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PERCEIVED IMPACT OF AMBIENT OPERATING ROOM NOISE BY CERTIFIED REGISTERED NURSE ANESTHETISTS

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PERCEIVED IMPACT OF AMBIENT OPERATING ROOM NOISE BY CERTIFIED REGISTERED NURSE ANESTHETISTS

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University.

by

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Dedication

"Work hard in silence. Let your success be your noise."

--Thegoodvibe.co, 2019

This manuscript is dedicated to the memory of my mother,

Diane DiSarle Scarpati

July 19, 1941 - December 14, 2017

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"*If I have seen further, it is by standing on the shoulders of giants*."

--Isaac Newton, 1675

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MC
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Abstract

PERCEIVED IMPACT OF AMBIENT OPERATING ROOM NOISE BY CERTIFIED REGISTERED NURSE ANESTHETISTS

By Marianne S. Cosgrove, PhD, DNAP, CRNA

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University.

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It is widely acknowledged that elevated levels of noise are commonplace in the healthcare environment, particularly in high acuity areas such as the operating room (OR). Excessive ambient noise may pose a threat to patient safety by adversely impacting provider performance and interfering with communication among perioperative care team members. With respect to the certified registered nurse anesthetist (CRNA), increased ambient OR noise may engender distractibility, diminish situation awareness and cause untoward health effects, thereby increasing the possibility for the occurrence of error and patient injury.

This research project critically examines the perceived impact of ambient noise in the operating room by CRNAs. It was hypothesized that CRNAs would describe noise levels as inappropriately elevated, particularly during the tenuous induction and emergence phases of the anesthetic. Noise would be depicted as detrimental to concentration, performance and team communication, causing a diminution in patient safety. CRNAs would identify repeated occupational exposure to OR noise as influential in causing adverse health effects in the provider.

After IRB approval from Virginia Commonwealth University, an Internet survey was distributed to a convenience sample of practicing CRNAs across the US. The survey garnered 502 valid responses. Findings from this study reveal that CRNAs perceive elevated noise to be regularly present in the OR, specifically during the emergence phase of the anesthetic. However, CRNAs feel that increased noise only occasionally limits their ability to perform procedures, concentrate and communicate with the perioperative team. OR noise rarely interferes with memory retrieval. CRNAs perceive that noise is sometimes a threat to patient safety and infrequently engenders adverse patient outcomes. CRNAs do not perceive noise in the OR to be detrimental to their health but strongly agree that excessive noise can and should be controlled.

This project contributes to the growing body of evidence that increased ambient OR noise is a veritable reality that may pose a potential threat to patient safety. Further research to identify elevations in ambient noise during critical phases of the anesthetic and delineation of significant contributors to its genesis are warranted and may inform the development of initiatives for noise mitigation in the OR.

Chapter 1: Introduction

Background

A 38-year-old, 127 kg African American male presented to the operating room (OR) for relief of airway obstruction exacerbating significant sleep apnea. Surgical procedures planned were tonsillectomy, uvulopalatopharyngoplasty (UPPP), and nasal septoplasty. After the uneventful induction of anesthesia, just before incision, the surgeon requested that his iPod be connected to the OR speaker system and set to "shuffle". Music played at a moderate volume for the duration of the procedure. The operation progressed without complication and with minimal blood loss.

At the conclusion of surgery, the surgeon increased the volume of the music. He, the circulating nurse and resident engaged in conversation by the computer terminal, a distance away from the OR table. Overall, the presence of music combined with non-essential conversation and rushed handling of metal instrument pans by the surgical technician contributed to an excessive level of ambient noise in the OR suite. Despite the cacophony, the patient emerged from anesthesia and was extubated awake. He moved himself from the OR table to a stretcher prior to transport to the post-anesthesia care unit.

Just prior to exiting the OR suite, the patient suffered an unanticipated laryngospasm. Unable to manage the critical situation singlehandedly, the anesthetist requested that the anesthesia attending be summoned “STAT” to the OR. Unfortunately, the perioperative team was oblivious to the situation, engaged in room breakdown and conversation amidst loud background music. The anesthetist attempted to alert the team to the dire situation a second time; however, they were otherwise occupied and continued to be unaware of his needs. The increasingly hypoxic patient became combative and difficult for the anesthetist to physically control. “*I need some help here*!” shouted by the anesthetist finally caught the attention of the circulating nurse and surgical team members. The circulator immediately sent an overhead STAT page that brought two additional anesthesia providers to the scene.

By the time responders entered the OR, the patient was severely hypoxemic and bradycardic. Immediately upon relief of the laryngospasm, copious pink, frothy secretions emanated from the oropharynx and the ETT, an ominous sign that the patient had sustained non-cardiogenic post-obstructive pulmonary edema (POPE). Once stabilized and sedated, he was transported intubated to the surgical intensive care unit.

Within 48 hours post-incident, the patient developed acute respiratory distress syndrome, a rare but catastrophic complication of POPE. Despite the application of varied ventilatory and pharmacologic interventions to optimize the patient’s oxygenation, he ultimately succumbed to the disease process. The patient expired on post-operative day 10 as a result of cardiopulmonary arrest secondary to persistent hypoxemia and acute cor pulmonale.

During a critical incident debrief session and root-cause analysis, the anesthetist admitted that his inability to garner the attention of the OR staff over the din of music, chatter and noisy instrument breakdown may have contributed to the rapid deterioration of the patient's condition. The fact that the anesthetist's pleas for help went unheard during the first critical seconds of the episode may have exacerbated the complication that eventually led to the patient's untimely demise.

Problem Statement

Noise. The word noise originates from Middle English, Old French and Latin roots. It is a derivation of the Latin word nausea, evoking a negative connotation. The word noise as it relates to sound is defined as:

A sound, especially one that is loud or unpleasant or that causes disturbance

A series or combination of loud, confused sounds, especially when causing disturbance (Oxford Online Dictionary, 2019)

(Sound) that lacks agreeable musical quality or is noticeably unpleasant

Any sound that is undesired or interferes with one's hearing of something (Merriam-Webster Online Dictionary, 2019).

Adjectives used to describe noise include loud, unpleasant, undesirable, and unexpected. Terms synonymous with noise include clamor, clatter, blast, blare, commotion, hullabaloo, racket and din, which are further described as discordant, distressing, unwanted, disagreeable and disturbing (The Free Dictionary, 2019). Kosko (2006; pg. 3) designates noise as a nuisance; an unwanted signal; a "*signal we don't* *like*." Noise has been labeled a "Modern Plague" (Goines & Hagler, 2007) and "The Third Pollution" (Berland, 1970).

The Impact of Ambient Noise. Ambient noise refers to the presence of background sound in the surrounding environment. Unlike primary sounds perceived during communication, ambient noise is meaningless, serving no real purpose. Ambient noise may emanate from various sources: nature, machinery, music, or human conversation. Although used in certain instances to facilitate relaxation or sleep, ambient noise may occasionally be considered an irritant and has occasionally been described as "noise pollution" (Berland, 1970).

Ambient noise in the workplace is cited as one of the most influential factors in decreasing job productivity. The Office Workplace Productivity Survey, a nationwide analysis of 2060 professionals aged 18 and above, found that sixty-one percent of respondents cited noise as the most impactful office distraction (Smith, 2013). Noise poses a persistent and significant problem in the healthcare milieu as well, particularly in high-acuity settings such as intensive care units and operating rooms (Chen, 2012; Eggertson, 2012; Ford, 2015; Ginsberg, 2013; Hasfeldt, 2010; Hodge, 1990; Hogan, 2015; Hsu, 2012; Katz, 2014; Kracht, 2007; Mac Kenzie & Galbrun, 2007; Shapiro, 1972).

