2004

The effect of attention-capturing salient speech disruptions on ATC performance

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DOI: <https://doi.org/10.31979/etd.yatt-a8m7>
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**THE EFFECT OF ATTENTION-CAPTURING SALIENT SPEECH DISRUPTIONS
ON ATC PERFORMANCE**

A Thesis

Presented to

The Faculty of the Graduate Program in Human Factors and Ergonomics

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree of

Master of Science

by

Samantha Starr

December 2004

UMI Number: 1425485

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ABSTRACT

THE EFFECT OF ATTENTION CAPTURING SALIENT SPEECH DISRUPTIONS ON ATC PERFORMANCE

by

Samantha Starr

This study evaluated recent changes in Air Traffic en route control rooms, whereby controllers are able to hear and comprehend similar, nearby speech verbalization. This study consisted of a part-task experiment with added dimensions of Attention Capturing Salient Speech Disruptions (ACSSDs) during high/low traffic densities, with/without “white noise” dampening, replicating the original and current control rooms. The results were inconclusive because of idiosyncratic attributes of the data, and ACSSDs did not influence performance. However, the traffic factor produced a significant result, exceeding the critical value by a large margin, thus indicating an influence on performance that was consistent with our hypothesis and more than a decade of study by experts concerning relevant cognitive theories in air traffic operations.

ACKNOWLEDGEMENTS

I would like to convey my sincere gratitude to my thesis chairperson, Dr. Kevin Corker, for his insight, encouragement, patience, and support, as well as to Dr. Ernie Unwin for his faith in this project and my abilities.

I am especially appreciative of the help and support I received in the completion of this study from Martijn Mooij, Pam Gauch, and the SJSU HAIL research team.

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CHAPTER I

Introduction

The Federal Aviation Administration (FAA) is a government agency with the responsibility of providing global aerospace operations and air traffic control for air-system-navigations in the United States and abroad. For decades, the FAA has conducted research in the development of air traffic operations, ensuring safe and reliable air travel. The FAA has strengthened performance measurements in aviation systems by employing the most advanced technologies and increasing the efficiency of automation (Hilburn, 2003; Mogford, Guttman, Morrow & Kopardekar, 1995; Mogford, Murphy & Guttman, 1994; Wyndemere, 1996). However, human operators-principally controllers and pilots-remain the fundamental safety mechanism in the air traffic system (Wickens, 1998). Reliable information about a controller's performance is essential to understanding the impact of various automation innovations on system operations (Hadley, Guttman & Stringer, 1999). Controller-pilot interactions are a major component of air traffic operations and are becoming all the more important as traffic complexity and automation are advanced (Cardosi, Brett & Han, 1996). While extensive safety improvements and advances in the air transportation industry are continuously applied, there are always further enhancements to complete (Majumdar & Ochieng, 2000).

Problem Statement

The interactions between air traffic controllers and aircrews are primarily through verbal radio transmissions. A controller's role is first to safely direct aircraft traffic, and to provide information and advisories. Since recent Air Traffic Control Center (ARTCC) room changes implemented by the FAA in 1998, controllers can hear the communications of nearby co-workers, thereby increasing the possibility that they could become distracted.

The following is an example of a miscommunication in an aviation environment. An aircrew flying at Flight-level 550 (55,000 feet) requests permission to descend to Flight-level 400 (40,000 feet). Although the controller recognizes the request, he or she is preoccupied with other disrupting verbal exchanges and inadvertently issues an erroneous directive as if the aircrew had requested Flight-level 300 (30,000 feet). In this incident, the controller's attention was diverted away from the primary task and a delay occurred, but the consequences could have been more serious. During busy times, a controller must work rapidly and efficiently with total concentration in order to keep track of several aircraft in his or her assigned sector (Grossberg, 1989; Fabiani, Buckley, Gratton, Coles, Donchin & Logie, 1989). In the best-case scenario, controllers are capable of accurately conceptualizing a range of actions; in reality, disruptions can interrupt or impede cognitive decision-making abilities.

Study Objectives

This study has evaluated the effects of the changes implemented by the FAA in 1998 that eliminated “ambient noise” that had been present in the previous control rooms’ environment of the Air Route Traffic Control Centers (ARTCC) (Mogford, Rosiles, Koros & Held, 1998).

The objectives of this study were to determine if routine activities, such as conversations, could interfere with the completion of controller tasks, and to what extent controller cognitive processes could become vulnerable to disruption. The study began by exploring previous research to establish an understanding of the general definitions of disruption, attention, and cognition. The study then focused on specific research aspects of task management, human performance, and interruptions in air traffic, relating to controller and pilot interaction. This knowledge made it possible to develop and produce an experiment that simulated the conditions in the previous and existing control rooms.

Key Aspects of the Air Traffic Control System

Given the focus of this research paper, it is important to understand several basic functions of managing air traffic. This section explains a number of features in an air traffic control-system, defining some of the specific characteristics in order to set a context for the study.

Airspace Configuration

There are 21 regional zones in the US airspace, with one Air Route Traffic Control Center (ARTCC) in each zone. In order to organize the airspace efficiently and ensure safe vertical separation between aircraft, these zones are structured into smaller sized sectors, with each single sector managed by an individual air traffic operator (Davis, Danaher & Fischl, 1963). Sectors have both horizontal and vertical boundaries: In one instance, one sector may cover a geographic area of 500 square miles with an altitude range from the ground to 23,000 feet; while another sector in the same geographic area may cover an altitude ranging from 23,000 to 37,000 feet.

Air Traffic Control Center (ARTCC)

The FAA deploys air traffic controllers and computer technicians to duty stations, such as the Air Route Traffic Control Centers. At these facilities, controllers and computer technicians use basic operating equipment, such as flight progress boards, radar displays, frequency control panels, weather instruments, and recorders for radio, data, and radar communications to the aircraft.

Advisory Content

To assist the pilot in the safe conduct of a flight, a controller formulates advisories by viewing the data block, identifying any potential proximity conditions (e.g., weather, altitude, flight routes, and geographic conditions), including a mental model of flights

moving within a sector. The controller issues an advisory to the aircrew based on that information. Possessing this mental picture of the overall traffic conditions, a controller watches for changes in aircraft movement while keeping in verbal contact with aircraft in his or her sector (Turner & Huntley, 1991).

Air Traffic Controller Assignments

Controllers have a number of different types of assignments and duties managing air traffic, each with individual in-depth training:

- A Tower controller manages the landing and departure of aircraft, the movement of aircraft on the airport surface and local airport airspace.
- A Terminal Radar Approach Control (TRACON) controller is responsible for all departing and approaching aircraft within a particular airspace.
- An en route controller maintains all air-to-ground communications for the safe separation of aircraft within each sector at both high and low altitude airspace (above and below 24,000 feet) and coordinates other sector and center activities as needed.

The En Route Controller Team

Under most operating conditions, the en route controller team consists of two members: a radar controller (R-side), who makes tactical decisions about sector traffic and acts as the main audio communicator to an aircrew, and a data controller (D-side), who is responsible for evaluating incoming data transmissions.

Controller-Aircrew Interaction

Controllers manage traffic while also engaging in other fixed or reactive responsibilities. Fixed tasks are often routine or predictable, while more complex or complicated situations involve potential conflicts.

A routine task would be providing “ride quality” route information to assist the aircrew with passenger comfort and flight efficiency.

Controller Duty Priority

All controller tasks are important responsibilities and according to the Air Traffic Controller Manual of controller duties 7110.65L, the FAA’s Duty Priority is structured in a fixed way, as cited verbatim here:

- a. Give first priority to separating aircraft and issuing safety alerts as required in this order. Good judgment shall be used in prioritizing all other provisions of this order based on the requirements of the situation at hand.
- b. Provide additional services to the extent possible, contingent only upon higher priority duties and other factors including limitations of radar, volume of traffic, frequency congestion, and workload (FAA/7110.65L, pp. 2-1-2, 1996).

