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The ATIS Message: A Study in One-Way Communication

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This thesis was prepared under the direction of the candidate's thesis committee chairman, Dr. John A Wise, Center for Aviation /Aerospace Research and Department of Aeronautical Science, and has been approved by members of his thesis committee. It was submitted to the Office of Graduate Programs and was accepted in partial fulfillment of the requirements for the degree of Master of Aeronautical Science.

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Abstract

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The purpose of this study was to explore the effects of high fidelity digital voice transmission, some aspects of information processing and the effect of short-term memory and long-term memory on one-way verbal communication. The experiment consisted of one realistic scenario with each of the twenty-four subjects involved recording on paper each of the sixteen Automatic Terminal Information Serice (ATIS) messages that they heard. Each subject heard each message one time, and the listening devices used were changed after four messages. The ATIS message consists of eleven item groups of information. The results were viewed in group, number, and word errors. The largest error was the error of omission, and the most errors were found in message item 11 of the remarks section. The lengthy and complex remarks section overtaxed the capacity of the short term memory and resulted in large numbers of omission errors.

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Introduction

Verbal communication is a vital aspect of the air transportation system. Errors in communication may be costly in property and life. The Federal Aviation Administration (FAA) is concerned with verbal communication because the results of miscommunication can be catastrophic to flight crews, passengers in the air and to the population on the ground. Verbal communication can be one-way, such as the Automatic Terminal Information Service (ATIS); or verbal communication can be two-way, such as the communication between flight crew and clearance delivery.

The pilot has many tasks in flight and on the ground. The mental process of listening and recording an ATIS message by the pilot involves many considerations including short-term and long-term memory. Understanding the basics of speech and speech intelligibility are additional considerations to good verbal communication.

Statement of the Problem

Approximately seventy percent of aviation accidents are attributed to human factor errors. Miscommunication is often a factor in some of those accidents. This study will attempt to illuminate one area of communication that may be of concern.

Review of Related Literature

Preview of Literature Review

The one-way communication of an ATIS message can be understood effectively by studying the many parts that comprise verbal communication and the environment in which it exists, especially the aviation environment. The basic element of verbal communication is sound. Frequency and amplitude are elements of sound that are explained along with the measurement units of Hertz and decibel. Hearing is second in importance only to vision from a flight physiological sense. Noise is defined and the role that noise plays in verbal communication in aviation is explained. Masking is defined and the relationship of noise and hearing are studied. Two types of hearing tests for pilots are mentioned.

Language is both a system that allows individuals to communicate with each other and a system of responses. Language is composed of a variety of sounds that are described. Speech intelligibility is the amount to which a speech message is correctly comprehended. The parts of a communication system are mentioned and discussed so that communication and intelligibility are understood. The steps of information processing are listed. The three stages of this processing are sensory storage, working or short term memory, and long term memory. Understanding these three stages and the relationship that they have with each other is an important step toward understanding and achieving effective communication. Sound, language and speech, and information processing have been explored in order to understand an effective verbal communication. The ATIS message is described in detail and it is the type message used in this study. Verbal communication errors are viewed in an effort to see where and why they have occurred. Successful verbal communication is achieved by understanding the total dynamics of verbal communication. Communication is the key to safety in the aviation environment.

Sound

Sound is comprised of pressure variations. When a sound is generated by a person or thing a pressure wave goes out through the surrounding medium. The distant sound has a different pressure than the near sound, and therefore is audibly different. This is partially caused by different types of reflections and refractions encountered in the path of the wave. There are three specific elements that are needed to describe a waveform. The pressure variations in the air (waveform) must show how rapidly the pressure is varying (frequency), how large a pressure is produced (amplitude) and when the waveform starts (its phase). Generally, the larger the amplitude of the waveform, the louder it sounds and the higher the frequency, the higher the pitch is. The frequency measurement unit is Hertz (Hz) which is one cycle per second (Lindsay and Norman, 1972). The amplitude measurement is commonly called a decibel. The bel (B) is the basic unit measurement and is the logarithm (to the base of 10) of the ratio of two sound intensities. The decibel (dB) is where 1 dB = 0.1B.

The signal-to-noise ratio is the difference between a meaningful signal and the background noise in decibels. If the signal is 100 dB and the noise is 60 dB, the signal-to-noise ratio is + 40 dB. The sound pressure is measured by sound meters. The standard to which the sound meters should conform has been established by the American National Standards Institute (ANSI) and the American Standards Association.

In general, the human ear is less sensitive to low-frequency sounds of approximately 20-500 Hz and more sensitive to the higher frequencies of approximately 1000-5000 Hz but less sensitive to higher frequencies 15,000-20,000 Hz (Sanders & McCormick, 1993).

From a flight physiological sense, hearing is second in importance only to vision. We communicate by what and how we hear. The duration of sound exposed to the ear determines how well the sound is heard. Noise can be defined as a sound that is perceived as being too loud, disagreeable, or distracting. The annoyance of noise is very subjective and varies from person to person. Very intense noise needs to be filtered out to prevent damage to the ear. The two types of noise are steady state and impulse. An example of steady state noise would be the noise in and around an aircraft with the engine operating. An aircraft propeller can make a noise ranging from 90 to 113 dB, and ventilation sounds of large and small aircraft have varying levels of noise. Examples of impulse noise would be an engine backfiring, a gunshot or any other short-term (a few milliseconds in duration) loud sound. Minimum results of exposure to noise could be annoyance, distraction, and possible interference with concentration, communication, and performance (Reinhart, 1992).

The purpose of FAA Advisory Circular No: 91-35 (1972) is to acquaint pilots with hazards of regular exposure to cockpit noise, especially in piston-engine, fixed-wing, and rotary-wing aircraft. Most pilots who have been flying for a long time have a mild hearing loss. Many pilots report unusual amounts of fatigue and temporary losses of hearing sensitivity after flights in noisy aircraft. Radio transmissions are not clearly understood, especially during critical periods with high power settings (takeoff).

Hughes and Koonce (1986) studied cabin noise levels in single engine general aviation aircraft at different flight segments (e.g., run up, taxi, climb, cruise power, and decent) obtaining time weighted noise values. The highest noise levels were flight segments at 65% cruise power with speaker communication (mean 94 dB), descent with speaker communication (mean 91 dB), and during maximum power (mean 94.5 dB). Taxi power with speaker communication was a mean of 87 dB. A substantial percentage of general aviation pilots will show some hearing loss because of the high levels of noise in their aircraft cabins as indicated by the results of this study. The hearing loss can be reduced with different hearing protectors.

Masking. Masking is defined by Sanders and McCormick (1993) as a condition in which one component of the sound environment reduces the sensitivity of the ear to another component. In an operational environment, masking can be defined as the amount the threshold of audibility of a masked sound is raised by the presence of another masking sound. There are many masking sounds in aviation that need to be reduced or eliminated, i.e., engine noise, propeller noise, radio static, air passing by the cockpit. In order to communicate effectively, speech must exceed the threshold of masking noise.

The time and intensity at which the sounds arrive at the two ears are cues that can localize a sound source. The sounds with the greatest intensity arrive first at the ear that is closest to the source. The head casts an acoustic shadow between the source and the ear on the distant side of the head. The low frequency sound wave is diffracted and moves around the head, causing little or no shadow. When the wavelength of high frequency sounds is short compared to the size of the head, very little if any diffraction takes place.

Sound localization is a two part system: temporal differences for low frequencies and intensity differences for high frequencies. Binaural listening is defined as using two ears to listen which adds a spatial dimension to the perception of sound and clarity. Many masking noises can be eliminated by turning the head or ear toward the desired sound. Many pilots use this technique to better hear a radio transmission. The masking level difference is a way in which binaural reception improves clarity. When a pilot is trying to hear a weak voice mixed with noise in one ear, the addition of the same noise to the other ear will improve the clarity significantly. The same signal and noise put in both ears would do no good because the signals and noise would cancel each other out (Lindsay & Norman, 1972).

Reinhart (1992) describes two methods of measuring one's hearing that are used in the aviation community. An audiometer is used while the subject is in a soundproof booth listening with headsets. A pure tone is sent to the ear at a specific frequency and at a specific intensity and the response by the subject can be identified for all frequencies. The FAA medical exam for aviators requires a hearing test. Many of these hearing tests are performed by what is referred to as the whisper-voice test, now called a voice test. This method does not quantify or qualify the frequency at which the pilot might have a hearing loss. The voice test lacks the reliability of a test with the audiometer.

Language and Speech

Carroll (1964) perceives language as serving two functions. Language is both a system of responses that allows individuals to communicate with each other and a system of responses that eases thinking and action for the individual. There are two aspects of human communication. One aspect is physical (e.g., telephone, radio communication, and wires) and the other is biological (i.e., speech apparatus of the human body) system. The second system is a sign system that allows messages to be formed. The sign system is composed of three systems of language which are expression, content, and meaning.