The World Health Organization (WHO) reports that noise levels in hospital settings have been steadily rising since the 1960s (Cunha & Silva, 2015). This finding resulted in the WHO's recommendation of a maximum noise level of 35 decibels (dB) in the operating room environment (Katz, 2014; Kracht, 2007; Hasfeldt et al., 2010).

Notwithstanding this suggested metric, sustained noise intensities in excess of 85-90 dB have been reported and are ubiquitous during the intraoperative period (Ginsberg et al., 2013, Hasfeldt et al., 2010; Katz, 2014). Broom and associates (2011) demonstrated peak elevations in noise specifically during the critical induction and emergence phases of an anesthetic, a finding that has been further substantiated by other researchers (Giv et al., 2017; Wadhera et al., 2010). Although there is a paucity of research that directly links excessive OR noise to adverse patient outcomes (Katz, 2014), it is postulated that elevated ambient noise in the OR could potentially increase the incidence of medical errors and may be injurious to both provider and patient. These untoward effects can ultimately lead to a substantial diminution in patient safety.

It is suggested that excessive levels of ambient noise in the OR may adversely affect anesthetist cognition and mental efficiency (Katz, 2014), short-term memory (Murthy et al., 1995), concentration and performance (Ginsberg et al., 2013; Katz, 2014), situation awareness (SA), vigilance and communication (Broom et al., 2011; Elks & Riley, 2009; Endsley, 1995; Weinger & Englund, 1990). Functioning in an environment with sustained levels of elevated noise has been shown to increase psychological and physiological strain, resulting in irritation, fatigue and chronic stress. With repetitive exposure to noisy conditions, continual secretion of cortisol and endogenous catecholamines via stimulation of the hypothalamic-pituitary-adrenocortical axis (HPA) has been shown to negatively impact provider health over the long term (Hasfeldt et al. 2010, Katz, 2014; Oliviera, 2012). Provider hearing loss may also be sustained after repeated, long-term exposure to noisy conditions (Katz, 2014).

Furthermore, increased ambient noise in the OR has the potential to impart deleterious effects on the surgical patient. The possibility of otic injury exists as a result of the diminution of protective aural mechanisms while receiving a general anesthetic (Choiniere, 2010; Katz, 2014). This may lead to permanent hearing loss in the anesthetized patient. In addition, the rate of surgical site infection (SSI) has also been shown to increase when surgery is performed in noisy conditions. This effect is proposed to be due to provider distraction from careful aseptic practices (Dholakia et al., 2014; Kerman et al., 2011).

It is speculated that the effects of noise on the anesthesia provider escalate the potential for the occurrence of error leading to a decrease in patient safety. Moreover, increased levels of ambient OR noise may negatively impact the anesthetized patient directly. Therefore, attention to this ongoing issue is of paramount importance. It is recommended that modalities to decrease levels of ambient noise in the OR be enacted; however, conventional disciplinary approaches are typically disregarded and may serve to engender poor interdisciplinary relations and collegiality among the perioperative team.

Rationale and Significance

The Patient Safety Initiative. In 1999, the Institute of Medicine (IOM) released the seminal paper *To Err is Human: Building a Safer Health System*. In this report, mortality rates in American hospitals secondary to medical mishaps were estimated to occur between 46,000-98,000 times, with an additional accident rate of approximately one million incidents per annum (Kohn et al., 2000; Shaw, 2012). As a result of these staggering findings, attention to advances in patient safety began to proliferate. This initiative continues to present day. Dissemination of *To Err is Human* has been associated with a heightened attention to patient safety, substantiated by an increased number of related publications and research awards. Despite the amplified focus on building a stronger culture of safety in the field of medicine, the impact on overall improvement in patient care remains undetermined (Stelfox et al., 2006).

Physician Lucien Leape (1994) suggested that the crux of accident prevention in healthcare should be a focus on root causes and deficits in system design and implementation. As a result of Leape's proposition, it has been widely accepted that the optimization of patient safety should begin with the knowledge and recognition of possible contributory precursors to error. Once these factors are delineated, interventions to mitigate their effects may then be employed. Likewise, in the seminal paper *Catalogue of Human Error* (1997, pg. 645), Arnstein aptly stated the following:

"*Understanding causality enables prevention*."

Clearly, until patient injury and death is eradicated, plausible etiologies such as excessive ambient noise in the OR should be explored as precursors to medical error.

The Practice of Anesthesia. The practice of anesthesia has been described as complex, dynamic, tightly coupled and event-driven. Due to the task-dense nature of the anesthetist's role, carried out in a highly inconstant environment, error and possible critical incidents may result from any issue which causes divided attention leading to distraction (Biddle, 2009; Broom et al., 2011; Endsley, 1995; Gaba, 2000; Oliviera, 2012; Wadhera, 2010). This includes the presence of excessive extraneous noise during the intraoperative period (Gaba et al., 1994; Hogan, 2015; Way et al., 2013).

Despite advances in technology and a clearer understanding of extenuating factors, critical incidents in anesthesia continue to occur at a disturbing rate (Biddle, 2009; Gaba, 2015). As the science of anesthesia has evolved, so have anesthesia delivery equipment and monitoring systems. Although the primary intent of these technological advances is to increase safety, they introduce an unintended consequence by adding an increased level of complexity to the job of the anesthetist (Biddle, 2009; Gaba, 2015).

The anesthesia provider encounters a juxtaposition of many variables in the delivery of anesthesia: patient comorbidities and medication profiles, surgical procedures, anesthetic techniques, effects of procedures and anesthetics, potential problems with combinations of anesthetics and patient comorbidities and medications (Flin & Patey, 2010; Gaba; 1994, 2015; Leedal & Smith, 2005). Deficits in provider condition while administering an anesthetic can adversely impact outcomes. Attention to and prioritization of the tasks at hand, situation awareness and smooth integration with other members of the perioperative team may be jeopardized in the presence of distraction, fatigue, annoyance, increased stress, an inability to recruit information from short- and long-term memory and attenuated auditory capability. These issues may very well be the end result of sustained exposure to elevated noise in the OR milieu, a potential occupational hazard for the anesthesia provider (Chen, 2012; Ford, 2015; Ginsberg, 2013; Hasfeldt, 2010; Hodge, 1990; Hogan, 2015; Katz, 2014; Kracht, 2007; Mac Kenzie & Galbrun, 2007; Shapiro, 1972). Although not expressly proven to date, it is hypothesized that noise in the OR may lead to untoward patient outcomes (Katz, 2014).

The Anesthetist's Complex Role. Gaba and associates (1994) graphically depict the anesthetist's complex role through *Intraoperative care of the patient while functioning in a vastly dynamic environment*. Comprehensive, safe and sound anesthetic practice that occurs in a high-stress environment is dependent upon a multitude of factors:

- Vigilance: continuous and sustained monitoring and cross-checking of the patient's vital signs
- Swift recognition of problems
- Delegation of tasks and responsibilities
- Allocation of attention to multiple incoming sources of information
- Filtering of data: reliable vs. artifact
- Retrieval of information from short- and long-term memory
- Communication with perioperative team members
- Utilization of resources
- Abstract reasoning
- Prioritization and performance of procedures and interventions
- Maintenance of situation awareness (SA): a comprehension of present status of the patient, evaluation and re-evaluation of interventions, and prediction of future events (Fig 1.)