When a controller communicates a clearance to a pilot, the pilot responds by repeating the communication in the same terminology to verify the correct reception of the communication. Monan (1988) stated that as a pilot repeats a communication, he or she is essentially asking, “Did we correctly understand your communication?”

Control Center Changes

The premise of this thesis has concentrated on changes that have occurred in the Air Traffic Control Center (ARTCC) work areas. Therefore, it is essential to illustrate these changes, textually and visually. In the Spring of 1998, in addition to relocating the control-centers' work areas to another part of the facility, the FAA replaced the outdated Plain View Display (PVD) monitors and the UNIVAC CPU systems (Mogford et al., 1998) (see Figure 1).

Original Air Traffic Control Center (ARTCC)

The dimensions of the original control rooms were approximately 139 by 60 feet, with a ceiling height of approximately 30 feet. The original control rooms occupied approximately 80% of the 8000 square-foot building. The UNIVAC computers (see Figures 1 and 2) were bulky systems generating large amounts of constant heat. To cool these large computers, each workstation contained a built-in fan at its base. Additionally, the high ceilings contained fans that assisted in circulating heat away from the workstations (Gray, 1999).

UNIVAC Plain View Display Components

The Philadelphia Unisys Solid State Computer (UNIVAC) was one of the first computers to use solid-state component central processing units. The US Air Force accepted a UNIVAC prototype in 1956, and Remington Rand produced a commercial version the following year. Components in the first generation UNIVAC Computer

included mercury delay lines, electrostatic tubes, and magnetic drums. The solid-state system held a central processing unit and a large magnetic drum for memory (16,384 24-bit words). A large number of vacuum tubes (15-18 magnetic amplifiers called FERRACTORS) took up space and generated large amounts of heat. The vacuum tubes were bulky, hot, and needed regular maintenance to avoid failure (Gray, 1999).

Figure 1. Photo of original Air Traffic Control Center (ARTCC) Plain View Display (PVD) monitors and the UNIVAC CPU systems, from the Unisys History Newsletter (Gray, 1999).

Figure 2. Photo of original Air Traffic Control Center (ARTCC) Plain View Display (PVD) monitors and the UNIVAC CPU systems, from the Unisys History Newsletter (Gray, 1999).

Current Control Rooms

The current control room dimensions are approximately the same as the original: 134 by 60 feet, with a ceiling height of 13 feet, occupying approximately 70% of the 8000 square-foot building.

Differences between the original (see Figures 1 and 2) and the new control rooms (see Figures 3 and 4) included removal of old computers and terminal desks, and changes in the physical space. Previously the disruptions of what this study has termed Attention-Capturing Salient Speech Disruption (ACSSD) was masked and dampened by white noise from fans in the base of each computer workstation in combination with the fans overhead in the high ceilings of the original control rooms (see Table 1).

Figure 3. Photo of current Air Traffic Control Center (ARTCC) computer system from the National Air Traffic Controller Association Media Center Photography Library (NATCA, 2004).

Figure 4. Photo of current control room Air Traffic Control Center (ARTCC) computer system from the National Air Traffic Controller Association Media Center Photography Library (NATCA, 2004).

Table 1

Control room design changes: Differences in original Air Traffic Control Center (ARTCC) and current control room areas

<i>Original Control Room</i>	<i>Current Control Room</i>
Larger Work Area	Smaller Work Area
Larger Workstations	More Compact Workstations
High Ceiling ** 30 Feet	Lower Ceiling ** 13 Feet
Fans in Workstations and Ceiling	Fans Absent in Workstations
Added Masking/Dampening	Added ACSSD

Definitions of Terms

Ambient Noise

Ambient noise is a level of acoustic noise that exists in a given environment, such as a composite of airborne sounds from multiple sources in a room.

Air Route Traffic Control Center (ARTCC)

An Air Route Traffic Control Center (ARTCC) is a facility containing air traffic controllers and the equipment required to identify and direct aircraft, primarily during the en route portion of flights.

Attention-Capturing Salient Speech Disruption (ACSSD)

The term Attention-Capturing Salient Speech Disruption (ACSSD) is used to identify the circumstances evaluated by this study. *Attention* is defined as the direction of all thought or effort toward one particular task, idea, or subject. *Capturing* is the domination of one's thoughts, referring to occurrences in which attention is attracted to the speech of a nearby individual. *Salient* refers to something noticeable or particularly relevant, such as the phraseology of a controller. *Speech* refers to words carrying information to those perceiving it. *Disruption* conveys the impact of an unexpected break in the cognitive process with the result that the perceived words are of no use to the listener.

Aviation Safety Reporting System (ASRS)

The Aviation Safety Reporting System (ASRS), established in 1975 in a Memorandum of Agreement between the FAA and the National Aeronautics and Space Administration (NASA), is responsible for collecting, analyzing, and responding to voluntarily submitted aviation safety incident reports from the National Aviation System (NAS) (US Department of Transportation, 1996).

Cognition

In this study, the term cognition describes the processes involving knowledge, expertise, and learning, as well as the act of knowing and knowledge in terms of the possession of information. Wickens (1991) suggests the possibility of a cognitive processing “informational channel” where information flows through certain relevant processing stages characterized by some distinct perceptual property at their source.

Communications in the airspace systems

Flight crews and air traffic controllers communicate verbally through radio transmissions using Very High Frequencies (VHF) between 118 and 136 megahertz and through datalink text communications. Pilots tune to the frequency of the controller tracking their flight, switching frequencies as they are “handed off” from one controller to another in each sector along the aircraft’s flight path

Communication Error-Defined

Communication errors include readback errors and hearback errors.

Readback errors are defined as important discrepancies between the clearances issued by a controller and what the pilot reads back. A hearback error occurs when a controller fails to correct a pilot's readback error.

Common errors are as follows:

- A pilot reads back a communication incorrectly and the controller fails to catch the error (hear-back type-I error).
- A pilot makes a statement of action or intent that the controller should have identified as a problem (hearback type-II error).
- A pilot correctly repeats the communication issued by the controller, but the controller fails to notice that the communication issued was not correct.
- A pilot accepts a clearance directed to another aircraft, and the controller fails to notice that the readback had the wrong call sign associated with it.

Data Controller (D-side)

The D-side controllers are responsible for monitoring flight progress strips and other written data pertaining to aircraft in their sector. D-side controllers also provide a "second set of eyes" on the radar, assisting the R-side controllers in pre-planning of flight routes and/or requests for vector changes, although the R-side controllers have final responsibility and authority over the development and implementation of all flight plans and their outcome.

Dampening or Masking of Sound

Sound is a pressure wave traveling through air or water. A sound wave resembles the surface wave the dropping of a stone makes into a calm pool of water (except that a sound wave consists of tiny fluctuations in air pressure). The vibration of an object or surface (e.g., human vocal cords) generates sound. The vibrating surface radiates pressure waves into the adjoining air as sound. The frequency is the number of wave crests per unit of time. The wavelength or distance between wave crests defines the frequency, with lower frequencies having longer wavelengths. In air, all frequencies of sound travel at the same speed.

Flight Plan

A flight plan (filed in advance of the flight with the FAA) is a mandatory document that provides the expected operational details of a flight, such as destination, route, and fuel allotment requirements.

Noise

Noise refers to a measure in acoustical units (decibels) of energy in the environment. Noise is any loud, discordant, or disagreeable constantly and/or spontaneously occurring sound or set of sounds. Noise is not usable information because it is a loud, unpleasant, or undesired sound (Eschenbrenner, 1971).

