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Effects of Lighting and Noise on Performance and Situation Awareness in Air Traffic Control Tasks

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EFFECTS OF LIGHTING AND NOISE ON PERFORMANCE AND SITUATION AWARENESS IN AIR TRAFFIC CONTROL TASKS

by

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A Graduate Capstone Project Submitted to the College of Aviation,
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This Graduate Capstone Project was prepared under the direction of the candidate's Graduate Capstone Project Chair, Dr. Steven Hampton, Professor, Daytona Beach Campus, and has been approved. It was submitted to the Department of Graduate Studies in partial fulfillment of the requirements for the degree of Master of Science in Aeronautics

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Abstract

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Title: Effects of Lighting and Noise on Performance and Situation Awareness in Air Traffic Control Tasks

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Work environment influences an individual's performance and situation awareness (SA). This study aims to investigate the effects of lighting and noise on the performance and SA in air traffic control (ATC) tasks. These two variables are important in the domain of ATC because the tasks require an individual to receive and process information both visually and auditorily. The results are useful for designing air traffic control rooms, which are set differently among different air navigation service providers. The subjects are 16 students majoring in Air Traffic Management (ATM) at Embry-Riddle Aeronautical University (ERAU) – Daytona Beach, FL. The research uses a within-subject research design to test how lighting and noise affect performance and SA of participants working on air traffic control tasks. A two-way Analysis of Variance (ANOVA) is used to test the main effects and the interaction between lighting and noise. The result indicates that noise has a significant effect on performance, but lighting has no significant effect on both performance and SA.

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Chapter I

Introduction

The work environment is a significant component which may support or hinder an employee to perform effectively (Palvalin & Vuolle, 2016). In the aviation industry, International Civil Aviation Organization (ICAO) adopted a conceptual tool called the SHELL model used to analyze multiple interrelated components affecting human performance: Software (S), Hardware (H), Environment (E) and Liveware (L). The model identifies ambient light and noise as parts of the internal workplace environment that all sectors of the aviation system must assess and consider (ICAO, 2012).

In many industries, including air traffic control (ATC), employees work under an artificial lighting on a daily basis. Lighting, combined with other environmental factors, can physiologically and psychologically affect employees' performance and productivity. Without sufficient lighting, it is more difficult for individuals to maintain high visual acuity (Hawes, Brunye, Mahoney, Sullivan, & Aall, 2012). For air traffic controllers, sufficient lighting is important when the controllers work with aircraft information on small paper strips, or when they input numbers and letters through a keyboard. Many research papers, in the area of environmental influences on human performance, examine effects of lighting on human physiology (Schweitzer, Gilpin, & Frampton, 2004). Kim, Lee, and Lee (2017) reported that there was evidence that indicated the relationship between insufficient light exposure with sleep fragmentation, and previous studies showed that more nighttime awakenings could be predicted by the exposure to lower light levels. Given these effects of lighting on human physiology, there is an increasing number of studies that further attempt to examine the effects of lighting conditions on psychological processes, such as mood, memory, and processing speed (Hawes et al., 2012). However, lighting is one of many factors that affect air traffic controllers' performance, because ATC tasks highly demand both visual and auditory perception (Shorrock, 2007).

To provide ATC service, a controller monitors a traffic situation display (TSD) while communicating with pilots through a radio communication system for position inquiries, direction issuances, information provisions, and so on (Federal Aviation Administration [FAA], 2015). Effective radio communication between controllers and pilots is recognized as a significant contribution to aviation safety. In a setting where safety is the primary concern, distractions and barriers to communication can result in miscommunications, errors or accidents (Barshi & Farris, 2016). Thus, it is necessary to take noise into consideration when designing ATC workplace environment as it is mentioned in the SHELL model under the Liveware-Environment (L-E) interface (ICAO, 2012).

According to Leather, Beale, and Sullivan (2003), noise can negatively affect employees' job satisfaction and, as a result, has negative effects on workers' productivity and performance (Shikdar & Das, 2003). For example, Lamb and Kwok (2016) mentioned that "a novel stress such as an arbitrary noise may be a mild inconvenience in an experiment, but an irregular but frequently experienced noise at work (e.g. loud air conditioning) may have a large impact on work performance" (p. 105). In addition, Smith (1991) identified that noise exposure in the work environment had a negative effect on performing tasks needing concentration. Also, some studies claimed that the acoustic environment in an open-plan office resulted in increased concentration difficulties, reduced task performance and reduced co-operation between workers (Kaarlela-Tuomaala, Helenius, Keskinen, & Hongisto, 2009; Liebl, Haller, Baumgartner, Schlittmeier, & Hellbruck, 2012).

Apart from performance, situational awareness is another aspect which can be affected by work environment in the form of physical stressors (e.g. noise, vibration, heat/cold, lighting) and social/psychological stressors (e.g. anxiety, mental load, consequences of events) (Hockey, 1986; Sharit & Salvendy, 1982). Situational Awareness and Situation Awareness (SA) are used interchangeably. SA is defined as the "perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1988, p. 97). Failure in maintaining any of these SA levels may lead to a lower level of flight safety and potentially results in a serious accident (Endsley & Jones, 2012).

Significance of the Study

"The primary purpose of the ATC system is to prevent a collision between aircraft operating in the system and to organize and expedite the flow of traffic, and to provide support for National Security and Homeland Defense" (FAA, 2010). According to FAA order 7110.65T (2010), a controller must give first priority to the task of separating aircraft and issuing safety alerts with good judgement in prioritizing all other provisions. To separate aircraft, a controller relies on visual and auditory information from radar displays and flight progress strips to issue instructions to pilots through radio communication (Aeronautical Information Manual [AIM], 2017). Therefore, visual and auditory perception is considered as the key factors that influence performance and SA in ATC tasks.

An ATC task is unique in that a controller may perform the task under a low-lighting condition (Wilson, Wilson, & Jha, 2007). Wilson (2015) and Healthbeat (n.d.) indicated that reading in dim light was one of the common causes of eye strain. Apart from lighting which can affect human perception and performance, background noise in the control room may distract a controller's attention from the radio communication and may lead to a lower level of SA.

Therefore, it is important to know under which working environment individuals can perform the ATC task efficiently while maintaining their SA. The significance of the study is to understand the impact of lighting and noise on performance and SA in ATC tasks. The results of the study are useful for those involved in the design of ATC workplace environment such as ATC training academies, aviation regulators and air navigation service providers (ANSPs).

Statement of the Problem

Since the introduction of radar displays, ATC rooms at Air Route Traffic Control Center (ARTCC) and Terminal Radar Approach Control (TRACON) have been kept in the dark to minimize undesirable effects (i.e. reflections and glares) caused by light sources (Kopala, 1977). However, the technology of displays and their accessories are developed so much more than they were decades ago (EIZO Corporation, 2018). Now users can adjust the brightness and contrast of the display according to their preference. Moreover, anti-glare and anti-reflective displays are also available. Therefore, it is questionable whether keeping the ATC room dark is still necessary and whether performing ATC tasks under normal office lighting would result in any change in human performance and SA.

Becker and Milke (1998) claimed that the ability to handle simultaneous visual and auditory input was critical to success in the domain of ATC. Thus, apart from lighting, noise is another physical factor to be considered, as well as the interaction effect between lighting and noise. It is possible that the effect of background noise will be emphasized when the intensity of the light is lower.

Purpose Statement

The purpose of the study is to explore the effect of lighting and noise on performance and situation awareness in performing air traffic control tasks.

Research Question

Is there a significant effect of lighting and noise on performance and situation awareness when performing ATC tasks?

Hypothesis

The following null hypotheses are tested.

H1: There is no significant difference in performance between a group working under low lighting and a group working under normal lighting.

H2: There is no significant difference in performance between a group working in a noisy environment and a group working in a quiet environment.

H3: There is no significant interaction effect between lighting and noise in terms of performance.

H4: There is no significant difference in SA between a group working under low lighting and a group working under normal lighting.

H5: There is no significant difference in SA between a group working in a noisy environment and a group working in a quiet environment.

H6: There is no significant interaction effect between lighting and noise in terms of SA.

Delimitations

The first delimitation is that all the subjects in the study are Air Traffic Management (ATM) students in second, third or fourth year at Embry-Riddle Aeronautical University (ERAU) – Daytona Beach, FL. Thus, the result of the study is only applicable to this group of ATM students. Second, the experiment was conducted in a laboratory, where lighting and noise levels could be manipulated. Third, the study only looks at an individual SA; a team SA is not in the scope of the study. Finally, the traffic was simulated by a simulation software.

Limitations and Assumptions

Due to the limitation on participants' identification, the researcher assumes that all participants volunteering for the experiment are qualified to participate meaning that they are in an ATM major and study in a second, third, or fourth year. Another limitation entails the presence of an experimenter during the simulation. This limitation cannot be avoided, as the experimenter must ensure that participants proceed on a scenario as planned and the SA assessment is taken properly. However, the presence of an experimenter may alter the participants' performance and SA in the ways unknown to the researcher.