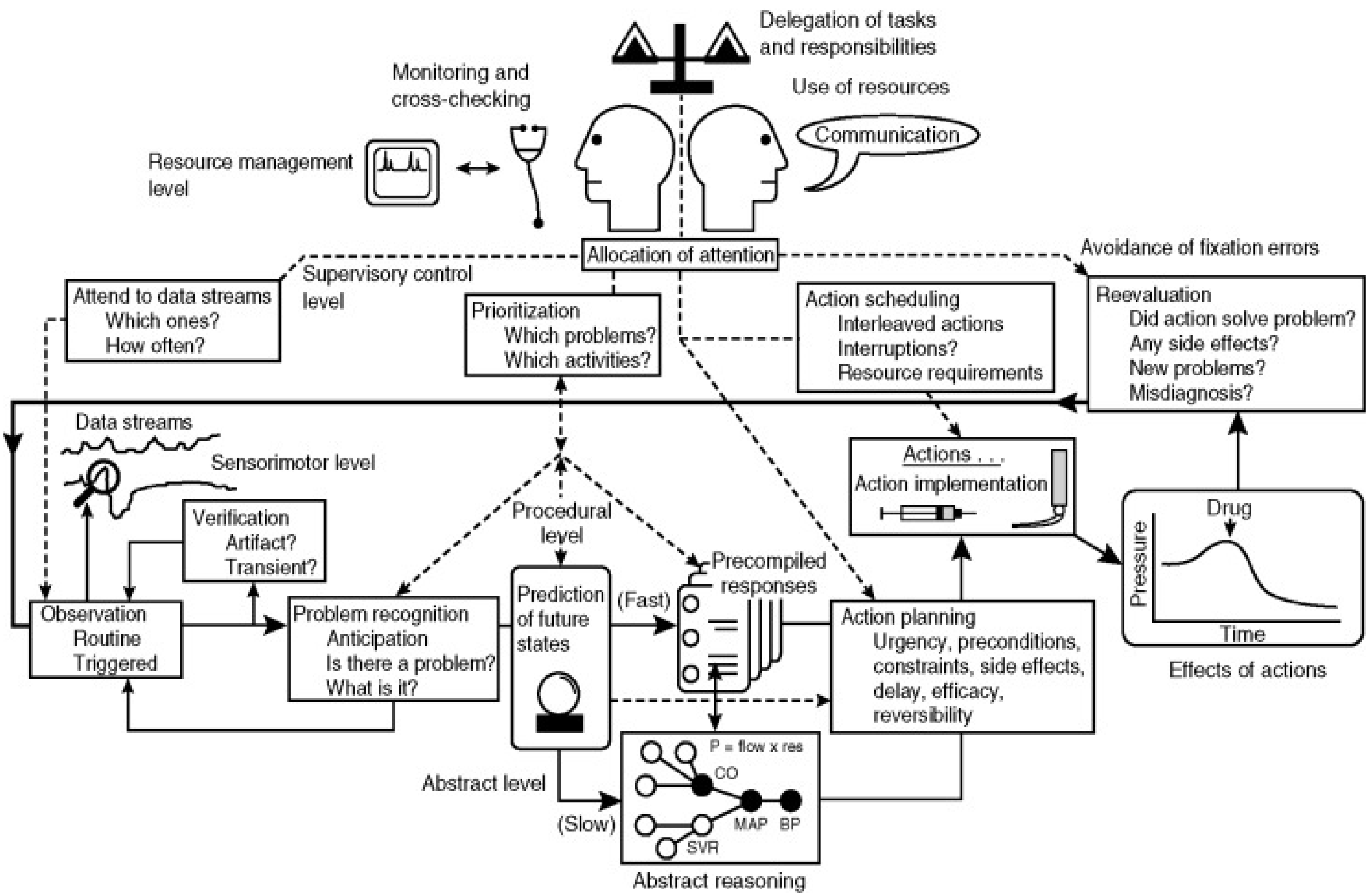

Figure 1. Model of the anesthetist’s complex process of intraoperative decision making, depicting a highly dynamic environment. (Adapted from Gaba et al., 2015, pg. 18)

According to Gaba (2015; p. 19) “Expert performance in anesthesia involves these features in a repeated “loop” of observation, decision, action and reevaluation.” In observing this multifaceted yet delicate system, it is clear that the multifocal demands on the anesthetist require adaptability, concentration, flexibility and a broad knowledge base. Factors such as poor health, fatigue, and distraction from environmental derangements such as noise may increase the potential for error and consequential patient harm.

Expanding on previous work by Fletcher and associates (2003), Flin and Patey (2010) described fundamental attributes of the anesthetist that are critical to the safe practice of anesthesia. They emphasized the evaluation of four key elements of performance, citing that deficits in any one area may contribute to the genesis of error and critical incidents. Modeled after a similar taxonomy utilized by the aviation industry to assess airline pilot proficiency, the “Anaesthetists Non-Technical Skills” (ANTS) framework was formulated. This systematic rating scale encompasses four major determinants of performance: task management, teamwork (including clear communication and coordination), situation awareness (including vigilance and anticipation) and decision-making.

According to the ANTS prototype, a key behavioral marker for poor practice is the attenuated ability to monitor due to the presence of distractions (Flin & Patey, 2010). This ultimately results in the decline of SA. Elevated ambient noise in the OR may very well represent of this type of interference. Additionally, noise can inhibit successful teamwork. Excessive levels of noise may engender irritation leading to anger, poor collegiality and both physical and psychological obstruction of communication between members of the perioperative team (Fletcher et al., 2003).

Anesthesia and Critical Incidents. Across all medical domains, the field of anesthesiology has long been acknowledged as a frontrunner in the movement to improve patient safety. While anesthesia is presently safer than it has been historically, there are still many improvements to be made in this initiative (Gaba, 2000; 2015).

In an effort to increase cognizance of anesthetic-related mishaps, Biddle (2009) designated factors that increase the risk of error in anesthesia leading to the development of critical incidents. A concept first described in aviation, the critical incident is defined as a resolved or unresolved event that has the potential to cause a major complication. (Biddle, 2009; Gaba, 2000; 2015). Biddle (2009) interprets potential etiologies for critical incidents in anesthesia that may include (but are not limited to):

- Use of technologically complex equipment
- Increased task density
- Loss of situation awareness/distraction
- Poor communication

Because the presence of noise is widespread in contemporary operating rooms, it may represent a crucial element influencing these etiological factors. Coupled with the use of complicated equipment and increased task density, elevated and disruptive levels of noise pose a problematic issue which may ultimately impede anesthetist performance via decreased situation awareness (SA). Situation awareness, a factor that is central to the safe practice of anesthesia, is the perception, knowledge and accurate interpretation of environmental inputs with a conception of their influence on future events (Endsley, 1995). Increased levels of ambient noise in the OR may severely diminish SA in the anesthesia provider. This deleterious effect on performance is further compounded by increased anesthetist distractibility and impeded communication between OR staff members (AORN, 2014; Battie, 2014; Way et al., 2013).

Statement of Purpose

In order to study the impact of noise on patient safety, it is reasonable to start by exploring CRNA perceptions of the presence and potential effects of excessive noise in the OR. Future initiatives directed at minimizing noise in the OR could be better justified and embraced should a consensus on CRNA perceptions of noise in the OR be substantiated. This non-experimental, cross-sectional, descriptive study exploring CRNA perceptions of the presence and potential negative impact of excessive noise in the OR is important to enhance and understand patient safety. At the time of this project, no studies have been identified that pertain explicitly to perceptions of intraoperative noise in the CRNA population. It may also provide a framework for additional enquiry regarding both individual and interdisciplinary attitudes about increased ambient noise levels in the OR. Moreover, data garnered from survey responses may potentially steer the employment of novel modalities to decrease the occurrence and effects of intraoperative noise through adaptations in OR architecture, equipment and materials.

Project Objectives

The objectives of this study are to determine if there is a perception among CRNAs that:

1) Ambient noise in the OR is excessive throughout the intraoperative period and specifically during the critical induction and emergence phases of anesthesia,

2) Ambient noise in the OR may adversely impact CRNA performance and health,

3) Ambient noise in the OR is problematic, potentially posing a threat to patient safety and contributing to adverse outcomes.