Operational Error

An Operational Error (O/E) is an occurrence attributable to an element of the air traffic system where two or more aircraft, or an aircraft and an obstacle or the terrain, breach the acceptable minimum separation distance. The US Department of Transportation (DOT) and the Federal Aviation Administration (FAA) provide exacting procedures and regulations for recording any oversight or inaccuracy, and utilize intensive investigational levels for the examination of those performance errors. The DOT and the FAA take operational oversights or inaccuracies seriously, using both mandatory and voluntary reporting systems.

Strict classifications of Operational Errors (O/E) are defined in the Air Traffic Controller Manual 7110.65M (DOT/FAA/OED, 1996). An Operational Error can be critical, allowing the separation to become less than appropriate between two or more aircraft, or be classified a less serious deviation with low severity, such as an aircraft penetrating airspace without coordination or approval (Rodgers & Manning, 1995; Rodgers & Duke, 1993; Rodgers & Nye, 1993; Rodgers, Mogford, & Mogford, 1998).

Radar Controller (R-side)

Radar controllers are in charge of all air-to-ground communication, maintaining the safe separation of aircraft within their sector and coordinating activities with other sectors and/or centers. The R-side controller monitors the airspace at low and high altitude (above and below 24,000 feet), providing pilots with current weather and air

traffic information. A controller monitors an aircraft in his or her sector, eventually “handing off” the aircraft to a controller in another sector.

White Noise

White noise is the combination of all tones perceptible to the human ear. It is analogous to the description of the combination of all colors as white light (Newton, 1740). As a combination of all frequencies of sound, white noise masks other sounds. White noise is characterized as background noise from multiple sources that is unrelated to a particular sound of interest.

White Noise Dampening

White noise dampening can be produced electronically (active dampening) to interrupt sound waves (static sounds), or passively (fans moving air with a “whooshing” sound, or the sound of rushing water). White noise is noticeable at first, but quickly blends into the background.

Some industries use certain types of masking to reduce the distance sounds or spoken words can travel.

- Active noise control or active noise cancellation is sound field modification or sound field cancellation by electro-acoustical means. A control system produces a sound field that is the mirror image of the disturbance. This cancels the disturbance, resulting in the deletion of any sound.
- Passive noise control treatments include insulation, silencers, dampening treatments, (white noise) and absorptive treatments.

Limitations of the Study

This research paper has confined the level of detail to objective measurements of performance that analyze participants' identification of recorded readback errors in a part-task medium-fidelity simulated environment. Although there are vast amounts of research regarding workload complexity, sector activity, and aircraft proximity, this study is restricted to evaluating participants listening and evaluating recorded pseudo-controller and pilot performance in a simulated control room setting of Attention-Capturing Salient Speech Disruptions (ACSSDs).

Summary

This chapter has described the changes in the control rooms' environment, this study examined, as well as the study's objectives. An account is included of the Air Traffic Control Systems operations in conjunction with controller tasks, so the reader can understand first, the responsibilities of the controller, and second, the context in which the events occur. Photo illustrations are presented of the original (Figures 1 and 2) and current control rooms (Figures 3 and 4) as visual clarification of changes in the areas environment. In addition, a number of acronyms and terms have been defined in order to make the studies circumstances understandable.

CHAPTER II

Review of Literature

A review of the relevant literature is necessary in order to understand the current situation in air traffic control-rooms. A significant amount of research has explored the impact of noise interruption on human performance. These studies were reviewed to determine the cognitive characteristics and filtering effects of speech and attention (Broadbent, 1954, Cherry, 1953; Wickens, 1997; Wickens, Kramer & Vanasse, 1983). Numerous theories on crosstalk, the delayed response selection of tasks, and timesharing concerning the cognitive aspects of attention, concentration, and awareness have been employed here as well (Greenwald, 1972; Greenwald & Draine, 1998; Pashler, 1990, 1992, 1994, 2000; Schumacher, Seymour, Glass, Fencsik, Lauber, & Kieras et al., 2001).

In addition, analyses on cognitive disruption have provided structural and practical support for this study (Broadbent, 1971; Miller, 1942; Moray, 1969, 1979; Neisser, 1967; Pashler, 1998; Treisman, 1964; Wickens & Liu, 1988).

Finally, studies were examined that identified imprecision in pilot-controller communications, because of their particular relevance to this experiment (cf. Bürki-Cohen, 1995; Bürki-Cohen & Andrew, 2000; Cardosi, 1993, 1994; Jones & Endsley 1996; Jones, Alford, Bridges, Tremblay & Macken 1999; Endsley, 1996b; Morrow, Lee & Rodvold, 1993; Rodgers & Duke, 1993; Rodgers & Nye, 1993).

Studies of Attention

Numerous studies have addressed the extent to which people can remember and immediately perform perceptual motor tasks. For example, in his classic study, Cherry (1953) found that a person could selectively listen to a particular speaker while simultaneously “tuning out” other conversations in the area. This may be the opposite for controllers, as they can actually hear and recognize salient parts of speech. In that respect, Cherry also found that individuals were able to hear familiar words from a distance because they were sensitive to those particular words. Thus, if someone said a word that an individual recognized (Cherry used a person’s name as an example), the individual would be able to hear it clearly. Not unlike the salient words recognizable to a controller, such as call signs or altitude directives, these would be noticeable, as trained controllers use an extensive number of words in a specific vernacular with a particular cadence.

Treisman (1964) suggested that some words have a lower awareness threshold, which activates understanding when word content is well known. If the speech content is familiar, less volume is required to capture attention. Treisman (1991, 1993) investigated the salient aspects of speech-awareness, establishing the concept with reference to the way individuals use a set of what Treisman called “dictionary-type” words, that these words are recognized easily, even those words spoken at a low volume.

Dual-task Attention

Cognitive research literature has indicated that people are capable of performing two tasks simultaneously only in limited circumstances, regardless of whether they can skillfully perform each task separately (Pashler, 1984, 1991, 1992; Schumacher et al., 2001). Norman and Shallice (1986) grouped an individual's cognitive capacity into two distinct courses of action: The first cognitive action is purposeful and conscious, while the second type of cognition is more automatic as learned tasks become skills.

Individuals frequently use a mixture of both. Welford (1952) analyzed dual task interferences by examining the notion of "a bottleneck" in cognitive processes describing the response delays to secondary-task stimuli that occur right after first-task stimuli as a "psychological refractory period." Numerous experiments have combined cognitive responsibilities with the achievement of a physical exercise (Horrey & Wickens, 2002; Pashler, 1994, 2001). Examining dual task performance, Greenwald (1972) presented what he called "perfect timesharing." Greenwald believed that two tasks could be "ideomotor compatible" and a subject could "preserve sensory-motor paths for those responses in as high a state of activation as in the timeshared condition" (p. 52). Pashler (1984) disagreed with Greenwald's conclusions, finding in his study that in some situations subjects could engage in several different mental operations simultaneously, while in other situations they could not. Pashler called this delay a "response selection bottleneck." Pashler (1991) found that even trained subjects experienced this delay because of limitations in their cognitive ability. Pashler believed the "response selection bottleneck" did not involve motor skills.

Controllers have many simultaneous responsibilities apart from exchanging information with an aircraft. While an aircrew focuses on its aircraft, a controller is working with many aircraft at once. As attention capacities increase, cognitive and processing demands become greater (Chou, Madhavan & Funk, 1996).

Divided Attention

Divided attention is the ability to process more than one piece of information simultaneously. For controllers, divided attention involves visual search, multiple-target detection, and dual tasking. In this experimental setting, each individual participant processed multiple pieces of information and activities in combination with looking and listening for communication errors, (see Figure 6) while also working with the multi-task secondary task exercise and then making cognitive and operational decisions (see Figure 7).

