DOT/FAA/AM-98/17

Office of Aviation Medicine
Washington, D.C. 20591

An Analysis of Voice Communication in a Simulated Approach Control Environment

O. Veronika Prinzo
Civil Aeromedical Institute
Federal Aviation Administration
Oklahoma City, OK 73125

May 1998

Final Report

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

U.S. Department of Transportation

Federal Aviation Administration

NOTICE

Technical Report Documentation Page

1. Report No. DOT/FAA/AM-97/17	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle An Analysis of Voice Communication in a Simulated Approach Control Environment		5. Report Date May 1998
		6. Performing Organization Code
7. Author(s) Prinzo, O. V.		8. Performing Organization Report No.
9. Performing Organization Name and Address FAA Civil Aeromedical Institute P.O. Box 25082 Oklahoma City, OK 73125		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency name and Address Office of Aviation Medicine Federal Aviation Administration 800 Independence Ave., S.W. Washington, D.C. 20591		13. Type of Report and Period Covered
		14. Sponsoring Agency Code

15. Supplemental Notes

This work was performed under Task AM-B-96-HRR-513

16. Abstract

This report consists of an analysis of simulated terminal radar approach control (TRACON) air traffic control communications. Twenty-four full performance level air traffic controllers (FPLATC) from 2 TRACON facilities participated in the simulation study. Each controller worked 2 light- and 2 heavy-traffic density scenarios for feeder and final sectors. All communications were audio recorded and transcribed verbatim by a retired FPLATC. Once transcribed, transmissions were parsed into communication elements. Each communication element was assigned a speech act category (e.g., address, instruction, request, or advisory), an aviation topic (e.g., altitude, heading, speed) and then coded for irregularities (e.g., grouping numbers together when they should be spoken sequentially, or omitting, substituting, or adding words contrary to required phraseology) (ATSAT, Prinzo et al., 1995). The simulated communications were compared to an analysis performed on audiotapes from the same TRACON facilities. Percentages in 3 speech act categories were comparable (Instruction, 55% versus 51%; Address; 14% versus 26%; Advisory, 24% versus 18%). Detailed analyses revealed that, although there were fewer irregular communications produced during simulation, the distributions of those communication irregularities were very much the same, with the exception of aircraft call sign. The differences in those distributions were attributed to the voice recognition system; it could not recognize a call sign spoken sequentially and then restated in grouped form.

17. Key Words ATC Communications, Communication Taxonomy ATC Phraseology		18. Distribution Statement Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 30	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

ACKNOWLEDGMENTS

This research was sponsored by the Federal Aviation Administration's Offices of Aviation Safety Analysis (ASY-200) and the Quality Assurance Division of Air Traffic System Effectiveness (ATH-200). We also acknowledge Barbara Burke, Monte "Buzz" Taets, Sandy Dooty, Elaine Pfleiderer, and Jennifer Thompson for the many monotonous and tedious hours of effort that they devoted to transcribing, coding, encoding, and analyzing the data presented in this report.

TABLE OF CONTENTS

An Analysis of Voice Communication in a Simulated Approach Control Environment

Words differently arranged have a different meaning, and meanings differently arranged have different effects.

— Pascal

1.0 INTRODUCTION

Accurate communication between air traffic control specialists[1] and pilots is essential to air safety (see Prinzo & Britton, 1993 for a review of the literature). To gain a better understanding of the problems that arise from spoken communication, analyses on the message contents and acoustic properties of speech are often performed. The results from those analyses range from describing current communication practices among pilots and controllers to determining causal factors in accident investigations.

Researchers and investigators who perform message content analyses often develop their own classification schemes to identify patterns of communication and organize similar communication problems into categories. Message content analyses were recently performed on field tapes obtained from various air traffic control (ATC) facilities (en route, Cardosi 1993; tower, Burki-Cohen 1995; terminal, Morrow, Lee, & Rodvold, 1993; Cardosi, Brett, & Han, 1996; Prinzo 1996) and cockpit voice recorder transcripts obtained from the National Transportation Safety Board (Helmreich 1994; Predmore 1991). Generally, the results indicate that clearances and instructions make up the largest proportion of communication between controllers and pilots.

Typically, acoustical analyses examine the frequency spectrum and temporal amplitude of identical words or parts of words spoken by the same person at different times to determine whether changes are present (Mayer, Brenner, & Cash, 1996). These changes might serve as markers or indicators of stress (Brenner, Shipp, Doherty, & Morrissey, 1985; Griffin & Williams, 1987) or physiological change (Lieberman, Protopapas, & Kanki, 1995). Generally, a frequency shift to the right (pitch gets higher) is indicative of emotional stress and a shift to the left (pitch gets deeper) indicates stress-reduction. Brenner, Doherty, and Shipp (1994) analyzed crew conversations recorded during routine and emergency situations. In all of the tapes, the fundamental frequency (pitch) increased significantly during emergency air to ground communications.

Frequently, the research question and paradigm direct the manner in which data are selected, collected, extracted, and analyzed (see Kanki & Prinzo, 1996). As long as these paradigms and their associated protocols lead researchers and investigators to view aspects of the same event differently, conflicting interpretations may occur. The lack of standardized metrics and representative measures can be problematic for many reasons. First, the comparison of results obtained from one laboratory to that of another is difficult or impossible to perform. Second, the results obtained by one laboratory can be difficult to replicate because the encoding process may not be consistent. Finally, the results and conclusions made by researchers and investigators often are difficult to translate into a curriculum or instructional practice. Fortunately, when communicating with pilots, controllers are required to use the phraseology presented in *FAA Order 7110.65 Air Traffic Control*[2] as the standard. Researchers also can apply it to the analysis of ATC communication.

[1] Air traffic control specialists may be referred to as controllers, specialists, or ATCSs in this document.

[2] For brevity, the publication will be referred to as FAA Order 7110.65 throughout this document.

Prinzo, Britton, and Hendrix (1995) developed the aviation topics speech acts taxonomy (ATSAT) to analyze communication elements[3] in accordance with *FAA Order 7110.65* and the *Aeronautical Information Manual* (AIM)[4]. Both were used to identify irregularities in spoken communication such as grouping numbers together when they should be spoken sequentially or omitting, substituting, or adding words contrary to required phraseology. These irregularities constitute departures from the standard phraseology specified in FAA Order 7110.65 and will be referred to as *irregular communication* (IC) in this report.

Communication elements combine to form messages that are transmitted over voice radio or data link communications systems (Prinzo 1996). One commonly referenced communication element is the speech act (Searle, 1969; Kanki & Foushee, 1989) which Prinzo defines as an utterance, either spoken or written, which describes or suggests one discourse function. There are five speech act categories in the ATSAT: Address, Instruction, Advisory, Request, and Courtesy. A sixth category, Non-codable, was included for communication elements that could not be categorized (the communication element could be an incomplete phrase or be unintelligible). The aviation topic is the subject matter of the speech act. It places a constraint on the communication element by imposing a restriction on its identified speech act category. For example, there are only two types of aviation topics in the Address speech act category: one identifies the speaker and the other identifies the receiver of a transmission.

To illustrate, consider the transmission, *"[Name] Approach, Universal 744 descend and maintain niner thousand."* It contains three communication elements. *[Name] Approach* and *Universal 744* identify the participants; each is tagged with the speech act category, Address. The aviation topic distinguishes one Address from the other by identifying *"[Name] Approach"* as the Speaker and *"Universal 744"* as the Receiver of the transmission. The third communication element, *"descend and maintain niner thousand,"* is an Instruction speech act, and its aviation topic identifies it as an altitude.

Recently, Prinzo (1996) performed a content analysis of ATC communications from field tapes provided by several terminal approach control (TRACON) facilities. The field tapes were used to develop a baseline database of typical controller and pilot voice communications. The results of that analysis found that 2,500 of 6,300 (40%) controller communication elements contained at least one irregularity. For controllers, 93% of those irregularities occurred in the Instruction (55%), Advisory (24%), and Address (14%) speech act categories. Of 5,900 pilot communication elements, 3,500 (59%) contained at least one irregular communication. For pilots, 96% of their irregular communications involved the Instruction (53%), Address (25%), and Advisory (18%) speech acts categories. Irregular communication involved call sign ambiguity, call sign confusion, two aircraft on frequency talking to each other, report of an emergency locator transmitter (ELT), open mike, traffic, weather, and others. The communication problems resulted in a loss of efficiency but did not result in hazardous consequences, such as loss of separation.

Based on telephone interviews with pilots and the content/acoustic analyses of field tapes, several researchers have attempted to identify some of the correlates and causes of communication problems. Morrison and Wright (1989) and Morrow, Rodvold, and Lee (1994) report that miscommunications tend to occur more often when controllers experience overload due to heavy traffic, frequency congestion, message length, etc. Three voice qualities appear to vary systematically with workload: pitch, loudness, and rate of speech. For example, Griffin and Williams (1987) reported that people under emotional stress or increased task complexity have a higher pitch and they tend to talk louder and faster. Brenner et al., (1994) indicate that mental workload also appeared to produce similar effects on language production.

To gain a better understanding of the relationship between workload and ATC communication, a simulation study was designed to examine the relationship between workload and the efficiency and accuracy of controller voice communication. Two components of controller voice communication, message content and speech production, were examined. An acoustic/phonetic analysis was performed on the controller voice characteristics thought to be associated with changes in workload. The results of that analysis are presented in Prinzo, Lieberman, and Pickett (in review).

[3] The communication element is conceptualized as a fundamental unit of meaningful verbal language.

[4] Previously called the *Airman's Information Manual.*

The results that are presented in this report are limited to a discussion of the analysis performed on the message content of controller transmissions. Full performance air traffic control specialists were recruited from two terminal radar approach control (TRACON)[5] facilities to participate in this study. They provided radar separation for simulated aircraft during periods of typical low and high traffic that represented actual traffic counts at their respective facilities. Recorded, digitized pilot messages were generated by a TRACON simulator in response to communications initiated by the controller. If the simulator failed to generate an appropriate pilot response, a certified "ghost pilot" from the FAA Academy intervened with the correct response. Simulated communications were analyzed in accordance with the procedures outlined in Prinzo et al. (1995). Communication irregularities were identified and statistically compared with irregular communications identified from field tapes obtained from two approach control facilities. If the results could be replicated in a simulation environment, then they could generalize to and have relevance in real-world applications.

2.0 METHOD

2.1 Participants

Twenty-four full performance level (FPL) controllers from two TRACON facilities completed this study. One facility provided 9 male and 3 female controllers. Collectively, they had 13.17 mean years of terminal experience (SD = 3.49) with 9.88 mean years (SD = 3.19) at the FPL. The other facility provided 10 male and 2 female controllers who, on the average, had 12.13 years of experience (SD = 3.16) with 10.04 mean years at the FPL (SD = 3.20) and 11.30 mean years working as terminal controllers (SD = 2.63).

2.2 Equipment

2.2.1 TRACON and Ghost Pilot Workstations. Wesson International's TRACONpro© software was installed on two 486/66 MHz DX2 personal computers. Each workstation displayed radar traffic on a 21" multi-scanning capable monitor (1280x1024x256) with high-resolution video adapters. The TRACON workstation included an amber 14" monitor for displaying ATIS, a track ball and ARTSIIIA-simulated keyboard, standard 101-style keyboard, Verbex 6000 Voice Systems continuous voice recognition "slave" computer board, push-to-talk headset, and SoundBlaster 16-bit digitized sound board. Figure 1 shows several TRACON workstations in use. The ghost pilot workstation included a standard 101-style keyboard and computer mouse. The TRACON workstation was housed in a room separate from the ghost pilot workstation. The workstations communicated with each other through a LANtastic network operating system.