The study assumes that the result from the Air Traffic Scenarios Test (ATST) software is valid and is comparable among participants. Moreover, participants are assumed to have some basic knowledge of ATC and understand the concept of ATC tasks as they at least passed their first year of ATM study.

Definitions of Terms

Air Traffic Control (ATC)	The service that aims to maintain sufficient separation between aircraft and between aircraft and obstructions to avoid collisions (Commission of the European Community, 1996).
Air Traffic Management (ATM)	The activities that ensure the safe and orderly flow of air traffic. ATM comprises three main services: Air Traffic Control (ATC), Air Traffic Flow Management (ATFM), and Air Space Management (ASM) (Commission of the European Community, 1996).
Ambient light	The generalized, omni-directional light present at a locale, originating from natural or artificial sources (Kroon, 2014).
Downwind	The path flown by aircraft parallel to but in the direction opposite to that for takeoff or landing on the airfield circuit pattern (Kumar, Remer, & Marshall, 2004).
Individual SA	The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future (Endsley, 1988).
Liveware	The human element placed in the middle as a core component of the SHELL model. Liveware covers human performance, capabilities and limitations. (Dumitru & Boscoianu, 2015)

Local Controller (LC)	One of the ATC tower positions who has primary responsibility for operations conducted on the active runways and must control the use of those runways. (FAA, 2010)
Team SA	The active construction of a situation partly shared and partly distributed between two or more agents, from which one can anticipate important states in the near future (Artman & Garbis, 1998, p.2).
Traffic Situation Display	A computer system that receives radar track data, organizes this data into a mosaic display, and presents it on a computer screen (FAA, 2015, p. 1088).

List of Acronyms

AIM	Aeronautical Information Manual
ANSP	Air Navigation Service Provider
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
ATCT	Airport Traffic Control Tower
ATM	Air Traffic Management
ATST	Air Traffic Scenarios Test
ERAU	Embry-Riddle Aeronautical University
FAA	Federal Aviation Administration
ICAO	International Civil Aviation Organization
LC	Local Controller

NTSB	National Transportation Safety Board
SA	Situation Awareness
SAGAT	Situation Awareness Global Assessment Technique
TRACON	Terminal Radar Approach Control
TSD	Traffic Situation Display

Chapter II

Review of the Relevant Literature

An air traffic controller is a person who directs the movement of aircraft on the ground and in the air by taking safety as the primary concern followed by efficiency (Hawkes, 1986). One of the challenges in performing ATC tasks is the requirement of multitasking. Controllers in the ARTCC and the TRACON control traffic by relying primarily on the traffic information represented on TSDs. Moreover, a paper or electronic strip is used to record flight information and instructions that a controller has given to a pilot (FAA, 2010). Instructions to pilots are delivered through a radio communication system (FAA, 2017). Pilots also use the same system to read back the instructions and to contact a controller. Because of this, the nature of ATC requires good visual and auditory perception. Factors that affect visual and auditory perception such as lighting and noise may alter performance and situation awareness of an individual when he/she performs ATC tasks.

Significance of Lighting and Display Viewing

Lighting has been a significant factor in a workplace environment. According to Engineering ToolBox (2004), Table 1 below is a guide for recommended light levels in different workspaces.

Table 1

Light Levels in Different Workspaces

Activity	Illumination (lux, lumen/m^2)
Public areas with dark surroundings	20 - 50
Simple orientation for short visits	50 - 100
Working areas where visual tasks are only occasionally performed	100 - 150
Warehouses, Homes, Theaters, Archives	150
Easy Office Work, Classes	250
Normal Office Work, PC Work, Study Library, Laboratories	500
Supermarkets, Mechanical Workshops, Office Landscapes	750
Normal Drawing Work, Detailed Mechanical Workshops	1,000
Detailed Drawing Work, Very Detailed Mechanical Works	1500 - 2000
Performance of visual tasks of low contrast and very small size for prolonged periods of time	2000 - 5000
Performance of very prolonged and exacting visual tasks	5000 - 10000
Performance of very special visual tasks of extremely low contrast and small size	10000 - 20000

Note. Adapted from "Illuminance - Recommended Light Level," by Engineering ToolBox, 2004 (https://www.engineeringtoolbox.com/light-level-rooms-d_708.html).

In the ATC realm, Kopala (1977) conducted a lighting study which was intended to improve the lighting situation at the Boston ARTCC. Kopala's study succeeded in reducing reflections that interfered with the observations of flight data on the display and increasing the lighting level in the control room to adequately illuminate the center aisles for walking and reading. In addition, illumination in ATC rooms varied among different ARTCCs (Kopala, 1977). The comparative mean illumination readings from four ARTCCs are provided in Table 2.

Table 2

Comparative Mean Illumination Readings at ARTCCs

	Boston	Washington	Atlanta	Cleveland
Ambient Illumination in Aisle	0.13 ft-c	0.13 ft-c	0.38 ft-c	0.38 ft-c
Flight Strip Illumination	10.0 ft.c	10.0 ft.c	8.0 ft-c	10.4 ft-c

Note. ft-c = foot-candle. 1 ft-c = 10.76 lux. Adapted from "Boston Air Route Traffic Control Center (ARTCC) lighting study," by A. J. Kopala, 1977.

The FAA recognizes the importance of lighting and the fact that traffic displays can affect controllers' performance. In 2003, the FAA conducted a field survey to determine and record illumination in the Airport Traffic Control Tower (ATCT) environment and to document display viewing data. In this survey, the amount of light striking the face of the display (incident illumination) was collected from 14 ATCTs and the data were shown in Figure 1.

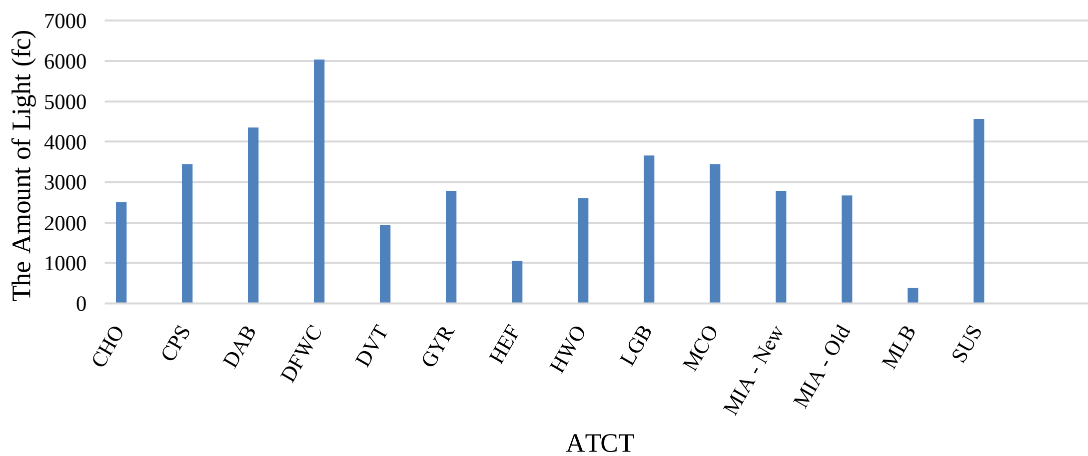

Figure 1. Incident Illumination of the displays at 14 ATCTs. Adapted from "Airport Traffic Control Tower Lighting and Viewing Measurements," by E. Wilson, D. Wilson, and P.D. Jha, 2007 (http://www.tc.faa.gov/its/worldpac/techrpt/tc07-9.pdf).

According to Wilson et al. (2007), the results from the survey enabled the FAA to provide display specifications and minimum viewing distances and angles under the maximum lighting levels for optimum performance. Xing (2006) reported that Color Analysis in Air Traffic Control Displays was performed due to the lack of standardization and documentation. The analysis evaluated color-coding, color usage, task purposes and effectiveness of color use, potential shortcomings, and color complexity for three types of radar displays used by operational controllers. The results of these investigations were beneficial for the development of design prototypes and for acquisition evaluation of new ATC display technologies.

For other areas such as the automotive industry, Akbari, Dehghan, Azmoon, and Forouharmajd (2013) investigated the effects of lighting and noise levels on the productivity of 181 workers in the automotive assembly industry. They found no significant relationship between lighting and human performance but did find that noise had a negative impact on human productivity. They concluded that noise control and reduction to less than the standard values (less than 85 dB) were necessary for employee productivity. Akbari et al.'s study raises the question whether noise can influence human performance in working on ATC tasks and whether the effect of noise can interfere the effect of lighting. Table 3 shows the sound levels and their sources.

