flight safety and mission effectiveness in daily operations. Focus areas for the applied research were identified by Army leadership and the Aircrew Coordination Training Working Group. They emphasized: Current ACT program revitalization and enhancement without repeating previous research; Automation and aircraft configuration issues; Course length reductions; Simplified assessment and evaluation procedures, and; Adult learning-based presentation, feedback, and discussion. The products from the first phase of research are research reports on the development and evaluation of computer-based Aircrew Coordination Training. They include as attachments two interactive multimedia courses of instruction with supporting training, the ACTE Aircrew Course and the ACTE Instructor Course. Both courses contain a fully integrated Data Management System that tracks student demographics, provides graphic feedback displays during evaluation exercises, and facilitates electronic course critiques. User testing and validation results indicate high levels of acceptance for both the training and performance evaluation components. Initial testing of the prototype courseware on the Army's distance learning suite supports both the web-based and instructor facilitated delivery strategies. The products have been presented to the U.S. Army Aviation Center for consideration for Army-wide implementation. Initial data suggest that web-delivered, interactive multimedia courseware provides effective realism and relevance for team training and evaluation. Ongoing ARI research activities include developing aircraft-specific training

support packages and a program to meet the particular training needs of non-rated crewmembers. The ACTE serves as a model for adult learning-based training supported by distance learning technologies.

Comments: Recap of research assessing the usability of web-based training directly related to crew coordination behaviors including information exchange objectives and supporting basic qualities. Provides contextual definition of aircrew coordination and suggests that distributed training means may be relevant to: 1) promote awareness of the importance of nonverbal communications, 2) gather field experience and success stories, and 3) develop and deliver nonverbal communications training interventions. (Cited item)

Title:	Automated Decision Aids in High-Risk Environments: An Example From the ATC Domain
Author:	Metzger, U., & Parasuraman, R.
Date	2003
Publication:	Human Factors in the Age of Virtual Reality. Shaker Publishing: The Netherlands
Volume:	
Issue:	
Page Numbers:	255-272
Abstract:	New concepts of air traffic management propose a sharing of responsibilities for aircraft separation between air traffic control and the pilots. Automated decision aids are introduced to support controllers in the detection and resolution of conflicts. However, the effects of such decision aids on controller performance and mental workload are not well studied. In simulations of the Free Flight concept, air traffic controllers were tested in en route Air Traffic Control (ATC) environments under manual as well as reliable and unreliable automation conditions. Dependent variables were controller performance in the detection of potential and actual conflicts, communication and secondary task performance. Subjective ratings of mental workload, heart rate variability and eye movement data were obtained. While reliable automation improved controller performance under conditions of shared decision-making, the detection of conflicts under unreliable automation conditions was worse under automated than under manual conditions ("complacency"). The reduced detection performance under unreliable automation conditions was associated with a reduced number of fixations on the automated task (i.e. a shift in attention allocation away from the automated task). Implications for theories of human-automation interaction and for the design of automated systems are discussed.
Comments:	Related topic - Automation.

Title: Distributed Team Performance: An Executive Summary
Author: Pharmer, J.
Date 2001
Publication: Proceedings of the Strategic Studies Group, Orlando FL: Naval Air Warfare Center Training Systems Division
Volume:
Issue:
Page Numbers:
Abstract: Advanced technology has brought with it such concepts as network-centric warfare in which individual members of the team may have to perform coordinated actions while physically located miles apart from one another. As a result, the use of information technology for coordination and communication is increasingly replacing traditional face-to-face interactions between team members. Consequently, there is a real need to understand how this physical separation of team members will affect their overall performance as a team. In recent years, team researchers have begun to focus on these distributed teams and the variables that may affect their performance. The purpose of this paper is to describe the directions of current research into distributed team performance, to identify gaps in this research, and to suggest directions for future research.
Comments: Automation related paper identifies the absence of necessary research on the effects of the loss of nonverbal cues commonly used to transmit and receive information in face-to-face teams. (Cited item)

Title:	Army Air Accidents Rise Dramatically
Author:	Rosenberg, Eric
Date	2005
Publication:	Seattle Post-Intelligencer
Volume:	
Issue:	Monday, July 18
Page Numbers:	
Abstract:	2005 could end up being worst year for accidents in recent memory. Article recaps recent Army aviation accidents and makes comparison with other service accident/mishap rates for FY 2005. Reader context information includes facts like--In 1997, the Defense Science Board, a high-level technical advisory panel to the secretary of defense, found that "human performance is a causal factor in over 70 percent of all Class A mishaps." Aircrew coordination is a subset of human error, Van Riper said, "such as one crewmember says to another an ambiguous phrase, which is misinterpreted and that leads to another event that is directly causal in an accident."
Comments:	Presents evidence that there remains a persistent challenge to maintain awareness of the need for aircrew coordination.