Additionally, CRNA perception of potential etiologies and quality of intraoperative noise will be examined. Finally, opinions as to the ability to and need for noise control in the operating room will be garnered.

Organization of Dissertation

The dissertation that follows is organized into four subsequent chapters. Chapter Two consists of a comprehensive and pertinent literature review exploring the following supporting topics:

- The patient safety movement
- The genesis of error in medicine
- Noise:
    - Evolution and methods of control throughout history

    - Human sensory perception
    - Measurement
    - Effects on provider and patient health
    - Sensitivity/annoyance
    - Effects on performance and communication
    - Prevalence, effects and control in healthcare settings
- Theoretical underpinning:
    - Endsley's Theory of Situation Awareness as an integral element of CRNA overall performance

Chapter Three outlines the methodology employed to create the survey tool, incorporating previously validated items and novel ones drawn from themes elicited in the literature review. The scheme for instrument piloting for internal consistency through the application of Cronbach's alpha is described. An overview of the population of interest, sampling plan, incentivization of subjects, necessary sample size to achieve adequate power and precision and statistical analyses follows.

Chapter Four disseminates the results and delimits the statistical analyses of collected survey responses.

Chapter Five includes further evaluation and discussion of survey results and a detailed delineation of potential project limitations. It offers proposed implications for future research projects pertaining to this interesting phenomenon. Modalities for the mitigation of increased levels of OR noise are also explored with a specific focus on operating room layout and design, use of noise-emitting equipment, stakeholder education and self-moderation through application of visual cueing techniques.

Chapter 2: Review of Relevant Literature

Overview

Chapter Two represents a multi-faceted review of the existing body of literature regarding noise. This chapter will examine the genesis, evolution and control of noise throughout time, the effect of noise in the environment and the workplace, the perception of noise by individuals, the impact of noise on physiological and psychological health, the influence of noise on human performance and the possible contribution of noise to the incidence of medical error via heightened distraction and attenuated SA of the provider. The issue of elevated noise levels in the operating room and its potentially deleterious effect on nurse anesthetist performance and SA will be examined. Chapter Two will also serve to delineate any gaps in knowledge and provide a framework for the design of the survey instrument and methodology of the research project.

Literature Review Methods

A thorough literature review was achieved through use of the following search engines: PubMed, CINHAL, OVID, Scopus and Google Scholar. Key words and phrases used were *patient safety, safety in anesthesia, noise, health effects of noise, noise and performance, history of noise, noise control, noise in hospitals, noise in healthcare* and *noise in the operating room*.

The Patient Safety Movement

"Health care is not as safe as it should be" (IOM, 1999) unfortunately continues to ring true today. Despite early estimates of 46,000-98,000 annual deaths secondary to medical mishaps (IOM, 1999), it was later hypothesized that this initial projection of mortality was grossly underestimated. In a subsequent publication by the IOM, it was posited that 195,000 injuries were caused by error and that this ten-fold increase merely represented "the tip of the iceberg" due to the probable underreporting of misadventures (IOM, 2000). As a result of these startling findings, attention to advances in patient safety began to proliferate. This worthy initiative continues to present day and provides an underpinning for the research project *Perceived Impact of Ambient Operating Room Noise by Certified Registered Nurse Anesthetists*.

The IOM report not only illuminated the issue of medical error but, more importantly, re-directed focus on causation. Rather than perseverate on human error as the causative factor in the occurrence of critical incidents, faulty systems and exacerbating environmental factors were brought to the forefront with an emphasis on their effects on human performance. Inadequacies in systems were found to be due to a multitude of factors, ranging from defective equipment to high task density to operator inexperience. Environmental derangements thought to cause provider distraction, such as excessive ambient noise, were also highlighted (Shaw, 2012).

Although great strides have been made with respect to a heightened awareness of medical error and mishaps, the healthcare domain continues to lag behind the aviation and nuclear industries. In 2016, a shocking report by the British Medical Journal cited that the third leading cause of death in the United States was due to medical errors, surpassed only by cancer and cardiac disease (Fig. 2). Due to the ubiquitous nature of unintended medical errors, the report proposed that a discrete ICD-10 code be designated to this particular etiology as a cause of death (Makary, 2016). The gravity of this proposition illustrates the ominous circumstances concerning impaired patient safety that are still prevalent in contemporary healthcare.

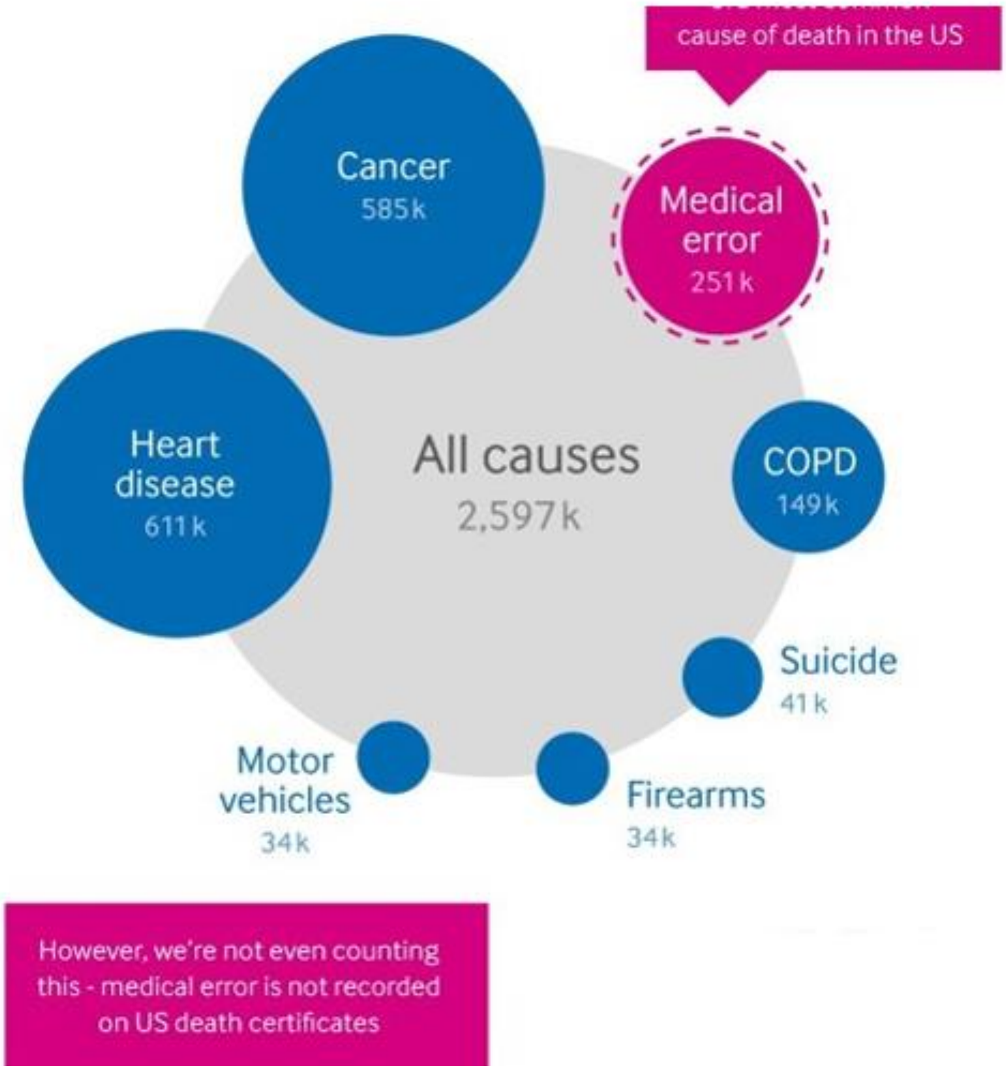

Figure 2. Medical Error: The Third Leading Cause of Death in the US (Makary, 2016)

Preservation of patient safety in the operating room is of utmost importance and patient outcomes may be closely linked to anesthesia provider performance. According to anesthesiologist David Gaba (2000), anesthesiology has long been a frontrunner in the examination, development and promotion of patient safety initiatives. Practices adopted from the aviation industry such as the development of checklists continue to serve as foundations for the advancement of patient safety in the anesthesia realm. Likewise, an understanding of latent elements that predispose to error is necessary in enabling prevention of critical incidents in the OR (Runciman et al., 2014).