Table 3

Comparison of Common Sound Levels

Source(s)	Sound Levels (dBA)	Note
Shotgun, Rifle, Handgun, Fireworks (at 3 ft.)	≥ 160	Impulse sound
Airplane (taking off)	140	Harmfully loud
Car horn, Symphony concert, Baby crying	100	Regular exposure of more than one minute risks permanent hearing loss. Physical discomfort. Maximum vocal effort.
Freeway traffic (at 50 ft.), Urban housing on major avenue (Ldn), Inside a car, TV audio	70	Interferes with telephone conversation. EPA Ldn for lifetime exposure without hearing loss.
Normal conversation, Sewing machine	60	Intrusive Interference with human speech begins at about 60 dBA
Quiet office, library, Quiet residential area, Rural Residential (Ldn)	40	

Notes. Ldn = day-night average sound level. Adapted from https://www.usbr.gov/uc/envdocs/ea/navajo/appdx-E.pdf.

Effect of Simultaneous Stimuli: Visual and Auditory

An air traffic controller monitors separation between many different pairs of aircraft, processes information to manage the traffic flow and pilot requests, keeps up with aircraft both entering and leaving the sector, and communicates with pilots and other controllers. These activities create a situation called “attention sharing” which affects performance and SA of human (Endsley & Jones, 2012, p. 32).

Sakuraba (2012) studied how the presence of multiple stimuli affected human attention and how much information a human could comprehend. He investigated how comprehension of information was affected when auditory and visual stimuli were presented simultaneously. Two types of information were provided to participants: consistent or inconsistent information. The results suggested that when delivering inconsistent multiple stimuli, attention was divided and information was less likely to be processed effectively. He suggested that certain drills might improve comprehension and attention. The results of Sakuraba's study support the statement that the limit of how many elements one person can pay attention to at a time affects how much information a person can process, forming a central bottleneck of SA.

Situation Awareness in ATC

The goals of maintaining aviation safety and providing efficient flow of air traffic cannot be achieved without good SA. The three levels of individual SA can be explained in the context of ATC as following.

- Level 1 is to accurately perceive relevant elements in the environment such as aircraft, obstructions, weather, etc.
- Level 2 is to understand the significance of those elements in relation to the goals of the ATC tasks.
- Level 3 is to project the future actions of the elements on the traffic pattern in the near future (Endsley & Rodgers, 1994).

In conclusion, controllers need to be aware of aircraft and obstructions in their control area, understand the traffic situation, and be able to project the status of those elements in a timely manner because having insufficient SA may cause errors or accidents as illustrated in the accident below.

An example of the accidents involving poor SA of an air traffic controller was a midair collision between two aircraft (Cessna 172M, N1285U and an Experimental Sabreliner, N442RM) occurring on August 16, 2015. The probable cause of the accident was the incomplete SA of the local controller (LC) when he took over communications from the LC trainee due to the high workload at the time of the accident (National Transportation Safety Board [NTSB], 2016). The voice record indicated that, before the accident, the LC had made several mistakes in giving directions to the aircraft under his control. Without understanding and having a correct picture of the traffic situation, he gave a direction to the Experimental Sabreliner, which was continuing downwind on the left side of the Cessna 172, to turn base for Runway 26L without realizing that the Cessna 172 was continuing on the downwind for the same runway. Less than half a minute after the direction was given, the two aircraft collided, and five people were killed in the accident. This accident clearly demonstrates a poor SA when misperception of one aircraft led to misunderstanding of the traffic situation and finally resulted in the incorrect action of the controller. (NTSB, 2016)

Measure of Situation Awareness

Endsley & Jones (2012) categorized measurement of SA into two types: indirect measures and direct measures. An example of direct measures is a verbal protocol in which an operator describes their thoughts, strategies, and decisions while interacting with the system. Psychophysiological metric is an example of indirect measures which relate reactions such as eye movements, electroencephalogram (EEG), or electrocardiogram (ECG) to cognitive processes. Observations of operators' behavior and measurement on their performance are also categorized as an indirect measurement.

Direct measurement can be conducted through several methods such as self-ratings, observer ratings, post-test questionnaires, online queries, and so on. Situation Awareness Global Assessment Technique (SAGAT) is one of the direct measures that has shown to be effective across a variety of domains, including aviation, air traffic control, driving, and military operations (Endsley & Jones, 2012).

Situation Awareness Global Assessment Technique (SAGAT)

In SAGAT, SA of participants is measured through a battery of queries. At randomly selected intervals, the exercise or the scenario is paused, and the display is blank. During this time, a rapid battery of queries will be administered to the participants. Their responses will be scored on the basis of objective data. Although SAGAT requires the interruption of the simulation, many studies choose to apply this method because it avoids retrospective recall, minimizes potential biasing of subject SA, and assesses SA in realistic and dynamic environments.

For instance, Sethumadhavan (2011) modified SAGAT and applied the method to measure SA of the subjects after they experienced an automation failure. In his study, he had participants perform ATC tasks using a simulation. At the time that the simulation was paused, participants were asked to recall the detail of the situation such as aircraft heading, altitude, call sign and so on. The results of his study showed that individuals working with higher order automation had lower situation awareness and were slower in responding to a subsequent automation failure compared to the other group working with lower order automation.

Summary

Lighting and noise affect performance and SA of individuals working on ATC tasks through visual and auditory perception. Thus, performing ATC tasks under different physical conditions can alter the performance and SA of an individual. Although there is much research studying on the effects of a workplace environment on workers' performance, this particular topic is underexplored in the realm of ATC. As the technology of ATC display advances, it becomes more questionable whether lighting in ATC rooms can be adjusted to the change of the technology and to the ergonomic design of the workplace.

Therefore, to answer the question, an experiment was conducted using a simulation software to simulate ATC tasks. The software provided performance reports of the operators at the end of the simulation. For SA measurement, there are several techniques available. However, SAGAT has shown to be effective in the domain of ATC (Endsley, Sollenberger, Nakata, Stein, & FAA Technical Center Atlantic City, 2000) and has been widely tested and validated (Endsley, 1995; Gardner, Kosemund, & Martinez, 2015; Snow & Reising, 2000). Therefore, the study chose to adopt SAGAT as a measurement of SA which is mentioned in more detail in the next chapter.

Chapter III

Methodology

The research explored the effects of lighting and noise on the performance and SA of individuals working on ATC tasks. The study was experimental and conducted in a laboratory. The study used a simulation software, Air Traffic Scenarios Test (ATST), to simulate ATC tasks. Participants performed the tasks under different working conditions, and their performance and SA were assessed and analyzed.

Research Approach

A quantitative research design using a within-subject research model to determine the differences in performance and SA when ATC tasks were performed under four different working conditions. The ATST was employed to simulate ATC tasks and to measure the performance of participants. The Situation Awareness Global Assessment Technique (SAGAT) was modified and adopted as a tool to measure the situation awareness of participants.

Design and procedures. This research study was an experimental, causal type study in which ATM students were asked to perform ATC tasks under different physical conditions. There were three main tasks that participants try to accomplish in each air traffic scenario: (a) routing an aircraft to its destination (b) maintaining separation between aircraft and keeping an aircraft a safe distance from airports and sector edges and (c) verifying pilot readback.

Two independent variables (IVs) (i.e. lighting and noise) were examined; each variable had two levels of conditions. The two levels of lighting intensity were dark (approximately 100 lux equivalent to the light condition in an ARTCC) and bright (approximately 250 lux equivalent to the light condition for an easy office work or a school class). The two levels of noise were quiet (approximately 40 dB corresponding to the sound level in a quiet office or in a library) and noisy (60 - 70 dB corresponding to the sound level ranging between a normal conversation and an urban housing on a major avenue). Having two IVs with two levels each, four different conditions were formed by the combination between the lighting levels and the noise levels as shown in Table 4.

Table 4

Four Working Conditions

Condition	Lighting	Noise
A	Dark	Quiet
B	Dark	Noisy
C	Bright	Quite
D	Bright	Noisy

Note. Dark condition had a lighting intensity of 100 lux. Bright condition had a lighting intensity of 250 lux. Quiet condition had a noise level of 40 dB. Noisy condition had a noise level falling in the range of 60-70 dB.

Each participant performed ATC tasks in all four working conditions and spent approximately 20 minutes in each condition. Before starting the experiment, a participant read through and signed a consent form. After the form had been collected, he/she was orally briefed about the overview of the experiment and the steps he/she would go through. Then, the participant would access the lab and be introduced to the ATST. A participant would spend five minutes exploring a sample simulation scenario to get familiar with the interface and the equipment. The participant had the option to question anytime during the 5-min trial period, and, at the end of the trial, he/she would be asked if he/she had any questions that had not been answered.

