



**SUPPLEMENTARY COMPUTER GENERATED CUEING TO ENHANCE AIR
TRAFFIC CONTROLLER EFFICIENCY**

THESIS

Laurienne C.R.A. Santana, Lieutenant, Brazilian Air Force

AFIT-ENV-13-M-25

**DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY**

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

**DISTRIBUTION STATEMENT A:
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED**

The views expressed in this thesis are those of the author and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the United States Government.

SUPPLEMENTARY COMPUTER GENERATED CUEING TO ENHANCE AIR
TRAFFIC CONTROLLER EFFICIENCY

THESIS

Presented to the Faculty

Department of Systems and Engineering Management

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Information Resource Management

Laurienne Cibelle Rodrigues de Assis Santana

Lieutenant, Brazilian Air Force

March 2013

DISTRIBUTION STATEMENT A:
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED

SUPPLEMENTARY COMPUTER GENERATED CUEING TO ENHANCE AIR
TRAFFIC CONTROLLER EFFICIENCY

Laurienne Cibelle Rodrigues de Assis Santana
Lieutenant, Brazilian Air Force

Approved:

Brent T. Langhals, Lt Col, PhD, USAF (Chairman)

Date

Dr. Michael E. Miller, PhD (Member)

Date

Dr. Victor Finomore Jr., PhD (Member)

Date

Abstract

Air traffic controllers are often required to simultaneously communicate with several aircraft over multiple radio frequencies. As a result, during peak loading, it is common for the controller to receive multiple concurrent communications, each from a different aircraft, making it difficult to discern audio messages received from multiple pilots simultaneously. To address this problem, a modified air traffic control (ATC) interface was prototyped with the goal of increasing controller-to-pilot communication efficiency. This prototype included supplementary text cueing which was provided by a hypothetical automated text to speech system in an on-screen text box for controller reference in the event of an obscured or indiscernible radio call. The prototype was then evaluated by a group of 35 participants, all with ATC experience including 12 students and 23 instructors at the Air Force controllers' school house Keesler AFB, MS. The text cueing improved controllers' comprehension of pilots' transmissions.

To God: for His unconditional love and grace. To my beloved husband and family: for their trust and support throughout this work.

Acknowledgments

I would like to express my sincere appreciation to my faculty advisor, Lt Col Brent Langhals, for his guidance and support throughout the course of this thesis effort. I would, also, like to thank my colleague Jason Russi for his observations and experience, which were most certainly appreciated.

Laurienne C.R.A. Santana

Table of Contents

Abstract	iv
Acknowledgments	vi
Table of Contents	vii
List of Figures	ix
List of Tables	x
I. Introduction	1
General Issue	1
Problem Statement	2
Research Objective	3
Summary	5
II. Literature Review	7
Chapter Overview	7
Description	7
<i>ATC Environment</i>	7
<i>Human Factors and ATC Communication</i>	9
<i>The role of computer generated text cueing</i>	16
<i>Memory recall</i>	20
<i>Design Considerations</i>	22
Summary	24
III. Methodology	26
Chapter Overview	26
Relevant Population	26
Research Design	27
Scenario Description	28
Permission to conduct research	31
Equipment	31
Experiment	32
Measurements Development	37
Pilot Study	39
Summary	40
IV. Analysis and Results	42

	Page
Chapter Overview	42
Results	42
Investigative Questions Answered	44
<i>H1: Supplementary text transcription of pilots' communication will increase controllers' comprehension of pilots' transmissions.....</i>	44
<i>H2: Supplementary text-cueing will improve memory recall on pilots' transmissions</i>	47
<i>H3: Supplemental text box will increase controller's distraction.....</i>	49
<i>H4: Additional text-cueing will reduce perceived difficulty of the communication task between controllers and pilots</i>	52
Summary	53
V. Conclusions and Recommendations	55
Chapter Overview	55
Findings.....	56
Limitations	58
Contributions to Research	59
Implications for ATC community and for Air Force	60
Future Research Recommendations	62
Conclusion	65
Appendix A: IRB Approval Letter	67
Appendix B: Authorization Letter to access controllers	68
Appendix C: Informed Consent	69
Appendix D: Timeline Procedure	75
Appendix E: Pre-Questionnaire	84
Appendix F: Training Scenario.....	86
Appendix G: Training Questionnaire.....	87
Appendix H: Post-Questionnaire Control Scenario	88
Appendix I: Post-Questionnaire Experimental Scenario	89
Bibliography	91
Vita.....	99

List of Figures

	Page
Figure 1: Radar display with proposed text on-screen technology.....	5
Figure 2: Wickens et al.'s (1997) cognitive model of the controller's task.....	11
Figure 3: Wickens' Four-Dimensional MRT Model	13
Figure 4: Drullman and Bronkhorst speech intelligibility results.....	16
Figure 5: Control Scenario - Radar Scope	30
Figure 6: Experimental Scenario - Radar Scope.....	30
Figure 7: Participants' workstation	33
Figure 8: Experimental workstation.....	33
Figure 9: SIGNAL Software.....	35
Figure 10: MMC System Interface	36

List of Tables

	Page
Table 1: Research Hypotheses	25
Table 2: Research Hypotheses and Measurements	39
Table 3: Descriptive Statistics H1	45
Table 4: Independent Samples Test - H1	45
Table 5: Coefficients H1	46
Table 6: Model Summary H1	46
Table 7: Descriptive Statistics H2	48
Table 8: Independent Samples Test - H2	48
Table 9: Descriptive statistics H3	50
Table 10: Independent Samples Test - H3	50
Table 11: Coefficients Table H3 - Model	51
Table 12: Model Summary H3	51
Table 13: Descriptive Statistics H4	52
Table 14: Independent Samples Test - H4	53
Table 15: Summary of Findings	56

SUPPLEMENTARY COMPUTER GENERATED CUEING TO ENHANCE CONTROLLER EFFICIENCY

I. Introduction

General Issue

Use of technology is increasing every day. Advances in hardware and software offer promising opportunities for automating or augmenting a greater range of information gathering, information processing, decision making, and control functions than has been possible in the past. Along with these advances comes the question of the degree to which emerging hardware and software systems impact human performance. It is the influence of the technology on user's efficiency during a decision making process that is interesting to this researcher, specifically in the air traffic control environment where the effectiveness of the tool facilitates critical decisions.

Many ways to automate routine tasks and to implement automated aids have been investigated to optimize the controller's workload (Erzberger, 2001; Oprins et al., 2009). Much of the effort to modernize air-traffic control services is focused on the development and implementation of effective computer-based decision support tools (Weber et al, 2007; Couluris, Schleicher, and Weidner, 1998). A common challenge in the application of decision support tools for air traffic control is to assure an adequate human factors design and also improve the time-critical aspect of controller decision making.

This research has implications for development of systems and tools for the increasingly congested environment of air traffic control, especially when it comes to controllers. Air traffic controllers play a critical role on Air Traffic Control System (ATCS). The human aspects of developing decision aids to enhance Air Traffic Control

(ATC) efficiency need to be carefully considered and carried out through detailed study about human factors and how they could be impacted by the tool to continually ensure safety of aircrews and passengers within the ATCS.

Problem Statement

“The safe, orderly, and expeditious flow of air traffic” (Hopkin, 1991a) have long been the fundamental objectives of ATC (see Federal Aviation Administration, 1989a). Controllers have a critical role in ensuring the achievement of these traditional fundamentals. The complex and dynamic environment that controllers deal with requires that they continually revise all the information available to base and make their decisions. The need of accurate information availability, decision making and action execution in time-critical ATC is explained well in a 2004 issue of The International Journal of Aviation Psychology (Rantanen, McCarley & Xu, 2004):

“To carry out their tasks, controllers rely on a mental picture comprising static information of the airspace layout, the rules and standard procedures regulating the conduct of flight, aircraft flight plan information and performance characteristics, and the dynamic traffic situation changing from moment to moment (Rantanen, 1994). Given the dynamic nature of ATC, the temporal aspects of the controllers’ mental picture are apparent, as are the temporal demands of their tasks: Controllers need to anticipate aircraft trajectories and pilot intentions well into the future, plan their actions, and then execute the planned actions at a proper time and in an appropriate sequence.”

Given this observation, it is extremely important that controllers have all the necessary and critical information available to make effective decisions in a timely manner. This makes availability of critical information invaluable to facilitate accurate decision making; the more critical information accessed by controllers, the better their ability to make good decisions.

The goal of this paper is to study the impacts of additional text tool on controller's performance. In light of the aforementioned, the focus question presented for this study is:

Does supplementary computer generated cueing enhances controller efficiency in a congested communication environment?

Research Objective

In the future, ATC will be frequently challenged due to the expected increase in the amount and complexity of air traffic (Stein and Garland, 1993). The Federal Aviation Administration (FAA) Aerospace Forecast for Fiscal Years 2012-2032 stated that in 2011, total activity at FAA en-route centers increased by 1.8 percent from the previous year to a total of 41.2 million, the fastest growth since 2005. It also predicts that airport tower operations are expected to increase by 23 percent. Also, the number of aircraft handled at FAA en-route centers, which separate high altitude traffic, is expected to increase by 50 percent (FAA, 2012).

The area of particular interest in this study is the communication between pilots and controllers, which is the foundation of air traffic control (Hopkin, 1995). As the air traffic load increases, the same is expected to occur with communication load in ATC. Frequency congestion is a sensitive situation that occurs during the communication process between pilots and controllers and "has become a factor that severely constrains the capacity of the National Airspace System (NAS)" (Rantanen, McCarley & Xu, 2004). Controllers often deal with a congested communication environment and are frequently required to communicate with several aircraft over multiple radio frequencies. As a

result, during peak loading, it is common for the controller to receive multiple concurrent communications, each from a different aircraft, and it becomes a challenge to discern audio messages received from multiple pilots simultaneously (this phenomenon is known as “step-on”). As operators monitor all frequencies through a single earpiece, it is impossible for the controller to interpret concurrent communications resulting in additional workload as the controller must then decipher the source of each communication and request each aircraft to repeat the communication asynchronously. In some extreme cases, improper or misunderstood communication is also the cause of many accidents (Rantanen et al, 2004).

The proposed method improves upon the existing ATC workstation by providing text transcriptions of pilot's audio communication to ATCs. The text transcriber technology is used to transcribe all pilots' communication from different frequencies into a single text box in the right side of the radar display with a timestamp, based on the actual time of the transmission - the last call is displayed sequentially as the last text-transcription - as shown in Figure 1, allowing a controller to easily read what is being said by pilots of aircraft under their control. The text allows the controller to respond without having to transmit a request for a repeat, wait for a re-transmission by a pilot, then respond, which adds exponentially to frequency congestion. This design provides the controllers with all the necessary information in a usable and readable format for the communication task, located on a single window, displayed in a sequentially manner, according to the sequence of pilots' transmissions, as it is desired in the design of the ATCS (Cardosi and Murphy, 1995). It should also decrease the time and steps needed to

answer pilots' requests, increasing controller's efficiency and safety within the National Airspace System (NAS).

The objective of this study is to identify possible benefits of using supplemental text cueing of pilots' transmissions in order to enhance controllers' ability to understand pilots' requests and potential improvement on controllers' efficiency and ultimately guarantee the safety of the NAS.

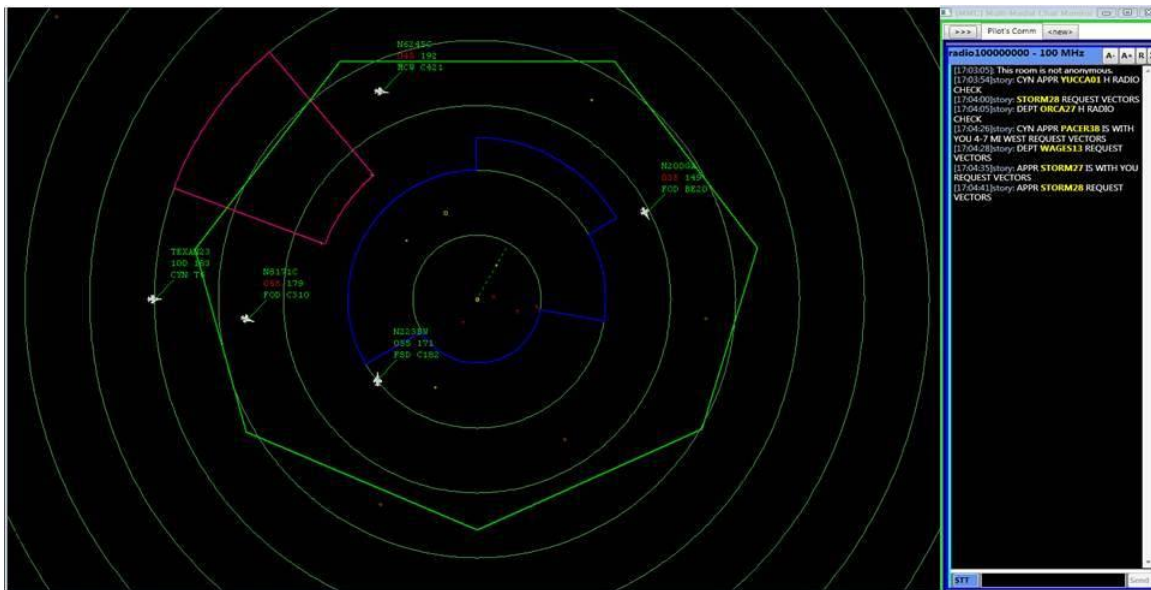


Figure 1: Radar display with proposed text on-screen technology

Summary

This chapter discussed the problems associated in dealing with a congested communication environment. The following chapter will review the literature around ATC and cognitive characteristics that may provide insight into improving controllers' performance. Specific, hypotheses concerning supplemental text cueing will be proposed. Chapter three will present the methodology for measuring the impact of this technology on controller efficiency, information on the relevant population, and the experiment data

collection techniques. Chapter four will analyze the data collected from the participants during the experiment. Chapter five will discuss the results, findings, limitations, and implications of this research effort to the ATC community and the US Air Force, and concludes with recommendations for future research.

II. Literature Review

Chapter Overview

This chapter contains a literature review with detailed information and research relevant to this effort. This portion of the writing culminates with the generation of five hypotheses that were developed to investigate the research question listed in Chapter 1.

Description

ATC Environment

The proposed technology is based on a user-centered design approach. This approach emphasizes that the system is expected to attend to the users' demands. The main idea behind an user-centered design is that "if a product, an environment or a system is intended for human use, then its design should be based upon the characteristics and needs of its human users" (Pheasant, 1989). According to the European Organization for the safety of Air Navigation (EUROCONTROL), in their paper regarding Human Factors (HF) Integration in Future Air Traffic Management (ATM) Systems (2000):

"User-centred design is an approach to systems design that emphasizes that the purpose of the system is to serve the user. It is important to understand who the users are, and the tasks they do."

In order to study the impacts of new technology in the ATCS, it is important to understand the characteristics of the environment that it is dealing with.

ATC is a dynamic environment where controllers constantly receive a large volume of information from multiple sources to monitor changes in the environment, make decisions, and perform effective actions in a timely manner (Xing & Manning, 2005). The NAS consists of a vast network of people and equipment designed to provide

a safe and efficient flying environment. ATC is a service provided by ground-based controllers that work within the NAS to direct aircraft on the ground and in the air. Controllers are responsible for managing and coordinating the flow of air traffic and ensuring safe flights, arrivals, and departures with minimal delays.

The role of controllers is a critical one. The ATC system's intricacies include thousands of separate facilities all communicating with each other and handling information via different sources (e.g., radar screen with a series of automated visual cues, paper or electronic flight progress strips, radio and interphone communication). Air traffic controllers have to deal with all these different sources of information and control complex, dynamic and time-constrained traffic situations to identify and resolve potential conflict and risky relationships between aircraft. Many studies have been conducted to assess the complexity of air traffic control (Mogford, Guttman, Morrow, & Kopardekar, 1995; Laudeman, Shelden, Branstrom, & Brasil, 1998). Controllers have to perceive, analyze, comprehend, and anticipate multiple characteristics and flight paths of many aircraft while new incoming aircraft create new traffic relationships for evaluation. All of this must be performed in real-time and for the purpose of separating aircraft and issuing safety alerts (FAA, 2012).

In dealing with dynamic and complex tasks it is important to understand how controllers are affected by technology to understand the impact of a new system in this environment.

Human Factors and ATC Communication

Human factors implications of automation have been heavily researched (Wiener and Curry, 1980; Wiener, 1985; Sarter and Woods, 1994, 1995a, 1995b). The EUROCONTROL, in another paper about HF case process (2007), stated that:

“The goal of HF is to better match the system to the human, and the human to the system. Incorporating the wider view of all the HF aspects into the design and ongoing operation of the ATM system increases efficiency, enhances safety, and reduces costs in the long term.

ATM system design must be user-centred and based on operational requirements to make the best use of human strengths and capabilities while compensating to the maximum possible extent for human limitations.”

The use of new tools requires that controllers integrate the interaction demands of the new system into the management of their cognitive resources (Bressolle, Benhacene, Boudes, & Parise, 2000). The automation should be carried out with analysis of controller information needs and an understanding of the perceptual and cognitive characteristics of the controller to effectively support decision making (Wickens, 1998). This leads to the concept of cognitive engineering, which implies the need to understand what really makes the task difficult for the operators and how this difficulty impairs human performance so as to define the most effective aids (Rasmussen 1986; De Montmollin & De Keyser, 1985; Mancine, Woods & Hollnagel, 1988).