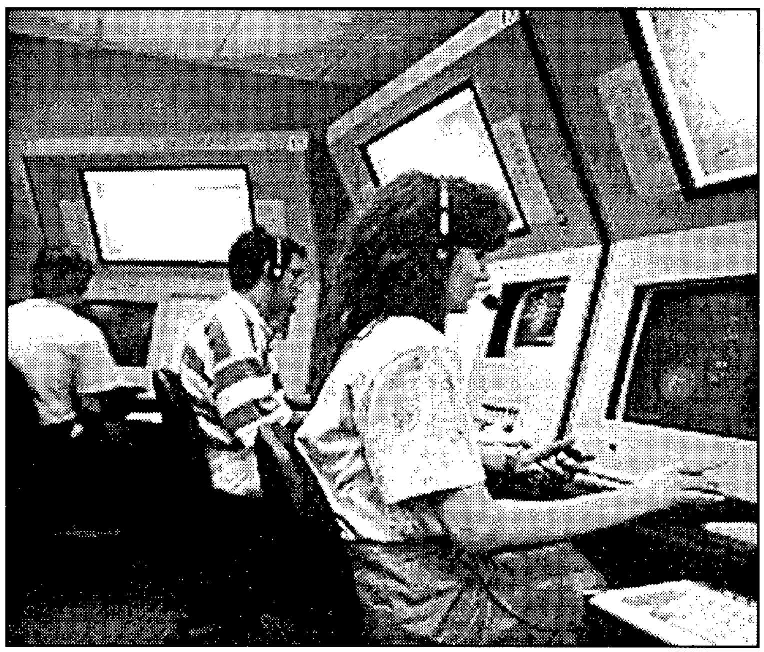

Figure 1. TRACONpro simulator

2.2.2 Video Recording Equipment. A Sony Handycam CCD-TR81 video Hi8 Camcorder, mounted on a Bogen 3165 tripod, was positioned approximately 4 meters to the left and 6 meters in front of the controller's workstation. Only the radar display, side view of the controller, and hand movements were recorded. The audio/video output of the Sony Handycam was routed to a Panasonic audio/video distribution amplifier (15-1103), displayed on

[5] A terminal radar approach control (TRACON) facility is associated with an air traffic control tower that uses radar to provide approach control services to aircraft.

a Sony color video monitor PVM2530, equipped with 2 Sony SS-X6A speakers, and recorded by a Sony video cassette recorder SVO-1610 on standard VHS T120 cassettes.

2.2.3 **Audio Recording Equipment.** A Sony Electret condenser microphone (ECM-77B) was attached to a Shurlite headset and positioned approximately 1.5cm from the controller's lips. The output signals of the microphone were amplified by a Panasonic audio mixer WR-450 and then sent to a Sony digital audio recorder PCM-2700, where each utterance was time stamped and recorded on 120-minute BASF DAT cassettes.

2.3 Simulation Support Staff

The simulation support staff consisted of one ghost pilot, a retired controller, and several representatives from each TRACON facility. The certified ghost pilot from the FAA Academy was trained on the scenarios constructed for this experiment. A recently retired FPL controller served as the subject matter expert (SME). He constructed the scenarios, trained the ghost pilot on the TRACONpro system and scenarios, developed briefing materials, and provided the ghost pilot with on-line instruction during each simulation. Several staff members from each TRACON facility provided subject matter expert information and guidance during the development of the airspace, procedures, and scenarios. Also, prior to the onset of the experiment, several controllers reviewed and offered suggestions, which increased the fidelity and realism of each scenario.

2.4 Materials

2.4.1 **Scenario Construction.** The number of aircraft requiring radar service was experimentally manipulated to simulate high- and low-workload scenarios. For example, light traffic density at one of the TRACON facilities averaged approximately 1.5 aircraft communicating with approach control per minute, and heavy traffic averaged 2 aircraft communicating with the controller per minute. Three controller positions from each facility were simulated. Traffic density was crossed with controller position to produce 6 scenarios for each facility.

2.42 **Ghost Pilot Communication Scripts.** Based on field tape analyses, normal and problematic pilot communication scripts were constructed and fully counter-balanced for use in each scenario. The scripts were used by the ghost pilot, who initiated calls to ATC at pre-determined times and responded to messages generated by the controller. The problematic transmissions that were incorporated in the communications are presented in Table 1.

Table 1. Target Aircraft Transmissions Made by the Ghost Pilot to Controllers

Target Pilot Transmissions to Controllers at TRACON Facility 1

I wanna confirm we are going to runway "3" "5" right.

Verify the altimeter is "3" "0" "0" "4" and our runway assignment is "3" "1" right.

Give us the wind and altimeter again and we would like to land "1" "8" right.

Can I reduce down to "1" "9" "0" knots on account of the chop?

Is it OK if we reduce to "2" "1" "0" now?

Request runway "1" "3" right if it's not too much of a problem for you.

Target Pilot Transmissions to Controllers at TRACON Facility 2

(Name) Approach, any chance landing north today for "3" "5" left?

(Name) Approach, I'd like to request the ILS "1" "7" on the right with a full stop at (airport name).

Request ILS approach at (airport name).

Requesting an ILS runway "1" "7" right approach.

Request runway "3" "5" right ILS approach.

Sir, we'd like to make a missed approach this afternoon and we'll just come back for the localizer.

Upon initial contact, the ghost pilot reported the aircraft call sign and current altitude to the controller. Once radar contact was established, the ghost pilot made a request for a lower altitude or particular runway. In addition to requests, a rule was established that every other ghost pilot response would include a realistic, yet incorrect readback.

2.4.3 Computer-Generated Pilot Responses. Each non-target aircraft computer-generated pilot response (CGPR) was created by the TRACONpro software. Each aircraft call sign, the (International Civil Aviation Organization) ICAO phonetic alphabet, and phrases used in operational communications were recorded, edited, and stored as SoundBlaster wave files. The intelligibility of the CGPRs was evaluated by the Federal Bureau of Investigation (FBI) Speech Processing Laboratory at Quantico, VA. A CGPR was selected at random and compared with the same message recorded live by the originator of both messages. The spectrograms were judged to be the same.

2.5 Procedure

Upon arrival at the TRACON simulation laboratory, the controller was told the purpose of the study, instructed on Verbex voice training procedures, completed voice-training on a limited vocabulary, and gained familiarity and experience with the voice recognition system. It took approximately 2-3 hrs. to complete voice training. Once voice trained, the controller completed a 15-minute practice scenario at which time the SME determined whether additional voice training or practice was warranted.

On the second and third day, the controller again completed the same practice problem to re-establish baseline performance and then completed a 45-minute simulation, received a 15-minute break while the next scenario was loaded, and so on until each of 6 scenarios was completed. Using standard FAA phraseology, the controller provided ATC services to all arrival aircraft within the controller's area of jurisdiction. The following constraints were imposed on the order of scenario presentation: (1) The controller did <u>not</u> receive 3 consecutive heavy traffic volume scenarios, (2) the controller provided ATC service on each of the 3 positions before working the same position again, and (3) all controllers worked the FINAL or AR2 position first.

2.6 Data Encoding Tool and Procedure

2.6.1 Aviation Topics Speech Acts Taxonomy (ATSAT). The ATSAT is a tool for categorizing pilot/controller communications according to their purpose, operation, or action and for classifying Irregular Communications (IC) (Prinzo, Britton & Hendrix, 1995). Aviation topics are the subject matter of speech acts. The speech act categories and aviation topics are presented in Table 2.

There are two categories of ICs presented in Table 3: non-standard phraseology and delivery technique. Non-standard phraseology pertains to the use of words and/or phrases other than those prescribed in *FAA Order 7110.65*; delivery technique refers to stammers, stutters, or misspoken words. ICs may or may not lead to the occurrence of an operational error, pilot deviation, or mishap. *The reader is cautioned NOT to make the improper inference that an IC is in any way related to an operational error in this report.* Operational errors will not be presented nor discussed.

2.6.2 Aviation Topics Speech Act Taxonomy$_{pc}$. ATSAT$_{pc}$ (Prinzo & MacLin, 1996) is a computerized version of ATSAT$_{CF}$. It was used to post **transcribed** data into a pre-defined electronic spreadsheet according to the procedures outlined in Prinzo, et al. (1995).

2.7 Data Encoding Procedure

Transmissions between controllers and pilots were transcribed verbatim by one SME and then encoded by another who parsed each transmission into communication elements and classified them into speech acts and aviation topics. Communication elements that deviated from standard communication practices specified in *FAA Order 7110.65* were identified using the IC codes included in the ATSAT[6]. The context in which the transmission was spoken was vital to how the SME encoded the communication elements.

2.7.1 Intercoder Reliability. Intercoder reliability was assessed by computing the percentage agreement between the segmentation, categorization, and

[6] Pilots are not required to use the same standard phraseology as controllers when communicating. To achieve a standard for comparison between pilot and controller communications, the following rule was established: If a pilot attempted a verbatim readback of a controller's transmission, then the same coding procedures that were used on controllers transmissions were applied to the pilot's verbatim readback.

TABLE 2. Aviation Topics/Speech Acts Taxonomy

Speech Act Category	Aviation Topics
Address/Addressee	Speaker, Receiver
Courtesy	Thanks, Greetings, Apology
Instruction/Clearance--Readback/Acknowledgment	Heading, Heading Modification, Altitude, Altitude Restriction, Speed, Approach/Departure, Frequency Holding, Route/Position, Transponder Code, General Acknowledgment
Advisory/Remark--Readback/Acknowledgment	Heading, Heading Modification, Altitude, Altitude Restriction, Speed, Approach/Departure, Route/Position, NOTAM, ATIS, Weather, Sighting, Traffic, General Acknowledgment
Request--Readback/Acknowledgment	Heading, Altitude, Speed, Approach/Departure, Route/Position, Type, NOTAM, Weather, Traffic, Say Again, General Acknowledgment
Non-Codable Remarks	Equipment, Delivery, Other

TABLE 3. Types of Irregular Communications in ATC/Pilot Transcripts

Types of IC	Code	Definition
Non-Standard Phraseology		
Grouped	G	Grouping of numerical information contrary to paragraph 2-85, FAA Order 7110.65G.
Sequential (Non-grouped)	N	Failure to group numbers in accordance with paragraphs 2-87, 2-88, 2-90, and non-use of the phonetic alphabet in accordance with paragraph 2-84, FAA Order 7110.65G.
Omission	O	Leaving out number(s), letter(s), word(s), prescribed in communication requirements in FAA Order 7110.65G.
Substitution	S	Use of word(s) or phrases(s) in lieu of communication outlined in FAA Order 7110.65G (e.g., "verify altitude" vs. "say altitude").
Transposition	T	Number(s) or word(s) used in the improper order (e.g., "Universal six forty-five" instead of "Universal five forty-six").
Excessive Verbiage	E	Adding word(s) or phrase(s) to communication outlined in FAA Order 7110.65G, and the communication suggested in the Aeronautical Information Manual (e.g., "Universal the number one airline six forty-five").
Partial Readback*	P	Pilot report or readback that does not include specific reference to a topic subject (e.g., altitude topic "out of six for four" would be recorded as a P.).
Delivery Technique		
Dysfluency	D	Pause(s), stammer(s), utterance(s), that add no meaning to the message (e.g., "uh," "ah," or "OK" when not used as a General Acknowledgment.
Misarticulation	M	Improperly spoken words (i.e., slurs, stutters, mumbling, etc.).