Language is composed of a variety of sounds, and the study and description of these sounds is known as phonetics. A phoneme is a term for a range of sounds that are functionally the same and that are different from other ranges of sound. Phonemes are used to compose grammatically functional forms. Miller (1963) states that the grammar of any language has two parts; these parts are morphology and syntax. Morphology is the study of words, and syntax is the study of the words that compose phases and sentences. For the English language to be transcribed, approximately 40 phonemes are needed. Nine of these 40 make up more than half of the English vocal behavior and the most frequent sounds are used more than 100 times as often as the least used phonemes.

Several researchers have concluded that phoneme perception is based on acoustic or physical characteristics of sound (Gawron & Bock, 1990). Haberlandt (1994) points out that speech perception is a puzzle to researchers. Speech perception is usually very fast, and the complex human mechanism that processes speech must also be extremely fast.

The pilot must recognize individual spoken words to understand a verbal message. The recognition process is a fast process that occurs as the words are being spoken. Word recognition is rapid, occurring in less than 1/10 of a second. Sekuler and Blake (1990) found that people have a characteristic rhythm to their speech. Some people speak fast and other people speak slow. Accents vary from one region of the United States to another which can cause speech perception problems. Lengthy verbal instructions are not the most effective mode of delivery because they are transient and cannot be easily referenced. Further, hearing is not the same as comprehension. (Wickens, 1992)

Speech intelligibility. Intelligibility is the amount to which a speech message is correctly comprehended. Sanders and McCormick (1993) have divided the speech communication system into five parts (speaker, message, transmission system, noise environment, and hearer); one may better understand the whole by understanding the components. The voice of better speakers, with high intelligibility, has longer syllable duration, greater intensity, less pauses with more total time with speech sounds, and varied vocal frequencies.

The message intelligibility is affected by the phonemes, the words, and the context used to construct the message. Some speech sounds are similar to the sounds of others and may be confused. Those sounds should be avoided. Familiar words have greater intelligibility than unfamiliar words, and longer words have greater intelligibility than short words. Sentences have higher intelligibility than isolated words. Speech intelligibility can be improved for a speech communication message by: (a) use small vocabulary, (b) use of sentence transmitted in the same order, (c) use of long words and the word-spelling alphabet, e.g., alpha, bravo, charlie, etc. and, (d) certainty that the hearer is familiar with the words and sentence structure to be used.

Speech transmission can be new with very high fidelity or it can be old with various forms of distortion in frequency, filtering, and amplitude. Speech intelligibility is destroyed by noise either externally (e.g., environment) or internally (e.g., transmission system). The hearer is the last component of the speech communication system. The hearer should have normal hearing and should be trained to receive the types of messages that are transmitted. Headsets, helmets, and earplugs also greatly affect the level of speech intelligibility.

Whitaker and Peters (1994) have developed a model of auditory workload to predict the impact of communication factors on human performance. An effective communication message is influenced by its context, its content, and the demands of the task. The model can be three sets of factors: (a) transmission, (b) linguistic and, (c) individual differences. Transmission factors are speech intelligibility, task difficulty, communication structure, and net size (i.e., number of people communicating). Linguistic factors are meaning (i.e., semantics) and form (i.e., syntax). A message is more difficult when the words are difficult to pronounce, unfamiliar sentence syntax, or phonemically similar. The criticality, expectancy, and complexity are three more linguistic factors that have an affect on the workload. Ability and training are individual difference factors that affect the communication task. People differ in their prior experience with a task, their ability to process information, and their hearing. Skill levels and the amount of training that individuals have has an impact on good communication intelligibility. van Deelen and Blom (1990) performed tests on hearing loss and radiotelephony (RT) intelligibility and found that pilots' ability to understand RT was not only a function of hearing, but it also depends on knowledge of aviation jargon and experience. Williams, Forstall, and Greene (1971), in a communication study with noisy military aircraft, recommend that helmets provide proper noise attenuation and also provide good intelligibility. The selection of the proper helmet will reduce auditory fatigue and improve intelligibility.

Information Processing

Wickens and Flach (1988) have used an information processing model with four stages. The first stage is a sensory store with a separate sensory store for each sensory modality. The second stage is pattern recognition which is very important and least understood. The third stage is the decision and response selection stage. The fourth stage is made up of three ways to store information: sensory store, working memory (WM) or short-term memory (STM), and long-term memory (LTM). The information processing model using three stages is used by many psychologists (Lindsay & Norman, 1977; Sanders & McCormick, 1993; Edwards, 1990; Morris, 1993). These three stages of memory are sensory storage, working or STM, and LTM.

Sensory storage. Sensory storage is the entry point for raw information from the senses. Of special interest to this study is the auditory or the echoic aspects of memory. The sensory storage lasts from less than one second to as much as two seconds. Auditory information does not fade as swiftly as visual information. All raw information from the senses goes into the sensory storage where it is lost or processed further. Information that is to be processed goes into STM where it is forgotten or moved into LTM. Morris (1993) believes attention is what holds information that is not lost in sensory storage for further processing. Attention is a conscious process of looking, listening and using all the senses. The attention process gives meaning to incoming information. Raw information coming into the sensory storage or register must have meaning to be processed further.

Short term or working memory. STM or WM is referred to by Morris (1993) as consciousness. STM has two tasks: to store new information and to work on that information and other information. Lindsay and Norman (1977) explain STM as the system that takes already encoded information. STM is where we store information temporarily while we are trying to organize or permanently store that information. STM appears to retain the immediate interpretation of those events rather than the complete image of those events. Haberlandt (1994) views STM or WM as the most active part of the memory and is the main cognitive processor where mental operations such as rehearsal, elaboration, search, comparison and others are thought to take place. Sanders and McCormick (1993) believe that information in WM is coded into three different codes: visual, phonetic (auditory), and semantic. The visual and auditory codes respond to visual and auditory stimuli. Semantic codes respond to abstract representation of the meaning of a stimulus. Semantic codes are very important in LTM. Wickens and Flach (1988) explain WM by way of an example. When a pilot hears a navigational waypoint over communication radio, the pilot enters that waypoint with a keyboard. WM is usually where verbal information is maintained using an acoustic-phonetic rehearsal.

Miller (1956) described his study of the capacity for information processing as the magical number seven plus or minus two. He referred to what is called WM or STM today as immediate memory. His studies showed that the seven plus or minus bits of information in the memory could be expanded by grouping related clusters together (chunking). For example, the thirteen numbers 1400302112005 could be reduced or put into three groups or chunks (1400, 3021, and 12005). The three chunks represent time

(1400), barometric pressure (30.21), and wind direction and velocity (120/05). Baddeley (1990) refers to auditory short term memory in terms of duration and not capacity. He defines this duration to be about 5 or 10 seconds. Baddeley refers to other researchers who believe STM can last somewhere between 2 and 20 seconds. A brief pause between successive groupings of numbers will usually improve recall of those numbers. The first and last group of items is usually remembered better than the middle group or groups.

Wickens and Flach (1988) state the main cause of loss of information or forgetting information from the WM is interference. Previously stored (proactive interference) or new information (retroactive interference) confuse or replace information that is to be stored in the WM. They suggest four steps that may reduce forgetting that is caused by interference:

- spread the material to be held in memory over time
- decrease likeness between items
- remove unnecessary redundancy
- reduce within-code interference

Morris (1993) explains that the loss of material stored in the STM can be caused by the passing of time. This is known as the decay theory.

Lindsay and Norman (1977) explain rehearsal as a method to delay the loss of information from the STM. The silent repetition of material to help maintain this information is called maintenance rehearsal. Morris (1993) refers to the silent or out loud repetition of material in the STM as rote rehearsal. Morris defines elaborative rehearsal as connecting new information in STM to familiar material stored in LTM. Reason (1990) discusses one view of the WM that has three components: (a) a central executive that controls capacity limits and is identified with attention and consciousness, (b) the articulatory loop and, (c) the visuospatial scratchpad. The articulatory loop and the visuospacial scratchpad have a passive store and an active rehearsal process. They are similar in structure but they store different kinds of information. Logie (1993) gives similar explanations for this process but he calls the articulatory loop the phonological loop.

Long term memory. Morris (1993) refers to LTM as the storage place for everything that we know. Wickens and Flach (1988) have classified LTM into two categories: semantic memory, which is the memory for meaning, general facts and information, and episodic memory, which is memory of knowledge for specific events and more specific information that has personal meaning. Edwards (1990) states that a good LTM is a permanent storage of material that can be called out with ease. Sanders and McCormick (1993) state that information is transferred to LTM by semantically coding it, which gives the information meaning and connecting it to information already stored in the LTM. Lindsay and Norman (1977) view the LTM as having three aspects: (a) the storehouse of information (data base), (b) the interpretive mechanisms which operate in coordination with the data base, and (c) a monitor that supervises the operation (e.g., retrieval of information). Edwards (1990) states that the fundamental of any memory system or mnemonics is using an organization of existing memory. Mnemonics are certain techniques that make material easier to remember. An acronym is a very simple mnemonic device that is used to recall a small number of items in a fixed order. An acronym is a cue for the pilot (e.g., ATIS message, FAA, NASA ASRS). Any important list can be set up by the acronym schema (working structure in the memory). Loci and images are also methods for remembering more elaborate material using previously memorized systems. Some place or location used in aiding memory would be the loci method. Another concept of memory training is imaging or putting a strong connection between the place and the item to be memorized.