Controllers deal with timely decision making and need to be provided with the necessary information to make an effective decision. In addition to designing systems that provide the operator with the needed information and capabilities, it must be provided in a way that it is usable cognitively (Endsley & Garland, 2000). If information provided by the tools overwhelms controllers' cognitive capacities, critical information

could be either missed or misinterpreted and put performance at risk (Xing & Manning, 2005). The way information is presented to controllers should reduce complexity and improve understanding of the environment. For air traffic control, complexity reflects the difficulty to formulate an accurate mental representation of the situation, given many sources of information about aircraft, sectors, and flight rules (Xing & Manning, 2005). This is an important concept that needs to be considered when designing a system in an ATC environment, and it is known as situation awareness (SA).

A generic model of the cognitive processes involved in the ATC's task, proposed by Wickens et al. (1997), illustrated in Figure 2, which states that SA is the principal input to decision making and planning. Situation awareness is a fundamental requirement for effective air traffic control forming the basis for controller decision making and performance (Endsley & Rodgers, 1994; Endsley & Smolensky, 1998). It can be said that SA is the operator's internal model of the state of the environment. Based on that representation, operators will make decisions about the presented situation (Endsley, 1995b). SA is the result of the continuous extraction of environmental information, integration of this information with previous knowledge to form a coherent mental picture, and the use of that picture in directing further perception and anticipating future events (Dominguez et al. 1994). SA is the design objective of systems to support the operator's ability to obtain the needed information under dynamic operational constraints (Endsley & Garland, 2000).

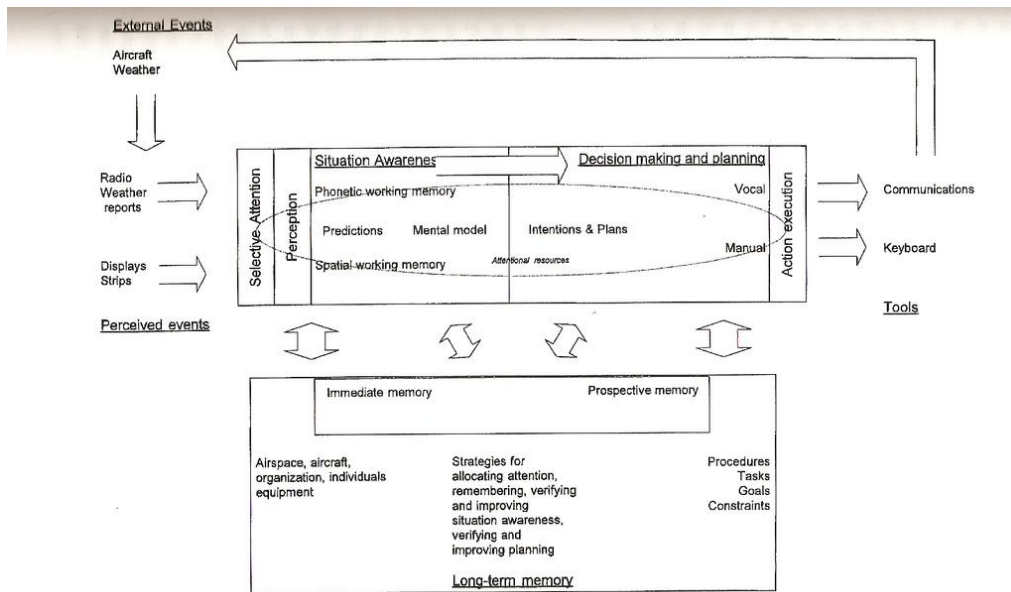


Figure 2: Wickens et al.'s (1997) cognitive model of the controller's task

The model in Figure 2 shows five cognitive stages that lies between events and actions involved in the controller's task: selective attention, perception, SA, decision making and planning, and action execution. In the controllers' tasks, actions (on the right) are driven by events (on the left). The model also includes the influence of memory in the controller's task where the immediate memory supports the SA for dynamic events, while the prospective memory supports actions to be made in the near future. Each of the five processes draws on knowledge stored in the structures of long-term memory. The model suggests that controllers selectively perceive events to develop and maintain SA of the situation, and that SA is the principal input to decision making and planning, which may result in the execution of actions such as communications and keyboard use (D'Arcy and Rocco, 2001). Controllers respond to events from many different forms, including visual changes on the radar display, such as the one proposed by the additional text cueing. For

this reason, based on this model, decision aids in the radar display, may influence decision making and planning because it influences the process of building and maintaining SA.

To provide systems and cues that better support the decision making process and enhance situation awareness it is also important to understand how human processing of information occurs. Wickens' (2008) multiple resource theory (MRT) 4-D model, illustrated in Figure 3, identified the structural dimensions of human information processing and proposes that there are four dimensions (processing stages, perceptual modalities, visual channels, and processing codes) with two categorical levels of each dimension (i.e. separate resources). According to the author (Wickens, 2002), in another paper relating multiple resources and performance prediction:

“All other things being equal (i.e. equal resource demand or single task difficulty), two tasks that both demand one level of a given dimension (e.g. two tasks demanding visual perception) will interfere with each other more than two tasks that demand separate levels on the dimension (e.g. one visual, one auditory task)”.

The theory proposes that distinct pools of resources require different types of processing. It is based on the assumption that separate attentional resources (audio, visual, etc.) are associated with different processing stages, processing codes, and sensory channels.

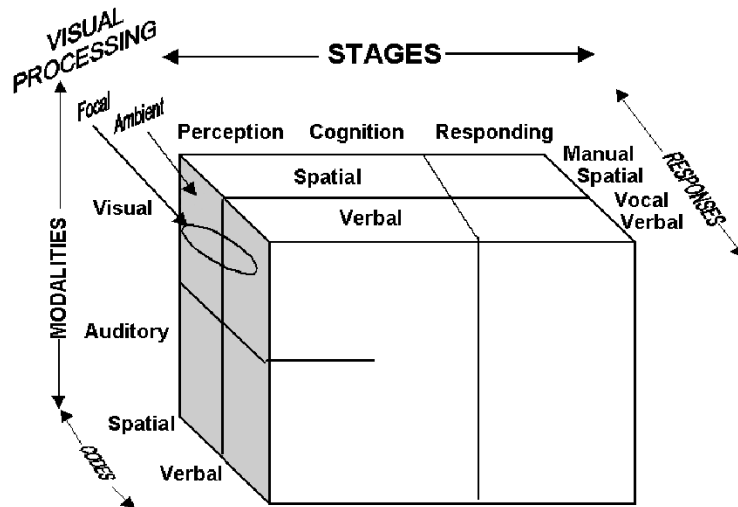


Figure 3: Wickens' Four-Dimensional MRT Model

This theory suggests that cognitive resources used to process information from one modality do not compete with the resources used to process input from another modality, resulting in a task-sharing benefit if information is distributed across different resources. According to this theory, an improvement in performance would be expected when different input modalities are addressed in a multitask environment (Parasuraman & Metzger, 2006).

Multiple Resource Theory has been heavily explored by researchers to study the effects generated by the inclusion of systems or different cues that require different attentional resources in the ATC environment (Weikert, 2002; Hopp, Smith, Clegg & Heggstad, 2006). Parasuraman & Metzger (2006), in their study about effects of automated conflict cueing on air traffic controller performance and visual attention, stated that the use of auditory feedback is already being investigated by the FAA (Newman & Allendoerfer, 2000). Auditory channels are not currently utilized for feedback or cueing

from automation tools in ATC due to the heavy use of voice communication in today's ATC operations.

Typically a controller wears a single-ear headphone in which they receive inputs from many different audio sources including but not limited to; air to ground radios, inter and intra facility coordination phones, speakers (ambient "shout" lines), other controller positions, and/or landline telephones including both direct dial and party lines. These are used to communicate with other controllers and well as listening to and transmitting on (monitor) different frequencies. Often a controller may monitor as many as a dozen different UHF/VHF frequencies, to receive communication from pilots. Of particular interest for this study is the situation when two or more pilots are operating on different frequencies but being handled by one controller, as is very frequently the case between civilians using VHF and military aircraft on UHF for example. The pilots do not hear each other but the controller can have one transmission completely obscured by the other, permitting the controller to understand bits and pieces but not all of both communications leading to potential misunderstandings. "Step-ons" as they are commonly referred to, are simply two or more users transmitting simultaneously resulting in interference from the perspective of the controller regarding both transmissions.

To correct this, a controller follows a simple but time consuming and labor intensive process, distracting them from their primary task usually during periods of increased traffic volume and complexity. Once a step-on occurs and two transmissions are overridden, distorted or obscured, the controller, if he/she saw which frequencies transmitted, will isolate at least one of them by de-selecting the transmit function of the other radio channels to prevent simulcasting a request for repeat. This involves asking a

pilot to repeat and getting the same step-on condition again. They will then transmit a "say again" call to get one of the aircraft to repeat themselves. The pilot will repeat and the controller may not monitor or "tune-out" one of the other frequencies to focus on what was previously missed – a risky practice during heavy traffic. Once the controller gets the requested information, they will respond and then deselect this frequency to key-up the previously de-selected frequency to repeat the process with the other pilot. This can cost precious time, and lead to loss of situation awareness as all other transmissions and pilot requests go unanswered or are delayed during this isolation repeat/isolation repeat sequence. In their study about time delays in the air traffic communication loop, Rantanen et al (2004) stated that “frequency congestion has become a factor that severely constrains the capacity of the National Airspace System (NAS)”.

Additionally, Drullman and Bronkhorst (2000), in their study about multichannel speech intelligibility and talker recognition using monaural, binaural, and three-dimensional speech stated that speech communication is degraded when speakers talk over one another. While ATC does not use ambient open-air speakers, but rather in-ear or over the ear mono-speaker headphones, Drullman and Bronkhorst’s results are still pertinent for determining the effectiveness of the communication while obscured by multiple transmissions. The percentage of words and sentences understood correctly in the study decrease as the number of competing talkers increases. Figure 4 shows the mean percentage of words (panel A) and sentences (panel B) correct for the different presentation modes (e.g. monaural, binaural, and 3D with individual or general head-related transfer functions) as a function of the number of competing talkers. As expected by the authors, the scores decrease as the number of competing talkers increases.

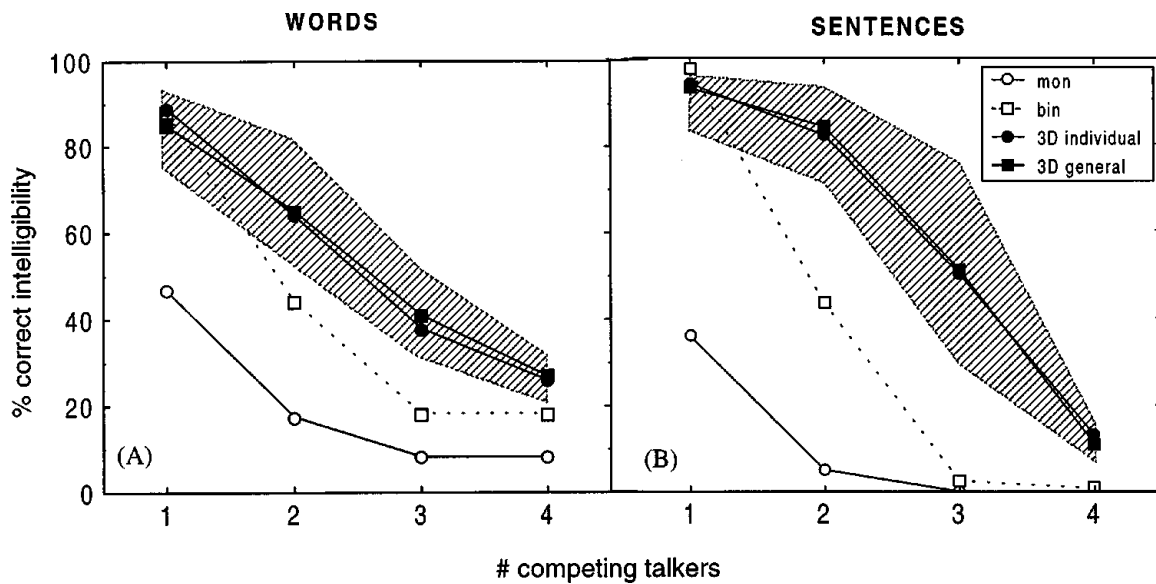


Figure 4: Drullman and Bronkhorst speech intelligibility results

Given the potential for decreased understanding arising from simultaneous speakers and the multitask environment of controllers, another source of attention, according to the MRT Model in Figure 3, would be useful to explore. Therefore, text cueing may be particularly useful, in the sense that it adds other source of attention to decrease audio congestion and potentially improve controllers' efficiency.

The role of computer generated text cueing

A European study (Nijhuis and North, 1998) called the "Role of the Human in the Evolution of ATM" provided a framework within which each automation concept may, in principle, be categorized. The report stated that "full automation" and "the controller as a supervisor of the system" are not suitable because of the negative impact on safety. The report also stated that "cognitive tools" seem to be the most promising method for improving ATC effectiveness. The report defined cognitive tools as "machine assistance for organizing controller tasks based on typical controller's heuristics". To improve

effectiveness, automation should be driven by a human-centered approach. Automation should assist and augment the capabilities of the controller.

In a critical environment, where information must be captured, processed and decisions must be made in a timely manner, and where errors are critical factors, the level of automation must be carefully limited. Technology must be used to support, not replace, the human in the decision making process in ATC. Computer systems are limited in technical knowledge and are not as versatile as the human expert (Will, 1991). Computers should not make decisions for the controller. Instead, to maximize its impacts, computers should provide assistance in making those decisions.

Willems and Truitt (1999) studied the effect of moving a controller from the current active control to a monitoring position. The author concluded that controller situation awareness was lower under monitoring conditions; however controllers perceived that their situation awareness did not change between active control and passive monitoring, which warrants even more careful examination.

Studies have shown that operators have a better mental model or awareness of the system state when they are actively involved in creating the state of the system than when they are passively monitoring the actions of another agent or automation (Endsley, 1996; Endsley & Kiris, 1995). Several studies have shown that conflict detection performance and situation awareness were reduced and mental workload increased under simulated free flight (FF) conditions, where there is a transfer of responsibility for separation between aircraft from controllers to pilots. (Castaño & Parasuraman, 1999; Corker, Fleming, & Lane, 1999; Endsley, Mogford, Allendoerfer, Snyder, & Stein, 1997; Endsley & Rogers, 1998; Galster, Duley, Masalonis, & Parasuraman, 2001; Metzger &

Parasuraman, 2001). These investigations provided the first empirical evidence of the effects of future ATM concepts on controller performance and pointed to the passive monitoring role (Metzger & Parasuraman, 2001) as factors contributing to reduced controller performance (Metzger & Parasuraman, 2005).

The addition of text cueing is proposed to be an optional tool for air traffic controllers. They should be able to choose to display it or minimize it on screen to increase their own efficiency. The role of the text is to supplement the audio communication from pilots and not substitute it, provide redundancy of audio communications received from pilots to provide better frequency management, and reduce superfluous transmissions to reduce frequency congestion, which will also reduce response time.

The text as visual information will co-occur with the audio transmission, which shall increase the probability that at least one signal will be detected. The advantage of adding a visual component to audio is by providing redundancy and to facilitate the understanding the audio communication. Redundancy is a useful technique that can be provided to decrease or even prevent information loss. Studies have shown that speech intelligibility performance generally improves as complexity increases and contains higher degree of redundancy and more contextual information (Rash, Russo, Letowski, and Schmeisser, 2009). Further voice communication is transient while text is persistent, permitting ATC personnel to choose to access the information at the earliest convenient time, as opposed to disrupting every other task to insure receipt of auditory information.

Therefore, in the light of the aforementioned, the text cueing is hypothesized to improve frequency congestion and ultimately controllers' efficiency in the sense that it

will reduce the need for say-again transmissions, because controllers will be able to better comprehend pilot's transmission with the additional text on-screen.

H1: Supplementary text transcription of pilots' communication will increase controllers' comprehension of pilots' transmissions.

In developing a system that enhances controllers' capabilities on the communication task, characteristics of the technology shall be considered in order to analyze the impact of the media on controllers' performance.

Media Richness Theory proposes that each channel has its own characteristics that determine its capacity of reproducing rich information (Daft and Lengel, 1984). According to this theory, specific messages should be communicated on the appropriate channel that provides the sufficient media richness capacity. Carlson and Zmud (1994) reformulated the Media Richness Theory, and proposed the Channel Expansion Theory (CET). The authors stated that media richness is seen not only based on the channel characteristics for itself, but to be more a perception of the user based on familiarity and experience with the medium, and less a characteristic intrinsic to the channel.

Based on this theory, an individual's perception about the richness of the channel may affect how the individuals improve their performance during the communication task using the channel. Additional text on-screen is the media presented to controllers in order to enrich their performance on the communication task. Familiarity and experience with the proposed technology may influence controllers' ultimate performance with the text cueing.

Therefore, it is expected that text cueing shall be perceived as a rich media by the participants that are already familiar with the technology more than the controllers that

are not so experienced with the on-screen text. Familiarity is expected to influence controllers' performance with the technology.

Memory recall

Short-term memory accuracy has been a fundamental talent required by controllers to base decisions and actions to ensure safety. It is an important characteristic in the decision making process in ATC because the scene is very dynamic, with rapid changes.

Decision making, in the context of air traffic control systems, is a continuing activity that utilizes the controller's comprehensive understanding of information at several levels of detail, together with the controller's knowledge of rules, procedures and instructions and their permissible flexibility (Hopkin, 1995).