*Note: A verbatim readback of a controller's instruction or advisory would not be recorded as a P; nor would a readback containing a General Acknowledgment and the aircraft identifier.

codification of 290 communication elements within 120 transmissions by the SME and one of the authors of the ATSAT[7]. If their encoding of a communication element matched, it received a value of 1; otherwise a 0 was assigned. Percentage agreement was defined as:

$$\textbf{Percentage agreement} = \frac{\Sigma \text{ concordant pairs of communications elements}}{\Sigma \text{ communication elements}}$$

There was 98% agreement for segmentation of the entire message into identical communication elements and 96% agreement for classification of communication elements in the same speech act category **and** aviation topic.

The **identical** match criterion for IC codes was stringent. It required that both SMEs assigned a communication element the same type and number of IC codes. For example, there are two communication elements in the transmission, *"American (uh) five five one / fly heading zero one zero."* Both SMEs might encode the *"uh"* in the first communication element as a Dysfluency; and only one encode *"five five one"* as Sequential (non-grouped). In such a case, the communication element received a value of 0. There was 81% agreement for selection of the same IC code associated with a communication element.

3.0 RESULTS

The results of the analysis performed on the communication elements are presented in three sections. In Section 3.1, all of the communication elements are presented by speech act category. In Section 3.2, communication elements that contained irregular communications are presented by speech act category. In Section 3.3, the communication elements that contained irregular communications were analyzed according to their speech act category using non-parametric and descriptive statistics.

3.1 Analysis of Communication Elements

A total of 13,900 ATCS transmissions (TRACON-1: 6,100 and TRACON-2: 7,800) consisting of 33,000[8] communication elements from the simulation tapes were compared with field taped transmissions. There were 1,900 ATCS transmissions (TRACON-1: 1431 and TRACON-2: 469) consisting of 5,336 communication elements from the field tapes. All transmissions were analyzed in accordance with ATSAT_{cr} procedures (Prinzo et al., 1995). Table 4 presents the distribution of the total number of communication elements within each speech act category by tape source. The majority of communication elements appeared in the Address and Instruction followed by Advisory and Request speech act categories. Communication elements in the Courtesy and Non-Codable speech act categories were absent from the simulation transmissions and virtually absent from the field communications (5% and 4% respectively).

TABLE 4. Distribution of All Communication Elements Within Each Speech Act Category

Speech Act Category	FIELD TAPE (5,336)	SIMULATION TAPE (33,045)
Address	36%	47%
Instruction	36%	43%
Advisory	16%	9%
Request	2%	1%
Courtesy	5%	0%
Non-Codable	4%	0%

[7] Both coders were retired FPL controllers.

[8] For reading ease, numbers have been rounded. For an exact count, see Appendix A.

3.2 Analysis of Irregular Communication Elements

Nineteen percent of the simulation and 40% of the field tape databases contained **at least** one IC code (i.e., communication element with non-standard phraseology or irregular delivery technique). Table 5 shows the distribution of those irregular communication elements within each speech act category by tape source. The majority of communication elements that contained one or more irregularities involved the Instruction speech act category for both the field and simulated TRACON environments (55% and 52%). In comparing Address and Advisory speech act categories, there were more irregular communication elements that involved the Address speech act category produced in the simulated TRACON environment and more irregular communication elements that involved the Advisory speech act category produced at real TRACON facilities. For both TRACON environments, less than 5% of the irregular communication elements involved the Request speech act.

3.3 Analysis of Irregular Communications. The Wald-Wolfowitz Runs Test[9], a nonparametric test of the null hypothesis that two samples come from the same population, was used to determine whether the simulation and field tape data samples differed in any respect from one another. The Runs Test requires that data from both samples are combined, ranked from smallest to largest, and the number of runs[10] in the distribution counted. The computed value is compared to an expected value obtained from a statistical table in which various sample sizes and probabilities are presented. If the computed value is larger than the expected value, then the null hypothesis is rejected. When the null hypothesis is rejected, it indicates that the two groups differ in some measurable way. Separate Runs Tests were performed on the total number of Instruction, Advisory, and Request ICs with $p = .05$. Since the ATCSs' communications during simulation were expected be the same or similar to those on the field tape, it was expected that the Runs Tests would be non-significant.

Since each irregular communication element could contain a maximum of three IC codes, the total number of IC codes could exceed the number of irregular communication elements. Irregular Communication that involved the Courtesy and Non-Codable speech act categories accounted for less than 1% of the total distribution and were omitted from all figures. The percentage for each type of IC was calculated separately for field and simulation tapes using the formula presented below:

$$\textbf{Percentage Irregular Communications} = \frac{\Sigma \text{ Aviation Topic Speech Act IC}}{\Sigma \text{ Address ICs}}$$

TABLE 5. Distribution of Irregular Communication Elements Within Each Speech Act Category

Speech Act Category	FIELD TAPE (2,157)	SIMULATION TAPE (6,385)
Address	14%	28%
Instruction	55%	52%
Advisory	24%	17%
Request	4%	3%
Courtesy	0%	0%
Non-Codable	3%	0%

[9] For brevity, the Wald-Walfowitz Runs Test will be referred to as *The Runs Test.*

[10] Runs are defined as: any sequence of scores from the same group (either from the simulation or field tape).

For example, 34% of the (104/307) ICs within the Address speech act category involved the omission of part of the Receiver ID aviation topic from field tapes (see Appendix C).

3.3.1 Address. The data presented in Figure 2 indicate that the majority of Address ICs involved the receiver identification (i.e., aircraft call sign). It was expected that there would be considerably fewer ICs that involved the Speaker ID, especially since there are fewer sector names (i.e., Tower, Approach Control, Center) that are prefaced with location or facility names and sector functions (e.g., ground, local, departure, approach) when compared with the number and type of aircraft flying in terminal airspace daily.

A Runs Test performed on the frequency of each type of irregular communication for Receiver ID was significant, $r = 6$, $z = -1.702$, $p = .04$. As shown in Figure 3, there were proportionally more omissions on field tapes than on tapes from the simulation laboratory. The omitted information could be a word(s) such as "heavy," type, model, name, etc. or number(s). Following initial radar contact, controllers might reply to a second transmission by simply saying, "four three Charlie" instead of "November four three Charlie." In the field, pilots are more likely to respond to an abbreviated call sign and, controllers knowing this, will omit portions of the call sign as a strategy to minimize their time on an already congested radio frequency. Applying this strategy during simulated conditions was counter-productive. The computer's voice recognition system would fail, forcing the controller to repeat the transmission. Repeating the transmission added to the controller's workload and frequency congestion.

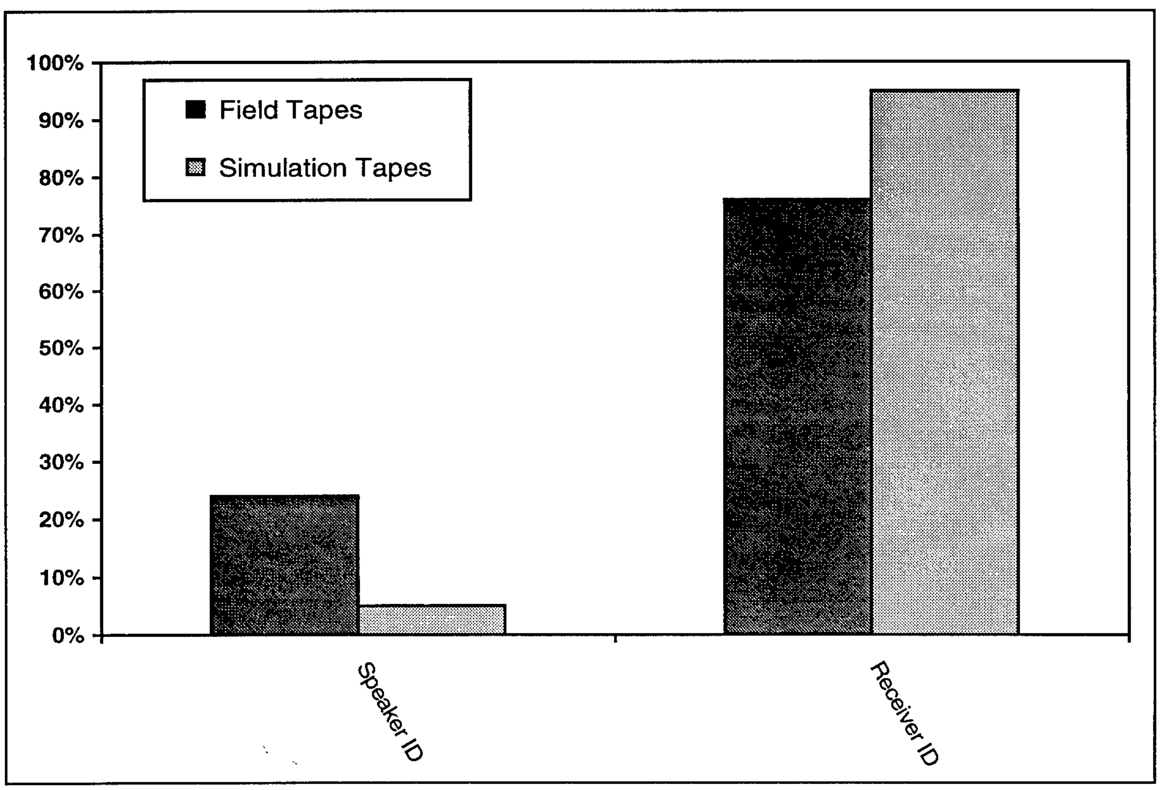

Figure 2. Distribution of Aviation Topics in the Address Speech Act Category That Contained Irregular Communications