Owing to the intense nature of the OR environment coupled with the tendency towards human error while enduring challenging conditions, anesthesia-related accidents continue to persist. In 1990, Gaba and DeAnde observed anesthesiology residents practicing during simulated OR scenarios. They found that unanticipated errors secondary to inadvertent mishaps or poor decision-making occurred at a rate of 6.9 incidents per case (Arnstein, 1997). Of those errors, 27% were considered to be critical. Findings from this research project are alarming in that the experiment was conducted in a simulated OR environment, devoid of the additional burden of caring for a live patient or exposure to excessive ambient noise. Intuitively, errors could potentially escalate in an authentic OR scenario.

The National Patient Safety Foundation has fittingly referred to preventable patient harm in health as a public health crisis. Their *Call to Action* initiative has been joined by the Anesthesia Patient Safety Foundation (APSF) with the intent of enacting a coordinated, national multidisciplinary response to this emergency (APSF, 2017). Four key actions are noted in their public health framework: 1) Inform the Community; 2)

Measure and Monitor; 3) Identify Causes and Interventions; and 4) Educate and Train. This research project bears each of these auspicious goals in mind with a specific emphasis on identification of causes.

Causes of Error in Healthcare

Due to the punitive nature of critical incident review, embarrassment and fear of repercussion by the practitioner at the “sharp end” of care, many errors committed in medicine remain unreported. This reality further exacerbates the problem of medical mishaps leading to increases in patient morbidity and mortality. Knowledge and comprehension of predisposing factors and their preemptive mitigation may be a crucial key to the eventual decline in this system-wide problem.

Human Factors. Despite rigorous training, a wide and varied knowledge base and keen clinical acumen, even the most skilled practitioner may fall prey to committing errors. Mistakes can be divided into three categories: errors of omission, commission and execution. Errors of omission occur when the individual inadvertently overlooks a necessary treatment, administration of a medication or elements of documentation. Errors of commission occur when the practitioner engages in or contributes to another clinician’s error, either knowingly or unknowingly. Errors of execution occur when the practitioner engages in the improper administration of a treatment or an intervention, either knowingly or unknowingly (Grober & Bohnen, 2005).

Multiple identifiable factors may affect human performance and engender erroneous practices. Task and cognitive overload, fatigue, boredom and sensory distraction from extraneous sources may unconsciously divert the practitioner from safe practice. Many errors committed are minor; some are never elucidated. Others may be egregious and result in critical incidents, patient injury and potentially death. Although errors are largely inadvertent, the repercussions from critical incidents and accidents adversely impact not only patients, but providers as well. These effects may be devastating for the patient and the provider involved, now the “second victim” of the catastrophic event (Daniels & McCorkle, 2016).

System Factors. In the 1980s, James Reason sought to reveal potential precursors to the development of critical incidents. In his “Swiss Cheese Model” (Fig. 3), Reason depicts the trajectory of accident opportunity facilitated by both active and latent failures in multiple barrier layers of perforated “cheese.” Latent failures, dangerous “resident pathogens,” may go unnoticed for prolonged periods of time. Active failures are deviations from safe practice that may be purposeful or accidental. Both are represented by holes in the slices of cheese. Other perturbations such as untoward mental and/or physical condition of the individual at the time of the error incite the genesis of a critical incident.

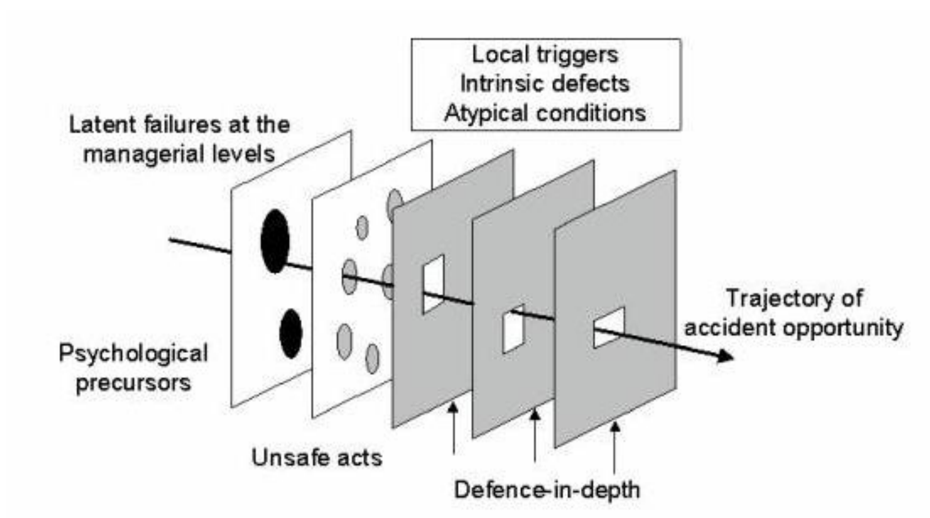

Figure 3. Reason's Swiss Cheese Model (1990) (Perneger, 2005)

Under normal circumstances, various defenses are in place to deter the end-effects of latent and active precursors. However, further elemental defects, local triggers or atypical environmental conditions such as elevated noise levels may allow for the alignment of holes in each successive piece of cheese, thereby allowing the trajectory of the accident to remain intact. Once through the gauntlet of defense mechanisms, a critical incident occurs with potential catastrophic outcomes (Perneger, 2005; Reason, 2005).

Reason's initial iteration of the Swiss cheese model focused mainly on causation. In 1997, he adapted his original prototype to the healthcare environment (Fig. 4). The updated model depicts hazardous acts or dangerous conditions that result in accidents ("losses") as protective barriers are breached. Reason depicts the same failures as in the original prototype but adds investigation as to the reason for the critical incident. This provides a framework for the application of root cause analyses after the occurrence of critical incidents.

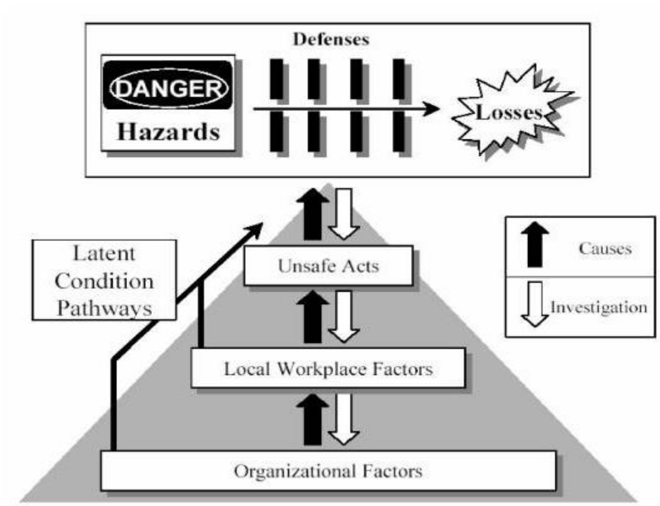

Figure 4. Reason's Swiss Cheese Model: Adaptation to Healthcare (1997) (Perneger, 2005)

Despite the continued focus on patient safety initiatives, injuries continue to occur. Many arise secondary to known issues and are therefore avoidable. Others such as patient non-disclosure of history or actual condition remain outside of the practitioners' control (Grober & Bohnen, 2005). Albeit a pessimistic viewpoint, one must consider Perrow's *Normal Accident Theory* (1999): "*Critical incidents will still occur despite mechanisms designed to thwart their progress*" (Gaba, 2000; van Beuzekom, 2010). This statement should encourage continued efforts to ensure improved patient safety.