Controllers are decision makers in a dynamic environment involving many factors; constant updating of relevant information, and, most of the time, conflict detection and avoidance. Controllers must address the sometimes conflicting goals of safety and efficiency, "through an intricate series of procedures, judgments, plans, decisions, communications, and coordinated activities" (Wickens, Mavor, & McGee, 1997).

Numerous studies have been done and different systems have been researched to enhance the efficiency of the ATCS (Weber et al, 2007; Couluris, Schleicher, and T. Weidner, 1998). Some of the new proposals and concepts, such as free flight (RTCA, 1995), distributed air ground traffic management (NASA, 1999), Automatic Dependent Surveillance-Broadcast (McCallie, 2011), and next generation air transportation system (Joint Program Development Office, 2004) will change the role of air traffic controllers

altogether. Pilots and airline dispatchers will receive greater freedom to choose speed, heading and altitude (Parasuraman and Metzger, 2006). Controllers must be able to remain in control of such complex and dynamic systems, which requires that the controller maintain a high level of situation awareness.

According to Endsley (1995b) there is a strong relationship between SA and memory. In her work, the author reviewed various methods for measuring SA and stated that “SA, composed of highly relevant, attended to, and processed information, should be most receptive to recall”. According to Endsley a participant’s SA can be accessed by measuring recall (Gronlund et al, 1997). In this sense, the importance of improving short-term memory recall is directly related to the improvement of situation awareness.

According to Tindall-Ford, Chandler, and Sweller (1997), the use of dual-mode presentation techniques (e.g., auditory text and visual diagrams) with students can result in superior learning to equivalent, single-modality formats (e.g., visual text and visual diagrams). According to the authors, this modality effect may be attributed to an effective expansion of working memory.

With the use of text transcription on screen, controllers should be able not only to listen, but also read what was said, allowing the participants to use two sensory modalities (e.g., auditory and visual) instead of just one (e.g., auditory), according to the MRT model. The information presentation will be split between auditory and visual display, in an attempt that neither mode will be overused, as desired for the design of ATCS (Cardosi and Murphy, 1995). As it occurs in the learning processing with students, when controllers listen and read pilots’ transmission it is hypothesized to also

improve memory recall. In this sense, text cueing is hypothesized to improve controller's recall of what was seen and heard within the air traffic scene.

H2: Supplementary text-cueing will improve memory recall on pilots' transmissions

Design Considerations

Design considerations were crucial to include the text on the radar screen to increase controller's performance and reduce potential distraction caused by the new text on screen, since a user-centered design approach was adopted for the proposed technology.

Distraction is a psychological error mechanism (PEM) that is known to affect performance (Shorrock and Kirwan, 2002). In their paper describing a human error identification (HEI) technique called TRACER, a technique for the retrospective and predictive analysis of cognitive errors in ATC, the authors stated that distraction can affect different cognitive domains, such as: perception and vigilance (i.e. errors in visual detection and visual search, and errors in listening); memory (i.e. forgetting or misrecalling temporary or longer-term information, forgetting previous actions, and forgetting planned actions); and action execution (i.e. actions or speech performed not as-planned). For this reason, potential causes of distraction in ATC should be carefully considered in the design of new aids to ensure that controllers' performance will not be impaired.

Today controllers are not experienced with supplementary text displayed on the side of the radar screen. Ensuring safety is a priority for the design of ATCS. Although the text box was carefully designed to reduce distraction such that safety would not be

compromised, this factor was measured as a self-reported question to check the potential distraction caused by the text on radar screen.

H3: Supplemental text box will increase controller's distraction

Some design choices were also considered in order to decrease potential distraction and increase controller performance through the addition of text. Parasuraman and Metzger (2006) suggested that the controllers' primary display is the radar display and this is also where critical events would most likely unfold and have to be detected. Visual attention might be directed there by default. If the visual alert indicating a conflict is integrated on the display, chances are low that it will be missed (Parasuraman & Metzger, 2006).

Considering some changes caused by all innovations proposed for ATCS and the increasingly congested environment, controllers will need tools to enhance performance and SA while monitoring the air traffic. Text cueing could improve performance and save controller's time, making more time available to monitor the radar display.

Also, Murray & Caldwell, 1996 found that the number of displays, in which participants should detect and identify objects, had a great impact on participant performance. When increasing the number of displays that need to be monitored the response time of the operators was reduced. Therefore, integrating the text in the radar display will reduce time spent to monitor different displays, which will better fit with controllers' visual attention when integrated on the radar display.

The text box that transcribes the audio communication was included on the radar display to be more effective and reduce time spent moving from one display to another and reduce time where controllers are not looking to the main screen (radar display).

Regarding positioning, it was also considered that the right side of the main display may be more effective. Cultural aspects should be considered while developing an interface that may be more useful. People tend to scan the elements in an interface similar to general reading (left to right; top to bottom – Western cultures). Western culture's interfaces should have a left to right flow of information (Russo and Boor, 1993). The most important information (radar screen) should be displayed in the left and the decision aid was included in the right.

The text box was located on the right side of the main display since the additional text must not block or obstruct the radar display which provides essential ATC information (Cardosi and Murphy, 1995).

Additionally, the text box on the main display is hypothesized to facilitate the communication task. The text should reduce complexity because controllers will not need to follow too many steps to understand and answer pilots' transmissions. The new technology should allow them to easily identify what was said and directly answer the requests.

H4: Additional text-cueing will reduce perceived difficulty of the communication task between controllers and pilots

Summary

This research effort proposes that the text cueing shall enhance controller's efficiency in a congested communication environment. Controllers that are more experienced and familiarized with text on screen will perform better than those that are not used to the proposed technology. Further it is hypothesized that the proposed

technology will reduce the need of say again transmissions for pilot's and improve controllers' short-term memory recall, which will also reduce the perceived difficulty of the communication task. A summary of the research hypotheses is provided in Table 1.

Table 1: Research Hypotheses

Hypothesis	
H1:	Supplementary text transcription of pilots' communication will increase controllers' comprehension of pilots' transmissions
H2:	Supplementary text-cueing will improve memory recall on pilots' transmissions
H3:	Supplemental text box will increase controller's distraction
H4:	Additional text-cueing will reduce perceived difficulty of the communication task between controllers and pilots

These hypotheses were developed to verify the potential of the proposed technology. It is upon the hypotheses proposed in this chapter that the experiment methodology in Chapter 3 is based to measure the impact of additional text cueing on controllers' communication task

III. Methodology

Chapter Overview

The preceding chapters identified the need for and the potential of supplementary text cueing technology in the ATC environment. The hypotheses presented suggest that voice-to-text transcriptions will enhance controllers' performance in their communication task with pilots by increasing comprehension of pilots' transmissions.

This chapter will present the methodology used to investigate the research hypotheses proposed in Chapter 2. Included are outline descriptions of the research design, population under study, survey instrument, data collection, pilot study, and the actual experiment.

Relevant Population

This research focuses on the whole air traffic control population. For the purpose of this study, the sample population was concentrated to a military training installation at Kessler Air Force Base, MS, where the experiment was conducted using thirty-five personnel, including instructors and students. Participation was voluntary and data was collected through a one week period. All the participants were familiar with the air traffic route and with the software used in the experiment. To avoid compromising the study, participants were asked not to share the details of the study or talk about the questionnaires with others until the end of the data collection period.

Research Design

To determine if support for the hypotheses identified in the previous chapter exists, an experiment was conducted which could both measure perceptions and test for efficiency improvement as an interactive measure during the experiment. The experiment was designed as a within subjects study to account for learning/sequence bias. According to Erlebacher (1997), a within subject approach results in an increased statistical power. Keren stated that a within-subjects study allows, "...the exclusion of individual differences resulting in a higher degree of sensitivity to treatment effects" (1992). Furthermore, the exposure sequence was assigned randomly, mitigating potential for learning bias and order bias and further strengthening the design for optimum management of participant pool and highest statistical yield.

All the participants were given a participant number, by which they were identified throughout the experiment. Participants were provided a brief training period, and then provided control and experimental conditions. Every participant was their own control baseline. The exposure sequence was assigned randomly, mitigating potential for learning bias.

A timeline that details the experimental sequence and standard steps was developed and exactly followed by the researchers to insure the same conditions and procedures were followed with all the participants. See APPENDIX D for the complete timeline procedure used for this experiment.

The three simulated scenarios were presented for the participants: training, control and experimental scenarios. The training was the first scenario, followed by a training questionnaire. To ensure the validity of the measurements, a treatment set provided to the

subjects consisted of a training session to familiarize them with the experiment flow and their role during the experiment. It offered no challenge to the participants and the data obtained from the training questionnaire were not analyzed. Participants were not presented to the new technology until the experimental scenario. After the training, the control and experimental scenarios were assigned to the participants in random order. Participants with odd numbers had the control condition first and participants with even numbers had the experiment condition first.

Data was collected during a one-week period, during the morning and afternoon, in order to access as many participants as possible in a limited time. On all questionnaires handed to the participants, they were asked to provide their participant number to track individual performance characteristics throughout the experiment tasks without linking any other personal identification other than the information provided in the questionnaires. The participant number was provided to the individuals as they arrived at the experiment location.

Scenario Description

For the experiment, 3 scenarios were recorded: training, control and experimental. The training scenario was developed to allow the controllers to become familiar with the experimental process and their role in the experiment. However, participants were not presented with the new technology until the experimental scenario. The control scenario was used as a baseline to compare controllers' performance and did not included any text boxes, only a standard radar screen that controllers would already be familiar with. The experimental scenario had the text box with the transcription of audio communication,

and a screen capture was shown to each participant immediately before the scenario to explain how the text would appear on the screen.

All the scenarios used for this study were previously recorded as movies that did not allow controllers' interaction. This attribute reduced changes on the scope between participants allowing comparison of subjects' performance. The scenarios were designed to be as realistic as possible in order to test the hypotheses of interest. Also, the control and experimental scenarios were developed to be equally complex in order to provide reliable comparison between controllers' performance regarding just the addition of the technology. The control and experimental scenarios included 8 aircraft each, 1 of which was a departure and 1 an emergency, see Figures 5 and 6. A total of 13 pilot transmissions were recorded for each scenario.

For the purpose of this study, a 100 % accurate transcription of the audio communication was assumed. The objective of the study is to collect initial data of controllers' performance and perceptions of the advantages of the additional text, and not to test the technology itself.

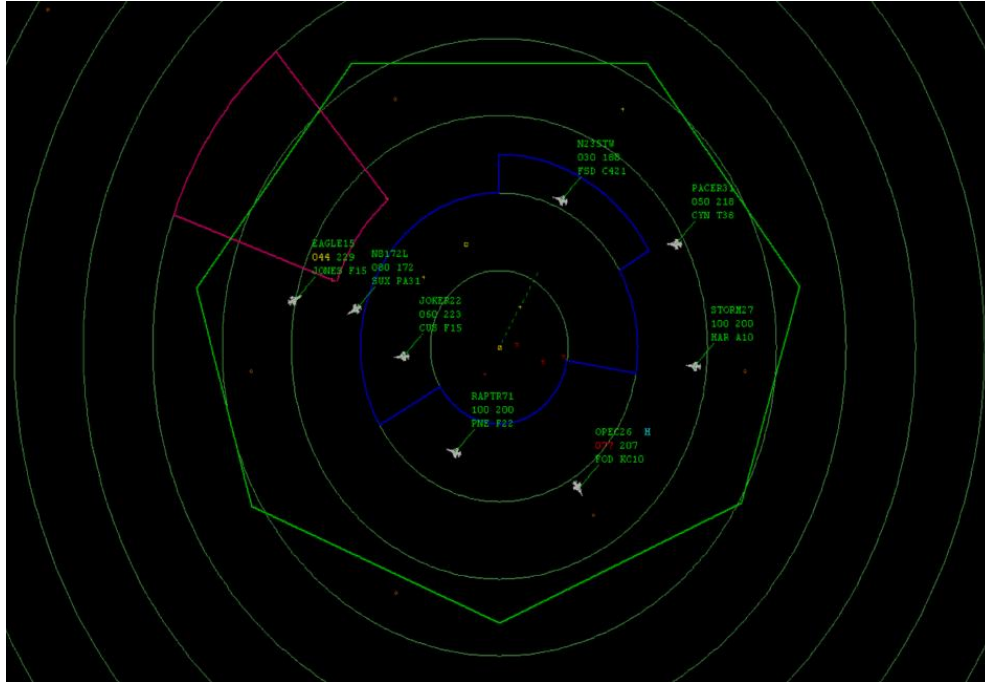


Figure 5: Control Scenario - Radar Scope

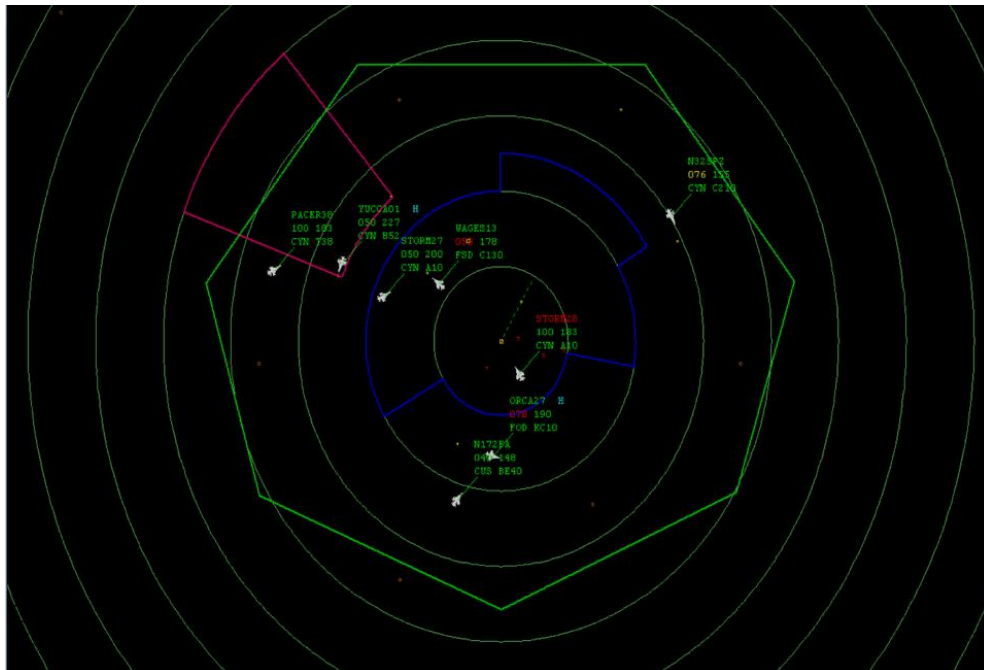


Figure 6: Experimental Scenario - Radar Scope

Permission to conduct research

This experiment involved the performance of Air Force personnel and conducted experimentation in accordance with human experimentation requirements (AFI 40-402). An exemption was sought to use Department of Defense personnel as volunteers for additional text cueing research. This exemption was granted by the Air Force Institute of Technology Institutional Review Board (AFIT IRB). Additional authorization to access active duty US Air Force and DoD Civilian controllers granted by USAF ATC Career Field Manager and Technical School Commander. See Appendixes A and B for authorization letters.

Equipment

To develop the ATC simulated scenarios and proceed with the experiment several equipment items including software and hardware were used and are described below:

1. Lenovo Thinkpad T420i , 64 bit, intel core i3-2310M processor, Windows 7 Enterprise OS, 4.00GB memory, 300 GB HD. It had Signal e MMC softwares installed that were used to develop and record the ATC scenes.
2. SIGNAL Air Traffic Control Simulation Program software. Authorized use by FAA to develop and record air traffic scenarios
3. Multi-Modal Communication (MMC) System. Authorized use granted by the inventor. Software used to transcribe the text
4. HP computer with MMC software used to record audio and it also had the clickcounter software installed
5. Clickcounter Software freeware mouse click tracking program used during the experiment to track the number of clicks for each participant.
6. Microsoft wireless mobile mouse 3500 (2). Used by the participants for subjects' real time inputs and used by the researcher to load the scenes on the monitor.
7. Epiphan DVI2USB Duo External DVI Capture box device. It was used to record the simulated ATC scenarios from the originating machine (Lenovo laptop) to the Receiver (Dell laptop)

8. Dell precision M4600 workstation, Windows Professional 7, 64 bit, 250 GiG HD, 16 GB DDR3 SDRAM, NVIDIA 3D suite, NVIDIA quadro 1000M discrete graphics card, intel core i7 extreme processor. It was used to capture the ATC scenes and it was connected to the main display that was viewed by the participants. It had NVIDIA 3D software installed.
9. StarTech display port to DVI Dual link Active Converter cable- USB powered. It was used to connect the Dell computer to the ASUS monitor to facilitate operating NVIDIA 3D active shutter display.
10. ASUS VG236 23.5" 3D 120Hz LCD display monitor (commercial).
11. NVIDIA 3D software used to load the ATC scenes that were showed for the participants
12. 3D vision USB Controller/IR Emitter. It is a needed component to NVIDIA software
13. Headphone: Beyerdynamic USB connected MMX1 over the ear headphones

All the scenarios were developed using the Signal software, also the MMC software for the text transcription. They were recorded from the Lenovo computer using the capture box to the Dell computer, which was connected to the ASUS Monitor. The scenarios were showed for the participants on the Monitor using the NVIDIA software installed on the Dell computer.