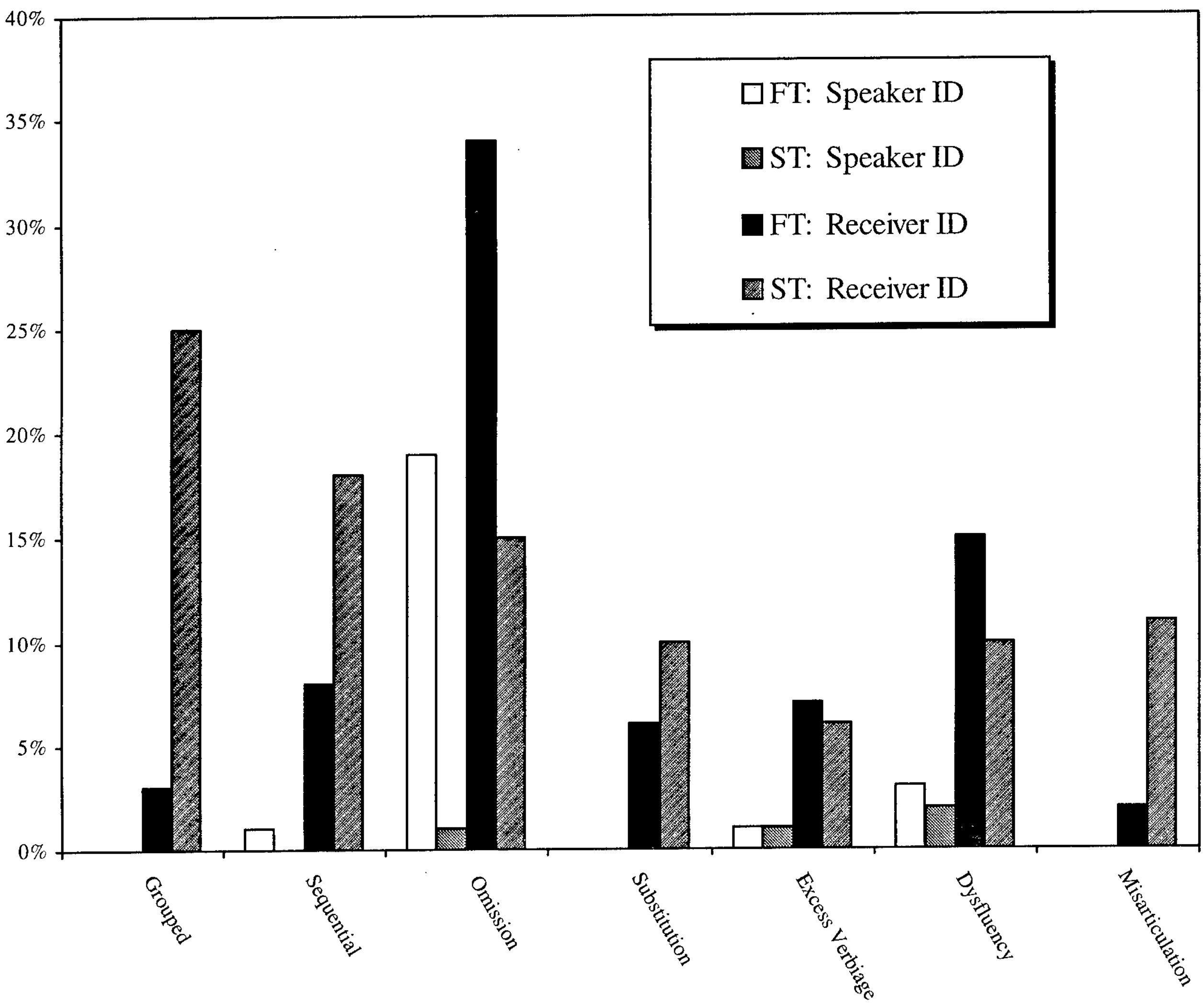

Figure 3. Distribution of Field and Simulation Address Irregular Communications

For simulated traffic, controllers made proportionally more ICs that involved how numbers were spoken[11]. For example, flight numbers in an air carrier's call sign are to be spoken in grouped format and for general aviation aircraft, the numbers of the aircraft registration are to be spoken sequentially. As stated in FAA Order 7110.65, "'Group form' is the pronunciation of a series of numbers as the whole number, or pairs of numbers they represent rather than pronouncing each separate digit [sic]." For example, a descent instruction to the pilot of SWA943 should have been spoken as "Southwest Nine Forty-three descend and maintain ...."

3.3.2Instruction. Figure 4 reveals that, for field communication, the majority of Instruction ICs involved Radio Frequency, Speed, and Heading aviation topics. For simulated communication, ICs occurred most frequently in the Approach/Departure, Radio Frequency, and Heading aviation topics. However, these differences were not statistically significant, $r = 11$, $z = -.218$, $p > .4$. Based on the outcome of the Runs Test, it was concluded that the simulation results were representative of the communication irregularities identified from field tapes.

A Runs Test was performed on the field- and simulation-tape distributions of IC codes (i.e., grouped, sequential, and so on). Overall, there was no

[11] See FAA Order 7110.65 2-4 *Aircraft Identification.*

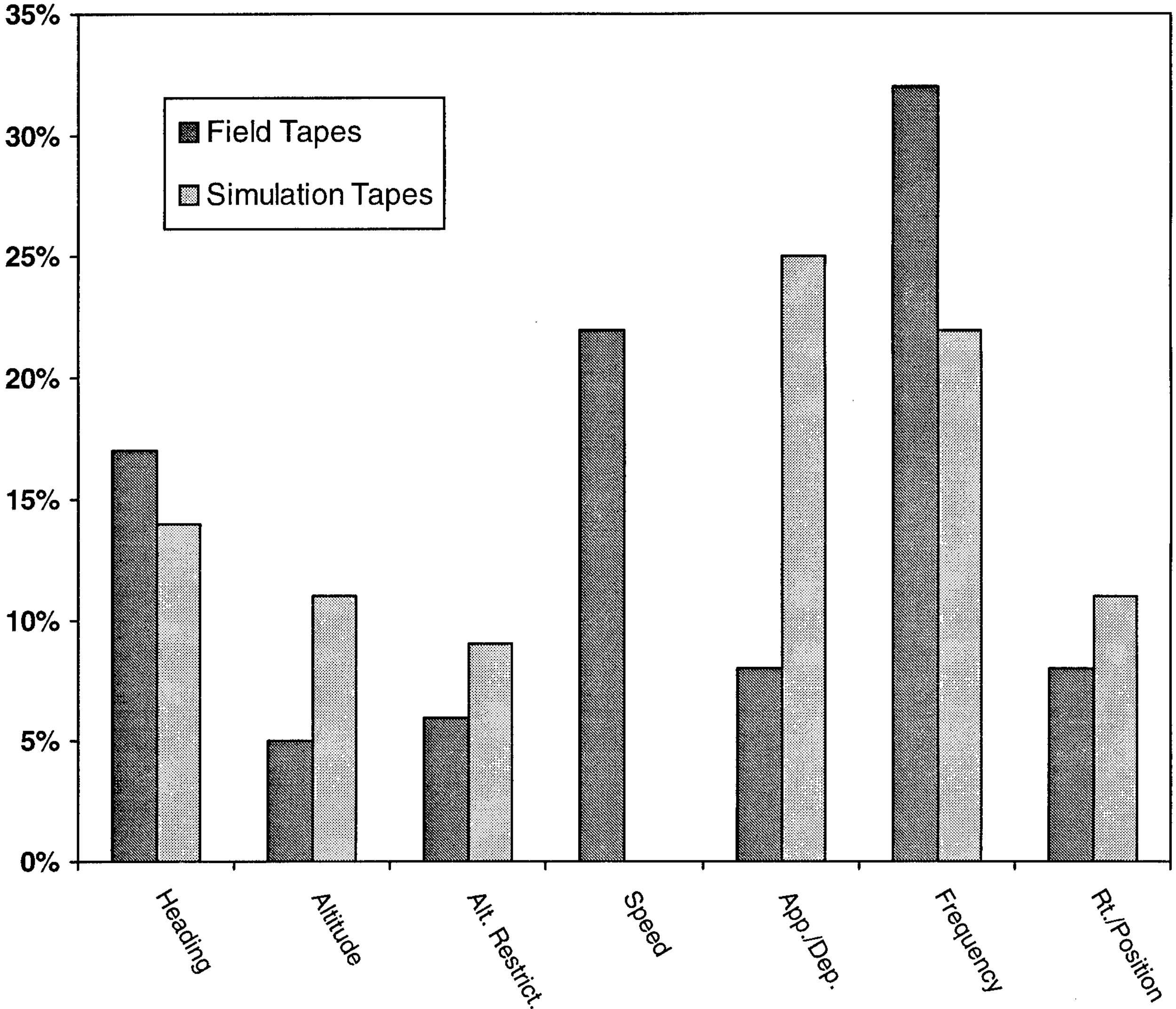

Figure 4. Distribution of Aviation Topics in the Instruction Speech Act Category that Contained Irregular Communications

significant difference in the two distributions, r = 8, z = -.729, p = .47. As shown in Figures 5 and 6, the most frequent IC involved the omission of part of a Radio Frequency. Other omissions involved Heading, Altitude, and Speed. In the transmission "American Fourteen Ninety Heavy contact approach," the controller failed to include the radio frequency in the transfer of communication. And in the transmission, "... expect localizer back course three five left approach," the controller omitted the word "runway" as part of the advance approach information.

3.3.3Advisory. As shown in Figure 7, Advisory ICs involving field tapes occurred most often in Approach/Departure, Weather, and Route/Position aviation topics. For simulated communication, Advisory ICs occurred most frequently in Sighting, Approach/Departure, and General Acknowledgment aviation topics. The Runs Test revealed that the distributions were not significantly different from one another r = 9, z = -1.092, p > .1, and it was concluded that the simulation results were representative of the communication problems identified from field tapes.

As shown in Figures 8 and 9, excess-verbiage was the most prevalent IC code for field and simulated communications. Omissions were higher on the field tapes because weather was a factor at one of the facilities and traffic was heavy. Under those conditions, controllers often would have additional demands placed on them by pilots who want to be vectored around weather cells. On one field tape,