Title:	How In The World Did We Ever Get Into That Mode? Mode Error And Awareness In Supervisory Control.
Author:	Sarter, N. B., & Woods, D. D.
Date	1995
Publication:	Human Factors
Volume:	37
Issue:	1
Page Numbers:	5-19
Abstract:	This paper is an attempt to improve our understanding of attentional demands imposed by complex highly autonomous (cockpit) technology. It explores pilots' monitoring strategies and their compatibility with the design and behavior of modem flight deck automation. The objective of this work is to support a use(r)-centered approach to system and feedback design that integrates the constraints arising from human, machine, and task environment.
Comments:	Automation related article addresses attention demands and change from traditional eye scanning behavior to individual pieces of information on the glass cockpit display. (Cited item)

Reviewed but Not Included

Title:	New Intercom Would Enhance In-flight Safety For SOCOM; Expected To Win Contract To Provide A Test Batch Of 138 Aircraft Wireless Intercom Systems
Author:	Fox, J. J. & Gormley, T. J.
Date	1996
Publication:	Aerospace Daily
Volume:	
Issue:	
Page Numbers:	477
Abstract:	Communications Applied Technology (Reston, VA) is expected to win a sole-source contract to provide a test batch of 138 Aircraft Wireless Intercom Systems (AWIS) for aircraft of the Special Operations Command (SOCOM). SOCOM will eventually need 357 AWIS units. Eight AWIS systems will be tested on all intended platforms, such as the MC-130H and the MH-60K. The wireless upgrade is driven by safety concerns, to eliminate the need for hand signals and long communications cords.

Title:	An Examination Of Nonverbal Cues Used By University Professors When Delivering Instruction In A Two-Way Video Classroom
Author:	Anderson, M. R.
Date	2001
Publication:	Dissertation Abstracts International: Section B: The Sciences & Engineering
Volume:	62
Issue:	2B
Page Numbers:	1205
Abstract:	As the education field further embraces technology and the classroom develops a distance component, more and more colleges and universities are delivering classes via two-way video. Research has established that nonverbal cues exist and play a significant role in classroom instruction (Arnold & Roach, 1989; Cyrs, Conway, Shonk, & Jones, 1997; Rosenthal & Jacobson, 1968). The growing popularity of two-way video and the fundamental concepts of communication establish a parallel between traditional classroom and two-way video instruction delivery. This parallel and the established effect that nonverbal cues have on instructional delivery support the need to study nonverbal communication in a two-way video classroom. Descriptive observation of six instructors, each teaching five 50-minute lectures, produced the data for this preliminary study. The nonverbal cues were recorded using the Two-way Video Nonverbal Cue Observation Instrument (TV-NCOI). The TV-NCOI consisted of seven nonverbal communication categories and 22 variables used to identify and quantify professors' nonverbal cue use in two-way video instructional delivery. Frequency response, common themes, and nonverbal cue delivery observations, collected by the TV-NCOI, were used to answer the research question; what nonverbal cues are used by university professors when delivering instruction in a two-way video classroom? The results suggest that professors in engineering and chemistry, the two focused disciplines, heavily used nonverbal cues when delivering instruction in a two-way video classroom. However, the majority of these cues have a technical delivery base. The traditional classroom nonverbal cues of board pointing, material pointing, and accent gestures are delivered via computer cursor, two-way video camera, and software applications in the two-way video classroom. More specifically, 87% of the nonverbal cues used in instructional delivery had a technological connection and only 13% of the nonverbal cues used were without a technical delivery base.

Title:	Talking Tactically
Author:	Witt, M
Date	1990
Publication:	Asian Defence Journal
Volume:	20
Issue:	5
Page Numbers:	52-58
Abstract:	Ferranti is developing a small size laser transmitter that is capable of projecting voice modulated signals over specific sectors surrounding a helicopter. The development of the system is being conducted as a method of getting around the limitations imposed by crewmembers having to communicate by hand signal and the risks inherent in using a radio. Receivers on the other aircraft pick-up the signals allowing normal speech to be used. The system permits almost complete security with almost no detection by hostile forces. However, the system is a short-range system and is hence, a tactical one. The article contains additional information on tactical communications systems, including cable, mobile radio, new technologies, miniaturization, and a look at the differences between strategic (trunk) and tactical communications.