Latent Factors. Van Beuzekom (2010) delineated latent factors in healthcare that may predispose the practitioner to commit inadvertent errors in healthcare. Table 1 depicts these precursors. Factors that may be directly impacted by the presence of elevated levels of noise have been highlighted with asterisks.

Table 1. Latent Risk Factors and Issues (van Beuzekom, 2010)

Latent Risk Factors	**Issues**
Equipment	Function; design; availability; standardization; maintenance
Staffing	Adequate numbers; skill
Training	Procedural; mechanical; team
Procedures	Presence of and adherence to protocols
Planning and organization	Process of care
Housekeeping	Hygiene
Communication*	Openness; interrelation; atmosphere; work-oriented
Teamwork*	Team performance
Incompatible goals*	Balance between goals and safety
Situation awareness*	Awareness of present situation, needed interventions and future developments

Error in Anesthesia. Leedal & Smith (2005; pg. 702) describe providing anesthesia as “managing a single highly interactive system composed of the patient, clinical equipment, surgeons, and other OR personnel, and the broader OR environment.” Due to the dynamic nature of the job, extraneous input from multiple sources, and interfacing with unknown comorbidities or surgical events, it is clear that errors have the potential to occur during the course of every anesthetic.

Despite the fact that anesthesia is presently safer than it has been historically, it is maintained that there are still many improvements to be made in this initiative (Gaba, 2000). In an effort to alleviate anesthetic-related mishaps, Biddle (2009) described factors that increase the risk of error in anesthesia leading to the development of critical incidents (Table 2). A critical incident, a concept first described in aviation, is defined as "*an occurrence that could have (if not quickly resolved) or did lead to a major complication*" (Biddle, 2009; Gaba, 2009; 2015). In examining Biddle's etiologies for critical incidents in anesthesia, multiple elements, namely the loss of SA, distraction and poor communication may be exacerbated by the presence of elevated levels of intraoperative noise.

Table 2. Potential Etiologies for Critical Incidents in Anesthesia (Biddle, 2009)

Potential Etiologies for Critical Incidents in Anesthesia
Inadequate pre-use inspection of apparatus
Use of technologically complex equipment
Inadequate trainee supervision
Medication errors (usually overdose)
Unrecognized airway obstruction
Aspiration of gastric contents
Insufficient monitoring
Inadequate post-operative care
Rushing secondary to production pressure
Task density too great
Loss of situational awareness/distraction*
Poor communication*

Noise

Historically, environmental noise levels have evolved and are continuing to escalate. These upsurges are largely due to expansion of the world population, shifts in residences from farmland to urban locales, introduction of multiple noise-emitting transportation modes, steam engines, horns, industry and war. Retail businesses and restaurants deliberately intensify the volume of background music to produce a frenetic milieu, an environment shown to increase food consumption and product sales (Rueb, 2013).

Types of Noise. Noise, previously defined in Chapter One, has been described as unwanted or unnecessary sound. Ambient noise occurs as a result of the production of background sound in the surrounding environment. Noise may be described as white, pink or brown. White noise is comprised of a wide spectrum of frequencies and creates a consistent sonic environment that is random and patternless. (Schafer, 1994: pg. 135; Schwartz, 2011; pg. 705). Pink noise is similar to white noise in that it provides a constant background of auditory stimulation with lower frequencies than transmitted by white noise (Kosko, 2006; pg. 93). Sounds of nature such as running water fall within the pink noise frequency range. Pink noise has been shown to facilitate sleep as well as increase memory formation in the elderly (Macmillan, 2017). Brown noise, softer and less harsh than white or pink noise, has the lowest frequency of the three and is akin to the sound of ocean waves or a strong wind (Kosko, 2006; pg. 93; Neal, 2016).

Noise Events and Abatement: A Historical View. Since the time of Hippocrates, noise has been a known detriment to human hearing and general health. As such, noise abatement efforts have a storied history, with records dating back to the 6th century B.C.E. (Goldsmith, 2015; Keizer, 2010; Rueb, 2013). Table 3 outlines major noise events, early research findings and noise control efforts throughout history.

Table 3. Timeline: Select Noise Events and Control throughout History (Adapted from Goldsmith, 2015; Keizer, 2010; Rueb, 2013)

Date	Event
6th Century B.C.E.	Sybaris Greece: 1st known noise ordinance Tradesmen were banned to live outside city walls; roosters forbidden
5th Century B.C.E.	Hippocrates is the first to describe tinnitus and denotes causative factor as sustained exposure to noise
500 B.C.E.	Buddha requests that his monks turn down the "chit-chat"
44 B.C.E.	Roman Empire: Julius Caesar bans use of horse- or oxen-drawn wagons in residential districts after sunrise or before the "10th hour of the night"
1378	London: First official noise complaint lodged
1400s	Physicians claim that noise can damage the ear
15th Century	1st reference to London as a "noisy city"
1595	London bylaw ("*bye-law*") forbids loud outcry in the night
1660s	The megaphone is developed by two separate inventors
1713	Bernadini Ramazzini: Ascribes deafness in coppersmith tradesmen to their occupation; first to be published
1770s	Introduction of the steam engine engenders the most significant noise increases in history
1831	Dr. John Fosbroke: First authoritative publication re: effect of occupational noise in the Lancet: "*Blacksmith deafness is a consequence of employment*".
1862	Dickens, Babbage, Bass: Progenitors of "*The Act for Better Regulation of Street Music in the Metropolis*"
1879	Mary Walton: Successful abatement of noise generated by elevated railway in NYC. Initiated installation of asphalt-topped cotton and sand-filled boxes over the rails

1880	Development and use of the Rayleigh disc as the1st noise-measuring instrument
1883	Eruption/explosion of Krakatoa, considered to be the loudest noise recorded in history (Fig. 5)
1886	Dr. Thomas Barr: First researcher to study quantitative noise-induced hearing loss (in Glaswegian boiler-makers)
Early 1900s	Julia Barnett Rice, M.D: Forms the Society for the Suppression of Unnecessary Noise (NYC). Principal target was motorcar horns
1907	Bennett Act: Forbids unnecessary blowing of whistles in U.S. harbors
1920s	Development of the decibel to measure noise
1929-30	First objective environmental noise survey carried out in NYC. Engenders landmark study: "*City Noise"*
1950s	Jet planes significantly add to environmental noise
1957	Chicago zoning ordinance; First in the world to specify maximal urban noise levels
1960	UK: Noise Abatement Act; Noise considered a statutory nuisance
1968	F. Murray Abraham introduces the concept of the "Soundscape"
1970	US: Occupational Safety and Health Act (via OSHA)
1972	US: Noise Pollution and Abatement (Noise Control) Act
1975	Arline Bronzaft: demonstrated the adverse effect of environmental noise on student performance
1978	US: Quiet Communities Act
1981	FAA: enacts the Flight Crew Member Duties (A.K.A. Sterile Cockpit Rule)
1986	Arline Bronzaft: Spearheads installation of "Do Not Honk" signs on lampposts in NYC

1989	"Noise barrage" with loud music[1] utilized as a warfare tactic in Panama by US troops to drive Noriega out of hiding
1995	International Noise Awareness Day established: April 25
1998	Mayor Rudolph Giulani (NYC) begins the Civility Campaign to limit annoying (noise producing) behaviors
2002-04	Mayor Michael Bloomberg (NYC): Establishes 311 Citizens Service Center and Operation Silent Night to enhance enforcement of anti-noise laws
2015	Quiet Communities Act revisited via Bill H.R. 3384: To reestablish the Office of Noise Abatement and Control in the Environmental Protection Agency, and for other purposes