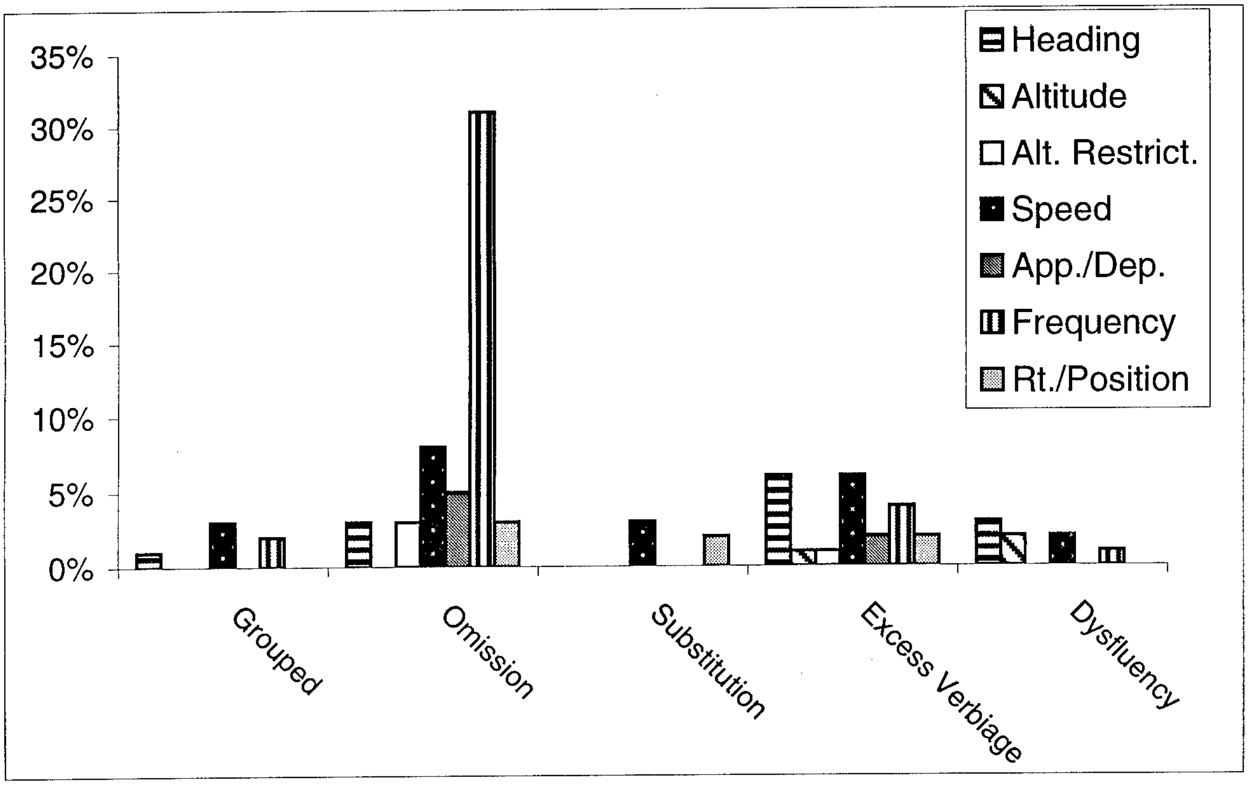

Figure 5. Field Tapes: Distribution of Instruction Irregular Communications

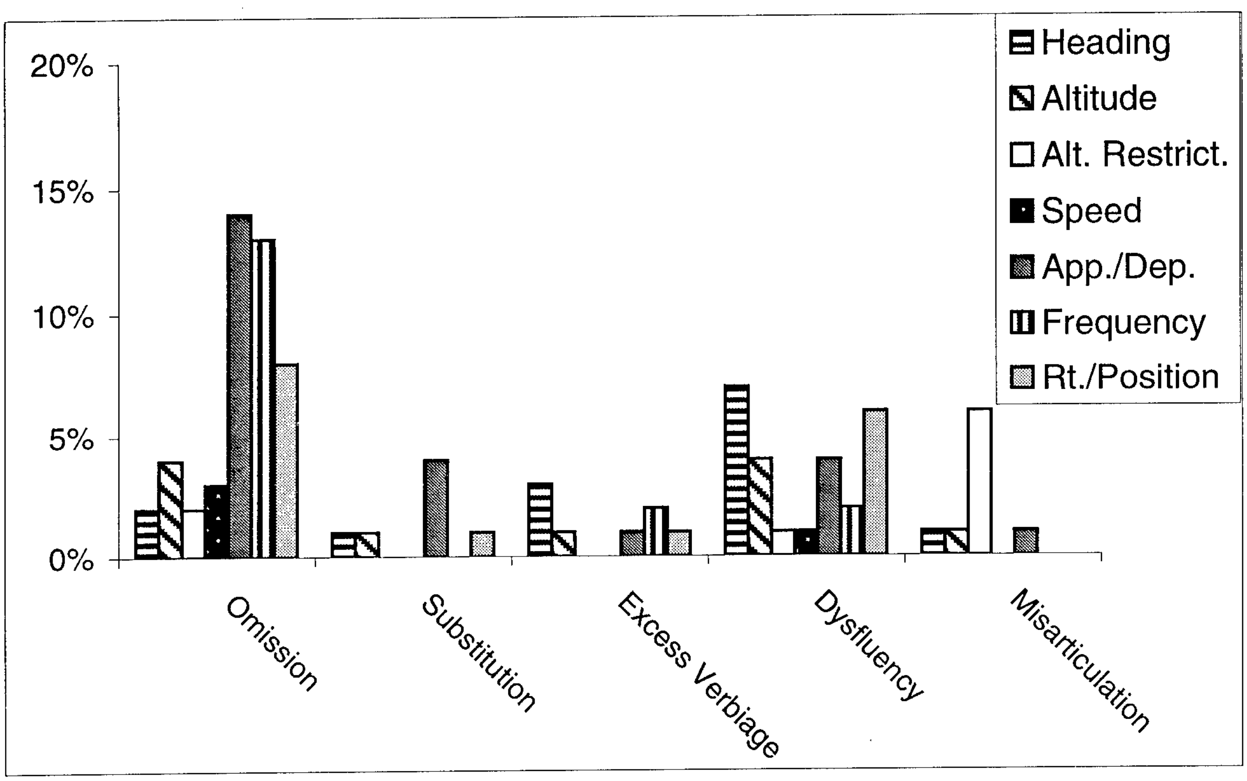

Figure 6. Simulation Tapes: Distribution of Instruction Irregular Communications

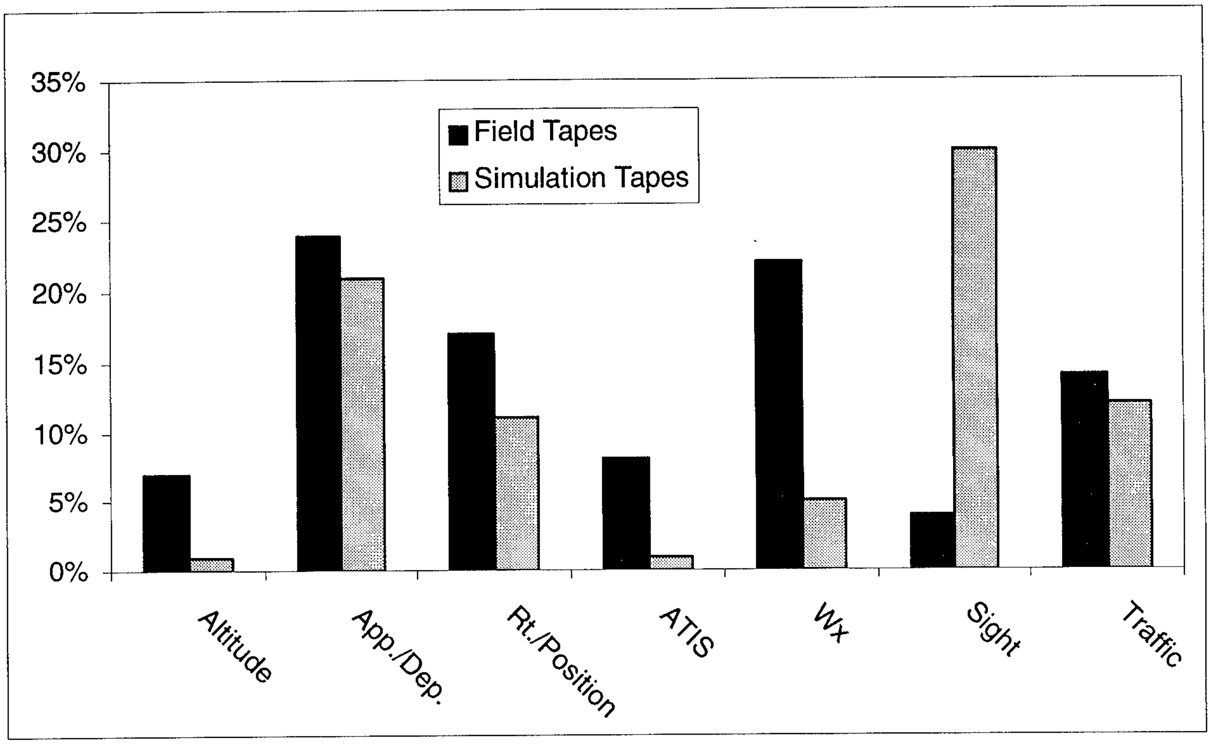

Figure 7. Distribution of Aviation Topics in the Advisory Speech Act That Contained Irregular Communications

moderate turbulence was reported by a pilot. As is often the case, other pilots who are listening in on the party line will use this information to avoid a "rough ride." Upon hearing other pilots' reports, they too will get on the radio frequency to either report current weather conditions and/or request deviations from their flight plan if weather seems to be a potential factor in their approved flight plans. These additional communications increase frequency congestion in an already complex situation and add to the controllers' workload. As an example of weather-related communications, a portion of communications between a controller and several different pilots is presented below.

"Company went through the weather [aircraft] straight ahead he said ten second [sic] of moderate turbulence the rest was light chop. [aircraft] approach roger I'm gonna let you find an area where you'd like to turn to the northwest and get through the weather uh company said there was ten seconds of moderate turbulence in the weather off to your right and the rest was light chop then a [aircraft] went through there and said that they were really getting down drafts in that. Roger [aircraft] ok thank you let me know how the ride is over the next five miles or so you should be west of that well about ten miles you should be west of the weather. Er [aircraft] you're eight miles behind [aircraft] increase to two zero zero if you like. If the weather permits [aircraft] the [airport] weather is five thousand scattered higher ceiling broken visibility one five wind three four zero at six altimeter two niner seven six expect runway three four right or left."

Although weather was not a factor in the simulation study, the ghost pilot did request a speed reduction because of mild chop. In the transmission, "American Thirteen Eighty- One Heavy, you can expect visual runway three five right approach," the phrase "you can" was coded as excess-verbiage. Since other ghost pilots were not present to make similar