Title:	The Large Interactive Screen: A Multimodal Dialogue Tool For The Future Pilot Cabin
Author:	Barbier, B., Filiatre, E., & Irigaray, I.
Date	1994
Publication:	Aerospace Medicine and Biology. National Aeronautics and Space Administration: Washington, DC.
Volume:	NASA SP 7011
Issue:	November 1994
Page Numbers:	54
Abstract:	The experimental make-up described is constituted of a large size projection screen displaying an image on which an operator acts in real time, under control of a specific dialogue software, using several control devices (speech recognizer, numeric data glove, oculometer). Various human communication channels are then simultaneously used: vision and audition for the system-to-man flow, voice, gesture and gaze, for the man-to-system flow. Various ways of using and associating these communication channels are discussed.

Title:	Barriers to Effective Communication: Implications for the Cockpit
Author:	Baron, R.
Date	2005
Publication:	http://www.airlinesafety.com/editorials/BarriersToCommunication.htm
Volume:	
Issue:	
Page Numbers:	
Abstract:	The communication process encompasses every part of our daily being. The use of both verbal and non-verbal communication is the very basis of how we converse, both on a personal and on a business level. This paper introduces the concepts of the communication process and then uses the aviation domain to exemplify how barriers to effective communication may manifest themselves. Two specific areas in aviation are discussed; barriers to effective communication between pilots, and, barriers to communication between pilots and air traffic controllers. The combination of case examples, empirical research, and studies of literature, is combined to give the reader a true picture of the effects of deficient communications processes in the aviation domain.

Title:	Talking Heads: Models And Applications For Multimodal Speech
Author:	Beskow, J.
Date	2003
Publication:	KTH, Department of Speech, Music and Hearing: The Netherlands
Volume:	urn:nbn:se:kth:diva-3561 (Doctoral Dissertation)
Issue:	
Page Numbers:	

Abstract: This thesis presents work in the area of computer-animated talking heads. A system for multimodal speech synthesis has been developed, capable of generating audiovisual speech animations from arbitrary text, using parametrically controlled 3D models of the face and head. A speech-specific direct parameterisation of the movement of the visible articulators (lips, tongue and jaw) is suggested, along with a flexible schema for parameterising facial surface deformations based on well-defined articulatory targets. To improve the realism and validity of facial and intra-oral speech movements, measurements from real speakers have been incorporated from several types of static and dynamic data sources. These include ultrasound measurements of tongue surface shape, dynamic optical motion tracking of face points in 3D, as well as electromagnetic articulography (EMA) providing dynamic tongue movement data in 2D. Ultrasound data are used to estimate target configurations for a complex tongue model for a number of sustained articulations. Simultaneous optical and electromagnetic measurements are performed and the data are used to resynthesise facial and intra-oral articulation in the model. A robust resynthesis procedure, capable of animating facial geometries that differ in shape from the measured subject, is described. To drive articulation from symbolic (phonetic) input, for example in the context of a text-to-speech system, both rule-based and data-driven articulatory control models have been developed. The rule-based model effectively handles forward and backward coarticulation by target under-specification. The articulatory control models are evaluated and compared against other data-driven models trained on the same data. Experiments for driving the articulation of a talking head directly from acoustic speech input are also reported. A flexible strategy for generation of non-verbal facial gestures is presented. It is based on a gesture library organized by communicative function, where each function has multiple alternative realizations. The gestures can be used to signal turn-taking, back-channeling and prominence when the talking head is employed as output channel in a spoken dialogue system. A device independent XML-based formalism for non-verbal band verbal output in multimodal dialogue systems is proposed, and it is described how the output specification is interpreted in the context of a talking head and converted into facial animation using the gesture library. Through a series of audiovisual perceptual experiments with noise-degraded audio, it is demonstrated that

the animated talking head provides significantly increased intelligibility over the audio-only case, in some cases not significantly below that provided by a natural face. Finally, several projects and applications are presented, where the described talking head technology has been successfully employed.