Spurrier, Topi, and Valacich (1994) reported that office workers experienced a cognitive type of overload after missing and/or repeating one or more tasks. They also found that selecting only part of a task is common in situations where an operator misses vital elements, which may inhibit the situation causing further delays.

Kahneman (1973) suggests that cognitive disruptions have various components that can have an effect on human performance. One element of a disruption can affect the thought process of the decision-maker while another can have an effect on an individual's response to the interruption. Kahneman concluded that divided attention deficits are the result of an individual's inability to divide attention among a set of

responsibilities. Individuals are not able to accommodate more than one task at a time, or they are unable to share actions between two or more concurrent items at once. Multiple disruptions can cause additional delays to task completion, affecting performance. In addition, if time is restricted, hurrying to complete a task may negatively affect the performance quality.

Disruption of Attention

Monan (1979) describes concentration loss as a diversion of attention or the loss of focused attention. The process of focusing attention differs for each individual, and it is sometimes impossible to filter out irrelevant sounds. The ability to focus on important stimuli is a trained aptitude (Schvaneveldt, et al., 1985).

Hoffman, Shadbolt, Burton, and Klein (1995) found that as individuals direct their attention to distractions, their focus shifts away from the primary task; they become attracted to the distraction, resulting in confusion when attempting to refocus on the primary task. Thus, task performance has been jeopardized.

Treisman and Gelade (1980) noticed that occasionally an individual could cognitively process all parts of a scene in parallel, while at other times he or she could only process parts of the scene serially. In the Treisman and Gelade study, while working in parallel on basic tasks, there were times when subjects could divide attention automatically, but in other instances, subjects were not able to when using complex mental processes or when more focused attention was required.

Research conducted by Laird, Laird, and Fruehling (1983) found that individuals lost information during distractions which then required extended recovery time to complete tasks, negatively affecting their performance. According to Corragio (1990), such disruptions are discrete events that can break the continuity of an individual's focus on a task, typically interfering with the cognitive processes that require significant demands and actions. Banbury, Macken, Tremblay, and Jones (2001) measured performance with interference from irrelevant sounds during memory tasks. Their studies demonstrated that the interference occurred during the encoding processes because of organizational conflicts.

Speier, Valacich, and Vessery (1999) reported the results of two experiments concerning the influences of interruptions on individual decision-making abilities. In the first experiment, decision-making improved on simple tasks, but during complicated tasks inferior performance resulted when interruptions occurred. In a second experiment, the incidence of disruption and variation in the content between the principle task and the interrupted task intensified the negative effect.

Studies of Air Traffic Controller Performance Issues

Situation Awareness

The loss of situation awareness can occur when a human operator focuses on a specific task and ignores others that are vital to performance (Endsley, 1996c, 1999; Endsley, Manning & Rodgers 1996).

In a study on workload, situation awareness, and performance, while testing air traffic controller-instructors as participants, Durso, Hackworth, Truitt, Crutchfield, Nikolic, and Manning (1997) found that some participants focused on the present to the detriment of the future. In addition, Durso et al. found that participants who were the best at predicting present actions had the greatest number of incomplete actions at the end of the sessions. An individual's cognitive attention capacity can become flooded with substantial amounts of informational input or increasingly complex tasks. As the span of awareness is inherently restricted, focusing on a specific task may mean a loss of situational awareness in another task. In a traffic management setting, loss of attention can generate various levels of impact. A reduction in attention increases the probability of the loss of aircraft separation, which is a serious infraction (Endsley, 1996a).

Latorella (1996) measured the elements of disruption in flight-deck simulations, characterizing the individual task factors that affect performance relating to datalink technology (datalink allows digital text-messaging communications to link to and from the aircraft and controller to relieve radio frequency congestion). Presenting datalink technology as a replacement for traditional voice communications to a flight deck, the

study found that auditory interactions had a disruptive, or negative, influence on performance. Latorella (1998) determined that “often accidents typically resulted from the convergence of several non-normal conditions, although the degree of performance degradation in this particular experiment was not of great operational significance, results provide some empirical support for flight deck interruptions being fundamental factors in accident and incident analyses” (p. 125).

In a study of controllers and supervisors, Conner and Corker (2001) reported disruptions in control rooms. Controllers reported difficulties concentrating on tasks when nearby co-workers were talking. A senior instructor reported procedural delays when the ability to concentrate was compromised.

Under normal working conditions, a controller or team of controllers in air traffic operations are responsible for multiple aircraft within each sector and must rapidly assess voluminous amounts of information from many different communication streams and inputs. This decision-making ability could be vulnerable to oversight when the new information is difficult to process through the added dimension of Attention-Capturing Salient Speech Disruptions (ACSSDs).

Communication Disruption

Norman and Bobrow (1975) reported that greater amounts of communication required more demands on cognitive processing, resulting in higher information loads which increased task-processing challenges. Attention failures can occur when an individual concentrates on only one element of a communication to the detriment of other

elements. Redding, Cannon, and Seamster (1992) theorized that interpretations of salient words are automatic cognitive reflexes; especially when an operator is watchful, alert, and in an attitude of readiness, salient phrases are almost impossible to ignore.

Laird, Laird, Fruehling and Swift (1975) found a decrease in decision accuracy when studying interruptions involving information overload. Controller and aircrew communication processes are attention intensive, with heavy demands on cognitive processing. When an error occurs, it requires additional amounts of reprocessing time and that can influence other immediate responsibilities.

Controller-Pilot Miscommunications

The Department of Transportation and the Federal Aviation Administration have studied aircrew and controller operational performance in training centers around the country. Numerous research efforts closely associated with automation in air traffic management have identified disruptions, with an emphasis on workload functioning and sector size (cf. Buckley, DeBaryshe, Hichener & Kohn, 1983; Mogford, et al., 1993; Stein, 1985). This study used some of these research reports to distinguish the types of interactions susceptible to disruption.

A controller-pilot communication error is an inconsistency between what command or clearance the controller issued and what the pilot actually heard. A readback error occurs when an aircrew member reads back the wrong information. A hearback error is failing to catch a readback error (Cardosi, Falzarano & Han, 1999).

Some circumstances may result in miscommunications during demanding traffic periods. If Attention-Capturing Salient Speech Disruptions (ACSSDs) are present, during high-traffic densities, performance may suffer.

Disruptions in cognitive processing could also affect performance by causing unintended deviations in some routine decisions. Typically, when an individual has an important task to complete, he or she will concentrate on a specific part of the task, attempting to be as accurate as possible. When procedures become complicated in an environment of interruptions, hesitation in speech may be an indication of a higher traffic load (Prinzo, Lieberman & Pickett, 1998).

Carnino, Nicolet, and Wanner (1990) identified two causes for performance compromises in communication settings:

- The operator becomes preoccupied in some circumstances.
- Time constraints along with transient information, or mistaken for other similar information, abbreviations or symbols may cause inaccuracy in communications.

After examining several air traffic-control facilities and reviewing 386 controller voice tape recordings, Cardosi (1994) found three common miscommunication errors: (a) there is an absence of pilot readback, (b) the pilot reads back a clearance incorrectly, or the controller fails to catch the error; (c) a controller mistakenly allows a pilot to repeat an erroneous communication. In addition, Cardosi found that the sources of many communication errors included slips of the tongue, expectancy factors (expectations from previous experiences or situations), and the confusion of similar aircraft call signs and/or

numbers. The highest numbers of difficulties were during busy traffic times when the pilot read back a clearance incorrectly and the controller failed to correct the error. A controller must understand what is happening in the present because those factors influence action in the future (Davies & Parasuraman, 1982).

Summary

In this chapter, an array of literature was reviewed; as well as several classic analyses about disruptions and how they can affect attention and human performance. These studies were used to determine a number of cognitive characteristics and filtering effects of speech and attention. Additionally, literature concerning air traffic management, examining relationships of communication complexity, and controller performance were the basis of the formation of an experiment for this study, comparing the original Air Traffic Control Center (ARTCC) and current control rooms' environments.