Experiment

The experiment was designed to follow the research design and experiment timeline, see Appendix D. The workstation that participants interacted with, see Figure 7, consisted of a display, which showed the radar scenarios, a mouse and a headphone. The researchers' workstation, see Figure 8, consisted of two computers: researcher 1 interacted with the computer that had the recorded scenarios that were loaded to the participants' display; and researcher 2 interacted with the computer that had the mouse click software installed to track the number of mouse clicks.



Figure 7: Participants' workstation



Figure 8: Experimental workstation

The SIGNAL software, see Figure 9, provided familiar training simulations using existing training scenarios developed at the technical school and incorporating their imaginary airfield, "Canyon Approach". By taking existing scenarios and modifying them to exacerbate the potential for "step-on" radio transmissions by injecting realistic aspects of aircraft traffic flow and event sequencing, we were able to develop scenarios that were realistic and familiar to the participants by using aircraft call signs, types, airspace parameters and runways familiar to them in their current training environment. This further eliminated the impact of minimal pre-exposure training, allowing the participants to focus on the conflicts and dynamic aspects of the scenes without unneeded distraction having to overcome any unfamiliarity with unique types, call signs and airspace/airfield characteristics. Communications between pilots and controllers were simulated using pre-recorded pseudo-pilots; the controllers' responses were not recorded allowing the observer's the opportunity to develop their own mental responses and plans-of-action eliminating any bias a pre-recorded "pseudo-controller" input may have caused.

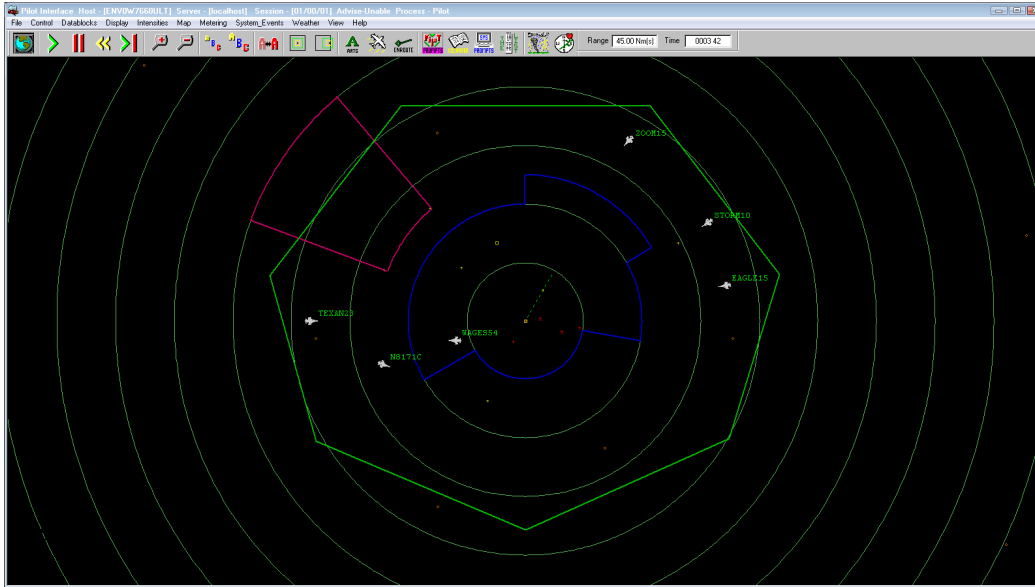


Figure 9: SIGNAL Software

MMC software is a Multi Modal Communication System that was developed by the 711th Air Force Research Laboratory's Battlespace Acoustic Branch, see Figure 10. MMC suite is an Integrated Network- Centric Communication Management Suite that provides operators with net-centric, collaborative tools to accurately monitor multiple communication channels and make quick and effective decisions (Finomore et al, 2010). It is a complex communication system that captures, records, transcribes and displays radio and chat communications to the operator with the goal of alleviating the workload and errors associated with intensive communication environments (Finomore et al., 2011), providing intuitive and immediate accessibility to communication data.

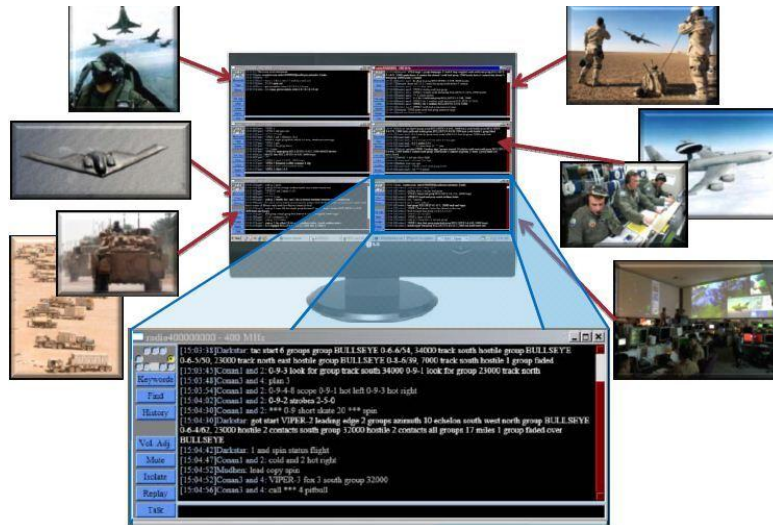


Figure 10: MMC System Interface

A limited and modified version of the MMC was used in this study to provide the on-screen speech-to-text transcription of all pilots' communication from different frequencies in a single text box in the right side of the radar display, allowing a controller to easily read what is being said by pilots of aircraft under their control.

Participants were briefed before starting the experiment about each section of the simulation. All participants received a consent form, see Appendix C, which they signed and stated that they voluntarily agreed to participate in this study. All the scenarios occurred in a dark room, consistent with an actual air traffic control facility. A pre-questionnaire was used to collect some demographics, see APPENDIX E. Participants were told that the scenarios would be stopped after a certain time and that they would be asked detailed questions about what they saw and heard. Controllers were asked to actively monitor the scene and to be able to respond to pilots' transmissions as they normally would because that would be most beneficial for the study.

The first exposure was always the training scenario, see APPENDIX F. After the training scenario, a training questionnaire, see APPENDIX G, was handed to the participants with questions about what they just saw and heard.

After the training, the control and experimental scenarios, see Figures 5 and 6, were assigned to the participants in different orders. After each 3 minute scene, the display was blanked and a questionnaire was handed to the participants. A paper copy of the last minute of the respective scene was provided to the participants with a limited radar scope, including just the position and the call signs of the aircraft. This was provided to yield a memory aid to help controllers recall the scene.

Measurements Development

All measurements were developed to accurately evaluate the research hypotheses. A total of 3 air traffic scenarios were presented to the participants. After each scenario, a questionnaire was handed to the participants. Again, participant numbers were used to mark and compare individual performance and perceptions about the technology.

The measure utilized for the first hypothesis was the number of mouse clicks. A free open software application named “Click Counter” was installed on a computer with a mouse connected that was used by the participants. One mouse click by the participants meant the need for a “SAY AGAIN” transmission. Participants were briefed to carefully monitor and listen for the pilots’ transmissions during the 3-minute air traffic scene. They were asked to monitor the scene as if they needed to answer all requests from pilots as occurs in a regular air traffic control task, but they should interact by just clicking the mouse one time if they feel that a “SAY AGAIN” transmission was necessary to

completely understand each pilot transmission and be prepared to accurately answer. During the experimental scenario, where controllers were presented with the text transcription of pilots' transmissions, participants were asked to utilize the new technology to the maximum extent possible, but if they felt that a "SAY AGAIN" transmission was still necessary to be able to fully understand and answer pilots' transmissions, they should click the mouse.

As subjects were submitted to the control and experimental treatments, the comparative aspect of this study between both groups was expected to identify that the need for "SAY AGAIN" transmissions with the new technology decreased, therefore, potentially decreasing frequency congestion and decrease the time to understand and answer pilots' transmissions.

For the second hypothesis, a query technique was used to measure recall. Currently, there is no general agreement upon a correct methodology to measure SA (Gronlund et al, 1997), but the query technique is the most commonly used method (Adams, Tenney, and Pew, 1995). This method measures what the participants recall from memory. Using this method, study participants engaged in a task simulation, which was temporarily suspended after several minutes. When the display blanked, the participant was required to answer a series of questions about what they just saw.

In this study, query technique was used to measure short-term memory recall after the controllers were exposed to a 3 minute air traffic scene. In his study on measuring controllers' memory, Gronlund et al (1997) stated that controllers relied on spatial information to remember large quantities of information. That is why, in this study, a

screen capture was provided for the controllers with the questionnaires to improve their ability to recall the scenario.

For the third hypothesis, self-reported questions about distraction were asked of the participants during each of the post-Questionnaires, and the answers were compared within participants on the control and experimental conditions.

For the last hypothesis, self-reported questions about perceived difficulty and facilitation of the task by the use of the text on-screen were asked of the participants during the post-questionnaire. The answers were again compared within participants on the control and experimental conditions. A summary of the hypotheses and measures used for this research is provided in Table 2.

Table 2: Research Hypotheses and Measurements

Hypothesis		Measures Used
H1:	Supplementary text transcription of pilots' communication will increase controllers' comprehension of pilots' transmissions	Mouse Clicks
H2:	Supplementary text-cueing will improve memory recall on pilots' transmissions	Post-questionnaire – Query technique
H3:	Supplemental text box will increase controller's distraction	Post questionnaire – Self-reported
H4:	Additional text-cueing will reduce perceived difficulty of the communication task between controllers and pilots	Post questionnaire – Self-reported

Pilot Study

A pilot study was carried out approximately three weeks before the initial experiment. The pilot study was conducted with 6 volunteers, from which 2 were Air Force Institute of Technology graduate students, 3 were air traffic controllers from Wright Patterson AFB Tower and 1 was a Human Factors researcher and a former airline pilot in a campus room on WPAFB, Dayton, OH.

The pilot study was conducted with a control and experimental scenario. There was no training section. The experimental scenario included 2 text boxes to transcribe audio communications from pilots.

The goals of the pilot study were: (1) check the validity of the current experiment structure, (2) check the validity of the current questionnaire structure, (3) gather feedback on the test and survey, and (4) verify the proposed technology.

Useful remarks were received from the pilot study. The initial use of two text boxes was viewed as distracting due to the lack of training for the new technology and no usable data was collect. Since the new technology was not used by participants, a training session was included to familiarize the participants with the experiment flow and purpose. The text box was adjusted in accordance with notable remarks to make it more readable and useful. Before the pilot study, the text transcription was all white, but after some controllers' remarks, the call-signs of the aircraft were coded to yellow in the text-transcriptions to help the controller maintain productive scanning by facilitating the identification of the aircraft that made the call.

Summary

This chapter presented the methodology for procuring data correlating theory to controller's efficiency. Specifically a research design was operationalized to an experimental model which could quantitatively measure the proposed hypothesis.

Treatments and questionnaires were administered to participants on control and experimental conditions so measurements could be obtained to enable a comparative analysis within participants. Finally, this chapter concluded with a complete description

of the procedures used in the experiment and instrument measurements and reliability, which lends further credence to the plausibility of data to be analyzed in the following chapter.

IV. Analysis and Results

Chapter Overview

The previous chapter identified the methodology for acquiring data in order to support the hypotheses. This chapter presents an analysis of data collected during the experiment and interprets results. Each hypothesis proposed on Chapter 2 is analyzed. All the statistical tests in this study were conducted using SPSS software.

The independent t-test was conducted to analyze if there is statistically significant difference between the means in the control and the experimental groups.

In the case that the t-test was significant, stepwise regression was conducted to identify significance between control and experimental groups for two reasons. First, stepwise regression it is the fastest way to analyze the data when there are many variables, especially when using a tool as advanced as SPSS or similar statistical software package. Second, in this procedure, each time a new variable is added to the model, the significance of each of the variables already in the model is re-examined, and this process continues until no more variables can be added or removed, leaving only the significant variables in the model.

Results

Realism was measured to validate the scenarios and the use of the new technology. There was no statistically significant difference between groups, which means that both scenarios were perceived to be equally realistic. Also, 94.3% (33/35) of the participants reported that they found the technology to be useful in this capacity.

The dependent variables for this study were number of clicks (H1), recall (H2), distraction (H3) and difficulty (H4). The main independent variable was group (control and experimental). Other independent variables also considered for this study were gender, experience, education, use of glasses, eye surgery, distraction, ability to multitask, individual ability to read, individual ability to understand transmissions, trust, computer use, open mind, and familiarity.

All these independent variables were considered to analyze the potential influence of those factors on controllers' performance. The main concern of this study is the difference between the control and experimental groups, but the other variables were also considered for their potential influence on the results. Gender was considered to analyze potential differences between men and women, but no significant influence was found. Experience in ATC was considered as a potential variable that could significantly influence performance. Education was considered since it could have been a potential factor to understand the benefits generated by the use of new technology. Use of glasses and eye surgery were considered to study their potential influence on participants' performance while scanning the radar display and/or reading text on screen. Self-distraction was considered to identify the participants that are easily distracted while working ATC. Individual ability to multitask was considered to identify the participants that have trouble multitasking, which could influence their ability to listen the transmission and read the on-screen text at the same time. Individual ability to read was considered because of its potential impact on participants' ability to rapidly read the text on-screen. Individual ability to understand transmissions was considered to measure individuals' potential to comprehend "step-ons" during pilots' transmissions. Trust was

considered to evaluate its influence on the use and individual performance with the additional text. Computer use was considered to measure time spend using the computer and its influence on participants' performance. Open mind was considered to evaluate participants' receptivity to new technologies and changes in their regular workstation. Familiarity with the proposed technology was also considered to study its influence on participants' performance.

An independent t-test was used to determine statistical differences between experimental and control means for each hypothesis. In the cases that t-test showed significance, stepwise regression was conducted to determine the influence of the independent variables considered in the model.

Investigative Questions Answered

H1: Supplementary text transcription of pilots' communication will increase controllers' comprehension of pilots' transmissions

Hypothesis 1 assumes a negative relationship between numbers of clicks and comprehension. The dependent variable was number of clicks (e.g. comprehension). High number of clicks was interpreted to imply low comprehension. The independent variable was group (control group as number 0 and experimental group as number 1) and other independent variables were also considered for stepwise regression (gender, experience, education, use of glasses, eye surgery, self-distraction, ability to multitask, individual ability to read, individual ability to understand transmissions, trust, computer use, open mind, and familiarity). All the independent variables collected with the Pre-questionnaire

were considered to analyze the potential influence of those factors on controllers' comprehension.

An independent t-test was conducted with 95% Confidence Interval (CI) to check for significant difference between control and experimental groups, see Tables 3 and 4, and since significance was found, stepwise regression was conducted to analyze the influence of the independent variables on comprehension, see Tables 5 and 6.

The data was assumed normally distributed for both groups, since a t-test is a robust test with respect to the assumption of normality, and there was homogeneity of variance as assessed by Levene's Test for Equality of Variances. Therefore, an independent t-test was run on the data as well as 95% CI for the mean difference. It was found that number of clicks in the experimental group (group 1, 1.14 +/- 2.341) were significantly lower than for the control group (group 0, 2.34 +/- 1.327) at $t(68) = 2.638$, $p = .010$ with a difference of 1.2 (95% CI, .292 to 2.108).

Table 3: Descriptive Statistics H1

Group	Mean	Std. Deviation	N
0	2.34	1.327	35
1	1.14	2.341	35
Total	1.74	1.983	70

Table 4: Independent Samples Test - H1

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% CI of the Difference	
									Lower	Upper
Clicks	Equal variances assumed	1.653	.203	2.638	68	.010	1.200	.455	.292	2.108
	Equal variances not assumed			2.638	53.813	.011	1.200	.455	.288	2.112

A statistically significant difference ($p < .05$) was discovered between the treatment and control groups, identifying a definitive change in comprehension. Therefore, stepwise regression was run to determine the influence of the independent variables on comprehension. The model indicated a variance explained of 47% (Adjusted $R^2 = .477$) with other independent variables that helped explain the model, such as open mind, familiarity, multitask and experience at $F(69) = 13.609$, $p = .000$.

Table 5: Coefficients H1

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
5	(Constant)	10.137	1.456		6.964	.000
	Open Mind	-.845	.238	-.330	-3.557	.001
	Familiarity	-.189	.094	-.200	-2.014	.048
	Group	-1.200	.343	-.305	-3.502	.001
	Multitask	-.358	.128	-.253	-2.799	.007
	Exper. (years)	.061	.025	.237	2.442	.017

Table 6: Model Summary H1

Model				Std. Error of the Estimate
	R	R Square	Adjusted R Square	
5	.718	.515	.477	1.434

Participants with open mind that reported they believe that new technologies can improve ATC had lower numbers of clicks and better comprehension. Participants that reported they are familiar with the text on-screen technology had a lower number of clicks as expected. Participants that reported they are able to multitask and feel comfortable listening and reading at the same time had a lower number of clicks.

Participants with higher experience in ATC had higher numbers of clicks. Individuals with more experience may have been more resistant to the change in presentation of the data due to its significant difference from their standard workstation. However, inexperienced controllers may have been more receptive to the new display not having been fully acclimated to the current standard display like the experienced group.

The findings for Hypothesis 1 indicate a strong relationship between the interface and the number of clicks which indicates that text cueing improved comprehension. The number of mouse clicks for the treatment group was significantly lower than for the control group, implying that the experimental group's comprehension was improved through the availability of text cueing.

H2: Supplementary text-cueing will improve memory recall on pilots'

transmissions

Hypothesis 2 predicts an improvement in memory recall with the use of the text on-screen. The dependent variable was the number of correct answers for the recall questions. The independent variable was group (control group as number 0 and experimental group as number 1).