Title: Automation, Task Difficulty, and Aircrew Performance
Author: Bowers, C., Thornton, C., Braun, C., Morgan, Jr., B. B., & Salas, E.
Date 1998
Publication: Department of Psychology, University of Central Florida
Volume: 10
Issue: (4)
Page Numbers: 259-274

Abstract: The effects of an automated system on team processes and performance were assessed in a laboratory simulation. Two-person crews were required to fly a complex emergency-response scenario under conditions of low and high workload. These flights were completed with or without the aid of an autopilot. The results indicated that the autopilot was effective in reducing subjective workload. However, the automation was associated with improved performance on only 1 of 4 performance measures. Furthermore, it was observed that problem-solving performance was worse in the autopilot condition during the high-workload flights. Investigation of crew process data indicated that workload savings afforded by the autopilot might have been invested in more explicit coordination. The results are discussed in terms of their implications for military aviators' performance, system design, and team training.

Title: The Relationship Among Eye Movements, Head Movements, And Manual Responses In A Simulated Air Traffic Control Task.

Author: Boyer, D. J.

Date 1995

Publication: FAA Office of Aviation Medicine Reports

Volume:

Issue: A357892

Page Numbers:

Abstract: Investigated sessional, daily, and event-type changes in eye and head movements as indices of alertness changes in 10 subjects, chosen from a previous study (J. A. Stern et al, 1994) for their propensity to make head movements when shifting gaze from the CRT display to the keypad. Subjects made manual responses to 44 infrequently occurring events of four types (e.g., two aircraft at the same altitude flying toward each other). The 2-hr session was divided into three equal time blocks. No significant eye-head movement differences occurred among the event types. Initiation of head and eye movement appeared to be a stable individual characteristic; it was consistent between days and within a session . Return saccades were task dependent; events requiring two manual responses showed different return saccade patterns.

Title:	Preliminary Results From The Evaluation Of Cockpit Resource Management Training: Performance Ratings Of Flightcrews
Author:	Chidester T. R., Gregorich S. E., Helmreich R. L., & Wilhelm J. A.,
Date	1990
Publication:	Department of Psychology, University of Texas, Austin 78712.
Volume:	61
Issue:	(6)
Page Numbers:	576-579
Abstract:	The first data from the NASA/University of Texas Crew Performance project on the behavior of flight crews with and without formal training in Cockpit Resource Management (CRM) are reported. Expert observers made detailed ratings of 15 components of crew behavior in both line operations and in full mission simulations. The results indicate that such training in crew coordination concepts increases the percentage of crews rated as above average in performance and decreases the percentage rated as below average. The data also show high and unexpected degrees of variation in rated performance among crews flying different aircraft within the same organization. It was also found that the specific behaviors that triggered observer ratings of above or below average performance differed markedly between organizations. Characteristics of experts' ratings and future research needs are also discussed.

Title:	Sextant Avionique Developing Data Glove
Author:	Defense Daily
Date	1990
Publication:	Defense Daily
Volume:	167
Issue:	55
Page Numbers:	
Abstract:	Sextant Avionique has developed a new "data glove" to be used for pilot/system communications in next generation cockpits. At a GIFAS conference in Washington this week, Jean Noel Perbet, manager, advanced avionics display R&D, described Sextant's developments in visual, auditory and hand communication channels, designed for efficient man-machine interfaces, particularly in cockpits with high performance electronic copilot aids. Perbet said the glove provides a high accuracy reading of the hand's attitude, to be used for hand gestures for simple messages or to detect hand shape and position, with a 3D tracker, to point out or manipulate objects in the cockpit.

Title:	An Empirical Comparison Of Copresent And Technologically-Mediated Interaction Based On Communicative Breakdown (Videoconferencing)
Author:	Doerry, E.
Date	1995
Publication:	Dissertation Abstracts International: Section B: The Sciences & Engineering
Volume:	67
Issue:	3A
Page Numbers:	1462
Abstract:	Within the area of Computer-Supported Cooperative Work (CSCW), there has been an explosion of interest in how recently developed network technologies might be applied to support the collaborative endeavors of widely distributed participants. Increasingly powerful systems for desktop conferencing, group meeting, and distributed design have been developed. Though the technologies applied in such systems vary widely, their underlying design goal is essentially the same: to support interactions that are functionally equivalent to face-to-face interaction. This dissertation evaluates the extent to which currently available technologies achieve this goal by comparing the amount of communicative breakdown experienced by pairs of participants interacting in three communications environments: copresent, audio-mediated and audio/video-mediated. In all three environments, participants had access to a shared workspace, in which they used a graphical computer simulation to collaboratively explore the behavior of a simple cardiovascular system. Videotaped interactions were analyzed in a series of three studies, intertwining the qualitative techniques of Conversation and Interaction Analysis with more traditional quantitative techniques to progressively refine understanding of the functional differences that exist between environments. Four categories of communicative breakdown were identified: failure to maintain shared conceptions of current topic, failure to establish shared reference, failure to regulate access to the verbal channel and to a shared cursor. Statistical results showed that copresent interactions were significantly less prone to breakdown than interactions in either of the two technologically-mediated environments; no significant differences in the incidence of breakdown were found between audio-only and audio-video interactions. A subsequent qualitative analysis showed that breakdowns in technologically-mediated interactions were related to a profound insensitivity to nonverbal displays like direction of gaze, deictic gesture and manipulation of objects in the task context. Thus, though visual access to a partner is clearly vital for avoiding breakdown, the visual access afforded by a video image is fundamentally unequal to that afforded by physical copresence. There is a great deal of difference between technically making more communicative resources available in an environment and the practical utility of such upgrades to participants.