It is hypothesized that Attention-Capturing Salient Speech Disruptions (ACSSDs) will influence performance: participants will correctly identify more readback errors in conditions with dampening, than those conditions without. It is also asserted that traffic density would have a negative influence on performance.

CHAPTER III

Methods

In an effort to determine whether Attention-Capturing Salient Speech Disruptions (ACSSDs) affect performance, a part-task medium-fidelity simulation was designed.

Senior certified professional controllers (CPCs) were used as participants, simulating the original and current control rooms' environment. White noise dampening was present or absent in various conditions, along with a mixture of traffic density conditions. A passive dampening technique (white noise) was used in certain trials and omitted in others to determine whether ACSSD would influence performance. Two different levels of traffic density variables were introduced to determine whether performance changed in conjunction with the dampening variable. Participants tested in the simulation were to identify readback communication errors in each scenario.

Hypotheses

Null Hypothesis

H_0 : There will be no influence of ACSSD on the performance of participants in a traffic control-monitoring task during any trials. Further, the participant will identify all readback errors in all conditions regardless of any conditions.

Alternative Hypothesis

***H*₁**: ACSSD will influence performance. Participants will miss a number of readback errors in the presence of ACSSD during the monitoring task without the presence of white noise dampening, although less so with white noise dampening.

***H*₂**: High-traffic density will have a negative impact on performance.

Scenario Elaboration Development Process

Several research sites were visited to observe simulations and working controllers in order to gain empirical knowledge about air traffic procedures. At Embry Riddle Aeronautical University, the researchers observed computer simulations conducted to study the effective integration of human decision and performance parameters with automated aiding systems. This exchange contributed to understanding controller communications and task complexity (Fleming, Lane & Corker, 2000).

The researchers observed visual, graphical radar displays and radio transmission interactions between pseudo-pilots and controllers at the Mike Monroney Aeronautical Air Traffic Control Training Center. This observation helped guide the development of the study's experimental design. At this FAA facility, the researchers also viewed medium-fidelity simulation exercises and performance-review trainings that were instructive in the understanding of pilot-controller verbal radio communication interactions.

An increased comprehension of typical work practices and customary procedures for En route controllers was acquired at the Oakland Air Route Traffic Control Center (ARTCC), where the research team members also gained considerable insight into the workings of primary and secondary radar procedures in aircraft separation.

In order to create realistic scenarios for the study, the research team visited the William J. Hughes Technical Center to learn about the priority of actions in operations and controller multi-tasking abilities. The researchers were invited to observe a full-fidelity simulation exercise during this visit. A wide range of knowledge was gained in these sessions regarding the standard Air Traffic Control procedures and protocol. In addition, the Air Traffic Control FAA-7110-65 manual has been an important source of information in identifying customary communication processes and air traffic standards (FAA, 2000).

Participants

The National Aviation Research Institute (NARI) recruited seven full-performance-level (FPL) certified professional controllers (CPC) at a standard rate for participation in the study (see Appendix C & D).

The participant group consisted of two supervisors and five en route controllers (six males, one female), ranging in age from 36 to 65, with an average of 15 years experience in air traffic control and at least five years experience as an en route controller in radar (R-side). All participants were either currently working or had recently retired.

The participants' unique subject expertise as en route controllers and high level of training made their involvement fundamental to the experiment.

Experimental Design

The experimental design was a four-trial simulation, in which all participants experienced Attention-Capturing Salient Speech Disruptions (ACSSDs) during either high-traffic or low-traffic density with or without white noise dampening (see Table 2).

Table 2

Experimental Design Configuration

PERFORMANCE		
Attention-Capturing Salient Speech Disruption		
In All Conditions		
TRAFFIC DENSITY	DAMPENING	NO DAMPENING
High-traffic	20-35 Aircraft	20-35 Aircraft
Low-traffic	15-24 Aircraft	15-24 Aircraft

Traffic Complexity

Several general guidelines were employed for the interactive recordings and as a foundation for the experiments graphical designs and simulation implementations. a) The simulation was a regular-sized sector as customarily controlled by ATC radar and

regulated by FAA standards. b) The recorded controller was in contact with the pilot from the time the aircraft entered the controlled airspace. c) All aircraft followed a determined flight path unless requested by the controller to make a change. d) The weather conditions were perfect for flying commercial-size airplanes, with no wind, precipitation, or visibility problems. e) The simulation used commercial airplanes.

Factors Investigated

Using the reviewed studies on attention and disruption as a structural and functional foundation, the experiment was established with performance as a dependent measure. For the four scenarios, the independent variables were the absence or presence of white noise dampening during either high-or low-traffic density conditions in an environment of Attention-Capturing Salient Speech Disruptions (ACSSDs).

The dependent measure of performance was the participant's ability to identify the verbal readback communication errors in an environment of ACSSD (see Table 3).

Table 3

Scenario randomization, all participants received identical scenarios in random order (Kendall & Smith, 1939).

	<i>Scenario One</i>	<i>Scenario Two</i>	<i>Scenario Three</i>	<i>Scenario Four</i>
<i>Specialist 1</i>	HT-D	LT- NO	HT-NO	LT-D
<i>Specialist 2</i>	LT- NO	HT-D	LT-D	HT-NO
<i>Specialist 3</i>	HT-NO	LT-D	HT-D	LT-NO
<i>Specialist 4</i>	LT- D	HT-NO	LT-NO	HT-D
<i>Specialist 5</i>	HT-D	LT-D	HT-NO	LT-NO
<i>Specialist 6</i>	LT-NO	HT-NO	LT-D	HT-D
<i>Specialist 7</i>	LT-NO	HT-D	LT-D	HT-NO

Table 4

Conditions for each scenario; with/without dampening (D or NO), either high/ low-traffic density (HT or LT).

-
- Example 1.* Participant watching screen movements, listening to communications from a pseudo-controller & pilot “working” a high-traffic density traffic sector 20-35 aircraft. ACSSD is constant; white noise dampening is introduced: depicted as high-traffic *with* dampening (HT-D).
- Example 2.* Participant watching screen movements, listening to communications from a pseudo-controller & pilot “working” a high-traffic density traffic sector 20-35 aircraft. ACSSD is constant; white noise dampening is not introduced: depicted as high-traffic *without* dampening (HT-NO).
- Example 3.* Participant watching screen movements, listening to communications from a pseudo-controller & pilot “working” a high-traffic density traffic sector 15-24 aircraft. ACSSD is constant; white noise dampening is introduced: depicted as low-traffic *with* dampening (LT-D).
- Example 4.* Participant watching screen movements, listening to communications from a pseudo-controller & pilot “working” a high-traffic density traffic sector 15-24 aircraft. ACSSD is constant; white noise dampening is not introduced: depicted as low-traffic *without* dampening (LT-NO)
-

Simulation Testing Area

Testing took place at the San José State University Human Automation Integration Laboratory (SJSU HAIL) Center during regular, daylight hours. All conditions were comparable to the actual working conditions of controllers. The simulation-testing area is set apart within the laboratory setting, with low lighting (see Figure 5).

Figure 5. Simulation area: Participant listening (via headphones) and watching traffic monitor of recorded verbal pseudo-controller/pilot interactions; responding to hearback errors, while simultaneously watching and performing action to the multi-task secondary task exercise.

Airspace Simulation Sector Map

Figure 6. Simulated Sector Map. Created from a previous model of International Airspace sector and modified into a generic sector of the United States National Airspace.