Independent t-test was conducted with 95% Confidence Interval (CI) to check for significant difference between control and experimental groups, see Tables 7 and 8.

The data was assumed normally distributed for both groups, since t-test is a robust test with respect to the assumption of normality, and there was homogeneity of variance as assessed by Levene's Test for Equality of Variances. Therefore, an independent t-test was run on the data as well as 95% CI for the mean difference. It was found recall in the experimental group (group 1, 3.14 +/- 1.517) was not significantly different than the

control group (group 0, 3.2 +/- 1.208) at $t(68) = 0.174$, $p = .862$ with a difference of 0.057 (95% CI, -.597 to .711).

Table 7: Descriptive Statistics H2

Group	Mean	Std. Deviation	N
0	3.20	1.208	35
1	3.14	1.517	35
Total	3.17	1.362	70

Table 8: Independent Samples Test - H2

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% CI of the Difference	
									Lower	Upper
Recall	Equal variances assumed	1.759	.189	.174	68	.862	.057	.328	-.597	.711
	Equal variances not assumed			.174	64.743	.862	.057	.328	-.598	.712

No statistically significant difference ($p > .05$) was discovered between the treatment and control groups. The findings for Hypothesis 2 indicate that there is no significant difference in memory recall due to the use of the new technology.

The role of memory has been heavily researched in the air traffic environment and its importance concerning whether the controllers should retain memory or not has been debated. Some studies defend that controllers deal with a constantly dynamic environment and therefore deal with dynamic memory since the scene changes every time. Hopkin (1980) stated that the ability to forget the information is as important as the ability to remember, allowing them to deal with just the necessary information required

and avoid the workload associated with keeping memory. A solution to the limitations and constraints of memory, according to Stein and Garland (1993), is to provide a more reliable visual display that shall increase the transient visual and/or auditory information.

According to the authors:

“Such memory aiding would allow prolongation and subsequent storing of the information, potentially enhancing the fidelity of working memory. A controller would then not need to overcome the fragilities of working memory, because the information would be physically present, requiring only simple perceptual processing.”

This additional information mentioned by the authors is also provided by the supplemental text that will be available for controllers on screen as a memory aid.

Even if doesn't improve memory recall, the text on screen still provide a good aid because controller can have the ability to quickly find and look the information instead of relying on his/her memory.

H3: Supplemental text box will increase controller's distraction

Hypothesis 3 predicts an increasing distraction with the use of the text on-screen. The dependent variable was distraction, self-reported by controllers in the post-questionnaires. The independent variables were group (control group as number 0 and experimental group as number 1) and other independent variables were also considered for stepwise regression (gender, experience, education, use of glasses, eye surgery, self-distraction, ability to multitask, individual ability to read, individual ability to understand transmissions, trust, computer use, open mind, and familiarity). All the independent variables collected with the Pre-questionnaire were considered to analyze the potential influence of those factors on controllers' distraction.

Independent t-test was conducted with 95% Confidence Interval (CI) to check for significant difference between control and experimental groups, see Tables 9 and 10, and then stepwise regression was conducted in order to analyze the influence of the independent variables on distraction, see Tables 11 and 12.

The data was assumed normally distributed for both groups, since t-test is a robust test with respect to the assumption of normality, and there was homogeneity of variance as assessed by Levene's Test for Equality of Variances. Therefore, an independent t-test was run on the data as well as 95% CI for the mean difference. It was found that distraction in the experimental group (group 1, 6.09 +/- 3.381) was significantly higher than the control group (group 0, 4.57 +/-2.779) at $t(68) = -2.047$, $p = .045$ with a difference of -1.514 (95% CI, -2.991 to -.038).

Table 9: Descriptive statistics H3

Group	Mean	Std. Deviation	N
0	4.57	2.779	35
1	6.09	3.381	35
Total	5.33	3.166	70

Table 10: Independent Samples Test - H3

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% CI of the Difference	
									Lower	Upper
Distraction	Equal variances assumed	2.623	.110	-2.047	68	.045	-1.514	.740	-2.991	-.038
	Equal variances not assumed			-2.047	65.540	.045	-1.514	.740	-2.992	-.037

A statistically significant difference ($p < .05$) was discovered between the treatment and control groups, but the model only explained 9.3% of the variance (Adjusted $R^2 = .093$). Due to the very low variance explained, definitive conclusions cannot be drawn for Hypothesis 3 at $F(69) = 4.537$, $p = .014$.

Table 11: Coefficients Table H3 - Model

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
2 (Constant)	9.114	2.166		4.209	.000
Multitask	-.560	.259	-.247	-	.034
Group	1.514	.721	.241	2.158	.039
				2.101	

a. Dependent Variable: Distraction

Table 12: Model Summary H3

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
2	.345	.119	.093	3.015

b. Predictors: (Constant), Multitask, Group

Participants that reported they are able to multitask and feel comfortable listening and reading at the same time had lower distraction caused by the additional text on screen.

The findings for Hypothesis 3 indicate a significant difference between the treatment and control groups on distraction. Additionally, participants that self-reported high ability to multitask and feel comfortable reading and listening at the same time had lower distraction. The distraction for the treatment group was significantly higher than for the control group, but no definitive conclusions can be made due to the very low variance explained.

H4: Additional text-cueing will reduce perceived difficulty of the communication task between controllers and pilots

Hypothesis 4 predicts a decrease in the perceived difficulty of the task with the use of the text on-screen. The dependent variable was difficulty, self-reported by controllers in the post-questionnaires. The independent variable was (control group as number 0 and experimental group as number 1).

Independent t-test was conducted with 95% Confidence Interval (CI) to check for significant difference between control and experimental groups, see Tables 13 and 14.

The data was assumed normally distributed for both groups, since t-test is a robust test with respect to the assumption of normality, and there was homogeneity of variance as assessed by Levene's Test for Equality of Variances. Therefore, an independent t-test was run on the data as well as 95% CI for the mean difference. It was found difficulty in the experimental group (group 1, 8.17 +/- 2.065) was not significantly different than the control group (group 0, 7.40 +/- 1.802) at $t(68) = -1.665$, $p = .100$ with a difference of $-.771$ (95% CI, -1.696 to .153).

Table 13: Descriptive Statistics H4

Group	Mean	Std. Deviation	N
0	7.40	1.802	35
1	8.17	2.065	35
Total	7.79	1.963	70

Table 14: Independent Samples Test - H4

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Difficulty	Equal variances assumed	.005	.941	-1.665	68	.100	-.771	.463	-1.696	.153
	Equal variances not assumed			-1.665	66.776	.101	-.771	.463	-1.696	.153

No statistically significant difference ($p > .05$) was discovered between the treatment and control groups. The findings for Hypothesis 4 indicate that there is no significant difference in perceived difficulty of the task due to the use of the new technology.

Summary

The findings from this data analysis identify some significant findings relative to the proposed technology. Specifically, Hypothesis 1 is supported since the new technology increased participants' comprehension. Hypothesis 2 was not supported, but the text available on screen is still good since it can be used by the controllers as a memory aid. Hypothesis 3 was not supported, since any definitive conclusions could be drawn due to the very low variance explained. Hypothesis 4 was also not supported, as the technology did not affect the perceived difficulty of the task, which means that the task was not perceived more difficulty with the aid of the new technology. The following

chapter will discuss and interpret the results of this study and their impact to academic and ATC field.

V. Conclusions and Recommendations

Chapter Overview

The problem of providing effective tools for controllers has long been discussed. Air traffic controllers play a critical role in the ATCS. The literature review highlighted the importance of considering the human aspects of developing decision aids to enhance ATC efficiency. The development of computer generated cueing to enhance efficiency needs to be carried out with careful study as the tool could impact safety within the ATCS.

Systems and computer cueing need to be designed with a cognitive engineering process to address human impact. It is also important to understand the limits of automation to enhance decision making. It is desired that controllers actively monitor the situation to develop a better situation awareness that allows understanding of the environment and improve the decision making process. Given the critical role of conflict detection and resolution on controllers' decision making, it is desired that decision aids support this activity.

Guided by MRT, the real-time application of supplementary computer cueing to enhance efficiency needs to be carefully studied. The competition for controllers' attentional resources resulting from the inclusion of the text on-screen shall be carefully considered to fit with situational priority. The supplementary cueing shall provide decision aids without reducing the controllers' mental picture about the environment.

The focus of this research was on identifying the impacts of additional on-screen text cueing on controllers' performance. Specifically understanding the potential benefits

of the technology and if it should enhance controller efficiency in a congested communication environment is the research question addressed.

Based on literature review, five hypotheses were developed in Chapter 2. A methodology and experiment for testing the hypotheses was presented in Chapter 3 and corresponding data analysis conducted on the results in Chapter 4. A summary of the findings of this research effort is provided in Table 15. This chapter further discusses the findings of this study, their contribution to academic research, their significance to practice and relevance to the Air Force, limitations of this study, and recommendations for future study.

Findings

This study presented many important findings that would be of great value to the future application of speech-to-text technology in an ATC environment, as shown in Table 15.

Table 15: Summary of Findings

Hypothesis		Finding
H1:	Supplementary text transcription of pilots' communication will increase controllers' comprehension of pilots' transmissions	Supported
H2:	Supplementary text-cueing will improve memory recall on pilots' transmissions	Not Supported
H3:	Supplemental text box will increase controller's distraction	Not Supported
H4:	Additional text-cueing will reduce perceived difficulty of the communication task between controllers and pilots	Not Supported

As predicted in H1, the additional text cueing had a significant effect on controllers' comprehension of pilots' transmissions. The number of transmissions that controllers would need to emit to be able to answer pilots was significant lower with the

use of the additional text on-screen. This fact is of great importance since the reduced number of transmissions would potentially reduce frequency congestion, which is a very sensitive situation that can potentially harm safety. Another important contribution of the reduced number of transmissions is that it automatically reduces time needed to answer each pilot's transmission, allowing controllers to continually focus their attention on monitoring the airspace instead of trying to comprehend previous transmissions.

Additionally, as expected, familiarity had a significance influence on controllers' comprehension. This finding is consistent with the Channel Expansion Theory (Carlson and Zmud, 1994) that states the richness of the medium is not only a characteristic of the channel itself but is also influenced by the perceptions of the user based on familiarity and experience with the medium. This fact is important in order to determine that future training and increasing familiarity may also increase the richness of the technology and its potential benefits for the ATC community.

According to the results for H2, H3 and H4, the proposed technology had no influence on memory recall of pilot's transmissions, perceived difficulty of the task or distraction. The fact that the proposed technology did not affect perceived difficulty of the communication task is a very important and interesting finding due to the fact that the additional text on the radar screen did not harm controller's ability to perform their task. The proposed text cueing did not reduce the perceived difficulty of the communication task between controllers and pilots, but also did not affect the perceived task difficulty in a harmful way. Even with the additional technology on the radar screen, controllers did not perceive the task to be more difficult as compared to a regular ATC workstation.

Also, as desired in the design of ATCS (Cardosi and Murphy, 1995), this design requires no unaided recall of information. It not only does not place greater demands on memory than the current workstation, but also provides a memory aid for controllers. Although the text cueing did not increase memory recall it is still a very important memory aid, since the information will be physically available on screen, relieving the controllers from the overuse of memory to retain information that could be accessed anytime during the decision making process.

Additionally, the proposed technology was hypothesized to increase distraction due to the additional text on-screen. Although distraction did appear to increase with the on-screen technology, no definitive conclusions could be drawn due to the very low variance explained in the model. This is an important finding since the low adjusted R-squared may indicate that while there was significantly more distraction in the experimental condition, the distraction may not have been due to the additional text. Other factors yet unknown may have also played a role.

Limitations

This study is based on controller's efficiency in a created ATC environment with a workstation designed to attend the research purpose. Though the participants were able to concentrate and act like in a real ATC workstation and environment, a more accurate environment or a real training workstation could be of great value when trying to access real measures of efficiency.

Additionally, in this study, due to limitations of the available technology, controllers were asked to monitor the created scenarios, but not allowed to interact or

make changes in the radar display or aircraft paths, since the scenarios were previously recorded and presented as a movie for the participants to monitor and keep track of the situation. This led the participants to a more passive position, although they were asked to active monitor as they were to issue instructions and act in real-live scenarios. A study that allows the controllers interact with the scenario would be a more realistic approach in order to get measurements of efficiency. Also, this would allow the researchers to obtain objective measurements of performance such as time to respond and number of transmissions issued, for example, instead of just self-reported measurements.

Another important consideration for the proposed technology is that many advances have been done to increase the reliability of the speech-to-text transcription. In this study, we assumed a perfect reliable text transcription of pilots' transmissions. An important study with a variation on the reliability of the transcriptions would importantly measure the impact of the actual state of the technology on controller's efficiency.

As reported by the participants, the lack of training with the technology in this specific application constituted a barrier for the participants to use the proposed technology in its full capacity during all their performance in that task due to the learning curve spent to learn how the technology worked in this application.

Contributions to Research

This study has implications for future study and development of systems and tools for the increasingly congested environment of ATC, especially when it comes to controllers. The results of this research further knowledge on the impact of speech-to-text

technology in an ATC environment, and demonstrated proof-of-concept for text-cueing effectiveness under realistic ATC conditions.

This study is novel to academic research in that it focuses on the application of the speech-to-text technology to improve controller' efficiency during the communication task in a simulated congested air traffic environment. The impact of the technology on performance was measured with actual air traffic controllers, and their perceptions about the usefulness and impacts of the technology were reported.

Implications for ATC community and for Air Force

The use of the proposed technology has many implications for ATC community and Air Force. The possible implications of this study to the Air Force are no different than those of the ATC community in general. It suits the entire community as the technology would apply in the same manner. The benefits generated with the use of additional text may potentially help improve aerospace safety and ATC efficiency. This research represents the initial steps for the implementation of the speech-to-text technology to improve air traffic controllers' efficiency in a congested communication task.

The primary consequence noticed from the results of this study is the frequency decongestion resulted from the increased comprehension of pilots' transmissions. Since controllers will be able to comprehend the transmissions without the need of a "SAY AGAIN" transmission, but will be able to indeed read what was said; radio congestion will be significantly reduced and allow for a safe increase in ATC traffic. In a real-time

application, this technology will potentially allow air traffic controllers to monitor more aircraft and large geographical spaces due to increased comprehension and efficiency.

Additionally, in the eventuality of accidents or incidents, controllers are called to transcribe all the radio communications recorded in order to help the investigations regarding the incident. The ATC recordings are usually very long and demands several working hours to be transcribed. In many cases, there are also many unintelligible parts that can not be transcribed and are considered missing or unintelligible. With the use of speech-to-text transcription technology, these transcriptions will be automatically done in real time, saving time and personnel potentially allocated to these tasks. The ATC recordings will be already transcribed and the availability of persistent transcriptions of all radio communication will be automatically provided by the proposed technology for consultation at any time it is needed.

In accordance to Weinstein (1991), in a paper issued from Proceeding of the IEEE: “Training for military (or civilian) air traffic controllers (ATC’s) represents an excellent application for speech recognition systems”. According to the author, a number of different studies have been done using this technology to improve ATC training, such as: the potential to eliminate pseudo-pilots; prototype ATC trainers; and integration with complex training systems including displays and scenario creation.

Another potential training application is the use of the generated text transcription by instructors to show the controller’s his/her performance during the training. The transcription could be used to show them what the request was and how the controllers responded in order to teach and show examples and easily identify errors associated with wrong instructions emitted by controllers while training.

Besides that, as reported by the participants, the use of speech-to-text transcriptions would be also of great value to reduce difficulty associated with understanding foreign accents. This is an important application since the correlation between accents and speech intelligibility has long been researched (Varonis and Gass, 1982; Gass and Varonis, 1984; Munro and Derwing, 1995), and according to Munro and Derwing (1995), the “effects of nonnative-like pronunciations on intelligibility are far from clear”.

Future Research Recommendations

This research represents the first step towards the implementation of speech-to-text technology for air traffic controllers. Many studies still need to be done in order to guarantee the safe application of the proposed technology to enhance controllers’ efficiency in ATM. Further aspects of HF design need to be explored to ensure a user-centered approach for the application of this technology.

To improve the results for this study, a new experiment could be run with training for the new technology. As it was reported by many participants, they would improve and better use the technology in all its extent if they were already familiarized to work with the proposed technology.

Although this study showed interesting results from controllers’ perceptions of the new technology, it is of greater value to pursue a study to obtain objective measures of operators’ performance, based on the fact that perceptions do not always reflect real performance. Real-time interaction would be of great value to be observed in future studies in order to provide objective measures of performance, such as time and accuracy

of the decisions. An important study would allow controllers to interact in order to collect objective measurements of controllers' performance, including time to answer requests with and without the text, for example.

The safety impact of the technology still requires detailed exploration. Any additional or proposed ATC technology would need to carefully consider its safety impact. The use of eye tracker to determine time spent reading (eyes off scope) the text would be of great value to deeply investigate the impact of text on safety. Future studies would combine the addition of text cueing with eye tracking in order to measure the amount of time that controllers spend reading the text instead of monitoring the radar display.

Another important consideration for a real-time application is to consider the use of the real state of the technology and study the use of real time speech to text transcription and the impact of a not 100% reliable speech-to-text transcription. For the purpose of this study, a 100% reliability of the speech-to-text transcription was assumed. Although great advancements have been done with this technology in reaching higher levels of reliability, it is still not a 100% reliable. Therefore, studies with different levels of reliability would be of great value to study the impact of the application of the technology in a real-time situation.