Title:	USAF Wing Takes Innovations Overseas
Author:	Fulghum, D. A.
Date	1993
Publication:	Aviation Week & Space Technology
Volume:	139
Issue:	24
Page Numbers:	18-26
Abstract:	The US Air Force's (USAF) rapid deployment force, the 366th Wing, has become an operational laboratory for the latest technological innovations, including nonverbal communications between fighters, the introduction of new radar-locating devices, and some of the service's most exotic precision weapons. The 366th operates a mix of twelve F-15Cs, twelve F-15Es, eighteen F-16s, seven B-52s, and six KC-135s and can be on its way to a war within 48 hours as the premier, fast-reaction unit for the Air Force. In late November and early December 1993, the unit honed its deployment capabilities with a Bright Star exercise in Egypt, operating with the air forces of several Middle Eastern countries. The wing's function is to focus its beefed up firepower quickly in order to avoid doing more later, according to Colonel Jerry Callen, 336th Wing vice commander. The wing can be used both as a political signal that the US is willing to use force or as a military instrument to quickly take away a key target or two in hopes of deterring an aggressive foe.

Title:	Multi-Cultural Considerations For Space Station Training And Operations
Author:	Hanssen, V., Stayton, W., & Wlaka, M.
Date	1992
Publication:	Proceedings of the Space Programs and Technologies Conference, Huntsville, AL
Volume:	
Issue:	
Page Numbers:	7
Abstract:	The present discussion of Space Station Freedom program-related Extreme Environment Training (EET) gives attention to cultural differences that can potentially create problems during EET, and explores those aspects of identified problems to which trainers can productively respond. These cultural differences cover the fields of native language, nonverbal communication , task-oriented behavior, assertiveness, decision-making processes, scheduling and time-management, patience and tolerance, interpersonal interest, relationship-oriented behavior, respect for foreign cultures, sensitivity to gender roles, and sense of humor.

Title:	Selecting Pilots With Crew Resource Management Skills
Author:	Hedge J.W., Bruskiewicz K.T., Borman, W.C., Hanson, M.A., Logan, K.K., & Siem, F.M.
Date	2000
Publication:	International Journal of Aviation Psychology
Volume:	10
Issue:	(4)
Page Numbers:	377-392
Abstract:	For years, pilot selection has focused primarily on the identification of individuals with superior flying skills and abilities. More recently, the aviation community has become increasingly aware that successful completion of a flight or mission requires not only flying skills but the ability to work well in a crew situation. This project involved development and validation of a crew resource management (CRM) skills test for Air Force transport pilots. A significant relation was found between the CRM skills test and behavior-based ratings of aircraft commander CRM performance, and the implications of these findings for CRM-based selection and training are discussed.

Title:	Quantitative Measurement Of Observed Workload In The Analysis of Aircrew Performance [Electronic version].
Author:	Laudeman I. V., & Palmer, E. A.
Date	1995
Publication:	International Journal of Aviation Psychology
Volume:	5
Issue:	(2)
Page Numbers:	187-197
Abstract:	A methodology for the quantitative evaluation of observed workload was proposed. The model was designed to provide point estimations of observed workload at any time during the performance of a set of tasks. The model was also designed to provide information about the task-scheduling strategies used to complete a set of tasks. The proposed model was then tested with data from a full mission flight simulation. The model predictions correlated significantly with expert ratings of workload management made during the flight simulation. The model was also able to distinguish between low- and high-performing aircrews when performance was based on the number of errors made during flight simulations.