The sector map design was a C++ program using graphics from Open GL (Graphics Library by Silicon Graphics®). Flight records, aircraft call sign, type, speed, altitude, and flight path-were in NASA's Pseudo Aircraft Systems (PAS) format. The adaptation of airspace (see Figure 6) was a redesign of an international airspace sector model modified into a generic sector of the United States National Airspace (US NAS) by a Subject Matter Expert (SME) with appropriate data blocks, waypoints, and sector

boundaries. A computer-cursor arrow detail permitted the participant to follow the visual movements of the pseudo-controller on the screen corresponding to the auditory communications. Audio sound files were prerecorded on desktop computers using Microsoft MP-3 ® recording software with Windows Media Player ®.

Scenario Speech Recordings

Confederates in this experiment, classified as pseudo-controllers and pseudo-pilots, reading from scripts, simulated the performance of actual controllers and aircrews. A SME supervised the design of the scenarios based on customary audio communications between a controller and aircrew during routine aircraft movement while conducting actual air travel activities in the United States. The simulated Attention-Capturing Salient Speech Disruption (ACSSD) defined as controller speech recordings came from strategically placed speakers (see Figure 5) to simulate actual control room communication sounds. Twelve different repeated recordings of traffic conditions (simulated ACSSD) of approximately 15 minutes each exposed all of the participants to all recordings.

Scenario Computer Hardware and Software

Seven personal computers (four laptops, three desktops) with a standard CPU Pentium III®, monitor, keyboard, and trackball mouse were used. Each desktop computer was equipped with 20-gigahertz of hard drive space to accommodate the recording and visual programs. Microsoft Sidewinder Program ® version 1.0 software

was used for the voice communications. The audio for the pseudo-pilot and-controller in the study was created using Loop Recorder ® software.

Scenario Description

The simulation incorporated audio communications between a pseudo-controller and pseudo-pilot working in generic airspace reconfigured from a sector of international airspace. The simulated aircraft moved at a climb/descend rate similar to that of actual air traffic in the United States. Recordings of controller audio communication from several US Air Traffic Control Centers were integrated into each scenario as Attention-Capturing Salient Speech Disruption (ACSSD) sounds. The audio communication sounds, with matching visual settings, were structured and synchronized to simulate customary traffic scenarios in the National Airspace system (NAS). The participants were required to listen to and view the scenarios, but did not manipulate traffic.

After the sixth minute of each scenario, readback errors were added until the end of the scenario at varied times by a senior certified professional controller (CPC) and a Subject Matter Expert (SME) before the experiment. The errors selected for the experiment were those most often implicated under actual operational conditions, such as similar call signs and words with parallel cadence (Cardosi, 2001). All recordings contained only commercial aircraft.

Task Environment

A research team member spent several minutes explaining how the simulation functioned and presented each participant with written instructions about the tasks that he or she was to complete (see Appendix A). In addition, all participants were presented with an informed consent document requiring their signature (see Appendix B). At the completion of the experiment, each participant received a written questionnaire (see Appendix C) to evaluate the experiment and an invoice for payment of compensation (see Appendix D).

Monitoring-listening Task

Using both physical-action and cognitive skills during the experiment, participants, seated at a table, listened to the verbal communications via headphones while simultaneously viewing a 24-inch color monitor on their left (Traffic scenario, Figure 6) and a 17-inch color monitor on their right (Multi-task, secondary task Figure 7). Each participant viewed and listened to four 45-minute (Table 3) matching recorded scenarios with various traffic and dampening densities. Participants were asked to identify all readback communication errors made by the pseudo-pilot by immediately pressing “E” on the keyboard at the recognition of the readback error. Each participant was also asked to measure the significance of this identified error (“E”) by rating it on a scale of 0-9 immediately after its recognition (using the keyboard). According to the SME, the standard decision time in usual practice was 5 seconds; thus, any response taking more than 5 seconds was an incorrect response (Zsambock & Klein, 1987).

Figure 7. Multi-task secondary task depiction: Colored squares moving into the center of a bulls-eye, with the goal of mouse clicking a moving square before it reached the center.

Multi-Task Secondary Task

The participants simultaneously viewed a Multi-task secondary task on a screen to their right (see Figure 5). This screen displayed colored squares moving toward the center of a bulls-eye configuration (see Figure 7). The squares appeared in a random order materializing five to ten seconds apart. The goal was to mouse-click on the moving square before it reached the center of the bulls-eye.

Unattended squares reached the center in seven to ten seconds. This software program provided an action-type task introducing an effort of functional concentration and supplementary levels of mental demand (Kaber & Riley 1998). The high level of controller expertise prompted a concern that just listening to a scenario would not hold interest; therefore, it seemed realistic to add a secondary task. Although these elements of the experiment were important as an operational exercise and added mental influence the evaluations of these data were not analyzed.

CHAPTER IV

Results

Participant Performance

Participants' performances were determined by analyzing the number of times that they identified the communication errors inserted into each scenario. These measurements were conducted in all conditions during high or low-traffic densities with or without white noise dampening, in a constant environment of Attention-Capturing Salient Speech Disruptions (ACSSDs). Given that participants were actually certified professional controllers (CPC) and experts in verbal interaction, it was likely that there would be a consequence only in conditions with ACSSD without dampening.

Furthermore, it was assumed that performance would only be affected under conditions of high-traffic density, that is, it was predicted that ACSSD would have a reduced impact during conditions characterized by low-traffic density and an increased impact during high-traffic density. It was also reasoned that there would be a limited amount of negative performance where participants would be unable to remember or follow along with the tasks in the scenarios, because of the participants' substantial knowledge of air traffic control practices, and procedures. In addition, the participants were expected to notice a large number of inserted readback errors because of their understanding of en route and terminal radar systems, and previous experience in air traffic dispatching operations.

In addition, because each participant is highly trained in control procedures and facility procedures, preparing daily written technical reports for air traffic control-operations as actual controllers. Boredom or tedium was considered a potential factor; with concern that the study results would show no difference in any scenarios. Thus, the addition of a multi-task secondary task was used to elevate a level of mental effort and demand by increasing the number of actions, corresponding with an actual of air traffic operations environments.

Treatment Conditions

A mixed number of readback miscommunications (8 to 13) were assigned in each scenario, with a traffic density factor (high or low-traffic density) and a dampening factor (presence or absence of white noise dampening) within a continuous Attention-Capturing Salient Speech Disruptions (ACSSDs) environment (see Table 4). To test the different treatment conditions and manage the unequal target set sizes, the data were organized and balanced: The data were *normalized* to find *ratios*, and then those *ratios* were *equalized* so that all trials had the same baseline of targets. The procedures (see Table 5, 6, and 7) for *equalizing* the number of targets in each sample was as follows:

Table 5

Method used for organizing and *normalizing* unequal target set sizes.

Summing the total of the individual participant's correct responses in each condition in all trials.

Dividing the participant's total of correct responses by the actual number of available targets in each precise trial (8-13), creating a *ratio*.

Transforming the *ratio* of the participant's correct responses into an *equivalent* target size.

Multiplying the *equivalent* target size by 8 (8 is the minimum common number of targets available across all treatments), creating an *equalized* number.

Rounding the final *equalized* number to the nearest integer (rounded up if the *equalized* number is higher [0.50] or down if lower than [0.50]).

Resulting in a *normalized equalized* target size.

Table 6

Example of *normalization* procedure for unequal target set sizes

	<i>Scenario One</i>	<i>Scenario Two</i>	<i>Scenario Three</i>	<i>Scenario Four</i>
<i>Specialist # 3</i>	HT-NO	LT-D	HT-D	LT-NO
<i>Specialist #4</i>	LT- D	HT-NO	LT-NO	HT-D

<i>Specialist #3</i>	1. Response condition HT-NO for <i>Scenario One</i> was 5 correct responses out of 13 available targets 2. $5/13 = 0.384 \times 8 = 3.074$: calculated as 3.0 as the <i>final equalized number (rounded down)</i>.
<i>Specialist # 4</i>	1. Response condition HT-D for <i>Scenario Four</i> was 6 correct responses out of 9 available targets. 2. $4/9 = 0.444 \times 8 = 3.55$ are calculated as 4.0 as the <i>final equalized number (rounded up)</i>.