Further research of the speech-to-text technology itself is of great importance. The ideal design of the text box - and also others techniques and capacities associated with speech-to-text tools requires further study. The MMC Suite, for example, has many others capacities that were not explored in this research. By allowing a real-time interaction with the participants, the technology usability itself could be explored. Other

capacities could be researched such as the availability of the audio recording associated with the text transcribed on screen. This capacity allows the controller to access the recorded audio anytime, clicking on the respective text transcription, even without a 100% text transcription reliability. This has the potential to help decrease frequency congestion even if the text transcribed was not completely understood, since the controller will be able to listen to the audio recorded without asking the pilots to retransmit.

Another area for further study is deeply investigating controllers' workload from the additional text. One variable that was not tested in the experiment was the controllers' workload or what effect did the proposed technology had on controllers' workload. This may be significant to study, since it is an important characteristic of controllers' efficiency and an increase on workload could adversely affect the operator's ability to manage complex communications tasks.

Another further step to improve controllers' efficiency is to study the impact of providing identification of the spatial location of the aircrafts while pilots' are transmitting their messages through radio. Providing spatial cue of aircraft location while pilots' are still transmitting their message would potentially reduce search time in the radar screen done by controllers' every time they receive a call from a different aircraft. Controllers are required to identify the position of each aircraft before they can respond for its transmissions. This results in a recurrent screen search every time a pilot calls in order to identify the aircraft and be able to answer its call. An additional cue of its spatial location would potentially reduce this search time and provide controllers with more time to be used in other tasks.

Conclusion

To provide cognitive tools to enhance controllers' decision making, it is very important to first understand how controllers can be affected. This study reviews a significant range of considerations from previous research in order to provide an overview of the importance of human factors considerations when designing a cognitive tool to enhance decision making in ATC environment.

The development of cognitive engineered tools must be addressed from a human factors perspective in order to support the human decision maker. This paper attempted to provide an overview of the cognitive factors that must be considered in order to provide a basis for the development of cognitive engineered tool to enhance efficiency and critical decision making.

By optimizing and providing all the information needed, the ATC system may benefit with highly optimized and correctly solutions and decisions made with all necessary information available. Since controllers will be able to read what was said instead of just relying on auditory memory and comprehension, this could lead to increased efficiencies in the NAS throughout reduced frequency congestion and potentially errors reduction associated with misunderstood transmissions.

There has been significant advancement in speech-to-text technology in recent years. The application of this technology is constantly increasing, specifically in military systems (Weinstein, 1991). Progress associated with the study of human factors design to air traffic controls has the potential to provide a valuable tool to enhance the time-critical aspect of controllers decision making in an increasingly congested communication environment.

This paper presented encouraging results from the application of this technology, transcribing pilots' transmissions to enhance controllers' efficiency. This research was an exploratory study to determine the effectiveness and efficiency gaining potential of this new technology and whether further research is warranted. A number of contributions and implications of the use of the text technology were described. Applications in training and real-time air traffic are seen to be promising for the proposed technology. Additionally, future research is recommended to guarantee the advancement of the technology and its application to enhance the ATCS efficiency and safety.

Appendix A: IRB Approval Letter



DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE OF TECHNOLOGY
WRIGHT-PATTERSON AIR FORCE BASE OHIO

25 Jan 2012

MEMORANDUM FOR LTCOL BRENT LANGHALS

FROM: Alan R. Heminger, Ph.D.
AFIT IRB Research Reviewer
2950 Hobson Way
Wright-Patterson AFB, OH 45433-7765

SUBJECT: Approval for exemption request from human experimentation requirements (32 CFR 219, DoDD 3216.2 and AFI 40-402) for study titled "The impact on performance of stereoscopic dimensional digital radar displays and integrated automated visual text cuing on air traffic controllers".

1. Your request was based on the Code of Federal Regulations, title 32, part 219, section 101, paragraph (b) (2) (i) Information obtained is not recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects, (ii) you are not collecting information that could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects financial standing, employability, or reputation, and (4) Research, involves the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available or if the information is recorded by the investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects.
2. Your study qualifies for this exemption because you are not collecting sensitive data, which could reasonably damage the subjects' financial standing, employability, or reputation. Further, the demographic data you are collecting will be maintained separately from experimental data so that a given response will not be expected to map to a specific subject.
3. This determination pertains only to the Federal, Department of Defense, and Air Force regulations that govern the use of human subjects in research. Further, if a subject's future response reasonably places them at risk of criminal or civil liability or is damaging to their financial standing, employability, or reputation, you are required to file an adverse event report with this office immediately.

ALAN HEMINGER, PH.D.
AFIT Research Reviewer

Appendix B: Authorization Letter to access controllers



DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON DC

7 Jan 2012

MEMORANDUM FOR AFIT/ENV

FROM: HQ HAF/A3O-BA
1480 Air Force Pentagon
Washington, D.C. 20330-1480

SUBJECT: Accessing Volunteer ATC Trainees at Keesler AFB, MS for AFIT Research

- 1) TSgt Russi and his research team are granted access to the USAF Air Traffic Control technical training school to conduct their research experiment with cooperation of the school's commandant, the career field manager and any volunteers willing to participate. It is understood that the research project is examining the potential of stereoscopic (3-D) digital radar display potential and textual cueing in congested communications environments. Our tech school provides the perfect environment for this study without affecting operational ATC while also allowing many AD controllers and apprentices the opportunity to participate.
- 2) This support is for the solicitation of volunteers at the school and is not an endorsement or expression of interest in the specific technologies being evaluated. We, as a highly technical field, understand the importance of research of technologies with potential for future use and enthusiastically support the AFIT mission of AF level research and development.
- 3) Please direct any questions regarding this correspondence to me at: joseph.kirk@us.af.mil.

KIRK.JOSEPH.C.102
8631681
JOSEPH C. KIRK, CMSgt, USAF
1C1 Career Field Manager

Digitally signed by KIRK.JOSEPH.C.102
DN: cn=J.C. Kirk, o=USAF, ou=USAF, email=j.c.kirk@us.af.mil
Date: 2012.01.07 14:48:00 -0500

Appendix C: Informed Consent

Informed Consent Document

For

The effect of stereoscopic dimensional digital radar displays and integrated automated visual text cuing on air traffic controller performance

AFIT/ENV, Air Force Institute of Technology, Wright-Patterson AFB OH

Principal Investigator: Lt Col Brent T. Langhals, DSN 785-3636, ext. 4352,
AFIT/ENV
Brent.Langhals@afit.edu

Associate Investigators: TSgt Jason Russi, DSN 785-3636, ext. 4352, AFIT/ENV
Jason.Russi@afit.edu

1 LT Laurienne Santana (Brazilian Air Force), DSN 785-
3636, ext. 4352, AFIT/ENV
Laurienne.Santana.br@afit.edu

1. **Nature and purpose:** You are being invited to take part in a research study. The information in this form is provided to help you decide whether or not to take part. Study personnel will be available to answer your questions and provide additional

information. If you decide to take part in the study, you will be asked to sign this consent form. A copy of this form will be given to you. Your participation will occur at Keesler AFB, MS.

The purpose of this study is to determine to what extent visual textual cuing and 3-dimensional air traffic representations may impact a controller's performance both in heightened situational awareness for longer durations and reduction in fatigue induced by multi-tasking, distractions, redundant transmissions and reduced mental image creation. The intent is to study what of these aspects can provide benefits to the already task saturated industry by providing increased human factors awareness.

The time requirement for each volunteer subject is anticipated to be a total of one hour over one or two visits as it need not be continuous. It is expected approximately 40 subjects will be enrolled in this study. Subjects shall be able to read and speak English, be between 18 and 60 years old, possess ATC experience or at least conceptual understanding and training with sufficient vision to perform simulated ATC tasks with a stereoscopic monitor.

2. **Experimental procedures:** If you decide to participate, the first task you will complete will be to fill out a short questionnaire to capture some demographic information. No personally identifying information will be asked of you in this questionnaire.

Next we will ask you to assume the role of an air traffic controller. You will be first presented with a common scenario to start the air traffic control activities, than you will be presented with a series of simulated air traffic situations with textual

cues, and after that you will be exposed to 3-D displays. Your task is to observe each simulation as different cues and presentations are added. You will be trained on 3-D displays and have an overview on the station you will deal with prior to the start of the experiment. No personally identifying information will be kept. About one hour will be needed to complete this study.

Your participation in this study is voluntary. You will not lose any benefit that would normally be entitled if you do not participate or withdraw from the research. You may decide to not begin or to stop the study at any time. If you are a student, your refusal to participate will have no effect on your student status. Also, any new information discovered about the research will be provided to you. This information could affect your willingness to continue your participation and will therefore be furnished to you.

3. **Discomfort and risks:** The tasks that you will be doing have no known safety or psychological risks. Although we have tried to avoid risks, you may feel that some questions or procedures we ask you to do may be stressful, or possibly even cause you to feel fatigue. If this occurs you can stop participating immediately, however this is what we are evaluating so please feel free to express these feelings and concerns as they arise. We can give you information about individuals who may be able to help you with these problems should they go beyond the scope of the trial.

Additionally, for this research study we may be using 3-D glasses for viewing the displays. There are no known risks from using this equipment as they are commonly available commercial models.

4. **Precautions for female subjects or subjects who are or may become pregnant during the course of this study:** There are no precautions for female subjects or subjects who are or may become pregnant during the course of this study.
5. **Benefits:** You are not expected to benefit directly from participation in this research study.
6. **Compensation:** If you are active duty military you will receive your normal active duty pay.
7. **Alternatives:** Your alternative is to choose not to participate in this study. Refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You may discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled. Notify any investigator of this study to discontinue.

Entitlements and confidentiality:

- a. Records of your participation in this study may only be disclosed according to federal law, including the Federal Privacy Act, 5 U.S.C. 552a, and its implementing regulations and the Health Insurance Portability and Accountability Act (HIPAA), and its implementing regulations, when applicable, and the Freedom of Information Act, 5 U.S.C. Sec 522, and its implementing regulations when applicable. Your personal information will be stored in a locked cabinet in an office that is locked when not occupied. Electronic files containing your personal information will be password protected and stored only on a secure server. It is intended that the only people having access to your information will be the researchers named above, the AFRL Wright Site IRB or any other IRB involved in the review and approval of this protocol. When no longer needed for research purposes your information will be destroyed in a secure manner (shredding). Complete confidentiality cannot be promised, in particular for military personnel, whose health or fitness for duty information may be required to be reported to appropriate medical or command authorities. If such information is to be reported, you will be informed of what is being reported and the reason for the report.
- b. Your entitlements to medical and dental care and/or compensation in the event of injury are governed by federal laws and regulations, and that if you desire further

information you may contact the base legal office (ASC/JA, 257-6142 for Wright-Patterson AFB).

- c. If an unanticipated event (medical misadventure) occurs during your participation in this study, you will be informed. If you are not competent at the time to understand the nature of the event, such information will be brought to the attention of your next of kin or other listed emergency contact.

Next of kin or emergency contact information:

Name

Phone# _____

- d. The decision to participate in this research is completely voluntary on your part. No one may coerce or intimidate you into participating in this program. You are participating because you want to. Lt Col Brent T. Langhals, or an associate, has adequately answered any and all questions you have about this study, your participation, and the procedures involved. Lt Col Brent T. Langhals can be reached at (937) 255-3636 ext 4352. Lt Col Brent T. Langhals, or an associate will be available to answer any questions concerning procedures throughout this study. If significant new findings develop during the course of this research, which may relate to your decision to continue participation, you will be informed. Refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You may discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled. Notify one of the investigators of this study to discontinue.
- e. Personal Identifiable Information to be obtained for this study includes gender, ethnicity, country of citizenship, age, and experience. Signing this document in no way alters your ability to obtain medical treatment that is not part of this study. Any Private Health Information obtained in the course of this study may be used by the investigator unless you revoke authorization to do so *in writing*. If your data is disclosed by the investigator to one of the parties listed above, those parties may pass on your data without further notification to you. Data collected in the course of this study may be withheld from you by the investigator for the duration of the study. If withheld, your data will be released at the conclusion of the study.

- f. Your participation in this study will not be photographed, filmed or audio/videotaped.

YOU ARE MAKING A DECISION WHETHER OR NOT TO PARTICIPATE.
YOUR SIGNATURE INDICATES THAT YOU HAVE DECIDED TO PARTICIPATE
HAVING READ THE INFORMATION PROVIDED ABOVE.

Volunteer

Signature _____ **Date** _____

Volunteer Name (printed) _____

Advising Investigator Signature _____ **Date** _____

Investigator Name (printed) _____

Witness Signature _____ **Date** _____

Witness Name (printed) _____

Appendix D: Timeline Procedure

Experiment Design Timeline:

Initial Briefing

TIME	DESCRIPTION
T +0	Subjects arrive at experiment room 1, adjacent to room 2 where researcher 2 will initiate scenario. Consent form introduced and signed by subject. (7 min) (<i>DISTRIBUTE CONSENT FORM AND PARTICIPANT NUMBER</i>)

“I am TSgt Jason Russi and this is my colleague, Lt. Santana of the Brazilian Air Force. We would like to welcome you and thank you for your voluntary participation in this valuable research. This study will take approximately 1 ½ hours to complete. Before we begin, please take a moment to read through the consent form Lt. Santana is handing you now with your participant number. (DISTRIBUTE CONSENT FORM AND PARTICIPANT NUMBER). Keep this number as it will be used as your sole identification throughout the experiment. If you have any questions, please do not hesitate to ask either one of us at any point now or during the briefings. Of note, your responses to this experimental scenario will not be used beyond our research and will be destroyed upon completion of this study. Once you have read through the entire consent form and agree to continue to participate in this study, please sign and date the consent forms and hand them to either one of us.”

Wait for participant to fill out consent form. (5 min)

T +7	Subjects read and fill in pre-experiment questionnaire. See Appendix X for full text of Pre-Experiment Questionnaire (PreQ). Questionnaire will include text and dimensional display questions (5min) (<i>DISTRIBUTE PreQ</i>)
------	--

“Lt. Santana is now handing out a questionnaire (DISTRIBUTE PreQ). As part of this study we need to collect some demographic and background information. None of this data will be personally identifying and will in no way be connected to your name. Please take a moment to fill out this questionnaire.”

Wait for participant to fill out PreQ. (5 min)

T+ 12 Subject is ushered into controlled scenario room/section housing Mock Control Terminal (MCT). Researcher #1 reads script of process and briefs subject and familiarizes them with system that will remain the same throughout all four scenarios (General Training section of this doc). Any questions are answered to ensure understanding of performance for subject. All scenarios will be overall briefed, as in what the four different types consist of and inform the subject that the order of presentation will be random, however, operation of the system will be the same. The specific details of each scenario (equipments and the new technology) will be introduced right before each scenario (5 mins) (***BRIEF GENERAL SCENARIO. JUST BEFORE EACH SCENARIO WE WILL BRIEF THE SPECIFIC CONDITION TRAINING AND SHOW PRINT SCREEN CAPTURES AND EQUIPMENTS FOR EACH SCENARIO***)

Training Briefing (2 mins)

General

“You have been invited to participate in this study due to your background or involvement in ATC; and you are expected to utilize your situation awareness as you would in a live ATC setting performing to the best of your individual ability.

If you are a student at Keesler AFB, ATC Technical School, this will in no way impact your training records or even be shared with the faculty of this school. There

will be no adverse actions or retribution of any type due to your performance. Furthermore, there will be absolutely no personally identifying information (PII) collected or retained on you as an individual. Your participant number will be the only identifying information recorded for purposes of this research.

The purpose of this study is to determine the impact and effectiveness of the technologies, NOT the controllers' individual performances or abilities.

For this study you are performing duties as an USAF Air Traffic Controller at Canyon Airport, an imaginary airfield. You will be tasked with observing several aircraft in four short ATC scenarios, divided into two parts. The first part will consist of 2 short scenarios to analyze the impact of 3D technology for observing vertical separation; and the second part will consist of 2 short scenarios to analyze the impact of additional text queuing in congested radio comm environments.

You will receive a short briefing about the specifics of the technologies right before each scenario. During all the scenarios, you will be expected to maintain situation awareness, allowing us to evaluate your comprehension, awareness and decision making. This performance will be evaluated on a series of measurable performance characteristics similar to the standard accepted ATC practices. After each scenario you will be asked to answer some questions about them.