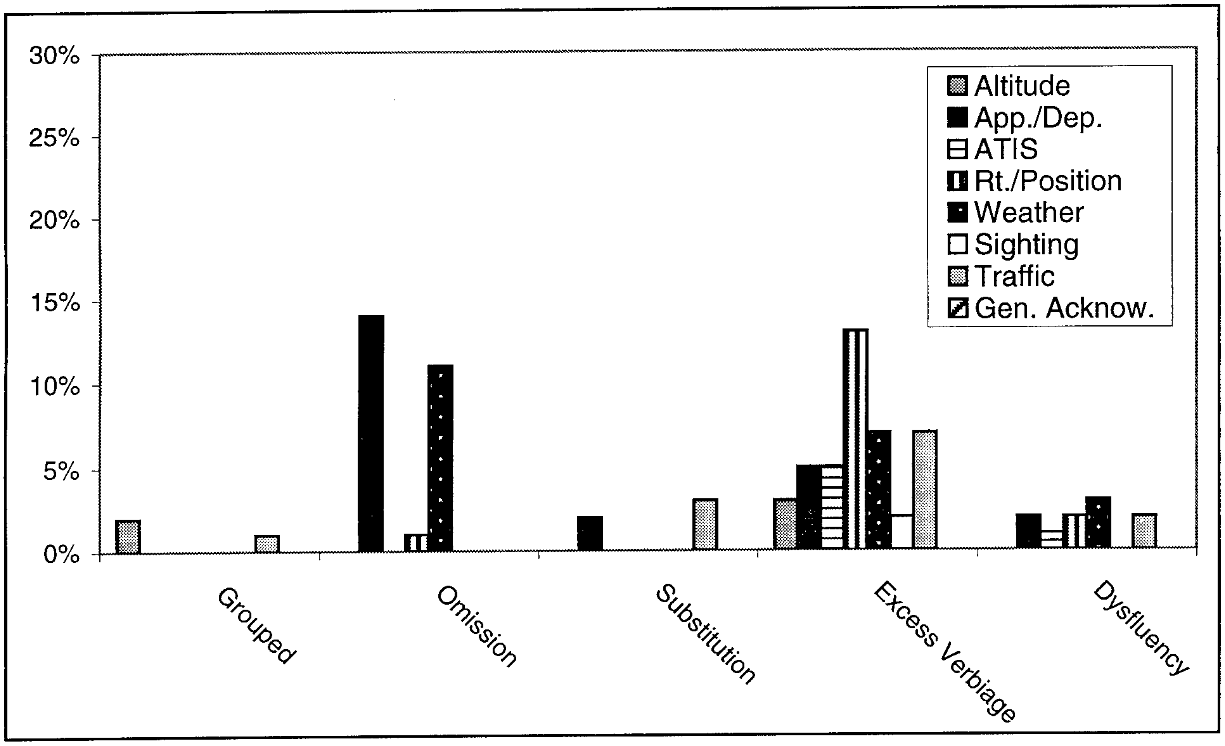

Figure 8. Field Tapes: Distribution of Advisory Irregular Communications

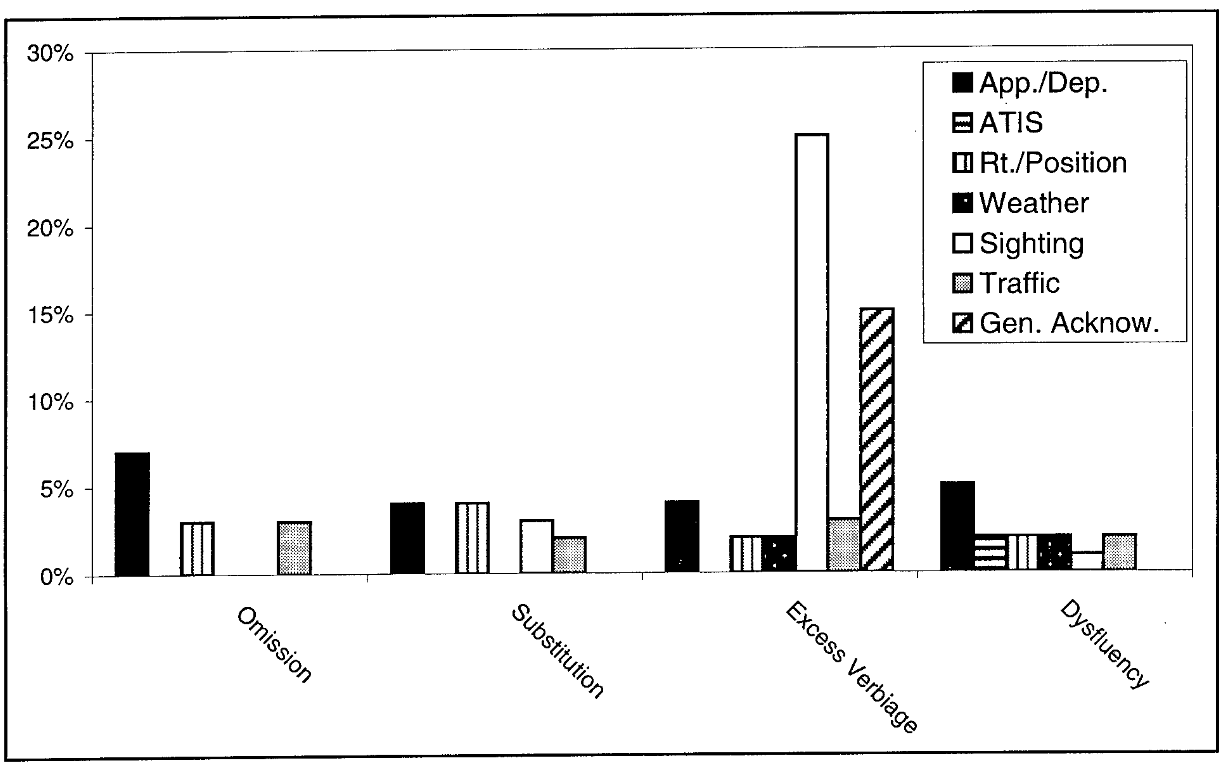

Figure 9. Simulation Tapes: Distribution of Advisory Irregular Communications

requests of the controller, there were fewer opportunities for the controller to issue deviations due to weather. A Runs Test performed on the field- and simulation distributions of irregular communication codes (e.g., grouped, sequential, and so on) was not significant, r = 10, z = 0, p = 1.0. This result indicated that, overall, there was no statistical difference in the types of irregular communications produced by controllers whether in the field or simulation laboratory.

3.3.4Request. It is important to remember that only 2% of <u>all</u> the communication elements made by controllers in the field and in the simulation laboratory involved Requests, and only 3-4% contained ICs. Figure 10 shows that, for field tapes, the majority of controller Request ICs involved Speed and Altitude aviation topics. For simulated communication, the majority of aviation topics involved General Acknowledgment followed by Approach/Departure and Altitude aviation topics. The Runs Test revealed that the distributions were not significantly different $r = 8$, $z = 0, p > .6$, and it was concluded that the simulation results were representative of the communication problems identified from field tapes.

Given the small number of irregular communications it was not possible to perform a Runs Test on the two distributions of types of irregular communications. As shown in Figure 11, the majority of the field ICs involved substitutions and/or excess-verbiage (36% Substitutions and 38% Excess-verbiage summed across aviation topic). For example, in the transmission, "American Fourteen Zero Eight Heavy *verify* heading," "verify" was coded as a substitution for the word "say." The controller should have said, "American Fourteen Zero Eight Heavy, *say* heading." Figure 12 shows that, for simulated communications, 37% of the excess-verbiage ICs involved General Acknowledgments.

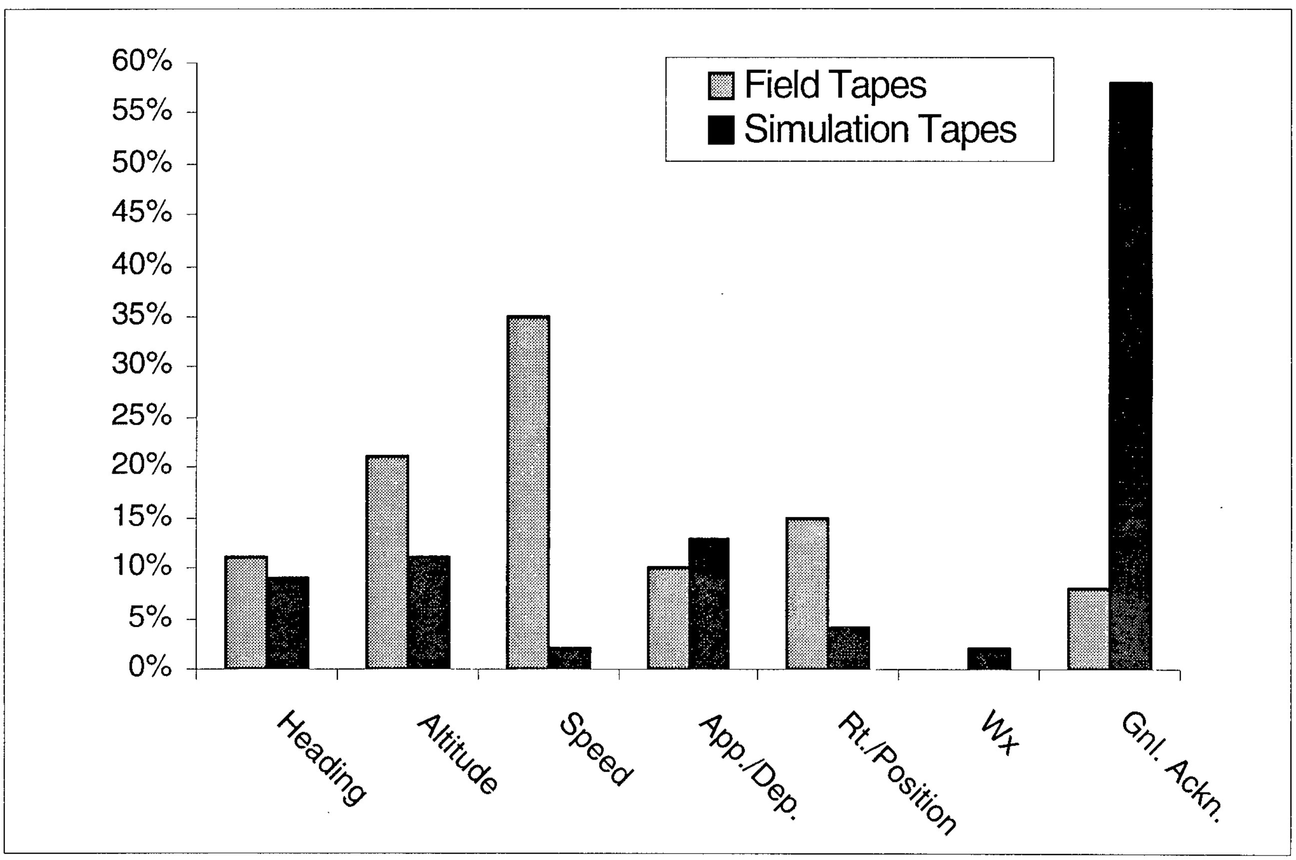

Figure 10. Distribution of Aviation Topics in the Request Speech Act Category That Contained Irregular Communications