Table 7

Completed *normalized* participant response conditions and *normalized available targets* set sizes

	<i>Scenario One</i>	<i>Scenario Two</i>	<i>Scenario Threes</i>	<i>Scenario four</i>
<i>Normalized Response</i>	35	28	36	26
<i>Normalized Available Targets</i>	56	56	56	56

The performance of each participant was based on the confirmation of all readback communication errors in all trials. The data were analyzed in a chi-square to examine the expectation of equal performance among the group of participants in a 2x2 contingency table comparing participant performances. The obtained value of χ^2 (18, N = 28) = 60.125, $p < .01$ was greater than the critical value 34.81 $p > .01$. As a result, the null hypothesis was rejected, concluding that equal performance was not attained. The assumption that all groups would perform equally well (i.e., 100% detection of all errors) was not met. While this test provided some information about the participants' decisions, it did not completely answer questions about the independent variables and ACSSD, and its influence on the dependent measure, participant performance.

Since the assumption of identical and perfect performance was not upheld, another analysis was prepared to identify the source of the differences.

A two-way within subjects repeated measures analysis of variance (ANOVA, Table 8) [Dampening] x 2 [Traffic] x 2 in all factors were used to determine the main effects and interactions of the participants.

Main Effects

White Noise Condition (Dampening/No Dampening)

The within-subjects repeated measure analysis of variance (ANOVA) was applied to determine whether there was any influence of the dampening/no dampening factors on performance, which there was not; (See Table 8) $F(1, 6) = 0.008, p > .01$

Traffic-Density Condition

The results of the traffic-density factors did produce a statistically significant outcome (see Table 8) $F(1, 6) = 25.54, p < .01$. This exceeded the critical value by a sizeable margin and indicated an influence on performance.

Traffic density or traffic count is a feature of traffic complexity (Arad, 1964a, 1964b). This is consistent with over a decade of studies by experts concerning situation awareness, workload complexity, and other relevant cognitive theories in air traffic operations (Jones et al. 1996; Laudeman & Palmer 1993; Mogford, et al., 1995; Rodgers & Duke, 1993).

Interaction Effects

The interaction factor was not statistically significant, $F(1, 6) = 0.321$, $p > .01$. On examination, performance seemed dissimilar in the low and high-traffic conditions. In order to test dissimilarity, a t-test was performed for differences between these means, with the result revealing no statistically significant difference ($df = 6$, $t = 0.2634$, $p > .01$).

Sources of Unsystematic Error

There was a large amount of variability (Subjects, 86.715, 1, 6, $p > .05$) between participants, while the variability of participants' interactions with the dampening factor was less (A $\times$ S, 26.714, 1, 6, $p > .05$). Additionally, variability of participants' interactions in the traffic factor was smaller still (B $\times$ S, 2.428, 1, 6), with the combination of both factors, traffic and dampening together being somewhat higher (A $\times$ B $\times$ S, 4.429, 1, 6, $p > .05$) (see Table 8).

Table 8

Within-Subjects Repeated Measure Factorial Design

Factor	Source	SS	df	MS	F
A	Dampening	0.036	1	0.036	*0.008
B	Traffic	10.322	1	10.322	**25.54
AxB	Interaction	0.321	1	0.321	*0.434
S	Subjects	86.715	6	14.452	
AxS		26.714	6	4.452	
BxS		2.428	6	0.404	
AxBxS		4.429	6	0.738	
Total		130.965	27		*p>.05 **p<.01

Discussion

There are substantial amounts of research concerning decision-making, situation awareness and disruptions within air traffic control-operations, which were the main components for review in this study. The goal of this study was to identify and evaluate a factor that may contribute to pilot-controller communication errors specific to the recent changes in control rooms, namely the existence of Attention Capturing Salient Speech Disruptions (ACSSDs) where ambient noise previously had been an unintended consequence in the original control rooms.

In this analysis, two independent variables with two levels each were manipulated: high or low-traffic densities and the presence or absence of white noise dampening. Continuous recordings of air traffic controller verbal radio transmissions were used in the simulation area as ACSSD (see Figure 5). The individual differences between participants that could potentially affect performance were limited to recruiting designations, as an increased difference did not seem practical and would require an enormous research effort, which was beyond the scope of this study.

Despite a significant chi-square statistic with the assumption that the differences were due to the independent variables, further analysis of each individual factor found that assumption to be incorrect. The independent variables of dampening or no-dampening and high or low-traffic density treatments resulted in a mixed outcome. The dampening or no-dampening observations did not have substantive significance when applied across the traffic densities (see Table 8; $F = 0.008$, $p > .01$).

However, the traffic factor was significant (see Table 8; $F = 25.54$, $p < .01$) when applied across the dampening factors. This result had the same indication of other relevant studies in air traffic operations (cf. Davis et al., 1963; Jones et al., 1996; Mills, Pfleiderer & Manning 2002; Mogford, et al., 1994; 1993; Rodgers & Manning, 1995).

Implications for Future Studies

A uniform level of performance in relation to the specialization and expertise of controllers was expected for several reasons:

- The training of Certified Professional Controllers (CPC) is extensive, with several years of intensive instruction and at least five years of service in the field.
- Processes and schedules of tasks were identical for all participants.
- The observed number of targets differed between participants only because of random trial-to-trial variability in coincidental order.

However, participant performance levels were not uniform; (see Table 8) therefore, it is considered that a more realistic experimental design may offer another outcome (including using human pseudo-pilots and controllers as participants in a real-time simulation). This approach would appear to offer a more realistic task environment and may produce different results (Stein, 1990).

In this case, the CPC participants were only required to listen to the interaction of a pseudo-controller and pilot while viewing traffic conditions. This may have been a contributing factor in the accurate identification of all readback errors and could be an explanation for the findings here. In addition, future studies may better address controller performance by using strict equivalent age, gender, work site, and time in position, reducing variability and unsystematic variations in subjects. In studies of air traffic operations, Endsley (1994), Bürki-Cohen and Kendra (2001) found that exposure to a

multifaceted environment leads to more practical results when developing realistic radio communications for simulated training.

Despite the fact that the procedure provided some understanding about the influence of Attention-Capturing Salient Speech Disruptions (ACSSDs) in an actual working environment, testing with both pseudo-controllers and pseudo-pilots would be an improved design and may facilitate different results (Endsley & Rodgers, 1998).

CHAPTER V

Conclusions

As noted in the existing literature, the process of cognitive attention often seems to fail when attempting to attend selectively to a multiple of thoughts or events. Everyone at times has attempted to focus on a complex cognitive function when attention has been diverted by disruptions, and despite an effort to refocus, the disruption seems to intrude into awareness.

This study provided an initial assessment of the consequences of a recent control room redesign, questioning the influence of Attention-Capturing Salient Speech Disruptions (ACSSDs) in this environment in an effort to understand how it may affect performance. This study examined prior research, observed associated research facilities, and conducted a part-task medium-fidelity experiment with the added dimensions of ACSSDs.

The results were inconclusive with respect to the influence of ACSSDs on performance with or without white noise dampening. However, traffic density did have a significant effect on performance, which was one of our assumptions and should act as the foundation for further investigation. This assumption and result is consistent with many other relevant theories in air traffic operations (cf. Cardosi, 1993, 2001; Endsley, 1995; Laudeman & Palmer, 1996; Mogford et al., 1995; Rodgers & Duke, 1993; Sollenberger, Stein & Gromelski, 1997).