*All scenarios will be viewed in a darkened room, the range marks are set to 10 miles, and the speed is twice that of a standard simulation to allow you to observe more in less time. The time on screen is double real time. Altitudes in data tags are; green = level flight, red = climbing and yellow = descending. You may talk but there will be no changes to the scenarios.” *SEPARATE SUBJECTS FOR SPECIFIC TREATMENT BRIEFS*

Condition A: 3D Briefing

-Equipment: Glasses, wireless mouse, ASUS 3D monitor. “In the next 2 scenarios, you will be asked to view only the large ASUS monitor. This mouse’s left button will be clicked as your only input”

****(Ensure Proper alignment of viewing, seat height, screen position etc.)*

A_c Control scenario (45 sec): *“You will be presented a unique 6 minute air traffic control scenario. You are asked to interact by clicking the left mouse button once for every instance you are unsure two or more aircraft may not safely pass over or under one another. You need to maintain overall S-A of the scene and monitor vertical separation throughout. Remember, green altitude digits are level flight, red is a climb and yellow is descending. All aircraft are considered IFR in your area of jurisdiction. Some may not be squawking Mode C. Do not assume you know aircraft characteristics based on callsign or intended route of flight. You will need to maintain vigilance as if you were to make decisions about and issue instructions for the aircraft. After the scenario, you will need to answer detailed questions about what you saw, so please try to maintain your highest level of situation awareness. Any questions? **Remember:** Click when you think they may not safely pass.”* (Answer Q’s if posed)

- A_e Experimental scenario (60 sec): *“You will be presented a specific unique 6 ½ min air traffic control scenario. This scenario will be in full stereoscopic 3-D. In this scenario, you will be asked to use a pair of 3D glasses to properly observe altitude variances. You will interact with a single left click of the mouse when you are unsure if aircraft will safely pass over or under one another. *NOTE: The 3D disparity view is 100% reliable and accurately reflects altitude variances. Any discernible depth difference indicates at LEAST the minimum vertical separation of 1,000’. You will need to maintain vigilance as if you were to make decisions about and issue instructions for the aircraft. After the scenario, you will need to answer detailed*

questions about what you have seen. Any questions? (answer Q's if posed) Please put on the glasses now. (HOLD THEIR GLASSES UNTIL SYNCRONIZED AND ADJUST POSTURE AND ALIGNMENT TO SCREEN). Remember: Click when you think they may not safely pass and ANY depth separation = safe separation! Tell us when you begin seeing 3-D"

Condition B: Text Briefing

-Equipment: Headphone (10 sec). "In the next two scenarios you will be asked to use these headphones to listen to pilots' communications."

- B_c Control scenario (35 sec): "You will be presented an unique 3-minute air traffic control scenario and you will hear pilot's communications to the controller without controller responses. You will interact with single left mouse clicks when you feel a "SAY AGAIN" transmission is needed on your part to understand a pilot. Please click the mouse once for every pilot transmission you would want repeated. They will not be repeated, we are merely tracking your comprehension. You need to consider each pilot's request as if you needed to reply to them with a response &/or decision. After the scenario, you will need to answer detailed questions about what you SAW and HEARD. Any questions? Please put your headphones on now. Remember: Click once for every pilot transmission you would want repeated."

- B_e Experimental scenario (45 sec): "You will be presented a specific 3-min air traffic control simulation of a congested radio environment and you will hear pilot's communications to the controller with no controller replies. For this scenario, there will be a narrow text box at the right side of the radar display that will transcribe all pilots' communications in real- time (show screen capture). The call signs will show up in yellow w/ the most recent call at the bottom of the text box. This automated

transcription is a 100% accurate and reliable. If you feel that a “SAY AGAIN” transmission is still warranted, left-click the mouse once for every pilot transmission you would want repeated. They will not be repeated, we are merely tracking your comprehension. However, if you can determine what a pilot has said well enough to respond whether it be through audio OR TEXT, then do NOT click the mouse. Click the mouse ONLY if you did not get enough information to understand the pilot. You are expected to utilize the new technology presented to the MAXIMUM EXTENT POSSIBLE to supplement audio communications for comprehension. You need to consider each pilot’s request as if you needed to reply to them with a response &/or decision. After the scenario, you will need to answer detailed questions about what you SAW and HEARD. Any questions? Please you can put your headphones now. Remember click once for every pilot transmission you would want repeated if you feel that a “SAY AGAIN” transmission is still warranted”.

Wait participants leave the room if there is more than 1

Experiment/scenarios presentation

- T +14 Researcher #1 and #2 fall back to operator’s station.(This may be in the same room, depending upon space availability.) First scenario is initiated.
- The first specific training and scenario is initiated according to the established order for each participant. ALL SCENARIOS WILL BE ADMINSTERED IN A RANDOM MANNER, according to the “participants’ list”. This will preclude any order effects that may skew data collection by bias. (10 mins) (*GIVE SPECIFIC TRAINING AND SET UP SCENARIO1 and MOUSE CLICK COUNTER*)
- T +26 First Subject scenario terminated and fill in post-experiment questionnaire.
- Subject briefed to wait in designated holding area for next scenario preparation; and a Post- experiment questionnaire is administered. See Appendix X for full text of Post-Experiment Questionnaire (PoQ). (10

min) (*DISTRIBUTE PoQ and TRANSCRIBE CLICK COUNT ONTO TOP*)

“(DISTRIBUTE PoQ). Please take a moment to fill out this questionnaire about the last scenario you were exposed to. There is no “penalty” for guessing and you may complete the questionnaire in any order with no time limit.” (offer screen capture)

T +36 Subject is ushered into MCT again. Second scenario is initiated.

Researcher #1 will initiate the next specific training for the second scenario. The second scenario is initiated according to the established order for each participant. (10 min) (*GIVE SPECIFIC TRAINING AND SET UP SCENARIO2*)

T +46 Second Subject scenario terminated and fill in post-experiment questionnaire. Subject briefed to wait in designated holding area for next scenario preparation; and a Post- experiment questionnaire is administered. See Appendix X for full text of Post-Experiment Questionnaire (PoQ). (10 min) (*DISTRIBUTE PoQ TRANSCRIBING CLICK COUNT ONTO TOP*)

“(DISTRIBUTE PoQ). Please take a moment to fill out this questionnaire about the last scenario you were exposed to. There is no “penalty” for guessing and you may complete the questionnaire in any order with no time limit.” (Offer MMC screen capture if applicable”)

T +56 Subject is ushered into MCT again. Third scenario is initiated. Researcher #1 will initiate the next specific training for the third scenario. The third

scenario is initiated according to the established order for each participant.

(5 min) (*GIVE SPECIFIC TRAINING AND SET UP SCENARIO 3*)

T +61 Third Subject scenario terminated and fill in post-experiment questionnaire. Subject briefed to wait in designated holding area for next scenario preparation; and a Post- experiment questionnaire is administered. See Appendix X for full text of Post-Experiment Questionnaire (PoQ). (5 min) (*DISTRIBUTE PoQ TRANSCRIBING CLICK COUNT ONTO TOP*)

“(DISTRIBUTE PoQ). Please take a moment to fill out this questionnaire about the last scenario you were exposed to. There is no “penalty” for guessing and you may complete the questionnaire in any order with no time limit.” (Offer screen capture for MMC)”

T +66 Subject is ushered into MCT again. Forth and last scenario is initiated. Researcher #1 will initiate the next specific training for the last scenario. The last scenario is initiated according to the established order for each participant. (5 min) (*GIVE SPECIFIC TRAINING AND SET UP SCENARIO 4*)

T +71 Forth/Last subject scenario terminated and fill in post-experiment questionnaire. Subject briefed to wait in designated holding area for next scenario preparation; and a Post- experiment questionnaire is administered. See Appendix X for full text of Post-Experiment Questionnaire (PoQ). (5 min) (*DISTRIBUTE PoQ*)

“ (DISTRIBUTE PoQ). Please take a moment to fill out this questionnaire about the last scenario you were exposed to.”

T +76 Subject is notified of experiment termination. (OFFER COMMENT SHEET)

*****One Subject Evaluated at ~ T + 80*****

T+ Simultaneously Researcher #2 resets the MCT for the next subject (3 mins) then will go administer the Pre-Experiment Questionnaire (PreQ). (5 mins)

(STEP 1, Subject #2) Subject is ushered into controlled scenario room/section of area. Researcher #1 reads script of process and briefs subject on the controls and familiarizes them with system that will remain the same throughout all three scenarios. This will constitute the training for the subject's interaction with system. Any questions are answered to ensure understanding of performance for subject. All scenarios will be briefed, as in what the three different types consist of and inform the subject that the order of presentation will be random, however, operation of the system will be the same. (10 mins)

Appendix E: Pre-Questionnaire

Pre-Experiment Questionnaire

1. What is your participant number? _____
2. What is your gender? _____
3. What is your ATC experience (yrs/mos.) _____
4. What is your age? _____
5. What is your highest level of education? _____
6. Do you wear contacts or glasses? _____
 If so, are you wearing them now? _____
7. Have you had corrective eye surgery? _____
8. Do you have any depth perception deficiencies? YES NO
9. Do you have aviation experience? YES NO
 If YES, what type? _____
 How many years in the field? _____

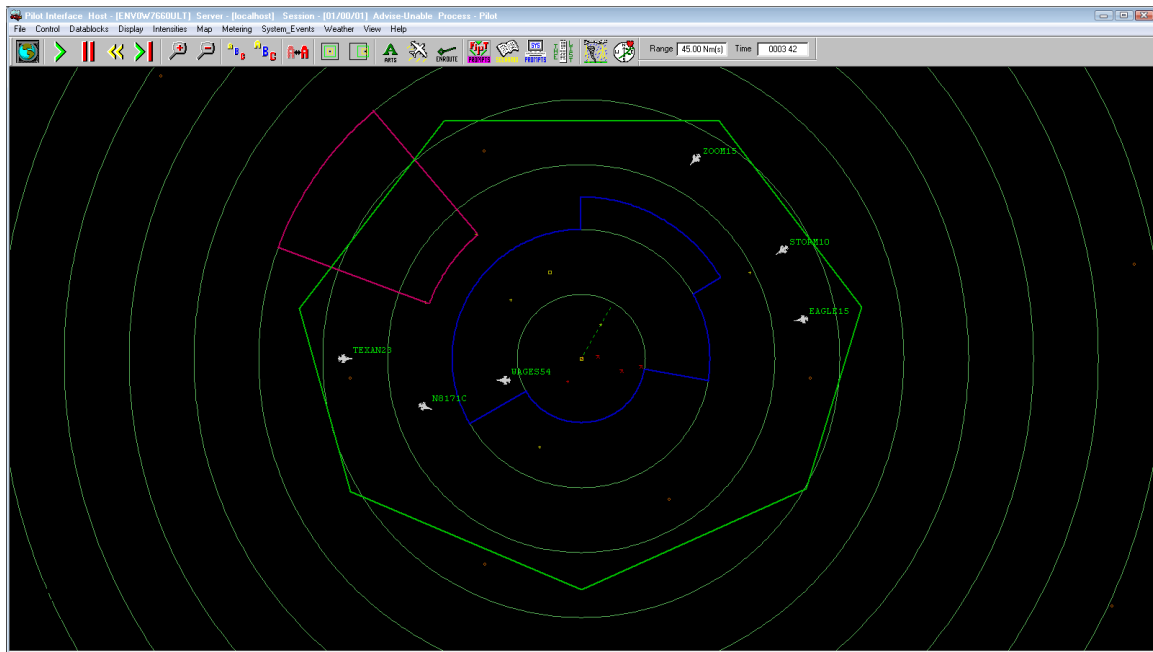
10. On a scale of 1 to 5, please answer whether or not you agree with the following statements (circle one of the numbers). There is no right or wrong answer.

	Strongly Disagree		Neutral		Strongly Agree
A. I can be distracted easily while working ATC.	1	2	3	4	5
B. I have trouble multitasking with many tasks.	1	2	3	4	5
C. I often ask pilots to repeat themselves when stepped on.	1	2	3	4	5
D. I think that new technologies can improve ATC.	1	2	3	4	5
E. I watch movies and/or play videogames on 3-D displays.	1	2	3	4	5
F. I use instant messenger text correspondence often.	1	2	3	4	5
G. I like to text a lot.	1	2	3	4	5
H. I consider myself a fast reader.	1	2	3	4	5

- I. If cost was not an issue, I would prefer 3D entertainment. 1 2 3 4 5
- J. I am not distracted by new on-screen text while working. 1 2 3 4 5
- K. I rely heavily on computer inputs for my duties. 1 2 3 4 5
- L. I don't feel comfortable listening and reading at the same time 1 2 3 4 5
- M. What percentage of your total day is on a computer? 0 25 50 75 100
- N. I have experienced dizziness when viewing 3-D movies. YES NO
- O. I feel that ATC is an important job. YES NO
- P. I feel 3-D displays show accurate imagery and depth YES NO

Thank-You for your honest responses and participation in this study.

Appendix F: Training Scenario



Appendix G: Training Questionnaire

Training Questionnaire

1. What is your participant number? _____
2. Specifics: (answer as you remember)
 - A. Who was the departure aircraft? _____
 - B. Who changed their type of approach request? _____
3. While monitoring the traffic scene, I observed the following: (circle one for each choice)
 - A. The highest aircraft in the scenario was (ZOOM15 , STORM10 or EAGLE 15)
 - B. Which altitude did WAGES54 requested? (FL180 FL230 or 130)
4. On a scale of 1 to 5, please answer whether or not you agree with the following statements (circle one of the numbers). There is no right or wrong answer.

	No		Somewhat		Yes		
A. I am comfortable with this simulation	1	2	3	4	5	6	7
B. I was able to understand the pilots clearly	1	2	3	4	5	6	7

Thank-You for your honest responses and participation in this study.

Appendix H: Post-Questionnaire Control Scenario

Post Questionnaire (Bc)

1. What was your participant ID number? _____ (Researcher use only: _____)

2. Specifics: (answer as you remember. Guess rather than leaving blank)

A. What type of emergency was EAGLE15? _____

B. What altitude did OPEC26 H initially climb to? _____

C. One aircraft requested to cancel IFR. Which one? _____

D. What altitude was JOKER22 requesting? _____

E. One aircraft requested direct point bravo. Which one? _____

F. Who changed its type of approach from vectors for ILS to direct initial? _____

3. While performing the air traffic control simulation: (please circle one)

	No		Somewhat				Yes
A. I felt distracted during the scenario.	1	2	3	4	5	6	7
B. I felt the task was over simplified.	1	2	3	4	5	6	7
C. I found it difficult to maintain concentration.	1	2	3	4	5	6	7
D. The task seemed too difficult.	1	2	3	4	5	6	7
E. The scenario seemed realistic.	1	2	3	4	5	6	7

4. In general, each time the aircraft stepped on each other (Circle all that apply. You can choose more than 1 option):

- a. I didn't understand either aircraft
- b. I understood the call sign (ACID) of at least one aircraft
- c. I could understand the request of at least one of them
- d. Completely understood one aircraft
- e. I copied all and was able to answer/make a decision

Appendix I: Post-Questionnaire Experimental Scenario

Post Questionnaire (Be)

1. What was your participant ID number? _____ (*Researcher use only:*_____)

2. Specifics: (answer as you remember. Guess rather than leaving blank)

A. What type of emergency was STORM 28? _____

B. What altitude did N172FA descend to? _____

C. One aircraft requested transition to delta surface area. Which one? _____

D. What altitude was ORCA 27 H requesting? _____

E. One aircraft requested vectors to straight in touch-n-go option tower. Which one? ____

F. Who changed its type landing from full stop to option tower? _____

3. While performing the air traffic control simulation: (please circle one)

	No		Somewhat			Yes	
A. I felt distracted during the scenario.	1	2	3	4	5	6	7
B. I felt the task was over simplified.	1	2	3	4	5	6	7
C. I felt confident relying on the on-screen text cues.	1	2	3	4	5	6	7
D. I found it difficult to maintain concentration.	1	2	3	4	5	6	7
E. The task seemed too difficult.	1	2	3	4	5	6	7
F. The scenario seemed realistic.	1	2	3	4	5	6	7
G. I think the additional text cueing was useful.	1	2	3	4	5	6	7
H. I would like to work more with additional texts.	1	2	3	4	5	6	7
I. I found it difficult to use the text cueing.	1	2	3	4	5	6	7
J. I used the text cueing to de-conflict the audio.	1	2	3	4	5	6	7
K. Even if I can read it in real time, I prefer to hear it from pilots	1	2	3	4	5	6	7

4. In general, each time the aircraft stepped on each other (Circle all that apply. You can choose more than 1 option):

- f. I referred to the text box
- g. I didn't understand either aircraft
- h. I understood the call sign (ACID) of at least one aircraft
- i. I could understand the request of at least one of them
- j. Completely understood one aircraft
- k. I copied all and was able to answer/make a decision

5. I find the text to be useful in this capacity (please circle one) Yes No

6. I see potential for the technology in this or other capacities. (please circle one) Yes No.

If yes, please briefly explain your opinion:

7. I have ideas to improve on this scenario/application and I am willing to submit additional inputs to the researcher to improve this experiment. (please circle one) Yes No

8. Please indicate whether you felt voice conflicts were easier to understand with the text cues and why:

9. Often controllers choose to employ strategies in an attempt to make decisions and improve performance. Did you find the additional text cueing to be conducive or helpful in your decision making?

Yes No If yes, please briefly describe how it influenced your performance, if at all:

Bibliography

- Adams, M. J., Tenney, Y. J., & Pew, R. W. (1995). Situation awareness and the cognitive management of complex systems. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 37(1), 85-104.
- AFI 40-402 (2005). *Protection of human subjects in biomedical and behavioral research*. Air Force Instruction, Medical Command, US Air Force.
- Bressolle, M. C., Benhacene, R., Boudes, N., Parise, R., & cedex France, B. T. (2000). Advanced decision aids for air traffic controllers: Understanding different working methods from a cognitive point of view. In *3rd International Air Traffic Management Seminar, Napoli, Italy*.
- Cardosi, K. M., & Murphy, E. D. (1995). *Human factors checklist for the design and evaluation of air traffic control systems* (No. DOT-VNTSC-FAA-95-3.1). JOHN A VOLPE NATIONAL TRANSPORTATION SYSTEMS CENTER CAMBRIDGE MA.
- Carlson, J., & Zmud, R. (1994). Channel expansion theory: A dynamic view of media and information richness perceptions. *Academy of Management Best Papers Proceedings* (D.P. Moore, Ed.): 280-284.
- Castaño, D., & Parasuraman, R. (1999). Manipulation of pilot intent under free flight: A prelude to not-so-free flight. In *Proceedings of the 10th International Symposium on Aviation Psychology* (pp. 170–176). Columbus: Ohio State University.
- Corker, K., Fleming, K., & Lane, J. (1999). Measuring controller reactions to free flight in a complex transition sector. *Journal of Air Traffic Control*, 4, 9–16.
- Couluris, G. J., Schleicher, D. R., Weidner, T., Faison, W., Simpson, R., & Ausrotas, R. (1998). Terminal Airspace Decision Support Tools Preliminary Technical Performance Metrics and Economic Quantification.
- Daft, R., & Lengel, R. 1984. Information richness: A new approach to managerial behavior and organization design. *Research in organizational behavior*, 6: 191 – 233.
- D'Arcy, J. F., & Rocco, P. S. (2001). *Air Traffic Control Specialist decision making and strategic planning-A field survey* (No. DOT/FAA/CT-TN01/05). FEDERAL AVIATION ADMINISTRATION, TECHNICAL CENTER, ATLANTIC CITY, NJ.