Title:	Human-Computer Interactions In Shared Virtual Environments
Author:	Loftin, R. B
Date	1999
Publication:	Human Computer Interactions (HCI)
Volume:	2
Issue:	
Page Numbers:	1120-1123
Abstract:	Since 1994, the authors have been exploring the application of shared virtual environments for team training within NASA and for Operations Other Than War within the defense community. Applications have been developed for: teams of astronauts training to conduct scientific experiments and maintenance within the International Space Station program; and military teams preparing to conduct peacekeeping operations. In order to more effectively employ shared virtual environments for these types of tasks, they have been led to investigate a number of human-related issues. Among these are: training transfer to real-world environments, the effect of communications latencies, successful interaction metaphors, human figure representations, necessary fidelity (visual, audio, haptic) for effective non-verbal, human-human communication, navigation methods, training transfer, and the psychology of team building. While much work remains to be done, this paper reports on progress made in two major areas, training transfer and non-verbal communication.
Comments:	Related topic – Automation.

Title:	The Helicopter: Some Ergonomic Factors [Electronic version].
Author:	Lovesey E. J.
Date	1975
Publication:	http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=15677178&dopt=Abstract
Volume:	PMID: 15677178 [PubMed]
Issue:	
Page Numbers:	
Abstract:	Helicopter pilots are some of the hardest working human operators, because of the machine's inherent instability and control problems. This article covers some aspects where ergonomists might help to improve the overall system. After considering basic differences between helicopters and fixed wing aircraft, the author examines controls, where there are prospects of using miniature hand levers; cockpit vision and displays with particular reference to night and instrument flying; seating and vibration where the effects of protective clothing and harnesses are considered; and cabin noise from the engine, transmission and intercom systems. Finally, he assesses pilot activity using cine film techniques for different types of flight.

Title:	Some Aspects Of Space Crew Member Interactions In Emergency Situations
Author:	Pavlov, V. L.
Date	1979
Publication:	Psychological problems of space flight. (A80-32976 13-53) Moscow, Izdatel'stvo Nauka
Volume:	Collected Work
Issue:	
Page Numbers:	84-90
Abstract:	A social psychological analysis of space based on crewmember interactions during an emergency situation is presented. Consideration is given to the influence of the unexpectedness and lack of time in emergency situations on the organizational structure of the crew, intercrew verbal and nonverbal communication and the coordination of competitive activities. Requirements for the experimental investigation of the effectiveness of small group interactions in emergency-type situations are then formulated.

Title: Emergency Operating System For Piloting An Aircraft In A Smoke Filled Cockpit

Author: Smith, E. S.

Date 2001

Publication: Innovation and Consolidation in Aviation. Ashgate Publishing: Burlington, VT.

Volume:

Issue:

Page Numbers: 231-241

Abstract: A system for operating equipment, aircraft or other like vessels in a smoke filled environment is presented. The system includes a facemask configured to surround a user's eyes and form an airtight seal against the user's face. The mask includes a screen viewable by the user for displaying critical operating system information that permits continued operation of the equipment or aircraft. A signal path means provides the display screen with appropriate signals from instrument display sources of the equipment or aircraft. One embodiment of the system includes a hand-operated communication device that enables non-verbal communication with others. Another embodiment of the system includes independently powered backup instruments covering minimum critical equipment or aircraft operating conditions. The backup instruments would be coupled to the mask by the signal path means in the event that the equipment or aircraft's instruments should become inoperable due to fire and/or electrical power interruption. Still another embodiment of the system includes a respirator that is integral with the mask and provides oxygen to the user. The display screen includes a first section for displaying equipment instrument information from instrument display sources of the equipment, a second section for normal viewing through the face mask, and a third section for displaying external image information from external environmental sensing systems of the equipment. A hand-operated communication device enables non-verbal communication with an air traffic controller. The communication device includes recording playback means for storing and playing pre-recorded messages which can be transmitted by the aircraft's radio transmission system to the air traffic controller, wherein the communication device being operable during an emergency situation when said smoke fills said cockpit and vision of said pilot is obscured.

Title: Remote Observation And Diagnostic Evaluation: Contact And Communication In Medical-Control Problems

Author: Uskov, F. N., Kushnereva, O. V., Popov, B. A., Bazhin, E. F., Valsiner, I. A., Durandina, A. T., Zaprisa, N. S., Kolinichenko, T. B., Korneva, T. V., & Moravek, M.