The next step was to perform the tasks in four 15-minute experimental scenarios. A participant needed to multitask by guiding traffic to its designated airport or designated sector gate while maintaining a separation distance between aircraft and keeping traffic a safe distance from airports and sector edges. A readback to the instructions given by the participant was generated by the simulation software. If the readback did not correctly reflect the given instructions, the participant had to resubmit the instructions using the repeat button on the screen. Instructions to the aircraft were submitted using the computer mouse and the options available on the computer display.

Two types of data were collected: performance and SA. The data on performance were reported at the end of each scenario by the simulation software. SA was measured using SAGAT. In this approach, the simulation was paused at random, and the screen was covered at the time of the pause. During the pause, a participant would be asked to recall the current situation such as location, altitude, and heading of the aircraft. There were two pauses in each scenario. At the end of the simulation, there was a debrief about the use and confidentiality of the results. A participant received $25 for participating the experiment. Finally, he/she would have an opportunity to ask questions before leaving.

The performance and SA data were input into the SPSS for analysis. A two-way Analysis of Variance (ANOVA) was used to test the main effects and the interaction effect between noise and lighting. It was expected that there would be significant main effects of noise and lighting, and a significant interaction between the two factors.

Apparatus and materials. The following materials and equipment were used for the research.

Physical equipment

- *Computer with a headphone.* The computer had the ATST installed. During the experiment, a participant wore a headphone and used a mouse to input instructions to the aircraft, while the researcher took control on a keyboard to pause the simulation for administering SAAQs.
- *Floor lamp.* The floor lamp was used as another source of light, other than the ceiling light in the simulation room. It allowed the researcher to set lighting condition as specified in the lighting treatment.
- *Desk lamp.* The desk lamp allowed participants to work with the SAASs in the dark lighting condition.

Software and electronic file

- *Air Traffic Scenarios Test (ATST).* The ATST was used to simulate ATC tasks and report performance of the users in three main categories: Efficiency, Safety and Procedural Accuracy.
- *Snipping Tool.* A software, *Snipping Tool*, was used to capture the information displayed on the screen including traffic situations and performance results.
- *Microsoft Excel.* An Excel spreadsheet was used to record participant IDs, genders and performance scores. SA responses were scored according to the method mentioned in the Treatment of Data and these scores were input in the Excel spreadsheet as well.

- *SPSS Statistics Software.* The SPSS was used for data analysis and for creating graphical representations of the data.
- *Audio file.* The sound of a paper strip printer, commonly existing in ATC rooms, was played along the simulation to create a constant background noise or the noisy working condition.

Measuring tool

- *Light meter.* A mobile application, *Lux Light Meter Pro,* was used to measure the intensity of light in the unit of lumen per meter square (lux). It was used for setting up the simulation room to have a condition of light as specified in each treatment.
- *Sound meter.* A mobile application, *NIOSH Sound Level Meter*, was used to measure the noise volume in decibel (dB) unit. It was used to set up the simulation environment to have the noise level as specified in each treatment.
- *Situation Awareness Assessment Questions (SAAQs).* The SAAQs were a set of questions adopted from Endsley's and Kiris' (1995) SAGAT Queries for Air Traffic Control. These questions were designed to test the extent of SA by asking subjects to recall about the current traffic situation such as aircraft, airport, airspace, and so on (See Appendix B).
- *Situation Awareness Answer Sheets (SAASs).* The SAAS was an outline of the sector map used to collect SA responses from participants. The map on the SAAS had an exact same scale as that on the situation display (See Appendix B).

Population/Sample

The researcher recruited 16 students in the second, third or fourth year majoring in Air Traffic Management at ERAU, Daytona Beach, FL. Flyers to recruit participants were posted on the bulletin boards located on the third floor of the College of Aviation and were also handed out to the students in ATM classes to notify ATM students about the need for research volunteers. Students who were interested in participating contacted the researcher to set up an experiment schedule through emails and mobile messages. The flyer can be found in Appendix A.

Sources of the Data

The experiment was conducted in March and April 2018 at the Cognitive Engineering Research in Transportation Systems (CERTS) lab which is a part of ERAU College of Aviation facility. This study employed tools including a computer, a floor lamp, a desk lamp and a simulation software available in the lab to simulate ATC tasks and to create different working conditions. The performance data were obtained from the simulation software and the SA data were the responses that participants wrote down in the SAASs.

Data Collection Device

To capture the performance results of the participants, the researcher used Snipping Tool which was a software available in Window Operating System. Then, the performance reports were collected and stored in the form of images under .jpg file type. A sample of performance results captured at the end of each scenario is shown in Figure 2.

Results | Performance Graphs

Results

Efficiency	
Distance needed:	100.0 %
Time needed:	100.0 %
Safety	
Conflicts:	100.0 %
Collisions:	99.9 %
Prohibited airspace border crossings:	100.0 %
Prohibited airport border crossings:	100.0 %
Pilot readback:	78.8 %
Procedural accuracy	
Exiting the airspace:	
- Correct destination:	97.1 %
- Correct speed:	100.0 %
- Correct altitude:	97.1 %
Landing at airports:	
- Correct destination:	100.0 %
- Correct heading:	62.5 %
- Correct speed:	87.5 %
- Correct altitude:	100.0 %
General	
Set-up difficulty:	72.2 %
Total result:	**52.8 %**

Figure 2. Performance report generated by the ATST.

To collect SA responses, the SAAQs and the SAASs were used. While a participant was working on a traffic scenario, the simulation would be paused at random to administer the SAAQs. During this time, the computer display was turned to a blue screen to prevent the participant from seeing the traffic situation on the display. Next, the participant was asked to leave the computer to the provided area and worked on the SAAQs. The participant responded to the SAAQs by writing their answers onto the provided SAAS shown in Figure 3.

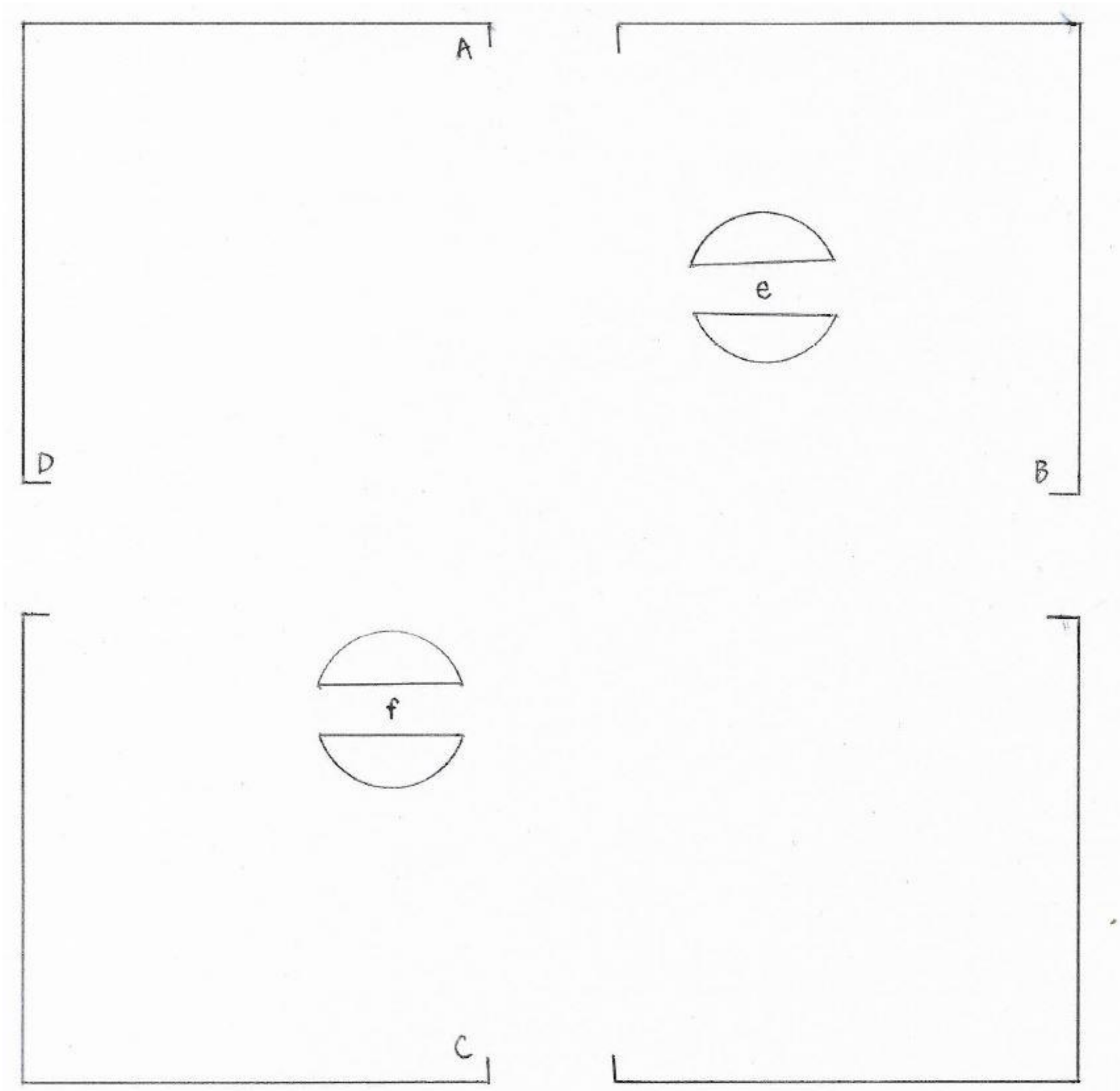

Figure 3. Situation Awareness Answer Sheet (SAAS).