- Dominguez, C., Vidulich, M., Vogel, E., & McMillan, G. (1994). *Situation awareness: Papers and annotated bibliography* (No. AL/CF-TR-1994-0085). ARMSTRONG LAB WRIGHT-PATTERSON AFB OH CREW SYSTEMS DIRECTORATE.
- Drullman, R., and Bronkhorst, A. (2000). Multichannel speech intelligibility and talker recognition using monaural, binaural, and three-dimensional auditory presentation. *J. Acoust. Soc. Am.* 107, 2224–2235.
- Endsley, M. R., & Rodgers, M. D. (1994). *Situation awareness information requirements for en route air traffic control*. (No. DOT/FAA/AM-94/27). FEDERAL AVIATION ADMINISTRATION, OFFICE OF AVIATION MEDICINE, WASHINGTON, DC.
- Endsley, M. R., & Kiris, E. O. (1995). The out-of-the-loop performance problem and level of control in automation. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 37(2), 381-394.
- Endsley, M. R. (1995). Toward a theory of situation awareness in dynamic systems. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 37(1), 32-64.
- Endsley, M. R. (1996). Automation and situation awareness. *Automation and human performance: Theory and applications*, 163-181.
- Endsley, M. R., Mogford, R. H., Allendoerfer, K. R., Snyder, M. D., & Stein, E. S. (1997). *Effect of free flight conditions on controller performance, workload, and situation awareness* (No. DOT/FAA/CT-TN97/12). Federal Aviation Administration Technical Center, Atlantic City, NJ.
- Endsley, M. R., Rogers, M. D. (1998). Distribution of attention, situation awareness and workload in a passive ATC task: Implications for operational errors and automation. *Air Traffic Control Quarterly*, 6, 21–44
- Endsley, M. R. & Smolensky, M. W. (1998). Situation awareness in air traffic control: The picture. In M. W. Smolensky & E. S. Stein (Eds.), *Human factors in air traffic control* (pp. 115-154). Boston, MA: Academic Press.
- Endsley, M.R. & Garland D. J. (Eds.) (2000), *Situation awareness analysis and measurement*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Erlebacher, A. (1977). Design and analysis of experiments contrasting the within-and between-subjects manipulation of the independent variable. *Psychological Bulletin*, 84(2), 212.

- Erzberger, H. (2001, December). The automated airspace concept. In *4th USA/Europe Air Traffic Management R&D Seminar*. Santa Fe, New Mexico, USA.
- European Organization for the Safety of Air Navigation (2007). The Human Factors Case: Guidance for Human Factors Integration, ref. 07/06/22-35, ISBN Number 978-2-87497-002-3, Jun. 2007.
- Federal Aviation Administration (1989a). Air traffic control: Order No. 7110.65F. Air Traffic Operations Service: United States Department of Transportation
- Federal Aviation Administration, *FAA Aerospace Forecast Fiscal Years 2012 – 2032*, U.S. Department of Transportation, 2011
- Federal Aviation Administration Order JO 7110.65U (2012), Air Traffic Control. Air Traffic Organization Policy, Federal Aviation Administration, U.S. Department of Transportation, Feb. 2012.
- Finomore, V.J., Popik, D., Dallman, R., Stewart, J., Satterfield, K., & Castle, C. (2011) Demonstration of a Network-Centric Communication Management Suite: Multi-Modal Communication. *Proceedings of the Human Factors and Ergonomics Society*, 55, 1832-1835.
- Finomore, V.J., Popik, D., Dallman, R., & Castle, C. (2010) Effects of a Network-Centric Multi-Modal Communication tool on a Communication Monitoring task. *Proceedings of the Human Factors and Ergonomics Society*, 54, 2125- 2129.
- Galster, S. M., Duley, J. A., Masalonis, A. J., & Parasuraman, R. (2001). Air traffic controller performance and workload under mature free flight: Conflict detection and resolution of aircraft self-separation. *The International Journal of Aviation Psychology*, 11(1), 71-93.
- Gass, S. M., & Varonis, E. M. (1984). The effect of familiarity on the comprehensibility of nonnative speech. *Language Learning*, 34(1), 65-89.
- Gronlund, S.D., Dougherty, M.R.P., Ohrt, D.D., Thomson, G.L., Bleckley, K., Bain, D., Arnell, F., & Manning, C.A. (1997). *The role of memory in air traffic control*. (No. DOT/FAA/AM-97/22). FEDERAL AVIATION ADMINISTRATION, OFFICE OF AVIATION MEDICINE, WASHINGTON, DC.
- Hopkin, V.D. (1980). The measurement of the air traffic controller. *Human Factors*, 22, 547-60.

- Hopkin, V. D. (1991a). The impact of automation on air traffic control systems. In J. A. Wise, V. D. Hopkin, & M. L. Smith (Eds.), *Automation and systems issues in air traffic control* (pp. 3-19). Berlin: Springer-Verlag.
- Hopkin, V. D. (1995). *Human factors in air traffic control*. CRC.
- Hopp-Levine, P. J., Smith, C. A. P., Clegg, B. A., & Heggstad, E. D. (2006). Tactile interruption management: tactile cues as task-switching reminders. *Cognition, Technology & Work*. In Press
- Joint Program Development Office. (2004). An integrated plan for next generation air transportation system. Washington, DC: Author.
- Kelly, C., Goillau, P., Bowler, Y., Enterkin P. (2000). Human Factors Integration in Future ATM Systems – Design Concept and Philosophies. (No. HRS/HSP-003-REP-01). *European Air Traffic Management Programme Guideline*. Eurocontrol, 2000.
- Keren, G. (1992). Between-or within-subjects design: A methodological dilemma. A *Handbook for Data Analysis in the Behavioral Sciences: Volume 1: Methodological Issues Volume 2: Statistical Issues*, 1, 257.
- Laudeman, I. V., Shelden, S. G., Branstrom, R., & Brasil, C. L. (1998). *Dynamic density: An air traffic management metric* (No. NAS 1.15: 112226, NASA/TM-).
- Mancini, G., Woods, D. D., & Hollnagel, E. (Eds.) (1988) Cognitive engineering in dynamic environments. London: Harcourt Brace Jovanovich
- Metzger, U., & Parasuraman, R. (2001). The role of the air traffic controller in future air traffic management: An empirical study of active control versus passive monitoring. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 43(4), 519-528.
- McCallie, D. L. (2011). *Exploring Potential ADS-B Vulnerabilities in the FAA's Nextgen Air Transportation System* (No. AFIT/ICW/ENG/11-09). AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH DEPT OF ELECTRICAL AND COMPUTER ENGINEERING.
- Metzger, U., & Parasuraman, R. (2005). Automation in future air traffic management: Effects of decision aid reliability on controller performance and mental workload. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 47(1), 35-49.

- Mogford, R. H., Guttman, J. A., Morrow, S. L., & Kopardekar, P. (1995). *The complexity construct in air traffic control: A review and synthesis of the literature*. (No. DOT/FAA/CT-TN95/22.1). FEDERAL AVIATION ADMINISTRATION, Washington, DC.
- Montmollin, M. de, and De Keyser, V. (1985). Expert logic vs. operator logic. In G. Johannsen, G. Mancini, and L. Martensson (Eds.), *Analysis, design, and evaluation of man-machine systems*. CEC-JRC Ispra, Italy: IFAC.
- Munro, M. J., & Derwing, T. M. (1995). Foreign accent, comprehensibility, and intelligibility in the speech of second language learners. *Language learning*, 45(1), 73-97.
- Murray, S. A., & Caldwell, B. S. (1996). Human performance and control of multiple systems. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 38(2), 323-329.
- NASA. (1999). Concept definition for distributed air/ground traffic management (DAG-TM): Version 1.0 (Advanced Air Transport Technologies [AATT] Project, Aviation System Capacity [ASC] Program). <http://www.asc.nasa.gov/aatt/dag.html> Accessed 5 Jan 2006
- Newman, R. A., & Allendoerfer, K. (2000). *Assessment of current and proposed audio alarms in terminal air traffic control* (Tech. Rep.). FEDERAL AVIATION ADMINISTRATION, TECHNICAL CENTER, ATLANTIC CITY, NJ.
- Nijhuis, H.B., North, C.J. (1998). Role of the Human in the Evolution of ATM, *RHEA Report*, Air Transport Research Actions, ref RHEA/NL/SPR/01.
- Oprins, E., Zwaaf, D., Eriksson, F., van de Merwe, K., & Roe, R. (2009, June). Impact of future time-based operations on situation awareness of air traffic controllers. In *8th USA/Europe Air Traffic Management R&D Seminar*, Napa, CA.
- Parasuraman, R., & Metzger, U. (2006). Effects of automated conflict cueing and traffic density on air traffic controller performance and visual attention in a datalink environment. *International Journal of Aviation Psychology*, 16, 343-362.
- Pheasant, S. (1989) User-centred design – an ergonomist’s viewpoint; in, A.S. Nicholson & J.E. Ridd, (Eds.) *Health, Safety and Ergonomics*, Butterworths, 73-96.
- Rantanen, E. M. (1994). The role of dynamic memory in air traffic controllers’ situation awareness. In R.D. Gilson, D. J. Garland, & J. M. Koonce (Eds.), *Situational*

awareness in complex systems (pp.209–215). Orlando, FL: University of Central Florida, Center for Applied Human Factors in Aviation.

Rantanen, E. M., McCarley, J. S., & Xu, X. (2004). Time delays in air traffic control communication loop: effect on controller performance and workload. *The International Journal of Aviation Psychology*, 14(4), 369-394.

Rash, C. E., Russo, M. B., Letowski, T. R., and Schmeisser, E. T. (eds.), *Helmet-mounted displays: Sensation, perception, and cognitive issues*. U.S. Army Aeromedical Research Laboratory, 2009

Rasmussen, J. (1986). *Information processing and human machine interaction: An approach to cognitive engineering*. New York: North-Holland.

RTCA. (1995). *Report of the RTCA board of director's select committee on free flight*. Washington, DC: Author.

Russo, P. & Boor, S. (1993). How fluent is your interface? designing for international users. *Human Factors in Computing Systems*, 24-29. Proceedings of INTERCHI '93, Amsterdam. New York: ACM

Sarter, N. B., & Woods, D. D. (1994). Pilot interaction with cockpit automation II: An experimental study of pilots' model and awareness of the flight management system. *The International Journal of Aviation Psychology*, 4(1), 1-28.

Sarter, N. B., & Woods, D. D. (1995a). How in the world did we ever get into that mode? Mode error and awareness in supervisory control. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 37(1), 5-19.

Sarter, N.B., & Woods, D.D. (1995b). Strong, silent, and 'out-of-the-loop': Properties of advanced (cockpit) automation and their impact on human-automation interaction (CSEL Report No. 95-TR-01): Columbus: Cognitive Systems Engineering Lab., Ohio State University.

Shorrock, S. T., & Kirwan, B. (2002). Development and application of a human error identification tool for air traffic control. *Applied Ergonomics*, 33(4), 319-336.

Stein, E. S., & Garland, D. (1993). *Air traffic controller working memory: considerations in air traffic control tactical operations* (No. DOT/FAA/CT-TN-93/37). FEDERAL AVIATION ADMINISTRATION, TECHNICAL CENTER, ATLANTIC CITY, NJ.

- Tindall-Ford, S., Chandler, P., Sweller, J. When two sensory modes are better than one. *Journal of Experimental Psychology: Applied*, Vol 3(4), Dec 1997, 257-287. doi: 10.1037/1076-898X.3.4.257
- Varonis, E. M., & Gass, S. M. (1982). The comprehensibility of nonnative speech. *Studies in Second Language Acquisition*, 4, 114-136.
- Weber M.E., Evans J.E., Moser W.M., & Newell O.J. (2007). Air Traffic Management Decisions Support During Convective Weather. *Lincoln Laboratory Journal*, vol. 16, No. 2, pp. 263-275.
- Weikert, C. (2002). Human Factors and Safety in Aviation. *Proceedings of a Conference*, Lund, Sweden: Swedish Centre for Aviation R&D, ref. ISBN 91-975058-0-3
- Weinstein, C. J. (1991). Opportunities for advanced speech processing in military computer-based systems. *Proceedings of the IEEE*, 79(11), 1626-1641.
- Wickens, C.D., Mavor, A.S., & McGee, J.P. (1997). *Flight to the future: Human factors in air traffic control*. Joseph Henry Press.
- Wickens, C. D. (1998). The future of air traffic control: human operators and automation. *Testimony of the 105th Congress (Second Session) of FAA Modernization*, March 1998. www7.nationalacademies.org/ocga/testimony/Air_Traffic_Control.asp. Accessed 5 Feb 2013.
- Wickens, C. D. (2002). Multiple resources and performance prediction. *Theoretical Issues in Ergonomics Science*, 3(2), 159–177.
- Wickens, C. D. (2008). Multiple resources and mental workload. *Human Factors*, 50:449 – 455.
- Wiener, E. L., & Curry, R. E. (1980). Flight-Deck Automation: Promises and Problems, NASA TM.-81206.
- Wiener, E. L. (1985). Human factors of cockpit automation: A field study of flight crew transition (NASA Contractor Report 177333). Moffett Field, CA: NASA Ames Research Center.
- Will, R.P. (1991). True and false dependence on technology: Valuation with an expert system. *Computers in Human Behavior* 7:171-183.

Willems, B., & Truitt, T. R. (1999). *Implications of reduced involvement in en route air traffic control* (No. DOT/FAA/CT-TN99/2). FEDERAL AVIATION ADMINISTRATION, TECHNICAL CENTER, ATLANTIC CITY, NJ.

Xing, J. and Manning, C. A. (2005). Complexity and automation displays of air traffic control: Literature review and analysis (No. DOT/FAA/AM-05/4). FEDERAL AVIATION ADMINISTRATION, OFFICE OF AEROSPACE MEDICINE, WASHINGTON, DC.

Vita

Lieutenant Laurienne C.R.A.Santana graduated from the Brazilian Air Force Academy in Pirassununga, São Paulo, in November 2006. She graduated as the top student of her class and she was assigned to DIRINT in Rio de Janeiro, Brazil, in 2007. While stationed at DIRINT, she had the opportunity to study Information Systems Analysis, Design and Management, at the Catholic University (PUC-RJ), in Rio de Janeiro, Brazil (2007-2009). At DIRINT she worked as Country Systems Section Leader for the National Payroll Sub Department for 4 years. In August 2011, she entered the Graduate School of Engineering and Management, Air Force Institute of Technology. Upon graduation, she will be assigned to the DIRINT again.

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 074-0188	
The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of the collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.					
1. REPORT DATE (DD-MM-YYYY) 21-03-2013		2. REPORT TYPE Master's Thesis		3. DATES COVERED (From – To) October 2011 – March 2013	
4. TITLE AND SUBTITLE SUPPLEMENTARY COMPUTER GENERATED CUEING TO ENHANCE AIR TRAFFIC CONTROLLER EFFICIENCY				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Santana, Laurienne C.R.A., Lieutenant, Brazilian Air Force				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S) Air Force Institute of Technology Graduate School of Engineering and Management (AFIT/ENV) 2950 Hobson Way, Building 640 WPAFB OH 45433-8865				8. PERFORMING ORGANIZATION REPORT NUMBER AFIT-ENV-13-M-25	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) INTENTIONALLY LEFT BLANK				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT DISTRIBUTION STATEMENT A: APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT Air traffic controllers are often required to simultaneously communicate with several aircraft over multiple radio frequencies. As a result, during peak loading, it is common for the controller to receive multiple concurrent communications, each from a different aircraft, making it difficult to discern audio messages received from multiple pilots simultaneously. To address this problem, a modified air traffic control (ATC) interface was prototyped with the goal of increasing controller-to-pilot communication efficiency. This prototype included supplementary text cueing which was provided by a hypothetical automated text to speech system in an on-screen text box for controller reference in the event of an obscured or indiscernible radio call. The prototype was then evaluated by a group of 35 participants, all with ATC experience including 12 students and 23 instructors at the Air Force controllers' school house Keesler AFB, MS. The text cueing improved controllers' comprehension of pilots' transmissions.					
15. SUBJECT TERMS ATC, EFFICIENCY, VERBAL COMMUNICATION, SPEECH-TO-TEXT TECHNOLOGY					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Brent T. Langhals, Lt.Col., PhD, USAF
U	U	U	UU	111	19b. TELEPHONE NUMBER (Include area code) (937) 255-6565, x 4352 (brent.langhals@afit.edu)