Date: 1982

Publication: Psychological problems of space flight. (A80-32976 13-53) Moscow, Izdatel'stvo Nauka

Volume:

Issue: 112

Page Numbers: 24-45

Abstract: The monitoring of professional and psychological adaptation of cosmonauts to flight stress factors is described. A series of external signs (including speech, gesture, body movements, and posture), which are insignificant in the usual diagnostic situation, become the major source of significant flight stress information. The problem of limited doctor-patient communication is considered and a solution is offered in the form of automatic recording and analysis of dialogue time parameters, which are important in studying the details of doctor-patient rapport. The involvement level of the diagnostician is discussed; his role as observer is stressed. It is proposed that specific verbal and nonverbal behaviors are indicative of psychosomatic manifestations in conditions of weightlessness.

Title:	Multi-Touch: A New Tactile 2-D Gesture Interface For Human-Computer Interaction
Author:	Westerman, W, Elias, J. G., & Hedge, A.
Date	2001
Publication:	Human Factors and Ergonomics Society 45th Annual Meeting
Volume:	
Issue:	
Page Numbers:	632-636
Abstract:	The naturalness and variety of a touch-based hand gesture interface offers new opportunities for human-computer interaction. A new type of capacitive sensor array, a Multi-Touch Surface (MTS) can be created that is not limited in size, can be presented in many configurations, is robust under a variety of environmental operating conditions, and is very thin. Typing and gesture recognition built into the Multi-Touch Surface allow users to type and perform bilateral gestures on the same surface area and in a smaller footprint than is required by current keyboard and mouse technologies. The present approach interprets asynchronous touches on the surface as conventional single-finger typing, while motions initiated by chords are interpreted as pointing, clicking, gesture commands, or hand resting. This approach requires learning only a few new chords for graphical manipulation, rather than a vocabulary of new chords for typing the whole alphabet. Graphical manipulation seems a better use of chords in today's computing environment.

Appendix B

Proposed Research Area and Approach

Pilots report that nonverbal communications do occur in the cockpit. The extent to which nonverbal communications are relied upon to supplement verbal coordination and to direct behaviors relating to mission performance and safety is unclear. With some Army rotary-wing aircraft using a tandem-seating configuration and with the limited in-cockpit visibility afforded by night flight and NVG flight operations, the impact of restricted nonverbal communication on crew coordination and performance is an important issue to address, particularly in situations where flight safety is impacted by the inability to transmit and interpret nonverbal communications. Little is known concerning the potential threat to effective crew coordination and communication posed by a lack of nonverbal communications training and awareness.

Research Area

The initial focus of this research area would be to conduct a preliminary investigation on the types, functions, and effects of nonverbal communication on aircrew coordination. Research in the area of nonverbal communications would include establishing a definitional base, developing a standardized framework, relating framework categories to behaviors and performance, developing training methods and materials, developing evaluation methods and materials, validating methods and measures, and finally applying training and evaluation knowledge to non-aviation applications, such as battle command.

The technology required to support this type of research is already available. Desk top trainers, system task trainers, visual flight simulators (side-by-side and tandem), and mission simulators (side-by-side and tandem) are all useful tools for providing significant insight into the use and importance of nonverbal communications between crewmembers within a cockpit. For example, research simulators with the capability to record and log aircrew's body movement, hand position, eye movement, digital communication, and verbal communication can be used to support experiments and evaluations. This would be particularly useful during experiments in which aircrews are to be monitored as they interact with the cockpit controls and displays. Subjective measures have indicated that aircrews tend to rely on visually monitoring each other's interactions with controls. Aircrew interactions with cockpit displays present an opportunity to employ a manipulation of technology, i.e., change the properties or position of display items to enhance nonverbal cues for task coordination and communication.

Research Approach

A progressive methodology is needed to support the nonverbal communications technical research program. The research approach should embody a deliberate use of surveys, questionnaires, and test bed experiments, e.g., confirm nonverbal communication constructs, methods, and measures before proceeding to full simulator missions (see Figure B-1).

Survey, Questionnaire, Interview
Topic Survey
Detailed Questionnaire
Structured Interview
Tests and Experiments
Audio Recording (existing, new mission/equipment)
Audio Transcripts
Video Recording (existing, new mission/equipment) (single or multiple views of aircrew, environment, systems indicators)
Coding and Analysis (C^4T*)
Simulation
Mission scenario segments
Aircrew coordination tasks
Participants (crewmembers, expert ACT** observer/evaluators, expert NVC*** observer/evaluators)
Equipment (visual flight simulator)
Experimental design (standardized behavioral training)
Measures (NVC frequencies, NVC categories, aircrew coordination behaviors, mission/task performance)

* Controller-to-Controller Communication and Coordination Taxonomy
** Aircrew Coordination Training
*** Nonverbal Communications

Figure B-1. Research methods.