To evaluate participant responses, the researcher needed to know the traffic situation that a participant was experiencing at the time the SAAQ was administered. After the simulation was paused and the participant had left the computer, the researcher then took control on the computer and used Snipping Tool to screen capture the traffic situation on the display as shown in Figure 4. The full-screen capture would create an image of the traffic in the exact same scale as it was displayed during the simulation. The image was later used to verify the answers of the participants.

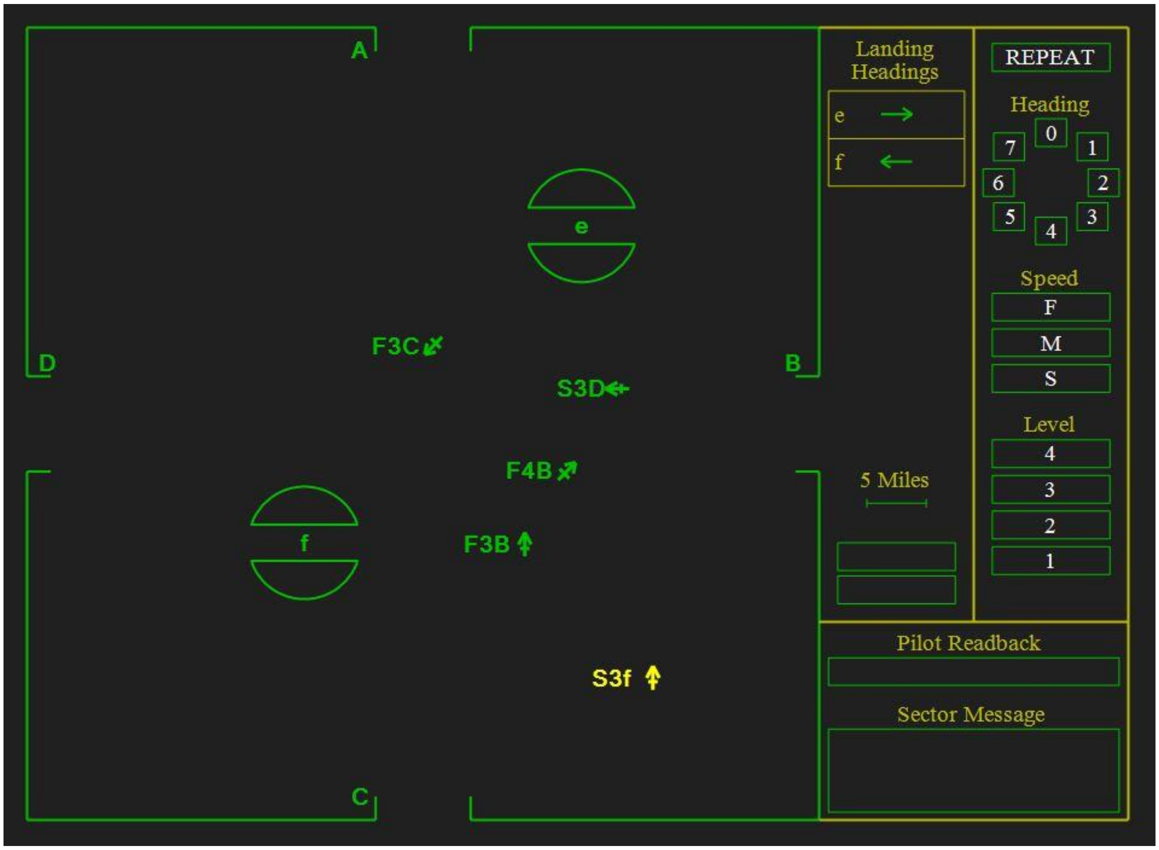

Figure 4. Image of the traffic situation captured by Snipping Tool at the time that the SAAQs were administered.

Instrument reliability. First of all, to minimize the effects of treatment order, Latin Square technique was used. Using Latin Square with four different treatments (A, B, C and D), the researcher had four different treatment sequences to assign to the participants. The treatment orders and the assignments to the orders are shown in Table 5.

Table 5

Treatment Orders and Assignments of Participants

Treatment Orders	Participant Number
ABDC	1, 5, 9 and 13
BCAD	2, 6, 10 and 14
CDBA	3, 7, 11 and 15
DACB	4, 8, 12 and 16

Note. Refer to Table 4 for the treatment detail. The treatment order of ABDC means that treatment A is the first working condition of a participant. Treatment B is the second. Treatment D is the third and treatment C is the last working condition in which a participant performs the task. The other treatment orders can be interpreted in the same way.

Second, to be successful in SA measurement, Endsley and Jones (2012) suggested that the timing of the stops must be unpredictable to prevent participants from predicting the time of question administering. Thus, this study used a random function in Excel to generate the timing of stops in each scenario. Third, to minimize a fatigue effect, a two-minute rest was provided to participants before starting each scenario.

Instrument validity. The mobile application used to measure light intensity, *Lux Light Meter Pro*, and the one used to measure sound level, *NIOSH Sound Level Meter*, were calibrated with a professional light meter and a professional dB meter respectively. According to Gutierrez-Martinez, Castillo-Martinez, Medina-Merodio, Aguado-Delgado and Martinez-Herraiz (2017), the smartphones can be used in lighting measurement tasks when high precision of data is not required (e.g. in the undergraduate physics laboratory). Because the lighting conditions (i.e. dark and bright) applied for this study were very different, the accuracy of the light measuring tool did not play a significant role in altering the results of the experiment. For noise measuring, *NIOSH Sound Level Meter* was tested and verified for accuracy (± 2 dB) against a reference type 1 Sound Level Meter at the NIOSH Acoustics Laboratory (Kardous & Shaw, 2016).

For measuring ATC performance, software developed by Aviation Media & IT GmbH company, was used. This is commercial software designed to help students prepare for the Air Traffic Selection and Training (AT-SAT) Exam. The ATST is part of the software developed in accordance with the AT-SAT which was used as a screening tool for air traffic controller applicants. The test has subsequently changed to Air Traffic Skills Assessment (ATSA). Therefore, the results reported by the software can reflect participant performance in an ATC task.

For measuring SA, SAGAT was employed because this technique has been widely tested and validated (Endsley, 1995; Gardner, Kosemund, & Martinez, 2015). In addition, several studies reported that it is effective in the domain of ATC (Endsley, Sollenberger, Nakata, Stein, & FAA Technical Center Atlantic City, 2000). The technique was used together with SAGAT Queries for Air Traffic Control which were developed and validated by Endsley and Kiris (1995). The questions are developed to reflect the SA requirement of the operator. Also, wording of the questions is developed to be consistent with both the terminology of the domain and the manner in which the operator processes the information (Endsley & Jones, 2012).

Treatment of the Data

Performance data. The percentages obtained from the performance reports generated by the ATST came in three categories (efficiency, safety, and procedural accuracy). Each category contained certain performance variables shown in Table 6.

Table 6

Performance Variables

Category	Variable
Efficiency	
	Distance Needed
	Time Needed
Safety	
	Conflicts
	Collisions
	Prohibited Airspace Border Crossings
	Prohibited Airport Border Crossings
	Pilot Readback
Procedural Accuracy	
Exiting the Airspace	
	Correct Destination
	Correct Speed
	Correct Altitude
Landing at Airports	
	Correct Destination
	Correct Headings
	Correct Speed
	Correct Altitude
Difficulty	
	Set-up Difficulty

Note. All variables were reported in percentage unit. The percentages were calculated based on the number of correct answers, response times, and comparison with the most efficient routing ways.

All 15 performance variables were then combined into a single overall performance percentage or the total performance score which was reported at the end of each scenario by the software. The total performance score was further used in hypothesis testing.