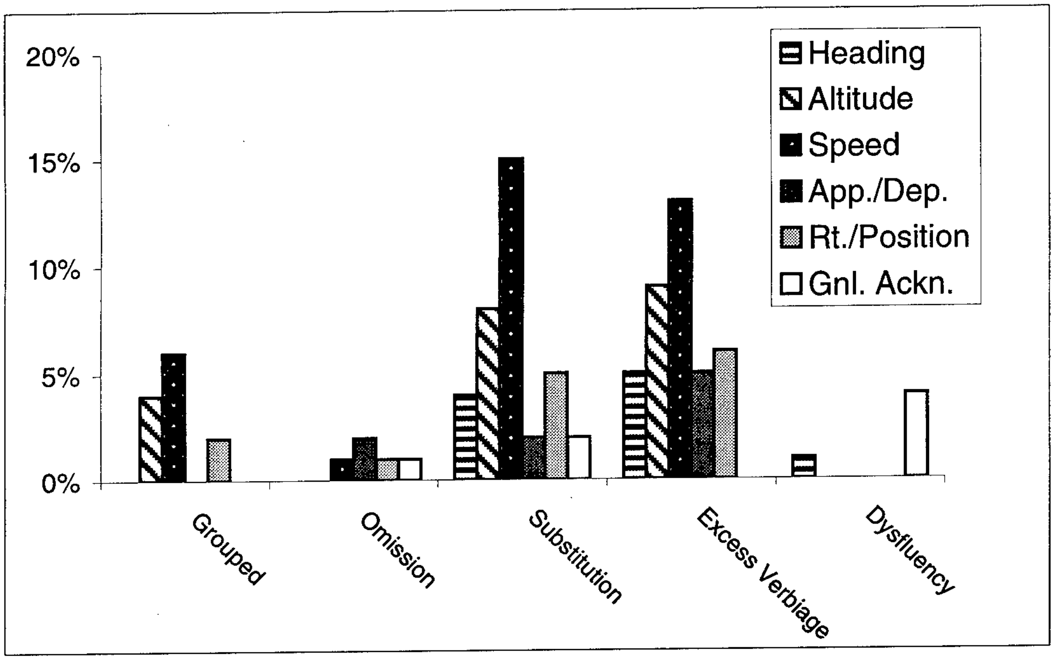

Figure 11. Field Tapes: Distribution of Request Irregular Communications

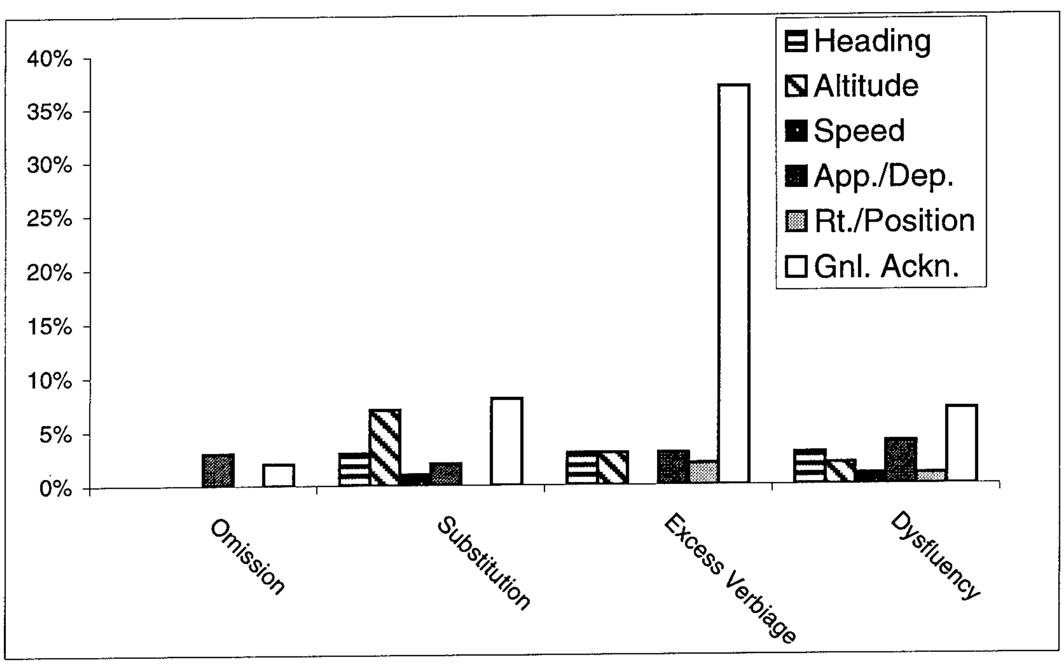

Figure 12. Simulation Tapes: Distribution of Request Irregular Communications

4.0 DISCUSSION

Following the installation of radio communications equipment in the Cleveland, Ohio control tower in 1936, radio communication became the primary means of relaying information between controller and pilots in the domestic air traffic control system. Communication is an integral component in an air traffic controller's ability to maintain separation between aircraft and obstacles. A standard phraseology was developed by the FAA to ensure that miscommunication was kept to a minimum. Likewise, to reduce the possibility of mishearing similarly sounding numbers and/or letters, a standard for pronunciation was developed. Both are included in *FAA Order 7110.65 Air Traffic Control.* This standard was applied to the analysis of controller communication derived from field and simulation tapes that were transcribed verbatim.

There were three sets of analyses performed on the data. The overall analysis of all communication elements revealed the percentages of Address, Instruction, Advisory, and Request speech acts within each database to be very similar. Only Courtesy and Non-codable communication elements were present on field tapes. Courtesy speech acts often signaled pilots that the transaction was completed (much like saying good-bye) and radio communication switched to another controller. Courtesy speech acts during simulation were misinterpreted by the Verbex voice recognition system and controllers were provided the opportunity to experience this first-hand during training. It is not surprising that Non-codable communication elements appeared on field tapes because tapes become unclear and unintelligible as they are reused and then duplicated onto recycled cassettes. Simulated communication was always recorded onto new cassette tapes.

The second set of analyses examined only irregular communication elements. The primary difference between field and simulation communication was that there were 21% fewer irregular communications produced by controllers during simulation than in the field. There are several reasons why this occurred. First, although controllers are required to use FAA standard phraseology in the field, this requirement was stressed by the SME during Verbex voice training and practice using the TRACONsim. Also, a note was posted at the workstation to remind the controller to use required phraseology. Second, controllers knew the Verbex voice recognition system would not work properly unless that standard was applied throughout the simulation. Third, prior to the onset of the first simulation, each controller received extensive practice with the voice recognition system and the opportunity to correct irregular communication; and lastly, controllers were aware that their communication would be audio- and video-recorded. Results of studies on social facilitation, brought on by the observation of behavior by spectators (i.e., audience effects), indicated that when participants knew they were being observed on tasks in which they were skilled, their vigilance and performance improved (Triplett, 1897; see the review article by Zajonc, 1965). Knowing that they were being recorded contributed to the improved performance of controllers in this study. The secondary finding, revealed by the Runs Tests, was that the distributions of irregular communication elements (distributions of aviation topics) within each of the speech act categories were not significantly different for field and simulation communications. Thus, although there were fewer irregular communication elements that were produced under simulated conditions, the distribution of those elements were much the same as those in the field.

The final set of analyses examined the field- and simulation tape distributions of the 8 types of irregular communication codes (grouped, sequential, and so on). Given the type and complexity of the irregular communications, only a global test was performed on the Receiver ID aviation topic, and the Instruction, and Advisory speech act categories. Requests were excluded because there was insufficient data with which to perform an analysis. Only the distribution of irregular communication codes for Receiver ID differed from the field communications. This finding is easily explained. In the field, controllers know that pilots will communicate with them even if a portion of the aircraft call sign is omitted[12]. During simulation training, controllers quickly learned that omitting a part of the aircraft call sign often required them to re-transmit the entire message. The Verbex voice recognition system was less forgiving than a pilot. Knowing that omitting a portion of the aircraft call sign would increase their workload was effective in reinforcing the importance of including the entire call sign in a message.

[12] Often, while pilots are listening on their assigned radio frequency, they will question the controller about a transmitted message if the numbers in the call sign are similar to their own.

5.0 CONCLUSION

The overall research findings indicated the controllers generally communicate with the simulation pilots in ways that are consistent with how they communicate with pilots at their TRACON facilities. Although there were proportionately fewer irregular communication elements produced during simulation, the distribution of those irregularities was consistent with those produced in the field. This conclusion also holds true of irregular communication codes for Instruction and Advisory speech act categories. Simulation can be a useful tool to address issues associated with the effects of changes in procedures and technology on the communication process.

The use of voice recognition technology can be instrumental in teaching and reinforcing basic air traffic control phraseology as demonstrated by the fewer irregular communications produced by controllers once trained on the VERBEX voice recognition system. A limitation of the technology is that it is not advanced enough to accommodate everyday language usage. Sometimes it is necessary for controllers to restate numbers spoken sequentially in a call sign, instruction, advisory, or request in a grouped format for emphasis or clarification. Although pilots easily understand what is spoken, current voice recognition capabilities lag behind.

6.0 REFERENCES

Airman's Information Manual, Official Guide to Basic Flight Information and ATC Procedures. (1994). Washington, DC: US Government Printing Office.

Brenner, M., Doherty, E.T., & Shipp, T. (1994). Speech measures indicating workload demand. *Aviation, Space, & Environmental Medicine*, 65, pp. 21-6.

Brenner, M., Shipp, T.T., Doherty, T., & Morrissey, P. (1985). In I.R. Titze and R.C. Scherer (eds.), *Vocal fold physiology, biomechanics, acoustics, and phonatory control.* Denver: The Denver Center for the Performing Arts, pp. 239-48.

Burke-Cohen, J. (1995). *An analysis of tower (ground) controller-pilot voice communications* Washington, DC: US Department of Transportation, Office of Research and Development Report DOT/FAA/AR-95/19.

Cardosi, K.M. (1993). *An analysis of en route controller-pilot voice communications.* Washington, DC: US Department of Transportation, Office of Research and Development Report DOT/FAA/AR-93/11.

Cardosi, K.M., Brett, B., & Han, S. (1996). *An analysis of TRACON (Terminal Radar Approach Control) controller-pilot voice communications.* Washington, DC: US Department of Transportation, Office of Research and Development Report DOT/FAA/AR-96/7.

FAA Order 7110.65G Air Traffic Control. (March, 1992). Washington, DC: Air Traffic Rules and Procedures Service.

FAA Order 7110.65H Air Traffic Control. (September, 1993). Washington, DC: Air Traffic Rules and Procedures Service.

Griffin, G.R., & Williams, C.E. (1987). The effects of different levels of task complexity on three vocal measures. *Aviation, Space, & Environmental Medicine*, 58, pp. 1165-70.

Helmreich, R.L. (1994). Anatomy of a System Accident: The Crash of Avianca Flight 052. *International Journal of Aviation Psychology*, 4, pp. 265-84.

Kanki, B.G., & Foushee, H.C. (1989). Communication as group process mediator of aircrew performance. *Aviation, Space, and Environmental Medicine, 60*, pp. 402-10.

Kanki, B.G., & Prinzo, O.V. (1996). *Methods and Metrics of Voice Communications*, Washington, DC: Federal Aviation Administration, Office of Aviation Medicine Technical Report DOT/FAA/AM-96/10, Available from: National Technical Information Service, Springfield, VA 22161; ordering no. ADA307148.

Lieberman, P., Protopapas, A., & Kanki, B.G. (1995). Speech production and syntax comprehension deficits on Mt. Everest. *Aviation, Space, and Environmental Medicine, 9*, pp. 857-69.

Mayer, D.L., Brenner, M., & Cash, J.R. (1996) Development of a Speech Analysis Protocol for Accident Investigation. In B.J. Kanki & O.V. Prinzo (eds.) *Methods and metrics of voice communications.* Washington, DC: Federal Aviation Administration, Office of Aviation Medicine Technical Report DOT/FAA/AM-96/10. Available from: National Technical Information Service, Springfield, VA 22161; ordering no. ADA307148.

Morrison, R., & Wright, R.H. (1989). ATC controls and communications problems: An overview of recent ASRS data. In R.S. Jensen (ed.,) *Proceedings of the Fifth International Symposium of Aviation Psychology*, Columbus, OH: The Ohio State University, pp. 902-07.

Morrow, D., Lee, A., & Rodvold, M. (1993). Analyzing problems in routine controller-pilot communication. *International Journal of Aviation Psychology, 3*, pp. 285-302.

Morrow, D., Rodvold, M. & Lee, A. (1994). Nonroutine transactions in controller-pilot communication. *Discourse Processes*, 17, pp. 235-58.

Predmore, S. (1991). Microcoding of communications in accident investigation: Crew coordination in United 811 and United 232. In R.S. Jensen (ed.), *Proceedings of the Sixth International Symposium on Aviation Psychology*. Columbus OH: The Ohio State University, pp. 350-55.

Prinzo, O.V. (1996). *An analysis of approach control/pilot voice communications*. Washington, DC: Federal Aviation Administration, Office of Aviation Medicine Technical Report, DOT/FAA/AM-96/26. Available from: National Technical Information Service, Springfield, VA 22161; ordering no. ADA317528.

Prinzo, O.V. & Britton, T.W. (1993). *ATC/pilot voice communications: A survey of the literature*. Washington, DC: Federal Aviation Administration, Office of Aviation Medicine Technical Report DOT/FAA/AM-93/20. Available from: National Technical Information Service, Springfield, VA 22161; ordering no. ADA274457.

Prinzo, O.V., Britton, T.W., & Hendrix, A.M. (1995). *Development of a coding form for approach control/pilot voice communications*. Washington, DC: Federal Aviation Administration, Office of Aviation Medicine Technical Report DOT/FAA/AM-95/15. Available from: National Technical Information Service, Springfield, VA 22161; ordering no. ADA295009.

Prinzo. O.V. & MacLin, O. (1996). *Aviation topics speech acts taxonomy (ATSAT)pc user's guide version 2.0.* . Washington, DC: Federal Aviation Administration, Office of Aviation Medicine Technical Report, DOT/FAA/AM-96/20. Available from: National Technical Information Service, Springfield, VA 22161; ordering no. ADA314179.