Recommended methodology includes the sequence of research activities listed below:

1. Review unit SOPs
2. Review existing video recordings (ACTE data collection events)
3. Observe experienced aircrews in simulator training events
4. Develop and administer survey to identify NVC topics
5. Develop trial taxonomy of Functions, Topics, and Expressions
6. Develop and administer questionnaire
7. Refine taxonomy
8. Develop candidate measures based on taxonomy
9. Design and conduct NVC experiments to test measures (Checklist—Run up, Emergency procedure, Landing)
10. Develop NVC critical event scenarios (Low-high workload)
11. Design and conduct simulation (Level 1—Critical event)
12. Develop NVC mission segment scenarios (Low-high workload)
13. Design and conduct simulation (Level 2—Mission segment)
14. Develop NVC complete mission scenarios (Low-high workload)
15. Design and conduct simulation (Level 3—Complete mission)

Simulation activities for a complete mission (Level 3) would follow the design outlined in the following example. Two scenarios validated during previous ACTE phases could be used for two sessions in the simulator: one of which would take place without obstructing nonverbal communications (Open Cockpit condition), the other would include some obstruction of the visual space within the cockpit (Closed Cockpit condition) to compromise nonverbal communication capabilities (see Table B-1).

Table B-1

Proposed Experimental Design

Counterbalanced, Within Subject's Design 2 (Open vs. Closed Cockpit) x 2 (mission scenario)		
	Scenario 1: Open Cockpit	**Scenario 2: Closed Cockpit**
Crew 1	Baseline	Nonverbal Blocked Condition
Crew 2	Baseline	Nonverbal Blocked Condition
Crew 3	Baseline	Nonverbal Blocked Condition
Crew 4	Baseline	Nonverbal Blocked Condition
Crew 5	Baseline	Nonverbal Blocked Condition
	Scenario 1: Closed Cockpit	**Scenario 2: Open Cockpit**
Crew 6	Nonverbal Blocked Condition	Baseline
Crew 7	Nonverbal Blocked Condition	Baseline
Crew 8	Nonverbal Blocked Condition	Baseline
Crew 9	Nonverbal Blocked Condition	Baseline
Crew 10	Nonverbal Blocked Condition	Baseline

This task will gather and report on information in multiple areas using data collection instruments validated in previous ACTE phases. Observer evaluator sheets and video-recording instruments will constitute the bulk of the data collection effort. Measurement materials are listed in Table B-2.

Table B-2

Data Collection Instruments and Associated Measures

Instrument	Measurement
Observer Evaluator Worksheet	ATM Task Performance Standard, S+, S, S-, U Navigation and Mission Errors Time to complete mission critical task: error recognition to crew action Crew reaction correct or incorrect for presented situation
Video and Audio Capture	Number of verbal communication events attempted Number of nonverbal communication events attempted Number of crew actions and cross checks (external) Verifications with and without nonverbal cues present Categorization of nonverbal communications (C^4T)
Simulator Data Capture	Eye movement (tracking, frequency, dwell time) Hand movement (tracking, frequency, dwell time)
ACTE Behavioral Anchored Rating System (BARS)	5 Crew Coordination Objectives: Below, Meets, or Exceeds Standards (1 through 7 Scale)
Structured Interview	Subjective reactions to nonverbal (open cockpit) versus nonverbal-blocked (closed cockpit) conditions

Requirements to complete this research task are:

- 10 UH60 crews consisting of qualified pilots available for one 8-hour duty day (Two 3.5-hour sessions with 1-hour lunch) or two (3.5 hour) sessions
  - Pilots must be UH60 qualified, with no minimum time
  - Crews must have some degree of experience flying together, either in actual or simulated flight, prior to participation
  - Pilots can not be qualified in the tandem seat aircraft (AH-1 or AH64 series)
- Crews must remain constant across all events
- UH60 Flight Simulators, both a research version and a mission training version.
  - Research flight simulator with eye and hand movement tracking and recording capability
  - Briefing room for 20 (twenty persons)
  - Twenty 3.5-hour periods; each UH60 crew will fly 2 scenarios of 2 hours each with 1 hour for pre-mission planning and 0.5 hours of mission debriefing/interviewing
- One small room with electrical power for use as a research operations center