SA Data. Participant responses written in the SAASs were evaluated by comparing the responses with the image of the simulation screen captured at the time the questions were administered. Participant responses were scored as either correct or incorrect when assessing responses on aircraft position, heading, speed, altitude and destination. The operationally determined tolerance intervals by Endsley and Rodgers (1996) were adopted in the assessment of aircraft location. The tolerance was within five miles of the actual position. The SA questions regarding conflicts and plans for future actions were evaluated by the researcher. The researcher compared their responses with the traffic image and determined whether the conflicts really existed and whether the plans were appropriate and would be successful in achieving its goals. The number of correct answers was calculated into an overall percentage of correctness (P_{SA}) using the formula below.

$$P_{SA} = \frac{N_C}{N_T} \times 100\%$$

Where:

N_C = The number of correct SA responses.

N_T = The number of total SA responses.

The percentage derived from the equation was further used in the hypothesis testing.

Hypothesis testing. A two-way Analysis of Variance (ANOVA) was used to test any significant difference in the performance scores and the SA scores of participants. The results of the test determined if lighting and noise affected the performance and the SA of individuals working on ATC tasks. A two-way ANOVA was the appropriate method to use for statistical analysis of all six hypotheses. The significant level for all of the tests was set at .05.

Chapter IV

Results

The results reflect performance and situation awareness of individuals working on ATC tasks under four different conditions. Performance is measured and calculated based on efficiency, safety and procedural accuracy that participants perform in three different tasks and the difficulty setting of the scenario. SA is measured using SAGAT and the scores reflect individual SA accuracy. In this chapter, the mean scores of performance and SA are illustrated under Descriptive Statistics. The results of identifying significant differences among the mean scores are shown under Hypothesis Testing.

Descriptive Statistics

The data were collected from 16 participants including six female ATM students and 10 male ATM students. Every participant worked on the same scenario for four times; each time was performed under different working conditions.

Performance. The average scores of performance variables from all 64 runs are shown in Table 7. Verifying Pilot Readback has the lowest mean score. Landing an Aircraft with Correct Heading has the second lowest mean score and all other variables have the mean scores higher than 90.

The ATST takes the scores from all 15 performance variables into consideration for calculating the total performance score reported at the end of each run. Table 8 shows the descriptive statistics of total performance scores when participants performed ATC tasks under four different working conditions.

Table 7

Mean Scores of Performance Variables

Performance Variable	*M*	*SD*
Efficiency		
Distance Needed	98.00	7.47
Time Needed	97.09	7.42
Safety		
Conflicts	94.29	5.77
Collisions	98.51	6.89
Prohibited Airspace Border Crossings	99.90	0.19
Prohibited Airport Border Crossings	98.85	6.26
Verifying Pilot Readback	76.56	10.64
Exiting the Airspace		
Correct Destination	98.97	2.06
Correct Speed	99.36	2.39
Correct Altitude	98.29	3.18
Landing at Airports		
Correct Destination	96.69	5.90
Correct Headings	86.35	13.76
Correct Speed	92.90	9.74
Correct Altitude	96.01	6.51

Note. The percentages are calculated based on the number of correct answers, response times, and comparison with the most efficient routing ways.

Table 8

Performance Scores in Four Working Conditions

	N	Min	Max	*M*	*SD*
PM_A	16	49.10	55.30	52.70	1.63
PM_B	16	48.90	54.30	51.95	1.50
PM_C	16	49.30	54.60	52.20	1.45
PM_D	16	48.20	54.60	51.68	1.81

Note. PM_A = Performance measured from condition A (dark and quiet); PM_B = Performance measured from condition B (dark and noisy); PM_C = Performance measured from condition C (bright and quiet); PM_D = Performance measured from condition D (bright and noisy).

Situation Awareness. Table 9 shows the descriptive statistics of SA scores when participants performed ATC tasks under four different working conditions.

Table 9

SA Scores in Four Working Conditions

	N	Min	Max	*M*	*SD*
SA_ A	16	40.00	85.00	56.41	12.58
SA_ B	16	35.00	85.00	57.19	13.35
SA_ C	16	42.50	80.00	61.41	11.40
SA_ D	16	7.50	85.00	52.19	17.56

Note. SA_A = SA measured from condition A (dark and quiet); SA_B = SA measured from condition B (dark and noisy); SA_C = SA measured from condition C (bright and quiet); SA_D = SA measured from condition D (bright and noisy).

Hypothesis Testing

After the performance and SA data were collected, a two-way ANOVA for a within-subject design was conducted to determine the differences in the mean scores obtained from four different working conditions. Six null hypotheses mentioned in Chapter I were tested.

Performance. Three of the six hypotheses (H1, H2, and H3) mentioned in Chapter I look at the change in participant performance. A two-way within-subjects ANOVA was used to determine whether lighting, noise, and the interaction between these two factors had an effect on the participant performance. The test shows that all effects are not statistically significant at the .05 significance level except for the noise factor. Table 10 displays the means and standard deviations for each factor and the results of three hypothesis tests.

Table 10

Means, Standard Deviations and Hypothesis Testing Results of Performance

Factor	*M*	*SD*	*F*	*p*
Lighting			1.272	.277
Dark	52.33	.32		
Bright	51.94	.34		
Noise			5.447	.034
Quiet	52.46	.32		
Noisy	51.82	.31		
Lighting x Noise			.103	.753
PMDarkQuiet	52.71	1.54		
PMDarkNoisy	51.95	1.27		
PMBrightQuiet	52.21	1.79		
PMBrightNoisy	51.68	1.69		

Note. PMDarkQuiet = Performance measured from the dark and quiet condition; PMDarkNoisy = Performance measured from the dark and noisy condition; PMBrightQuiet = Performance measured from the bright and quiet condition; PMBrightNoisy = Performance measured from the bright and noisy condition.

Figure 5 displays the mean performance and how it changes across different levels of two factors (i.e. lighting and noise). The performance is lower in the noisy condition compared to that in the quiet condition.

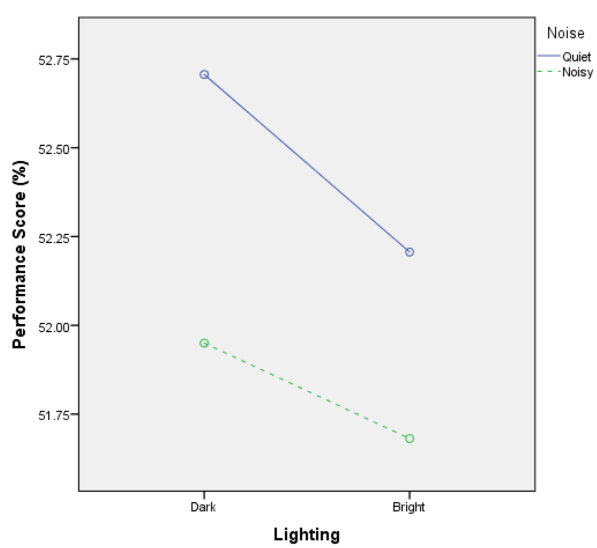

Figure 5. Performance Means.

Situation Awareness. The other three hypotheses (H4, H5, and H6) mentioned in Chapter I look at the change in participant SA. A two-way within-subjects ANOVA was used to determine whether lighting, noise, and the interaction between these two factors had an effect on the SA of participants. The test shows that all effects are not statistically significant at the .05 significance level. Table 11 displays the means and standard deviations for each factor and the results of three hypothesis tests. Figure 6 displays the mean SA and how it changes across different levels of two factors (i.e. lighting and noise).

Table 11

Means, Standard Deviations and Hypothesis Testing Results of SA

Factor	*M*	*SD*	*F*	*p*
Lighting			0.000	1.000
Dark	56.80	2.48		
Bright	56.80	2.61		
Noise			1.820	.197
Quiet	58.91	2.45		
Noisy	54.69	2.74		
Lighting x Noise			1.959	.182
SADarkQuiet	56.41	3.15		
SADarkNoisy	57.19	3.34		
SABrightQuiet	61.41	2.85		
SABrightNoisy	52.19	4.39		

Note. SADarkQuiet = SA measured from the dark and quiet condition; SADarkNoisy = SA from the dark and noisy condition; SABrightQuiet = SA measured from the bright and quiet condition; SABrightNoisy = SA measured from the bright and noisy condition.