Prinzo, Lieberman, and Pickett (in review). *An acoustic analysis of ATC communication*. Washington, DC: Federal Aviation Administration, Office of Aviation Medicine Technical Report.

Searle, J.R. (1969). *Speech Acts*. London: Cambridge University Press.

Zajonc, R.B. (1965). Social facilitation. *Science*, 149, 269-74.

APPENDIX A

Total Number of Communication Elements

DATA SOURCE	SPEECH ACT CATEGORY						TOTAL
	ADDRESS	INSTRUCTION	ADVISORY	REQUEST	COURTESY	NON-CODABLE	
FIELD TAPE	1,926	1,940	875	130	240	225	5,336
SIMULATION	15,504	14,148	2,879	336	29	49	33,045

APPENDIX B

Total Number of Irregular Communications Within Each Speech Act Category

DATA SOURCE	SPEECH ACT CATEGORY						TOTAL
	ADDRESS	INSTRUCTION	ADVISORY	REQUEST	COURTESY	NON-CODABLE	
FIELD TAPE	307	1,177	507	82	10	74	2,157
SIMULATION	1,815	3,282	1,083	192	8	5	6,385

APPENDIX C

Percentages of Types of Irregular Communications by Aviation Topics Within Each Speech Act Category

AVIATION TOPIC AND DATA SOURCE	ADDRESS SPEECH ACT – TYPES OF IRREGULAR COMMUNICATIONS																		TOTAL	
	Non-Standard														Delivery Technique					
	Grouped		Sequential		Omission		Substitution		Transposition		Excess Verbiage		Partial Readback		Dysfluency		Misarticulation			
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	N	
FIELD TAPE																				
Speaker ID	0	.00	3	.01	59	.19	1	.00	0	.00	4	.01	0	.00	8	.03	0	.00	75	.24
Receiver ID	10	.03	23	.08	104	.34	18	.06	0	.00	23	.07	1	.00	47	.15	6	.02	232	.76
																			307	1.00
SIMULATION																				
Speaker ID	3	.03	0	.00	19	.01	5	.00	0	.00	28	.01	0	.00	30	.02	6	.00	91	.05
Receiver ID	425	.25	318	.18	274	.15	185	.10	23	.01	106	.06	2	.00	184	.10	207	.11	1724	.95
																			1815	1.00

AVIATION TOPIC AND DATA SOURCE	INSTRUCTION/CLEARANCE SPEECH ACT — TYPES OF IRREGULAR COMMUNICATIONS																		
	Non-Standard														Delivery Technique				TOTAL
	Grouped		Sequential		Omission		Substitution		Transposition		Excess Verbiage		Partial Readback		Dysfluency		Misarticulation			
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	N	%
FIELD TAPE																				
Alt. Restriction	2	.00	0	.00	33	.03	9	.00	0	.00	16	.01	5	.00	5	.00	0	.00	70	.06
Altitude	0	.00	0	.00	6	.00	8	.00	0	.00	17	.01	8	.00	24	.02	0	.00	63	.05
Approach/ Departure	1	.00	0	.00	61	.05	3	.00	0	.00	26	.02	4	.00	3	.00	0	.00	98	.08
Frequency	23	.02	0	.00	365	.31	9	.00	0	.00	53	.04	15	.01	11	.01	2	.00	378	.32
Gen. Acknow	0	.00	0	.00	0	.00	0	.00	0	.00	1	.00	0	.00	1	.00	0	.00	2	.00
H. Modification	1	.00	0	.00	1	.00	2	.00	0	.00	4	.00	0	.00	0	.00	0	.00	8	.00
Heading	13	.01	0	.00	40	.03	8	.00	1	.00	65	.06	28	.02	41	.03	0	.00	196	.17
Route/Position	0	.00	0	.00	43	.03	18	.02	0	.00	22	.02	2	.00	6	.00	0	.00	91	.08
Speed	34	.03	0	.00	92	.08	33	.03	0	.00	65	.06	8	.00	22	.02	0	.00	254	.22
Transponder	0	.00	0	.00	2	.00	5	.00	0	.00	6	.00	0	.00	2	.00	0	.00	15	.01
Holding	0	.00	0	.00	0	.00	0	.00	0	.00	2	.00	0	.00	0	.00	0	.00	2	.00
																			1175	.99
SIMULATION																				
Alt. Restriction	0	.00	0	.00	80	.02	16	.00	1	.00	1	.00	0	.00	21	.01	186	.06	305	.09
Altitude	0	.00	0	.00	131	.04	19	.01	1	.00	33	.01	2	.00	145	.04	39	.01	370	.11
Approach/ Departure	0	.00	0	.00	466	.14	126	.04	5	.00	48	.01	8	.00	135	.04	20	.01	808	.25
Frequency	4	.00	17	.01	429	.13	3	.00	0	.00	63	.02	0	.00	50	.02	11	.00	719	.22
Gen. Acknow	0	.00	0	.00	3	.00	0	.00	1	.00	12	.00	0	.00	3	.00	0	.00	20	.00
H. Modification	0	.00	0	.00	0	.00	0	.00	0	.00	1	.00	0	.00	1	.00	0	.00	2	.00
Heading	6	.00	9	.00	54	.02	27	.01	6	.00	10 6	.03	5	.00	231	.07	25	.01	468	.14
Route/Position	0	.00	0	.00	276	.08	40	.01	0	.00	14	.00	0	.00	198	.06	4	.00	353	.11
Speed	15	.01	6	.00	114	.03	26	.01	0	.00	22	.01	2	.00	38	.01	9	.00	232	.07
Transponder	0	.00	0	.00	0	.00	1	.00	0	.00	1	.00	0	.00	3	.00	0	.00	5	.00
Holding	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
																			3282	.99

AVIATION TOPIC AND DATA SOURCE	ADVISORY/REMARKS SPEECH ACT — TYPES OF IRREGULAR COMMUNICATIONS — Non-Standard: Grouped		Sequential		Omission		Substitution		Transposition		Excess Verbiage		Partial Readback		Delivery Technique: Dysfluency		Misarticulation		TOTAL	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	N	%
FIELD TAPE																				
Altitude	8	.02	0	.00	1	.00	2	.00	0	.00	13	.03	6	.01	4	.00	0	.00	34	.07
Approach/ Departure	3	.00	0	.00	73	.14	11	.02	0	.00	26	.05	2	.00	8	.02	0	.00	122	.24
ATIS	0	.00	0	.00	5	.00	4	.00	0	.00	25	.05	0	.00	6	.01	0	.00	40	.08
Gen. Acknow	0	.00	0	.00	0	.00	0	.00	0	.00	2	.00	0	.00	5	.00	0	.00	7	.01
Gen. Sighting	0	.00	0	.00	3	.00	3	.00	0	.00	10	.02	0	.00	3	.00	0	.00	19	.04
Heading	1	.00	0	.00	0	.00	1	.00	0	.00	5	.00	0	.00	1	.00	0	.00	8	.01
Route/Position	1	.00	0	.00	6	.01	3	.00	0	.00	64	.13	0	.00	11	.02	1	.00	86	.17
Speed	2	.00	0	.00	1	.00	0	.00	0	.00	1	.00	0	.00	0	.00	0	.00	4	.00
Traffic	6	.01	0	.00	4	.00	13	.03	1	.00	36	.07	0	.00	10	.02	1	.00	71	.14
Weather	0	.00	0	.00	57	.11	2	.00	0	.00	36	.07	0	.00	17	.03	0	.00	112	.22
NOTAM	0	.00	0	.00	0	.00	0	.00	0	.00	3	.00	0	.00	1	.00	0	.00	4	.00
																			507	.98
SIMULATION																				
Altitude	0	.00	0	.00	1	.00	1	.00	0	.00	4	.00	0	.00	3	.00	0	.00	9	.01
Approach/ Departure	1	.00	0	.00	80	.07	43	.04	0	.00	43	.04	0	.00	54	.05	10	.01	231	.21
ATIS	0	.00	0	.00	0	.00	2	.00	0	.00	3	.00	0	.00	2	.00	0	.00	9	.01
Gen. Acknow	0	.00	0	.00	5	.00	1	.00	0	.00	164	.15	0	.00	26	.02	0	.00	196	.18
Gen. Sighting	0	.00	0	.00	5	.00	28	.03	0	.00	268	.25	0	.00	14	.01	5	.00	320	.30
Heading	0	.00	0	.00	4	.00	4	.00	0	.00	1	.00	0	.00	0	.00	0	.00	9	.01
Route/Position	1	.00	0	.00	31	.03	39	.04	3	.00	25	.02	0	.00	19	.02	0	.00	118	.11
Speed	0	.00	0	.00	0	.00	0	.00	0	.00	2	.00	0	.00	0	.00	0	.00	2	.00
Traffic	4	.00	6	.00	38	.03	22	.02	2	.00	35	.03	0	.00	21	.02	3	.00	131	.12
Weather	0	.00	0	.00	7	.00	0	.00	1	.00	22	.02	0	.00	24	.02	4	.00	58	.05
NOTAM	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
																			1083	1.00

AVIATION TOPIC AND DATA SOURCE	REQUEST SPEECH ACT — TYPES OF IRREGULAR COMMUNICATIONS																		TOTAL	
	Non-Standard														Delivery Technique					
	Grouped		Sequential		Omission		Substitution		Transposition		Excess Verbiage		Partial Readback		Dysfluency		Misarticulation			
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	N	%
FIELD TAPE																				
Altitude	3	.04	0	.00	0	.00	7	.08	0	.00	7	.09	0	.00	0	.00	0	.00	17	.21
Approach/Departure	0	.00	0	.00	2	.02	2	.02	0	.00	4	.05	0	.00	0	.00	0	.00	8	.10
Gen. Acknow	0	.00	0	.00	1	.01	2	.02	0	.00	0	.00	1	.01	3	.04	0	.00	7	.08
Heading	0	.00	0	.00	0	.00	3	.04	0	.00	4	.05	1	.01	1	.01	0	.00	9	.11
Route/Position	2	.02	0	.00	1	.01	4	.05	0	.00	5	.06	0	.00	0	.00	0	.00	12	.15
Speed	5	.06	0	.00	1	.01	12	.15	0	.00	11	.13	0	.00	0	.00	0	.00	29	.35
Weather	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00	0	.00
																			82	1.00
SIMULATION																				
Altitude	0	.00	0	.00	0	.00	14	.07	1	.00	5	.03	0	.00	4	.02	1	.00	22	.11
Approach/Departure	0	.00	0	.00	5	.03	3	.02	0	.00	5	.03	0	.00	7	.04	3	.02	25	.13
Gen. Acknow	0	.00	0	.00	4	.02	16	.08	0	.00	72	.37	0	.00	14	.07	2	.01	111	.58
Heading	0	.00	0	.00	1	.00	5	.03	0	.00	6	.03	0	.00	5	.03	1	.00	18	.09
Route/Position	0	.00	0	.00	1	.00	1	.00	0	.00	3	.02	0	.00	2	.01	1	.00	8	.04
Speed	0	.00	0	.00	0	.00	2	.01	0	.00	0	.00	0	.00	2	.01	0	.00	4	.02
Weather	0	.00	0	.00	1	.00	0	.00	0	.00	1	.00	0	.00	2	.01	0	.00	4	.02
																			192	.99

☆U.S. GOVERNMENT PRINTING OFFICE: 1998 -660-088/60085