The ATIS Message

The foundation for beneficial discussion of the experiment is understanding every aspect of the ATIS message. To properly do this, all eleven items shall be discussed individually and in places where they might be related they will be discussed together. Before the discussion of the ATIS message, it is necessary to know some of the purposes and the normal operational uses of ATIS messages. The primary use of the ATIS message is to brief the pilot to eleven groups of information prior to landing or prior to take off. The scenario of the pilot briefing prior to landing involves multiple tasks, flying the aircraft would be the number one task or priority and listening is somewhere after that task depending on the need of the cockpit chores. The scenario of the pilot on the ground prior to takeoff listening to the ATIS message would most likely be the primary task of the pilot. The pilot would have the parking brakes set while copying the message, and would then call ground control for taxi instructions.

The airport management personnel of each respective airport is responsible for notifying the air traffic control personnel of any problem area that might exist on their airport (e.g., taxiway under construction). The air traffic control personnel compile the

ATIS information and record that information for the ATIS broadcast. The ATIS message is operationally useful prior to takeoff for altimeter setting, the departure runway, wind , and wearther. Prior to landing the message is useful for landing information, altimeter, and wind. The ATIS message is recorded noncontrol information that is continuously broadcast in certain high activity areas. The purpose of this repetitive transmission of essential but routine information is to improve controller effectiveness and to relieve frequency congestion. The ATIS message includes the airport and an alpha identifier, the time of the latest weather sequence, ceiling, visibility (if the weather is above a ceiling/sky condition of 5,000 feet and the visibility is 5 miles or more), obstructions to visibility, temperature, dew point, wind direction (magnetic) and velocity, altimeter, instrument approach and runways in use, departure runway if it varies from the landing runway except at airports having separate ATIS messages for departure, and the last item is other pertinent remarks. The ATIS broadcast is updated upon receipt of any official weather and it shall be updated when pertinent data changes (e.g., runway change, instrument approach in use, runway conditions). The ATIS message is similar to most aviation communications and weather communications because acronyms, abbreviations, contractions, and symbols are used (Federal Aviation Administration, 1994).

Errors

Hawkins (1993) identifies three basic doctrines with respect to human error: (a) origins of errors can be fundamentally different, (b) anyone can and will make errors, and (c) consequences of similar errors can also be different. Hawkins gives a list of ways to classify errors and the most applicable group to communication errors is omission, commission, and substitution. Omission is one of the most common errors recognized (e.g., not hearing the complete message). An error of commission is doing something which should not be done (e.g., cleared to land runway 17R and landing runway 17L). An error of substitution is copying the altimeter setting down, but the wrong information (e.g., 29.92 instead of 29.29).

The double Boeing 747 disaster in 1977 at Tenerife demonstrates the magnitude of the results of communication errors in aviation. This accident resulted in 583 lives lost and $150 million in damages. In many cases expectancy, i.e., what a pilot expects to hear, may cause errors. A common and dangerous phenomenon of expectation occurs in the readback and confirmation of messages. Readback is a pilot/controller term that means to read my message back to me. The purpose of readback is to attempt to insure that the message was accurately understood. Readback does not guarantee that the message has been accurately received. Four causes of readback error are:

- similar aircraft call signs that result in confusion in transmission or reception
- only one pilot working and monitoring the Air Traffic Control frequency
- numerical errors (e.g., one zero thousand with one thousand)
- expectancy (e.g., hearing what one expects to hear).

Mis-communication happens in all aspects of aviation, but mis-communication between air and ground may be the most serious. Messages need to be unambiguous. Phrases are shortened due to time pressure. Aviation messages are frequently compressed containing critically high information elements in a very small part of the message (Hawkins,1993).

Reason (1992) has categorized errors into failure modes, and the mode most applicable to verbal communication errors is the failure mode at the skill based level. The skill based level is grouped under two headings: (a) inattention, omitting the required monitoring at the critical point (e.g., omission following interruptions, perceptual confusion, interference errors), and (b) overattention, making an attentional check at an inappropriate time during a routine action sequence (e.g., omissions, repetitions, reversals). Reason (1987) indicates that both general and specific task factors influence the incidence of everyday slips of action and omissions represent a large portion of those slips of action.

Aviation Safety Reporting System (ASRS), (1992), in a synopsis of data on pilot/controller communication, has identified communication problem areas broken down by type of event. The eleven types of events are: (a) controller communication technique, (b) headsets/speakers, (c) interfacility coordination, (d) intrafacility coordination, (e) language problems, (f) phraseology, (g) pilot communication technique, (h) readback/hearback, (i) similar alphanumerics, (j) simultaneous transmissions, and (k) stuck microphones.

Conclusions

Successful verbal communication is achieved by understanding the total dynamics of verbal communication. Sound must be understood and managed properly. The dimensions of language and speech must be applied to yield intelligible speech. The five parts of the speech communication system (speaker, message, transmission system, noise environment, and hearer) must each have a high degree of perfection for the whole system to achieve the proper amount of intelligible speech. If one or more of these parts is weak, the intelligibility of the whole system will suffer.

Information processing is different from one individual to the next. The LTM and STM can be improved with education and practice. Standard formats for aviation messages and standard phraseology help facilitate good communication. The more flight or ATC personnel practice or use aviation phraseology, the stronger this information is committed to their LTM. The more aware ATC or flight crews are of where errors might occur, the better chance they have at preventing those errors.

Purpose of the Study

Communication is the key to safety in the aviation environment. Poor communication is one possible or contributing cause in many aviation accidents and fatalities. Communication is not a single factor, but it is a group of factors that when properly combined results in a desired understanding or meaning. The purpose of this study is to look at the many components that comprise communication. Effective communication skills and practices can be understood and exercised by understanding the components. If there is a weakness in a component, that component can be corrected to make the communication more effective. ATIS message errors may illuminate other communication errors.

Method

Subjects

Twenty-four subjects volunteered to participate in this ATIS message experiment. The majority of the subjects were undergraduate students recruited from six airway science classes and the remainder were graduate students working at the Center for Aviation/Aerospace Research (CAAR). Three basic requirements were met for these twenty-four subjects: (a) possess at least a current third class Part 67-Medical Certificate, (b) possess at least a solo pilot certificate, and (c) English as primary language.

Instruments

The instruments used in this study were a single engine cabin and fuselage, an Onkyo digital amplifier, an eighty amp speaker, a cabin speaker, a David Clark H-10-60 headset, a Telex Airman 750 headset, a Telex 5x5 Pro III headset, sixteen digitally recorded ATIS messages, a digitally recorded engine noise at constant RPM, a Lanier hand held recorder for the practice ATIS message and pencil and paper to record messages. The instruments were used in producing and listening to the sixteen messages.

Design

The study consisted of one experiment with each subject listening to sixteen different ATIS messages. An effort was to made to make the experimental environment as close to the actual operational environment as possible. The operational environment was a single engine aircraft on the ramp with idle rpm with an inside cockpit noise of 103dB with brakes set . The 103dB was measured inside a single engine aircraft on the Embry-Riddle Aeronautical University (ERAU) flight line.

A salvaged single engine aircraft fuselage that CAAR has in a lab was used for this experiment. The cabin of the aircraft was equipped with a large speaker that was placed in the most forward position and was used to simulate the engine sounds. The speaker was placed facing forward and sound measurements were taken from the left seat thirty inches up from the bottom of the seat. The volume was set at 103dB for all twenty-four subjects. The sixteen messages and the engine sounds were recorded professionally by ERAU's Center for Instructional Development and Effectiveness. The sixteen messages were digitally recorded in a sound booth and the engine noise was digitally recorded at ERAU's maintenance line. The engine was recorded at a constant rpm for fifty minutes. The engine noise provided a masking noise that duplicated the sounds of an aircraft on the ramp.

Sixteen different ATIS messages were used for this study. Four people read four different messages each. These voices are referred to in the experiment as voices one, two, three, and four. Voice number one was read by a pilot licensed since 1965 with over twenty years aviation experience. Voice number two was read by a licensed pilot and professional researcher who had experience as an operations specialist at O'Hara International Airport. Voice number two's duties included notifying the tower of any runway or taxiway closings or any problems on the airport that might hinder the safe operation of aircraft. Voice three was read by a professional audio and visual person. Voice four was read by a former air traffic controller. All four of the vioces were male.