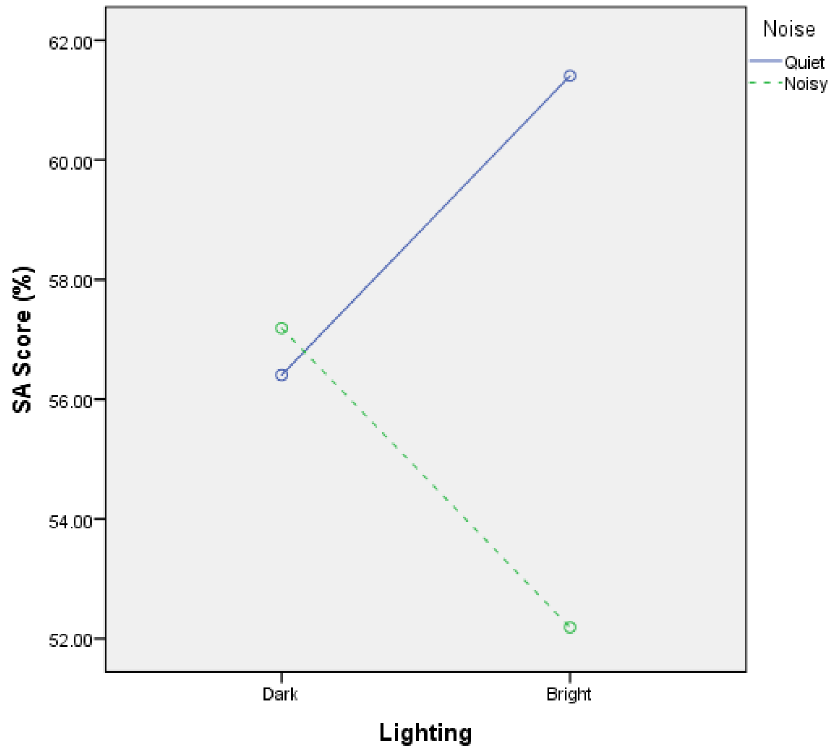

Figure 6. SA Means.

Chapter V

Discussion, Conclusions, and Recommendations

The results in Chapter IV reveal the effects of working conditions on performance and SA of individuals performing ATC tasks. This chapter contains three main sections: Discussions, Conclusions and Recommendations. The Discussion analyzes and interprets the results in detail. The Conclusions summarizes key findings of the research and finally, Recommendations provides applications to the real world and suggest ideas for further research.

Discussion

The mean scores of 14 performance variables, mentioned in Table 7 of Chapter 4, provide quantitative results which suggest the areas that ATM students need to be trained to improve their overall performance. The mean scores of the total performance and SA identify the condition that best support individuals working on ATC tasks. Finally, the results from hypothesis testing show whether those scores support the hypotheses.

Performance variables. According to the results in Table 7, out of the 14 measured variables, verifying pilot readback has the lowest score with the highest standard deviation. One of the possible reasons why participants perform the poorest in verifying pilot readback is that they assume the task is not as important as other tasks required (i.e. maintaining separation between aircraft, keeping aircraft from the prohibited area and routing aircraft to the designated destinations). However, their assumption supports the fact that preventing collisions between aircraft and maintaining separation are the first priority in air traffic control. The second possible reason is that the action of verifying pilot readback required by the simulation (clicking on a repeat button) does not accurately reflect the actual practice of the controllers (restating the instruction verbally). Therefore, the difference in practice can cause unfamiliarity and incorrect actions which result in the low score.

Another area that shows some room for improvement is landing aircraft with a correct heading. The simulation is set so that the landing direction may change during the flight. The change in landing directions mimics real-world situations where the wind direction may alter. As a result, controllers are required to verify the landing direction and may need to re-route an aircraft to have it land on the appropriate runway. Comparison among the mean scores of performance variables suggests that landing procedures and practices can be emphasized in order to improve ATM students' performance.

Overall performance for four different conditions. The mean scores in the overall performance vary minimally with a minimum of 48.20% and a maximum of 52.70%. The small variation in the mean scores indicates similarity among participants in terms of their performance. However, it is not surprising since they are all ATM students of ERAU at the Daytona Beach campus. They are taught and trained for ATC tasks under the same ATM program curriculum with the same group of instructors. Therefore, the cluster of the scores and the low standard deviations imply similarity in the ATM background and experience of participants. Although the mean scores are close in value to each other, one point to be noted is that, given the same lighting condition, the performance decreases when noise is present.

Overall SA for four different conditions. Participants have highest SA when they work in the C condition or in a bright and quiet room. SA is lowest in the D condition or in a bright and noisy room. The SA scores vary within a wide rage and the standard deviations are quite large compared to the means.

Hypothesis testing on performance. The results from two-way ANOVA indicate that performance decreases when the continuous sound of strip printer is present. Reduction in performance can be explained by the interference of noise with the communication between controllers and pilots. In the experiment, participants were asked to verify pilot readback which they heard from the headphone and saw the message in the textbox located at the bottom right corner of the screen. The sound of the strip printer or the generated noise might impede participants from hearing pilot readback clearly over the headphone and result in the performance decrease. In addition, noise may deteriorate controllers' concentration on the traffic situation displays as Bell, Roer, Dentale, and Buchner (2012) claim that noise can impair the locus of attention by diverting the attention away from visual information and relocating it to the sound which causes interruption to the task.

The p-value from the ANOVA analysis shows that lighting has no significant effect on performance. The result is what the researcher expected, and it supports the trend of lighting level set in an air traffic control room. Although lighting allowed participants to see things around, they are not attracted or distracted to the environment because the nature of ATC tasks requires much attention from the controllers. The controllers do not easily get distracted or turn their attentions away from the display to the objects around themselves. On the contrary, they cannot avoid hearing the noise played along the simulation. Therefore, the results show no significant difference in performance between working in the dark room and working in the bright room but show significant difference between quiet condition and noisy condition.

Hypothesis testing on SA. The two-way ANOVA analysis on SA scores indicates that lighting and noise have no significant effect on SA of participants. The result for the effect of lighting corresponds to that of the performance, but for noise there is no significant difference in the mean scores of SA between working in a quiet working condition and working in a noisy condition. One of the possible reasons is that the way SA is measured relies primarily on visual perception. To measure SA, participants were asked to recalled aircraft information such as speed, heading, altitude and destination which appear on the display in letters, arrows and numbers. Because of this, the SA score may not capture the effect of noise on participant awareness of the current traffic displayed on the monitor.

Conclusions

There are four main conclusions obtained from the results of this study. To begin, verifying pilot readback and landing direction are two aspects that ATM students can concentrate on practicing to significantly improve their ATC performance. Second, in a normal traffic situation, lighting does not affect performance and SA of individuals working on ATC tasks. The results do not show any significant change in performance and SA between working in a dark room and working in a bright room. Third, noise, on the contrary, can decrease performance in ATC tasks, but shows no significant effect on SA. Participants working in a noisy room with the sound level of 60-70 dB have a poorer performance than when they perform in a quiet environment. Last, there is no interaction effect of lighting and noise on performance and SA. In other word, the effect of noise does not change across different lighting conditions.

Recommendations

The recommendations can be beneficial for those people involved with designing an ATC room. Moreover, air navigation service providers may apply the recommendations to their work policies and rules to have the workplace environment better support their employee performance. Finally, researchers or academia, who are interested in further research or expansion to this study, can find some possible ideas mentioned in the last paragraph.

Lighting condition. The results show that lighting has no effect on performance and SA to individuals working on ATC tasks. Therefore, the ATC rooms are not necessarily kept in the dark as long as the light does not cause reflections and glares that interfere with visual perception and performance. Although many ARTCCs in Europe have a brighter lighting condition than what they used to have in the past, in the United Sates, the lighting of most ARTCCs is still kept in low level due to the requirement of the existing systems to avoid reflections and glares. So, it is recommended that the lighting level should be adjusted according to the capability of the display technology as well as the ergonomics of the workplace.

Sound level. The sound level in ATC rooms should not exceed 60 dB to avoid interference of noise to the radio communication and to maintain concentration of the controllers on their tasks. In general, the sounds in an ATC room are normal conversation and radio communication which usually do no exceed 60 dB. However, there might be a case where the trip printer is located close to the controller working area. Thus, the sound level generated by the strip printer and the location of the printer should be taken into consideration for the interior design of an ATC room.

Future research. This study considers two factors which are lighting and noise. However, there are some other treatment variables that could influence performance and SA such as the traffic volume and the type of ATC tasks (e.g. tower control, approach control and air route traffic control). It would also be interesting to include emergency situations and see whether the effects of lighting and noise will remain the same as for the normal operations. In addition, trials should include team SA by requiring coordination among participants to complete ATC tasks. This will make the experimental setting closer to the nature of ATC where controllers do not only communicate with pilots, but also coordinate with other controllers within the same sector, in the neighboring sectors or in other ATC units.

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Appendix A

Permission to Conduct Research

IRB Approval

Embry-Riddle Aeronautical University
Application for IRB Approval
Exempt Determination

Principle Investigator: Saralee Pruksaritanon

Other Investigators: Dr. Steven Hampton, Dr. Andrew Dattel

Role: Student **Campus:** Daytona Beach **College:** Aviation/Aeronautics

Project Title: Effects of Lighting and Noise on Performance and Situation Awareness in an Air Traffic Control Task

Review Board Use Only

Initial Reviewer: Teri Gabriel **Date:** 03/07/2018 **Approval #:** 18-113

Exempt: Yes

Dr. Michael Wiggins Michael E. Wiggins, Ed.D. Digitally signed by Michael E. Wiggins, Ed.D. DN: cn=Michael E. Wiggins, Ed.D., o=Embry-Riddle Aeronautical University, ou=Aeronautical Science Department, email=wigginsm@erau.edu, c=US Date: 2018.03.09 14:19:25 -05'00' **Date**: 03/09/2018
IRB Chair Signature

Brief Description:

The purpose of this experiment is to investigate the effects of lighting and noise levels on performance and situation awareness in an air traffic control (ATC) task using simulation software.