Although there is empirical evidence regarding speech disruptions and human performance effecting cognitive tasks and this study has offered anecdotal evidence of Attention-Capturing Salient Speech Disruptions influencing time sensitive-tasks, ACSSDs were not statistically significant in this research.

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APPENDIXES

APPENDIX A DEFINING YOUR ROLE IN EXPERIMENT TODAY

FROM: Samm Starr SJSU HAIL researcher

TO: Air Traffic Controller (CPC) Participants

RE: Defining your role in the experiment today

We at SJSU HAIL welcome you to this simulation session, this written document is to familiarize you with the study and the tasks we are asking you to complete.

The total period of your participation will be less than 7 hours with four 40-45 minute trials of different scenarios.

There will be a 15 minute introduction at the beginning

There will be a 10 minute breaks in between each scenario

There will be a 60 minute lunch break

There will be a 15 minutes discussion and final form completion

We have chosen you for this study because of your expertise in the field of Air Traffic Control, and believe that you can give us an unbiased appraisal of the performance in these scenarios.

It is of utmost importance to appraise the performance of the individuals decisively.

Although this study is a simulation, there are errors incorporated that have been found to have an impact on performance.

With your knowledge and experience, in this study, we can be critical.

You will be sitting at a computer monitor and will have headphones on, while listening to an audio of a generic air traffic simulation. We have included another monitor with a “game-like bulls eye task” ongoing through out the scenarios to mimic a realistic evaluation.

As the supervising evaluator, you will be presented with a number of aircraft inconsistencies in each scenario. The presentation is a recorded audio exchange of both ATC and pilot. A computer simulation (visual scenario) matching the audio will be presented simultaneously.

As the evaluator you will identify these errors by a keying ."E" for error, and then rating on a scale between 1-10 (10 very serious, 1 not serious) the significance of the error.

YOUR WORK NOW

You are a supervising evaluator for these scenarios

You are to listen for mistakes of readback errors from either pseudo-controller or pseudo-pilot

You are to rate (1= very slight error, 9 = critical error) what you believe of the error or mistake

You are mouse clicking on the spheres on the "bulls eye" continually

YOUR WORK AFTER EXPERIMENT

You will fill out a questionnaire at the end of your session stating

If you would allow the evaluated controller to work live traffic immediately

Whether you feel more training is needed and if so in what area? (Example: readbacks, computer entries, traffic scan etc. . . or any you feel warrants mentioning.

How you feel the session simulation will help/not help ATC performance

Other concerns you feel should be looked at pertaining to ATC performance i. e. controller style of work (i. e. are priorities in order?) Are there misuse/overuse of vector lines, route keys, j-rings, altitude encroachments, delay in responses and general attitude toward work.

Thank you!! For taking the time from your day to complete this simulation session,
It is appreciated!

Samm Starr

SJSU HAIL

Enclosure: NARI payment form
Informed consent form
Questionnaire

APPENDIX B SPECIALIST EVALUATION QUESTIONNAIRE

Specialist Evaluation of Study

I would allow the evaluated controller to work live traffic immediately

Yes ( ) No ( )

I feel more training is needed

Yes ( ) No ( )

If more training in what area

( ) readbacks

( ) computer entries

( ) traffic scan

( ) other

---

1. Other concerns you feel should be looked at pertaining to ATC performance i. e.
controller style of work (i. e. are priorities in order?)

---

2. Do you believe there were any?

Misuse/overuse of vector lines, route keys, j-rings, altitude encroachments, delay in responses and general attitude toward work, comment:

Thank you for your input and cooperation in this test

Please indicate if you are interested in being involved with other studies

You may contact us by sending an email to: samm.starr@sjsu.edu or calling 408-924-

3804

APPENDIX C Informed Consent Form

San José State
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& Systems Engineering**

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INFORMED CONSENT

**INDIVIDUALS CONSENT TO VOLUNTARY PARTICIPATE IN RESEARCH
ON AIR TRAFFIC CONTROLLER INTERACTION WITH TRAFFIC
FOCUSED ON AUDITORY RESEARCH IN ATCM**

The research into air traffic controller interaction with decision aiding and alerting systems is sponsored by SJSU HAIL. The research will be conducted by Samm Starr and the San Jose State University under the direction of the principal investigator Dr. Kevin M. Corker. The research shall consist of laboratory tests in simulated air traffic management operations.

I _____, understand "The impact of ACSSD on performance on Today's En Route Air Traffic Controllers" is sponsored by SJSU HAIL and is being directed by SJSU and Kevin M. Corker.

I have been recruited as a subject by the National Aviation Research Institute in the project named above. The purpose of this effort is determine what impact noise may have on performance of an air traffic controller. The research process will take approximately 40 minutes per session for 4 sessions in a day and all material, notes and opinions shall be confidential.

Through this effort, the SJSU HAIL expects to gain insight into controller performance and to develop a set of human performance guidelines to support future system design. The approach being will be a series of test scenarios under varied conditions of traffic focused on auditory research in ATCM

I understand that my participation in this study is voluntary. I am participating because I want to. Dr. Kevin Corker has adequately answered all questions I have about this study, my participation, and the procedures involved. I understand that Dr. Corker will be available to answer any questions concerning procedures throughout this study. I understand that if new findings develop during the course of this research that may relate to my decision to continue participation I will be informed.

I understand that records of this study will be kept confidential, and that I will not be identifiable by name or description in any reports or publications about this study. All records and interviews shall be classified and confidential.

I understand that I may withdraw from this study at any time without penalty.

If I have questions about this study or need further information, I will contact Kevin M. Corker, the Principal Investigator, at (408) 924 3988 or via email at: kcorker@email.sjsu.edu

Page 1 of 2

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Questions about research, subjects' rights, or research-related injury may be presented to Nabil Ibrahim, Ph.D., Associate Vice President for Graduate Studies and Research at (408) 924-2480 or via email at: nibrahim@sjsu.edu

I have read this consent document and freely consent to participate in this study under the conditions described. I have received a copy of this consent form.

Participant Signature

Date

Investigator's signature

Date

APPENDIX D NARI Compensation Form

INVOICE FOR SJSU HAIL PROJECT

HEADED BY SAMM STARR

Name _____

Address _____

Telephone _____

Email address _____

Social security: _____

Date(s) of work _____

Mileage _____

Parking _____

Wages _____

Total invoice amount _____

To be paid, this invoice **MUST** be mailed/faxed to the Attention of Kimberly Conner

National Aviation Research Institute

1303 Bellefonte Lane

Colleyville, TX 76034

Phone 817-416-xxxx

Fax**817-416-XXX**

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UNIVERSITY**

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To: Samm Starr and Kevin Corker
Eight Stratford Place
Gilroy, CA 95020

From: Nabil Ibrahim, *N. Ibrahim to J. Pearl*
AVP, Graduate Studies & Research

Date: February 7, 2003

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

"Questioning the effect of Attention Capturing Salient Speech
Disruption (ACSSD) on today's En Route Air Traffic Controller
Performance."

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to all data that may be collected from the subjects. The approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Nabil Ibrahim, Ph.D. immediately. Injury includes but is not limited to bodily harm, psychological trauma, and release of potentially damaging personal information. This approval for the human subjects portion of your project is in effect for one year, and data collection beyond February 7, 2004 requires an extension request.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services that the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2480.

The California State University:
Chancellor's Office
Bakersfield, Channel Islands, Chico,
Dominguez Hills, Fresno, Fullerton,
Hayward, Humboldt, Long Beach,
Los Angeles, Maritime Academy,
Monterey Bay, Northridge, Pomona,
Sacramento, San Bernardino, San Diego,
San Francisco, San José, San Luis Obispo,
San Marcos, Sonoma, Stanislaus