The listening devices represent four popular devices used by aviators. One device was used to listen to a tape with four messages read by one of the four voices. The sixteen messages were divided into four groups and recorded on four tapes. Four different readers each read a group of four messages. The engine noise was played continuously for each subject. All four tapes were played for each subject. Listening devices were changed for each tape.

The volume for each listening device was subjectively set to a volume that was loud enough for each member of a pilot group of six persons. These six persons were also used as the pilot group for the study. Each listening device had a volume setting that was consistently set for all sixteen messages and twenty-four subjects. The messages were counterbalanced within the schedule for the twenty-four subjects.

The subjects had one primary task of listening and recording what they heard on paper. There were no other tasks assigned to the subjects. There were thirty seconds between messages with an audio beep five seconds prior to the next message. After four messages, the listening devices were changed. The single major difference in this study from the operational environment is that the subjects were allowed to hear each message only one time. In the operational environment pilots may listen to an ATIS message as many times as they choose until they are confident of the message content.

Procedure

Pilot Study

The subjective volume settings for the listening devices and the verification of realism for the experiment were corroborated by the subjects for the pilot study. Three pilots with Ph.D's and three students with pilot licenses formed the trial study group. The members of this group all participated in the experiment. All members agreed that the experimental environment was similar to the operational environment.

Subject Briefing

The subjects received written and verbal instructions for the study. The same pilot experiment briefing form shown in Appendix A was used for the written brief and the oral brief. The four listening devices were introduced to the subjects. After being briefed, each subject listened to a recorded practice ATIS message. The subjects then were asked if they understood the study and any questions were answered. The briefing took approximately five minutes to complete. All subjects were briefed to record the messages using abbreviation codes or shorthand if they chose to.

Conducting the Experiment

The was experiment was administered by one person. The experiment took approximately 25 minutes to complete. The experiment schedule was used by the experimenter to determine the sequence of the tapes and listening devices. The engine noise was started after the subject entered the cockpit of the aircraft cabin. The subject was given a clipboard and four message recording sheets. The subject was given one of the three headsets or the subject was told to listen to the aircraft speaker in the non-headset condition. Four ATIS messages were broadcast and recorded as they were heard by the subject. At the end of the four messages, the experimenter took the four message recording sheets from the subject and gave the subject four more blank message recording sheets. The experimenter exchanged headsets or told subject the speaker would be used and this process was repeated until all four tapes and listening devices were used. Prior to each tape and corresponding listening device the predetermined volume was set. The experimenter reviewed all sixteen message recording sheets for legibility with the subject. The information used to analyze the experiment was gathered from the sixteen message recording sheets that the twenty four subjects each filled out.

Results

General

The demographics of the group was homogenous , hence nothing can be derived from this aspect of the experiment. The total errors of the subject group if measured by message items missed is 13%. The distribution by subject does little to explain the errors made other than the ability or inability of the individual subjects to listen and hear well during the experiment. The most beneficial information in this experiment comes from the analysis of the items in the messages. These eleven items are (a) identifier, (b) time, (c) ceiling, (d) visibility, (e) temperature, (f) dew point, (g) wind direction and velocity, (h) altimeter setting, (j) landing information, (k) departure information, (l) remarks.

Data Analysis

The experiment produced 4224 items of information (24 subjects x 16 messages x 11 items*)*. In this broad grouping there were 552 or 13% errors . The 4224 items were further broken down into (a) words representing numbers and (b) words other than numbers. The total of numbers was 10,248 and was derived by counting the total number of single digits in the messages. The total number of words was 3672 and was derived by counting the minimum words necessary to comprehend those items of the messages. There were 865 or 8% errors in the numbers and 17% were errors of commission and 83% were errors of omission. There were 540 or 15% errors in the words and 4% were errors of commission and 96% were errors of omission. The highest percentage of errors in numbers occurred with the number "9" at 15.9% and the lowest percentage of errors in numbers occurred with the number "0" at 4.3%. The most frequently missed number was the number "1" at 10.3%. The highest percentage of errors in words occurred with the word "permission" at 70% and the lowest percentage of errors in words occurred with the word "scattered" at 3%. The most frequently missed word was "right" at 15.8%. The word "pooling" resulted in a 33.33% commission error and the incorrect word the subjects thought they heard was "cooling".

Table 1

Analysis of Data by Message Item Errors

Item Number	Group Errors	Number Errors	Word Errors
1	1%	0%	<1%
2	9%	15.5%	<1%
3	9%	8%	8%
4	11%	4%	10%
5	7%	9%	0%
6	4%	6%	0%
7	7%	15%	1%
8	5%	7%	0%
9	11%	4%	13%
10	15%	16%	7%
11	21%	15.5%	60%

Note. In the Group Errors each group is viewed as a single item. The Number Errors are individual numbers and the Word Errors are individual words.

Studying the alpha numeric composition of each of the eleven items of the ATIS message adds to the clarity of the errors. Item one has no numbers and one word. Item two has four numbers and one word. Item three has a varying quantity of numbers and words. Item four normally has one or two numbers and one or two words. Item five has one, two or three numbers and no words. Item six normally has two numbers and no words. Item seven has five to six numbers normally and sometimes several words. Item eight always has four numbers and no words. Items nine and ten have a varying mixture of numbers and words. Item eleven is the least predictable part with the most varying amount of numbers and words. Table 1 gives the percentage of errors for the eleven items. Item eleven has the most errors in all three categories. This item varies in format the most of the eleven items, has the most verbiage, and a highest quantity of numbers in the message. Item one is the most simple part of the message always consisting of one alphabetical code word.

Discussion

The subjects were allowed to listen to each of the sixteen messages only once which differs drastically from their normal operating procedure. In an operational situation, whether the pilot is airborne inbound to an airport or on the ground waiting to take off, the pilot is able to listen to the ATIS message as many times as it takes until the information is completely understood. This habit pattern of listening to the message multiple times may account for the high number of errors that were committed by omissions. This experiment resembles most a pilot on the ground listening for the ATIS message prior to departure. The primary task is to record the ATIS message prior to receiving ground clearance to taxi.

The ATIS message consists of eleven items or groups of information. This information is part of the total weather information available to the pilot for flight planning purposes. The message is especially useful and necessary for the arrival and the departure phase of the flight. The first flight that the student pilot takes out of an airport that broadcasts ATIS messages is when the pilot starts learning the format for the ATIS message. The more a pilot listens to ATIS messages the more the message becomes a mental model or mental template in that pilot's long term memory. The format for the eleven items of the message does not change. The information in each item does change. The frequency of errors in this experiment is related to the complexity of the message item. In items 1, 2, 5, 6, and 8 the item size changes little if any (e.g., Alfa to Bravo, 1400Z to 1500Z, 29.92 to 29.97). Items 3, 4, 7, 9 and 10 are more complex and lengthy (e.g., 150/05 to100/10, landing runway 9 left to ILS/VOR 9). Item 11 is the most complex and has the most amount of all types of errors. Item 11 has no format of predictability that the ten other items have. The mental model that pilots form with repetition and rehearsal for the ATIS message is of little use for the item 11 remarks section. The chunking of information that may be possible in items 1-10 is not possible in most cases in item 11 because of the length and amount of information. Short term memory can effectively process most of the information in items 1-10, however, item 11 is too lengthy for short term memory to capture the information after hearing this information one time.

Many times an error of omission may be damaging or even fatal (e.g., failure to put the gear down). Most of the errors committed in this experiment are errors of omission. Omission is the proper action when listening to an ATIS message and not all of the message is understood. The best procedure in an operational setting is to listen to a message until all items are correctly understood. The subjects were told they would only hear each message one time. The omission errors in this experiment may be a good sign.

There is a possibility that some of the subjects have hearing deficits. The hearing ability of the subjects is only substantiated by an FAA flight physical that uses the "whispered-voice test".

Usually military pilots are the only pilots that have a hearing test in sound booth that tests for tone and frequency of sound and that are test results from an audiometer that are recorded on an audiogram.

Recommendations

This experiment has been an example of speech intelligibility. There are five parts in the speech communication system that need to be as close to perfection as possible. This ATIS message experiment has all five parts with varying degrees of perfection. Several messages had very complex item 11's which contributed to a high error rate. The speakers should rehearse as much as possible. The message should be as brief and clear as possible, especially in item 11. The higher fidelity of the transmission the less chance for errors. The noise environment should be as reduced as much as possible at the transmission location and at the reception location. The use of ear protection is important for the hearer and will result in hearing longevity.