[1] "*Never Gonna Give You Up*" by Rick Astley

Figure 5. The Eruption of Krakatoa, and Subsequent Phenomena. Lithograph: Parker & Coward (1888) (Adapted from Wikimedia Commons, 2018)

The Measurement of Sound

The Decibel. Sound intensity is measured in units called decibels (dB). The origin of the term decibel is posited to stem from the melding of Alexander Graham Bell’s name (Bel) times a factor of ten (deci). It is defined as “the ratio of the wattage or sound pressure bearing upon the tympanum (or on the diaphragm of a condenser microphone in a sound meter) to the wattage or sound-pressure of silence” (Schwartz, 2011; pg. 685). Simply stated, decibels allow the conversion of Pascals (Pa), the elemental measure of sound pressure, to more manageable 2- to 3-digit values. The ratio referred to is the current sound level measured as compared to a baseline value of 20 micro pascals (μPa), the estimated threshold of human hearing (the least perceptible sound). One atmosphere (atm) is equal to approximately 100,000 Pa. At the upper range of human hearing, deafening sound that produces physical pain is approximated at 2 X 108 μPa or 140 dB.

Because human auditory perception is capable of spanning an extremely wide range of sounds, decibels are best expressed as logarithmic functions. Decibels are computed by comparing the effective intensity of a sound relative to a baseline threshold reference value. According to Kosko (2006; pg. 48), the arithmetical conversion of the Pascal to the decibel produces geometric results: “*Adding 20 decibels multiplies the sound pressure by 10*.” In short, minor elevations in dB measurements effectively increase the actual sound pressure dramatically. This may have serious ramifications in environments with a tendency towards noisy conditions.

Human speech, typically measured between 55 and 60 dB, produces a sound pressure approximately 1000 times greater than the reference range for human threshold of hearing[2]. Noise reaching 120 dB has a sound pressure *one million times greater* than the reference range (Kosko, 2006; pg. 49). The formula for the measurement of decibels is:

$$ß = (10 \text{ dB}) \log I/I_0$$

Beta (ß) = sound intensity measured in decibels

Intensity of sound (I) = Power/area (W/m^2)

Power = $Watts/m^2$

Watts = joules/second

$I_0 = 10^{-12} W/m^2$ = the reference range for the threshold of hearing (the least amount of sound perceptible by the human ear)

More simply stated:

Sound intensity in decibels =

(10 decibels) X logarithm of (sound intensity/reference intensity)

Decibel Weighting. Measurement of ambient sound pressure using an audiometer is typically adjusted through the application of filtering or "weighting" to the decibel level. Decibels are weighted to provide a reference point that better depicts various ranges of sound frequencies, peak sound pressures and imperceptible sounds. For example, A-weighting threshold applies to the frequencies within the range of

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[2] 0 dB

human hearing[3], omitting those frequencies that are not detected (Keizer, 2010; pg.133). A-weighted decibels (dBA) are the most widely used when obtaining environmental sound measurements or assessing noise dose. C-weighted decibels (dBC) are used to measure peak sound levels, particularly lower (bass) frequencies that may be outside the range of human auditory perception. Z-weighting[4] measures a flat frequency between 10 Hz and 20 kHz and is used as a basal reference point for audiometers.

Figure 6 depicts human perception of sound level, its comparative measurement in decibels and micro Pascals (μPa), examples of conventional objects and their production of noise as a frame of reference and OSHA limits for permissible exposure to sustained and impulse noise (California EPA, 2000; pg. 28). Remarkably, the humpback whale's song traversing through water has been measured at 170 dBA (Keizer, 2012; pg. 275; Kosko, 2006; pg. 51)!

[3] 500 Hz to 6 kHz
[4] A.K.A. "zero weighting"

Perceived Sound Level	Sound Level dB	Sound Level μPa	Examples	
PAINFULLY LOUD	160	$2x10^9$	fireworks at 3 feet	
	150		jet at takeoff	
	140	$2x10^8$	threshold of pain	OSHA limit for impulse noise
UNCOMFORTABLY LOUD	130		power drill	
	120	$2x10^7$	thunder	
	110		auto horn at 1 meter	
	100	$2x10^6$	snowmobile	
VERY LOUD	90		diesel truck, food blender	90 dB OSHA permissible exposure limit
	80	$2x10^5$	garbage disposal	
MODERATELY LOUD	70		vacuum cleaner	
	60	$2x10^4$	ordinary conversation	
	50		average home	
QUIET	40	$2x10^3$	library	
	30		quiet conversation	
VERY QUIET	20	$2x10^2$	soft whisper	
BARELY AUDIBLE	10		rustling leaves	
	0	$2x10^1$	threshold of hearing	

dB= decibels
μPa= micro Pascals

Figure 6. Comparison of Sound Levels in the Environment (Adapted from California EPA, 2000; pg. 28)

Health Effects of Noise

Contact with sustained levels of noise over a course of time imposes a myriad of negative systemic effects. Structural compromise of the inner ear may result from physical perturbation of delicate cochlear components. Activation of the sympathetic nervous system (SNS) via indirect stimulation from noise results in increases in both cortisol secretion and cardiovascular parameters.

Exposure to increased levels of noise may occur in a variety of settings. Environmental noise continues to parallel increases in both population numbers and technological advances. Noise may be encountered in homes and urban neighborhoods, particularly impacting young children and the disadvantaged (Goines & Hagler, 2014; Keizer, 2010, pp. 55-57). Extreme sound conditions may be self-inflicted via recreational noise. Attendance at musical concerts, nightclubs, video games and overuse of earphones delivering high sound volumes are increasing trends, principally within the younger generations (Goines & Hagler, 2014). Noise may also be present in the workplace with origins ranging from machinery, heating, ventilation and air conditioning (HVAC) systems, or simply conversation among co-workers. Ramirez et al. (2002) report that exposure even to moderate low frequency noise (40-60 dB) over the long term may result in feelings of fatigue, difficulty in concentrating, annoyance, impaired mental performance, irritability, increased psychological stress and stimulation of the physiological stress response.

Hearing loss from noise exposure is the third leading cause of chronic disease in the US, with an estimated 1 in 3 individuals suffering from some form of the malady (CDC, 2016; NIOSH, 2018). The Veterans Administration cites that the highest level of medical compensation is awarded to military veterans suffering from hearing loss (Hancock & Szalma, 2008; pg. 24).

The effects of occupational noise were first observed in boilermakers in the 1800s (Stephens, 1986). Since then, efforts towards noise mitigation in the environment and the workplace have flourished (Table 3). In 1980, the Occupational Health and Safety Administration (OSHA) established guidelines to limit noise exposure in the workplace. In the OSHA Standard 29 CFR – 1910.95 A, *Occupational Safety and Health Hazards*, temporal limits are delineated for exposure to noise as expressed in A-weighted decibels. Table 4 depicts OSHA's established regulations for occupational noise exposure.

Table 4. OSHA Maximum Allowable Noise Exposure (OSHA Standard 29 CFR – 1910.95A, 1980)

Hours per day (continuous noise)	8	7	4	3	2	1	0.5
Sound level (dBA)	90	91	95	97	100	105	110

The Neuroendocrine Response. Noise is enigmatic: productive, protective and destructive simultaneously. It creates sound that provides a vehicle by which humans may "touch" at a distance (Hendy, 2013; pg. 14). In evolutionary terms, noise has played an integral role in the preservation of early man. Prehistoric ancestors relied on the production of noise from potentially dangerous sources: vicious and hungry feral animals, dangerous weather conditions and threatening enemies (Keizer, 2010; pp. 76-77). Auditory cues such as cries from hungry babies or screams from injured tribal members were delivered in the hopes of insuring a rapid response in the form of food, aid and comfort. Because these noises represented potential peril, the “Fight or Flight” response, coined by Hans Selye in 1936, was engaged in respondents. The inciting provocation, heralded by a stimulation of the sympathetic nervous system (SNS) caused an increase in heart rate, blood pressure, and cortisol production, thereby readying the organism to defend himself, seek shelter or flee the area.