This research falls under the **exempt** category as per 45 CFR 46.101(b) under:

☐ (1) Research, conducted in established or commonly accepted educational settings, that specifically involves normal educational practices that are not likely to adversely impact students' opportunity to learn required educational content or the assessment of educators who provide instruction. This includes most research on regular and special education instructional strategies, and research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

☑ (2) Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met:

- **(i)** The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects;
- **(ii)** Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the

subjects' financial standing, employability, educational advancement, or reputation.

☐ (3) (i) Research involving benign behavioral interventions in conjunction with the collection of information from an adult subject through verbal or written responses (including data entry) or audiovisual recording if the subject prospectively agrees to the intervention and information collection and at least one of the following criteria is met:

(A) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects;

(B) Any disclosure of the human subjects' responses outside the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement, or reputation.

☐ (4) Secondary research for which consent is not required: Secondary research uses of identifiable private information or identifiable biospecimens, if at least one of the following criteria is met:

(i) The identifiable private information or identifiable biospecimens are publicly available;

(ii) Information, which may include information about biospecimens, is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained directly or through identifiers linked to the subjects, the investigator does not contact the subjects, and the investigator will not re-identify subjects.

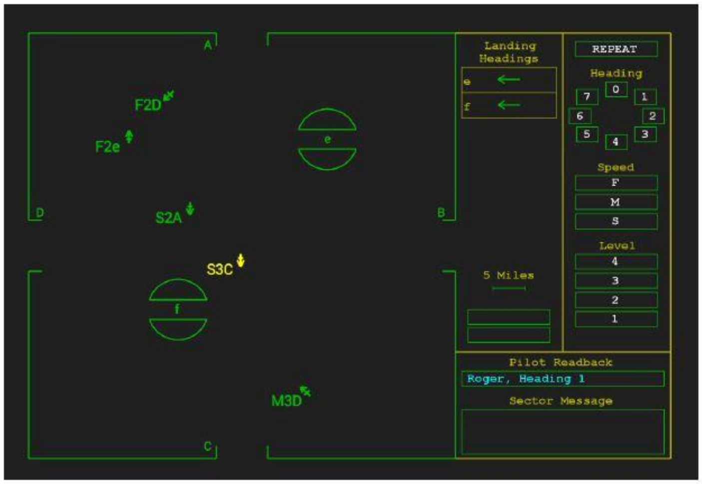
☐ (6) Taste and food quality evaluation and consumer acceptance studies:

(i) If wholesome foods without additives are consumed, or

(ii) If a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration or approved by the Environmental Protection Agency or the Food Safety and Inspection Service of the U.S. Department of Agriculture.

An exempt research project does not require ongoing review by the IRB, unless the project is amended in such a way that it no longer meets the exemption criteria.

Flyer to Recruit Participants



$25 PAY

VOLUNTEERS IN RESEARCH STUDY

Air Traffic Control Research Study

In this study, participants will have an opportunity to use the simulation software, *Air Traffic Scenario Test (ATST)*, which is a part of the AT-SAT exam. The study will take place at the CERTS lab located on the first floor of COA, room 131. Participants will spend 2 hours on ATC scenarios and a survey.

EMBRY-RIDDLE
Aeronautical University
DAYTONA BEACH, FLORIDA

Air Traffic Scenario Test

ATM Students in 2nd, 3rd or 4th year

2 Hours

ATC Scenario and a Survey

CERTS Lab

(COA 131)

TO PARTICIPATE

Contact Saralee

(434) 420-6018

pruksars@my.erau.edu

By March 25th, 2018

COLLEGE OF AVIATION
APPROVED
REMOVE AFTER 03/28/2018

Appendix B

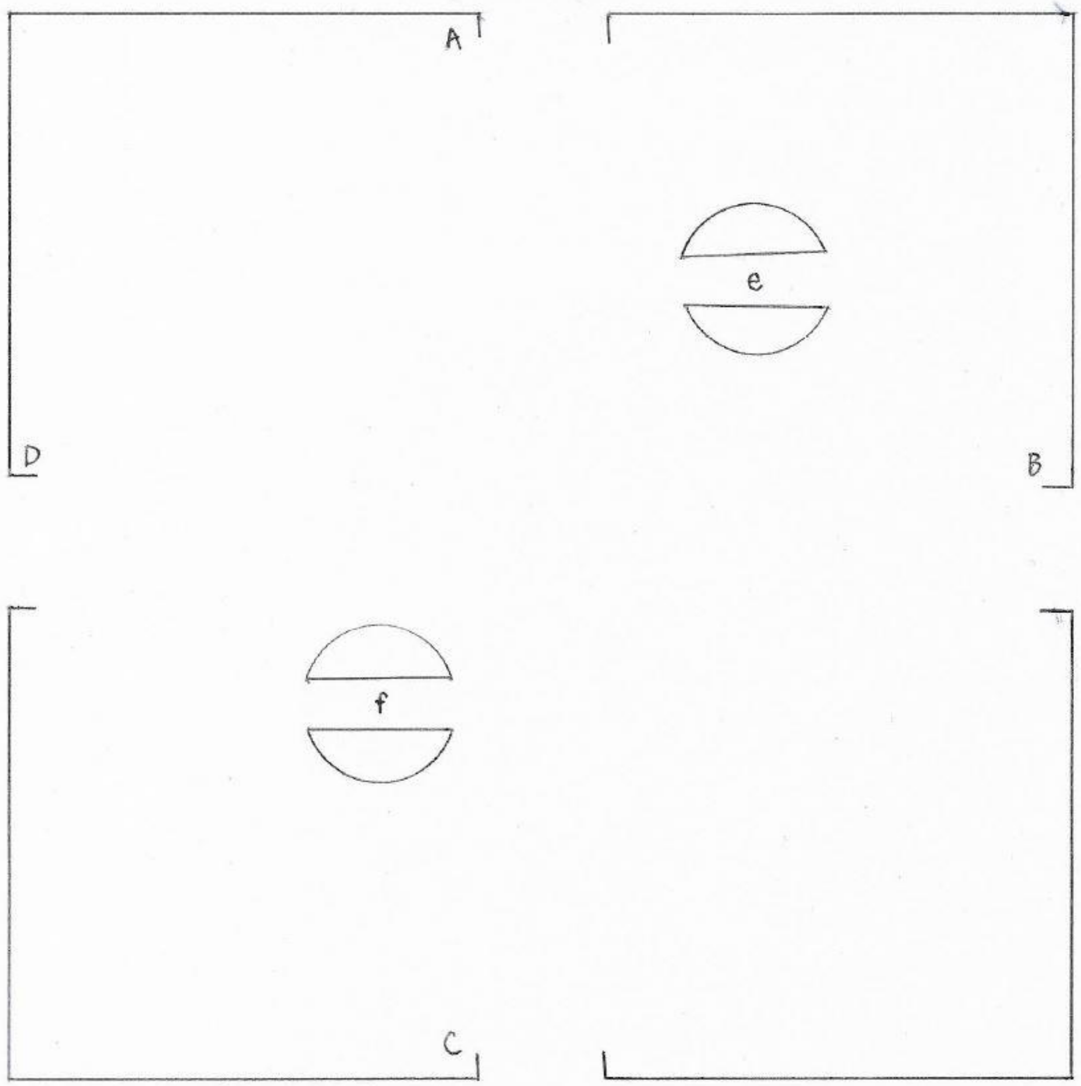
Data Collection Device

Situation Awareness Assessment Questions (SAAQ)

1. Enter the locations of all aircraft (using cross x marks)
2. Enter aircraft altitude (1, 2, 3 or 4)
3. Enter aircraft speed (S, M or F)
4. Enter aircraft heading (by drawing arrows)
5. Enter aircraft's destination
6. Which pairs of aircraft have lost or will lose separation if they stay on their current courses? (Circling to indicate them)
7. What current of future plans for action do you have for each aircraft?

Example of Situation Awareness Answer Sheet (SAAS)

Participant ID: P___
Condition: __
Pause #__
1,2,3,6



1. Enter the location of all aircraft (using a cross x mark)
2. Enter aircraft altitude (1, 2, 3 or 4)
3. Enter aircraft speed (S, M or F)
4. Which pair of aircraft has lost or will lose separation if they stay on their current courses? (Circling to indicate them)