The ATIS message is a form of communication in aviation that relates to many forms of two-way aviation communication. There are many VOR frequencies that broadcast ATIS messages along with the frequency Morse code identifier. The frequencies have a great deal of noise rendering the message barely intelligible.
New ways to transmit ATIS messages in those areas that use VOR frequencies should be devised. Verbal communication in aviation is needed for almost all normal operation in controlled airspace. While flying under instrument flight rules, verbal communication is essential for safe flight. An exception to this statement would be operating under lost

communication procedures. Any improvement that increases the intelligibility of verbal communication may save lives and enhance the safety of the overall communication system in aviation. The use of synthesized voice may standardize the speakers which may help intelligibility and reduce errors. Research to find the optimal rate of speech may result in increased performance and intelligibility. The vocabulary of messages needs to be standard. The intelligibility of the message may be greatly enhanced by creating synthesized speech with a standard rate of speech and a standard vocabulary. Research may provide reasons that justify the use of synthesized voice to the ATIS messages and other ATC communication.

The remarks portion of the ATIS message contains the largest amount of non-standard information. Pilots are required to check the Notice to Airman for the destination airport prior to departure. A study for alternate ways to present the remarks item of the message may result in increased intelligibility. If the speaker, message, transmission system, noise environment, and hearer are as near to perfection as individual components, the whole should yield high intelligibility and may reduce errors in communication.

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APPENDIX A

Experiment Briefing Material and Forms

ATIS MESSAGE EXPERIMENT

REQUIREMENTS:

1. PART 67-MEDICAL CERTIFICATE

   ___3RD CLASS ___ 2ND CLASS ___1ST CLASS

2. PILOT EXPERIENCE & CERTIFICATES

   ___ SOLO ___PRIVATE ___COMMERCIAL ___INST.

   ___OTHER-EXPLAIN________________________________

   FLIGHT TIME TOTAL__________ LAST 90 DAYS__________

EXPERIMENT WILL CONSIST OF LISTENING TO 16 ATIS MESSAGES THROUGH 4 HEARING DEVICES AND RECORDING THESE MESSAGES AND SHOULD TAKE 30- 40 MIN. TO COMPLETE.

NAME (PRINT):________________________________

ERAU BOX:________________

PHONE:

DAY__________________EVENINGS______________________

ACADEMIC MAJOR:________________________________

FIRST LANGUAGE:________________________________

DATE OF BIRTH: MONTH______DAY______YEAR_________

CONSENT FORM

Project: Thesis experiment on hearing ATIS messages through four different listening devices.

I agree to participate in a study using three different headsets and a speaker. Participation in this experiment is voluntary and without renumeration.

I understand that I am free to discontinue participation in the experiment at any time. I further understand that all information about my participation in this session will be kept strictly confidential, with only those directly involved in the study having access to the material. I understand that I am free to ask questions about the procedures to be used, and at the end of the session I will be fully informed as to its purpose. I also understand that the experiment is expected to have no direct benefit to me personally, but that the results will be used to further scientific knowledge about aviation headsets and speakers related to hearing.

The recording of the engine is played at approximately 103 dB; this level is similar to the cockpit level of aircraft on the ERAU flight line. If this level of noise is uncomfortable to you or you percieve it to put you at risk, please signal for the experiment to be stopped.

If you have any further questions concerning the experiment, please ask them.

Name (print) ____

Signature______________________________ Date ___________

PILOT EXPERIMENT BRIEF

This is an experiment to study the effects of different types of hearing devices used in airplanes. To test them we are using actual aviation equipment in a real cockpit with an actual recording of single engine aircraft noise.

The type of communication to be studied will be ATIS messages. These messages are based on actual ATIS messages that were collected across the USA. Your task will be to perform as a pilot and to record the ATIS message **verbatim**.

Engine noise will be turned on and will remain on throughout the study. The engine simulates a C-172 in a descent. You will **not** be able to control the volume of the ATIS message during the study.

The door will be shut. You will listen to each message and write down the information **exactly** as you hear it on the data sheet provided to you. There will be a total of **16** different ATIS messages. The study will proceed as follows:

- You will enter the cabin module, sit in the front seat, and take the clip board with 4 data collection sheets, and a pencil.
- The clip board and paper are to record the ATIS messages that you will hear. Each message will only be transmitted **once** (unlike in the real flight). The study task is to copy the ATIS message **exactly as you hear it one time** (there will be approximately **30** seconds between messages, approx. **5** seconds prior to message you will hear a beep).
- After recording a message, take the another data sheet for the next message.
- After 4 messages, the door will be opened and another headset or the speaker shall be used.
- The 4 data collection sheets shall be collected and 4 new ones will be given .
- This procedure will be repeated until all messages are heard and recorded.

Please write as neatly as possible — all data will be taken from your handwriting.

Do you have any questions?

Practice ATIS Message

William Hobby Airport / information xray / one four zero zero zulu weather / measured ceiling four hundred overcast / visibility one, fog / temperature four eight / dew point four seven / wind calm / ILS runway four approach in use / departing runway four / Notice to Airman three hundred foot crane one half mile North of the terminal / Advise controller on initial contact you have information xray.

APPENDIX B

Subjects Experiment Performance and Flight Credentials

SUBJECTS PERFORMANCE AND FLIGHT CREDENTIAL

Subject	Number errors	Word errors	Total errors	Flight certificate	Flight time	Medical	Age	Gender
1	32	15	47	COM/CFI/MEI	1,700	1st	29	M
2	21	11	32	PRI/INST	200	1st	22	M
3	76	15	91	PRI/INST	150	1st	23	M
4	27	19	46	PRI/INST	175	1st	26	M
5	12	7	19	COM/INST/MULT	400	1st	27	M
6	37	35	72	PRI	170	2nd	23	M
7	24	11	35	COM/INST	250	2nd	21	M
8	31	16	47	ATP	1,950	1st	25	M
9	12	10	22	PRI/INST/MULT	210	1st	22	M
10	9	9	18	COM/INST	320	1st	34	M
11	28	17	45	COM	250	1st	22	M
12	8	10	18	COM/MULT/INST	250	1st	22	M
13	7	12	19	PRI/INST	190	1st	24	M
14	59	49	107	PRI	85	2nd	28	F
15	64	27	91	COM/INST/CFI	300	1st	27	M
16	25	16	41	COM/INST	300	1st	24	F
17	31	52	83	COM/INST	350	2nd	25	M
18	46	30	76	COM/INST	1,250	2nd	31	M
19	78	34	112	COM/INST	280	1st	21	M
20	28	20	48	PRI/INST/MULT	190	1st	22	M
21	30	15	45	PRI	100	1st	22	M
22	43	23	66	PRI	130	1st	23	F
23	99	40	139	PRI	92	2nd	19	F
24	71	47	118	PRI/INST	220	2nd	26	M

APPENDIX C

ATIS Messages Used in the Experiment

EXPERIMENT ATIS MESSAGES

1. Los Angeles International Airport / information alpha./One three zero zero zulu Weather, / Measured ceiling two thousand overcast / visibility three, haze, smoke, / / temperature seven one, / dew point five seven / wind two five zero at five / altimeter two niner niner six / ILS runway two five left approach in use / departing runway two five left / runway two five right closed / advise controller on initial contact you have information alpha.

2. Bradley International Airport / information bravo / One five zero zero zulu Weather / Sky obscured measured ceiling two hundred overcast / visibility three quarter mile, light rain and fog/ temperature four niner / dew point four eight / wind one four zero at five / altimeter two niner eight zero / ILS runway six approach in use / departing runway six / Pooling water on all runways and taxiways / Advise the controller on initial contact that you have information bravo.

3. Craig Municipal Airport / information charlie / One three zero zero zulu Weather / Eight hundred overcast / visibility three, fog / temperature seven zero / dew point six eight / wind zero three zero at four / altimeter three zero two four / VOR runway three two approach in use / departing runway three two / Increased bird activity on and around the airport / Advise controller on initial contact you have information charlie.

4. Seattle International Airport / information delta / One five four five zulu Weather / Five hundred scattered, measured nine hundred overcast / visibility two, fog / temperature five five / dew point five three / wind zero four zero at six / altimeter three zero zero six / VOR runway three four right approach in use / departing runway three four right and three four left / Notice to airman ILS runway three four right and three four left out of service / Advise controller on initial contact you have information delta.

5. Tacoma Narrows Airport / information echo / One one zero zero zulu Weather / Two thousand scattered, four thousand five hundred scattered, one zero thousand broken / visibility seven / temperature four five / dew point four one / wind two one zero at six / altimeter three zero zero seven / Visual one seven approach in use / departing runway one seven / Numerous bird flocks within the airport vicinity / Advise controller on initial contact that you have information echo.

6. Des Moine International Airport / information foxtrot / One eight zero zero zulu Weather / Measured one thousand seven hundred broken / visibility seven, haze / temperature six two/ dew point five zero / wind two one zero at seven / altimeter two niner eight five / Visual runway two three approach in use / departing runway two three / Be alert for high speed low level military aircraft in the vicinity of the airport / Advise controller on initial contact you have information foxtrot.

7. Spirit of Saint Louis Airport / information juliet / Zero two zero zero zulu Weather / Measured one thousand six hundred broken, three thousand broken / visibility two, haze / temperature seven eight / dew point seven five / wind zero six zero at six / altimeter two niner seven niner / ILS runway eight right approach in use / departuring runway eight right and eight left / Airport closed to aircraft over ninety thousand pounds without twenty four hour prior permission / Advise controller on initial contact you have information juliet.

8. Lincoln Municipal Airport / information kilo / One one zero zero zulu Weather / Clear / visibility eight / temperature four six / dew point three three / wind three five zero at niner / altimeter three zero two eight / Visual runway three five left and runway three five right approach in use / Departing runway three five right / Notice to airman, VASI runway three five left out of service / Advise controller on initial contact that you have information kilo.

9 Grand Forks International Airport / information lima / One six zero zero zulu Weather / Measured eight hundred overcast, estimated one thousand four hundred overcast / visibility two blowing snow / temperature two eight / dew point two five / wind one three zero at eight / altimeter three zero zero six / VOR runway one seven right approach in use / Departing runway one seven right and runway one seven left / Student training activity within fifteen miles of the airport / Advise controller on initial contact you have information lima.

10. New Bedford Municipal Airport / information november / Zero five zero zero zulu Weather / Measured one thousand seven hundred overcast / visibility four, fog / temperature five eight / dew point five seven / wind zero niner zero at one zero / altimeter two niner eight four / ILS runway five approach in use / departing runway five / Notice to airman, Providence VOR out of service / Advise controller on initial contact you have information november.

11. Memphis International Airport / information oscar / One six zero zero zulu Weather / Five hundred scattered, measured one thousand six hundred broken / visibility three, blowing dust / temperature five six / dew point five three / wind one five zero at one zero gust to two zero / altimeter two niner eight zero / ILS runway one eight left approach in use / Departing runway one eight left, one eight right / Notice to airman, ILS one eight right out of service / Advise controller on initial contact you have information oscar.

12. Flying Cloud Airport / information papa / One seven zero zero zulu Weather / One thousand six hundred broken, four thousand broken / visibility four, smoke / temperature two eight / dew point two five / wind zero six zero at one five / altimeter two niner three two / Visual runway niner left, niner right approach in use / Departing runway niner right / Notice to airman, high intensity runway lights out of service runway niner right / Advise controller on initial contact that you have information papa.

13 Bangor International Airport / information quebec / Zero four zero zero zulu Weather / Five hundred scattered measured one thousand two hundred broken / visibility two, freezing rain / temperature one eight / dew point one seven / wind three six zero at one two gust to one eight / altimeter two niner six three / VOR/DME runway three three approach in use / departing runway three three / Notice to airman, ILS runway three three out of service / Advise controller on initial contact you have information quebec.

14. Salem Airport / information whiskey / Two one zero zero zulu Weather / Estimated four thousand broken / visibility five / temperature five five / dew point five one / wind one four zero at six / altimeter three zero five five / Visual runway one six approach in use / departing runway one six / Notice to airman, Locator Outer Marker out of service / Advise controller on initial contact you have information whiskey.

15. Miami International Airport / information zulu / Two three zero zero zulu Weather / Measured ceiling six hundred broken / visibility two , smoke / temperature seven niner / dew point seven two / wind zero eight zero at one zero / altimeter three zero one three / ILS runway niner right approach in use / departing runways niner left and niner right / Notice to airman, taxiway sierra closed for construction / Advise controller on initial contact that you have information zulu.

16 “Evansville Airport / information golf / One seven four niner zulu Weather / Measured ceiling three thousand overcast / Visibility three, haze / Temperature seven two / Dew point five eight / Wind one eight zero at five / Altimeter two niner niner five / ILS runway two two approach in use / departing runways two two and one eight / Notice to airmen, runway niner/two seven closed / Advise controller on initial contact you have information golf.

APPENDIX D

Experiment Schedule

EXPERIMENT SCHEDULE

A = BEST HEADSET = VOICE #1 = MESSAGES 1-4

B = GOOD HEADSET = VOICE #2 = MESSAGES 5-8

C = ONE EAR PIECE HEADSET = VOICE #3 = MESSAGES 9-12

D = SPEAKER = VOICE #4 = MESSAGES 13-16

SUBJECTS 1-24

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
A	B	C	D	A	D	C	B	C	D	A	B	A	B	C	D	A	B	C	D	A	B	C	D
B	C	D	A	D	C	B	A	D	A	B	C	D	A	B	C	C	D	A	B	C	D	A	B
C	D	A	B	C	B	A	D	B	C	D	A	B	C	D	A	B	C	D	A	D	A	B	C
D	A	B	C	B	A	D	C	A	B	C	D	C	D	A	B	D	A	B	C	B	C	D	A

APPENDIX E

Location of Message Errors

LOCATION OF MESSAGE ERRORS

Message	ID	Time	Ceiling	Vis	Temp	Dew	Wind	Altim	Land	Dep	Remarks	Total
1			1		1				3		1	6
2			3	5	3	1			1	4	8	25
3			1				1	1	2	1		6
4		2	1				5		1	1	1	11
5		8	8	5	5	5		1		10	10	52
6		6	2	3	2	1	1		1	9	20	45
7		2	4	6	3	1	3	4	14	9	23	69
8	1	4	2	3	2	2	7	6	1	8	10	46
9		2	7	5	2	2	2	1	8	3	9	41
10		1	1	1				1	2	6	2	14
11		2	4	5	2	2	2	5	2	3	5	32
12			3	5	7	5	2	1		6	6	35
13		2	4	6	6	2	9	2	11	7	5	54
14		3	2	1	3	1	3	2	5	7	2	29
15	1	2	6	6	1		3		7	3	6	35
16	1	15	3	10	3	1	2	1	3	5	8	52
	3	49	52	61	40	23	40	25	61	82	116	552
	1%	9%	9%	11%	7%	4%	7%	5%	11%	15%	21%	100%

APPENDIX F

Number Distribution of One Subject, of Twenty Four Subjects, and the List of Errors Sorted By Item

TOTAL DISTRIBUTION OF NUMBERS IN MESSAGES ONE SUBJECT

 # 1-0 **MESSAGES 1-16** **TOTALS**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
#1	2	2	1	1	7	3	1	2	7	2	7	3	5	5	2	3	53
#2	6	2	3	1	2	5	4	1	3	1	2	4	4	1	3	7	49
#3	2	3	6	7	1	2	1	8	2		2	1	8	1	3	2	49
#4		4	2	7	3		1	1	1	2		2	1	2		1	27
#5	6	2		6	2	2		5	2	5	4	2	1	6		3	46
#6	1	2	1	2	1	1	2	1	2		3	2	2	3	1		24
#7	2		1		4	3	3		3	1		1	1		2	3	24
#8		2	2			2	3	2	3	2	8	1	1		1	3	30
#9	2	2		1		1	1	1		2		5	1		4	4	24
#0	6	6	8	8	13	6	14	4	9	8	9	9	8	7	8	4	127
	27	25	24	33	33	25	30	25	32	23	35	30	32	25	24	30	453

TOTAL DISTRIBUTION OF NUMBERS TWENTY FOUR SUBJECTS

#1-0 **MESSAGES I-16** **TOTALS**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
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List of Number Errors Sorted By Item

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	9	21	7	11
	9	15	16	11
	4	22	7	11
	2	18	7	11
	0	18	7	11
	9	18	7	11
	9	7	12	11
	2	15	16	11
	1	24	9	11
	9	7	5	11
	7	14	16	11
	0	16	7	11
	3	24	13	11
	2	16	16	11
	9	16	16	11
	9	5	16	11
	9	16	12	11
	3	24	13	11
	5	5	9	11
	7	16	16	11
	5	16	9	11
	1	16	9	11
	9	5	12	11

	4	16	7	11
	2	16	7	11
	9	24	12	11
	2	17	1	11
	3	6	13	11
	1	5	9	11
	7	15	16	11
	3	6	13	11
	5	6	8	11
	2	6	7	11
	4	6	7	11
	2	15	7	11
	9	1	7	11
	4	15	7	11
	5	17	1	11
	4	1	7	11
	2	1	7	11
	0	1	7	11
	3	6	8	11
	2	23	16	11
	5	14	9	11
	7	23	16	11
	9	23	7	11
	2	20	7	11
	4	20	7	11
	5	19	9	11
	1	19	9	11
	2	11	16	11
	2	23	7	11
	0	23	7	11
	9	11	16	11
	4	23	7	11
	7	11	16	11
	5	19	8	11

	9	12	7	11
	0	12	7	11
	9	19	11	11
	4	11	7	11
	2	19	7	11
	1	9	8	11
	9	20	7	11
	0	20	7	11
	9	19	15	11
	2	9	7	11
	4	9	7	11
	9	4	7	11
	5	9	8	11
	2	11	7	11
	0	4	7	11
	2	4	7	11
	9	10	7	11
	0	10	7	11
	4	4	7	11
	4	19	7	11
	5	23	8	11
	3	23	8	11
	9	23	16	11
1	2	18	16	11
	9	8	7	11
2	3	2	13	11
	0	14	7	11
	2	14	7	11
	4	14	7	11
	2	2	7	11
	4	2	7	11
	9	23	12	11
	9	18	16	11
	3	14	8	11

2	5	22	9	11
	5	14	8	11
	1	14	9	11
	9	14	7	11
	9	3	7	11
	0	19	7	11
	9	13	7	11
	9	19	7	11
	3	20	8	11
	5	20	8	11
	4	8	7	11
	2	8	7	11
	0	8	7	11
	0	13	7	11
	0	3	7	11
	9	6	7	11
	2	13	7	11
	1	23	11	11
	8	23	11	11
	4	13	7	11
	9	3	16	11

APPENDIX G

Word Distribution of One Subject, of Twenty Four Subjects, and the List of Errors Sorted By Item

WORD DISTRIBUTION SIXTEEN MESSAGES ONE SUBJECT

WORD	MESSAGES 1-16																TOTAL
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
aircraft						1											1
airport			1		1	1											3
alpha	1																1
bird			1		1												2
blowing									1		1						2
bravo		1															1
broken					1	1	2				1	2	1	1	1		10
charlie			1														1
clear								1									1
closed	1						1								1	1	4
delta				1													1
dme													1				1
dust											1						1
echo					1												1
fog		1	1	1						1							4
foxtrot						1											1
freezing													1				1
golf																1	1
gusts											1		1				2
haze	1					1	1									1	4
high						1											1
hirl												1					1
hour							1										1
ils		1		1			1			1	2		1		1	1	9
juliet							1										1
kilo								1									1
left	2			1			1	2	1		2	1			1		11
level						1											1

light		1															1
lima									1								1
lom														1			1
low						1											1
military						1											1
november										1							1
obscurred		1															1
out				1				1		1	1	1	1	1			7
of				1				1		1	1	1	1	1			7
service				1				1		1	1	1	1	1			7
oscar											1						1
overcast	1	1	1	1					2	1						1	8
papa												1					1
permission							1										1
pooling		1															1
prior							1										1
Providence										1							1
quebec													1				1
rain		1											1				2
right	1			2			2	2	2		2	3			2		16
scattered				1	2						1		1				5
sierra															1		1
smoke	1											1			1		3
snow									1								1
speed						1											1
student									1								1
taxiway															1		1
training									1								1
vasi								1									1
vor			1						1	1			1				4
water		1															1
whiskey														1			1
zulu															1		1
	8	9	6	11	6	10	12	10	11	9	15	12	12	6	10	5	152

WORD DISTRIBUTION SIXTEEN MESSAGES TWENTY FOUR SUBJECTS

WORD	MESSAGES 1-16																TOTAL
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
aircraft						24											48
airport			24		24	24											72
alpha	24																24
bird			24		24												48
blowing									24		24						48
bravo		24															24
broken					24	24	48				24	48	24	24	24		240
charlie			24														24
clear								24									24
closed	24						24								24	24	96
delta				24													24
dme													24				24
dust											24						24
echo					24												24
fog		24	24	24						24							96
foxtrot						24											24
freezing													24				24
golf																24	24
gusts											24		24				48
haze	24					24	24									24	96
high						24											24
hirl												24					24
hour							24										24
ils		24		24			24			24	48		24		24	24	216
juliet							24										24
kilo								24									24
left	48			24			24	48	24		48	24			24		264

level						24											24
light		24															24
lima									24								24
lom														24			24
low						24											24
military						24											24
november										24							24
obscurred		24															24
out				24				24		24	24	24	24	24			168
of				24				24		24	24	24	24	24			168
service				24				24		24	24	24	24	24			168
oscar											24						24
overcast	24	24	24	24					48	24						24	192
papa												24					24
permission							24										24
pooling		24															24
prior							24										24
Providence										24							24
quebec													24				24
rain		24											24				48
right	24			48			48	48	48		48	72			48		384
scattered				24	48						24		24				120
sierra															24		24
smoke	24											24			24		72
snow									24								24
speed						24											24
student									24								24
taxiway															24		24
training									24								24
vasi								24									24
vor			24						24	24			24				96
water		24															24
whiskey														24			24
zulu															24		24

List of Word Errors Sorted By Item

wrong answer	right answer	subject	message	item
	zulu	8	15	1
	zulu	16	15	1
	kilo	16	8	1
	overcast	22	5	3
	broken	17	5	3
	overcast	17	1	3
	overcast	17	2	3
	overcast	17	3	3
	scattered	17	5	3
	overcast	17	9	3
	broken	17	7	3
	overcast	6	9	3
	broken	18	13	3
	broken	18	7	3
	overcast	18	2	3
	broken	17	6	3
	smoke	15	15	3
overcast	broken	5	7	3
	clear	8	8	3
	broken	6	13	3
	broken	6	14	3
	broken	6	15	3
	broken	7	5	3
	scattered	14	5	3
	broken	9	13	3
	clear	19	8	3
	broken	14	6	3
	broken	14	11	3
	broken	14	15	3
	broken	15	13	3
	broken	19	5	3

	overcast	6	9	3
	overcast	19	9	3
	scattered	19	12	3
	broken	21	5	3
	measured	1	16	3
	broken	23	15	3
	broken	19	12	3
	broken	23	7	3
	scattered	23	5	3
	broken	21	14	3
	broken	24	12	3
	broken	20	15	3
	overcast	20	9	3
	overcast	1	16	3
	blowing	7	9	4
	haze	12	16	4
	smoke	24	15	4
	haze	23	16	4
	broken	24	15	4
	rain	24	13	4
	blowing	24	11	4
	haze	13	16	4
	freezing	10	13	4
right	haze	11	16	4
	smoke	24	12	4
	freezing	24	13	4
	haze	6	16	4
	haze	10	7	4
rain	haze	9	16	4
	dust	24	11	4
	blowing	14	11	4
	smoke	6	15	4
	dust	23	11	4
	dust	14	11	4

	rain	18	13	4
	haze	17	7	4
	light	22	2	4
	light	19	2	4
	dme	18	13	4
	haze	17	6	4
	rain	19	2	4
	fog	19	2	4
	rain	22	2	4
	fog	22	2	4
	smoke	14	15	4
	snow	23	9	4
	smoke	23	15	4
	blowing	23	11	4
	haze	16	16	4
	smoke	16	15	4
	rain	23	2	4
	blowing	23	9	4
	fog	23	2	4
	freezing	18	13	4
	haze	24	16	4
	haze	3	16	4
	rain	4	13	4
	blowing	3	9	4
	fog	3	10	4
	smoke	3	15	4
	freezing	4	13	4
	smoke	4	15	4
snow	dust	2	11	4
snow	smoke	2	12	4
	snow	3	9	4
	haze	6	7	4
	gusts	14	13	7
	gusts	24	11	7

	gusts	16	13	7
	gusts	6	13	7
	gusts	15	13	7
	right	15	9	9
	ILS	2	7	9
	left	15	11	9
	right	18	8	9
	DME	15	13	9
	right	11	7	9
	right	10	14	9
	DME	10	13	9
	right	20	7	9
left	right	15	15	9
	ILS	5	1	9
	left	11	7	9
VOR		15	14	9
	VOR	23	13	9
	DME	23	13	9
	ILS	21	7	9
	VOR	15	9	9
	VOR	14	9	9
	right	23	7	9
	ILS	23	7	9
	right	14	7	9
	DME	2	13	9
	VOR	5	13	9
	ILS	14	7	9
	VOR	2	13	9
	right	14	9	9
	left	22	1	9
	right	15	7	9
	right	2	7	9
	ILS	15	7	9
	ILS	14	16	9

	VOR	23	9	9
	right	21	7	9
	DME	14	13	9
	ILS	14	15	9
VOR	ILS	21	10	9
	VOR	10	13	9
	VOR	16	13	9
	airport	16	9	9
	DME	22	13	9
	VOR	17	13	9
	right	19	7	9
	right	3	9	9
	VOR	17	9	9
	ILS	7	16	9
	ILS	17	10	9
	VOR	7	9	9
	ILS	17	11	9
	ILS	17	14	9
	DME	17	13	9
ILS	right	8	7	9
	ILS	17	15	9
	ILS	18	16	9
	right	24	15	9
	ILS	18	15	9
	ILS	18	7	9
	right	18	7	9
ILS	VOR	6	13	9
	DME	16	13	9
	VOR	22	13	9
	VOR	17	3	9
	left	17	1	9
	ILS	17	2	9
	VOR	17	4	9
	ILS	17	1	9

	right	24	7	9
left		19	16	9
	right	16	15	9
	VOR	19	9	9
	ILS	17	7	9
	VOR	3	9	9
	right	17	7	9
	right	22	7	10
	right	18	12	10
	left	22	7	10
	right	22	8	10
	left	18	7	10
	right	18	7	10
	right	15	8	10
	right	3	8	10
	left	15	11	10
	right	19	7	10
	left	19	11	10
	right	15	11	10
	right	19	11	10
	left	17	7	10
	right	15	12	10
	right	20	8	10
	left	19	7	10
left		16	12	10
	left	22	15	10
	right	24	9	10
	right	23	9	10
	right	1	11	10
	left	8	7	10
	right	8	7	10
	left	24	9	10
	right	1	15	10
	right	24	8	10

	right	24	12	10
	right	24	7	10
	left	24	7	10
	right	1	8	10
	right	22	15	10
	right	10	12	10
	right	7	12	10
	left	1	11	10
	left	24	15	10
left	right	6	8	10
	right	1	7	10
	right	24	15	10
	right	19	11	11
	permission	24	7	11
	taxiway	24	15	11
	VASI	24	8	11
	out	24	8	11
	left	24	8	11
	prior	24	7	11
	airport	19	9	11
	training	19	9	11
	student	19	9	11
	of	24	8	11
	airport	1	7	11
	hour	24	7	11
	right	19	15	11
	airport	24	6	11
	VASI	18	8	11
	airport	18	9	11
	ILS	18	11	11
	vicinity	24	6	11
	military	20	6	11
	aircraft	20	6	11
	without	24	7	11

	closed	24	15	11
	siera	24	15	11
	level	20	6	11
	low	20	6	11
	service	24	8	11
	permission	19	7	11
	VASI	19	8	11
	closed	1	7	11
	prior	1	7	11
	airport	19	5	11
	birds	19	5	11
	Providence	24	10	11
	permission	1	7	11
	closed	18	15	11
	level	19	6	11
	without	1	7	11
	more	1	7	11
	right	24	12	11
	aircraft	1	7	11
	low	19	6	11
	airport	24	9	11
	military	19	6	11
	prior	19	7	11
	without	19	7	11
	hour	19	7	11
	level	4	6	11
	low	4	6	11
	speed	4	6	11
	more	19	7	11
	training	24	9	11
	aircraft	19	7	11
	high	4	6	11
	airport	19	7	11
	student	24	9	11

	closed	19	7	11
	vicinity	20	6	11
	low	24	6	11
	permission	23	7	11
cooling	pooling	3	2	11
	permission	18	7	11
	hour	23	7	11
	speed	3	6	11
	prior	23	7	11
	low	3	6	11
	right	23	8	11
	aircraft	23	7	11
	prior	2	7	11
	VASI	21	8	11
	more	21	7	11
	aircraft	21	7	11
	closed	21	7	11
	airport	21	7	11
cooling	pooling	22	2	11
	military	23	6	11
	permission	2	7	11
	without	2	7	11
	without	22	7	11
cooling	pooling	23	2	11
	permission	22	7	11
	prior	22	7	11
	hour	22	7	11
	birds	23	5	11
	airport	23	5	11
	aircraft	22	7	11
	low	22	6	11
	closed	22	7	11
	airport	22	7	11
	low	23	6	11

	level	23	6	11
	military	22	6	11
	level	22	6	11
	hour	2	7	11
	aircraft	21	6	11
	airport	20	6	11
	without	20	7	11
	closed	23	15	11
	closed	23	16	11
	permission	20	7	11
	birds	24	5	11
	prior	20	7	11
	hour	20	7	11
	more	20	7	11
	taxiway	23	15	11
	aircraft	20	7	11
	closed	20	7	11
	airport	20	7	11
	airport	24	5	11
	high	24	6	11
	speed	24	6	11
	siera	23	15	11
	service	23	14	11
cooling	pooling	2	2	11
	ILS	23	11	11
	out	23	11	11
	military	21	6	11
	level	21	6	11
	low	21	6	11
	birds	21	5	11
	level	3	6	11
	military	3	6	11
	of	23	11	11
	of	23	14	11

	aircraft	3	6	11
	left	20	8	11
	VASI	20	8	11
	service	23	11	11
	right	23	12	11
	out	23	14	11
	high	3	6	11
	permission	17	7	11
	prior	18	7	11
	more	12	7	11
	level	12	6	11
	military	12	6	11
	aircraft	12	7	11
	without	12	7	11
	haze	6	7	11
	hour	12	7	11
	prior	12	7	11
	permission	12	7	11
	low	12	6	11
	right	11	11	11
	low	13	6	11
	more	11	7	11
	airport	11	7	11
	closed	11	7	11
	aircraft	11	7	11
	without	11	7	11
	left	11	11	11
	hour	11	7	11
	prior	11	7	11
	permission	11	7	11
	aircraft	6	6	11
	level	13	6	11
	level	11	6	11
	speed	14	6	11

	birds	14	5	11
	airport	14	5	11
	high	14	6	11
	low	14	6	11
	high	6	6	11
	level	14	6	11
	military	14	6	11
	aircraft	14	6	11
	broken	14	5	11
	ILS	14	4	11
	military	13	6	11
	more	13	7	11
	airport	13	7	11
	closed	13	7	11
	aircraft	13	7	11
	without	13	7	11
	speed	6	6	11
	hour	13	7	11
	prior	13	7	11
	permission	13	7	11
	military	11	6	11
	low	11	6	11
	airport	14	6	11
	right	7	12	11
sta	students	7	9	11
	training	7	9	11
	airport	7	9	11
cooling	pooling	8	2	11
	airport	7	5	11
	birds	8	5	11
	airport	8	5	11
	military	8	6	11
	more	6	7	11
	birds	7	5	11

	aircraft	8	7	11
	of	6	13	11
	VASI	6	8	11
	ILS	6	13	11
	out	6	13	11
	service	6	13	11
	without	6	7	11
	permission	6	7	11
	prior	6	7	11
	hour	6	7	11
	aircraft	8	6	11
	more	8	7	11
cooling	pooling	11	2	11
	low	10	6	11
	airport	9	8	11
	airport	6	7	11
	left	6	7	11
	level	10	6	11
	prior	9	7	11
	right	6	7	11
	right	6	7	11
	ILS	10	13	11
	permission	9	7	11
	hour	9	7	11
	without	8	7	11
	aircraft	6	7	11
	hour	8	7	11
	prior	8	7	11
	permission	8	7	11
	closed	6	7	11
	without	9	7	11
	birds	9	5	11
	airport	9	5	11
	military	9	6	11

	vicinity	14	6	11
	closed	14	7	11
	airport	14	7	11
	hour	18	7	11
	airport	4	6	11
	vicinity	17	6	11
	airport	17	6	11
	airport	4	7	11
	airport	17	7	11
	military	17	6	11
	closed	17	7	11
	aircraft	17	7	11
	more	17	7	11
	aircraft	17	6	11
	level	17	6	11
	hour	17	7	11
	more	4	7	11
cooling	pooling	17	2	11
	hour	4	7	11
	without	4	7	11
	aircraft	4	7	11
	low	17	6	11
	closed	4	7	11
	high	17	6	11
	speed	17	6	11
	without	17	7	11
	prior	17	7	11
	closed	17	1	11
	airport	18	6	11
	military	18	6	11
	aircraft	18	6	11
	vicinity	18	6	11
	military	4	6	11
	low	18	6	11

	aircraft	18	7	11
	more	18	7	11
	without	18	7	11
	level	18	6	11
	aircraft	4	6	11
	lights	6	10	11
	of	17	8	11
	VASI	17	8	11
	left	17	8	11
	out	17	8	11
	service	17	8	11
	airport	17	9	11
	vicinity	4	6	11
	student	17	9	11
	training	17	9	11
	prior	4	7	11
	right	17	1	11
	aircraft	14	7	11
	service	14	13	11
	lights	14	12	11
	out	14	13	11
	of	14	13	11
	LOM	14	14	11
	ILS	14	11	11
	right	5	12	11
	airport	5	9	11
	taxiway	14	15	11
	intensity	14	12	11
	birds	6	5	11
	closed	14	15	11
	prior	14	7	11
	more	14	7	11
	without	14	7	11
	hour	14	7	11

	permission	14	7	11
	airport	6	5	11
	VASI	14	8	11
	right	14	8	11
	airport	14	9	11
	sierra	14	15	11
	closed	14	16	11
	permission	4	7	11
	aircraft	16	7	11
	closed	15	16	11
cooling	pooling	16	2	11
	military	16	6	11
	right	16	9	11
	sierra	15	15	11
	right	1	4	11
	right	16	12	11
	closed	16	16	11
	closed	15	15	11
	taxiway	15	15	11
	birds	15	5	11
	aircraft	15	6	11
	airport	15	5	11
	low	15	6	11
	level	15	6	11
	aircraft	15	7	11
	aircraft	5	7	11
	prior	15	7	11
	permission	15	7	11
	training	5	9	11
	left	6	8	11
	level	24	6	11
	military	24	6	11
	aircraft	24	6	11