Likewise, the contemporary human response to noise, particularly that which is sudden and unexpected[5], precipitates a parallel response to that experienced by prehistoric man (California EPA, 2000; Keizer, 2010; Kosko, 2006; OSHA, 2011). In the OR environment, Hodge and Thompson (1990) measured the sound of a stainless-steel bowl dropped on the floor at a distance of 2 meters at 108 dBA, producing a noise considered to be “uncomfortably loud” (California EPA, 2000). Unanticipated noises at this sound level occurring at task-dense phases of the operative procedure may result in consequences for both the patient and the provider. Distraction from the inciting noise stimulates the startle reflex and diverts anesthetist attention, a commodity that may not be quickly recouped. Figure 7 depicts the human response to impulse noise and concomitant activation of the hypothalamic-pituitary-adrenal (HPA) axis (Heinonen-Guzejev, 2009).

[5] A.K.A. “impulse noise”

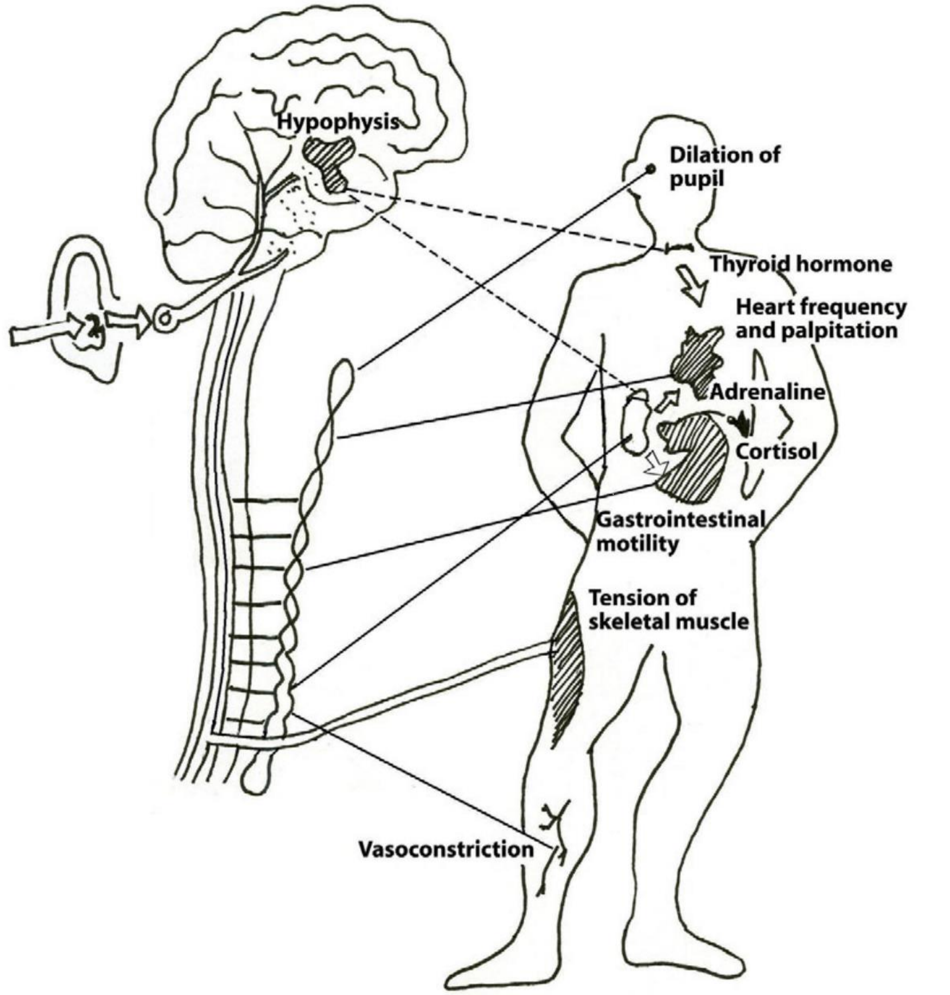

Figure 7. Transmission Paths of Direct Noise Effects (Adapted from Ising and Rebentisch, 1993 [in Heinonen-Guzejev, 2009])

It is clear that repeated exposure to sudden noises constitutes a health risk secondary to chronic stimulation of the HPA axis. Almost immediately, heart rate increases as does respiration and oxygen consumption. Increased cortisol secretion leads to increased blood glucose levels; repeated boluses of endogenous catecholamines may engender chronic cardiovascular issues such as dysrhythmias and hypertension. Gastrointestinal motility increases concomitantly with hydrogen ion secretion, eventually predisposing to the development of peptic ulcer disease. Over the long term, the physical insult brought on by these repeated bouts may provoke feelings of stress, fatigue, anger and, in extreme cases, psychological derangement. Pre-existing psychiatric conditions can be exacerbated and psychosis may eventually occur. (Goines & Hagler, 2007; Osada, 1988; WHO, 1995).

Dzhambov (2015) sought to find an association between long-term exposure to noise and an increased risk for the development of Type II diabetes mellitus (T2DM). Through a systematic review and meta-analysis, he examined the correlation between exposure to both residential and occupational noise and the risk for development of T2DM. Although his research findings were not statistically significant due to methodological deficits in a proportion of the original studies, the author did stress the potential for endocrine dysfunction as a result of sustained exposure to elevated noise (Dzhambov, 2015).

Self-perception of health status may also be affected by sustained exposure to noisy conditions. Researchers in Finland studied the effects of road-traffic noise and engine exhaust in 1112 adults. Self-perception of increased health risks from noise was found to be statistically significant ($p < .045$). Researchers concluded that respondents considered road-traffic noise to pose a significant risk; with health effects nearly as detrimental as those resulting from contact with engine exhaust and air pollution (Okokon et al., 2015).

The WHO classifies the deleterious consequences of noise pollution on human health in seven broad categories. Table 5 delineates a variety of issues, both physical and psychological, that may result from sustained exposure to noise and their potential sequelae (Goines, 2007; WHO, 1995).

Table 5. Seven Categories of Effects of Noise (WHO, 1995)

Hearing impairment
Tinnitus
Structural damage to cochlear stereocilia
Distorted loudness perception
Paracusis
Interference with spoken communication
Impaired speech discrimination
Loneliness
Isolation
Sleep disturbances
Cardiovascular disturbances
Increased heart rate
Increased blood pressure
Increased cortisol production
Disturbances in mental health
Depression
Escalation of psychiatric disorders
Psychosis
Impaired task performance
Impaired cognition
Negative social behavior and annoyance reactions
Anger
Inability to collaborate with others

The Anatomy of the Ear

The ears, our “biological microphones” (Alberti, 1970) are paired organs of hearing. Each ear is comprised of 3 main sections: the external ear (A.K.A. auricle or pinna), the middle ear and the inner ear. Changes in atmospheric pressure produced by sound waves are gathered by the head and cartilaginous whorls of the external ear and transmitted to the tympanic membrane (TM) via the auditory canal. The auditory canal funnels sound waves towards the TM, magnifying the sound by approximately 10-15 dB (OSHA, 2011). The TM, a flexible membranous structure approximately 10 mm thick, acts as an additional resonator for transmitted sound waves (Raff & Levitsky, 2011; pg. 152). Pressure changes at the TM translate to miniscule vibrations which stimulate the auditory ossicles: the malleus (hammer), incus (anvil) and stapes (stirrup) (Fig. 8).

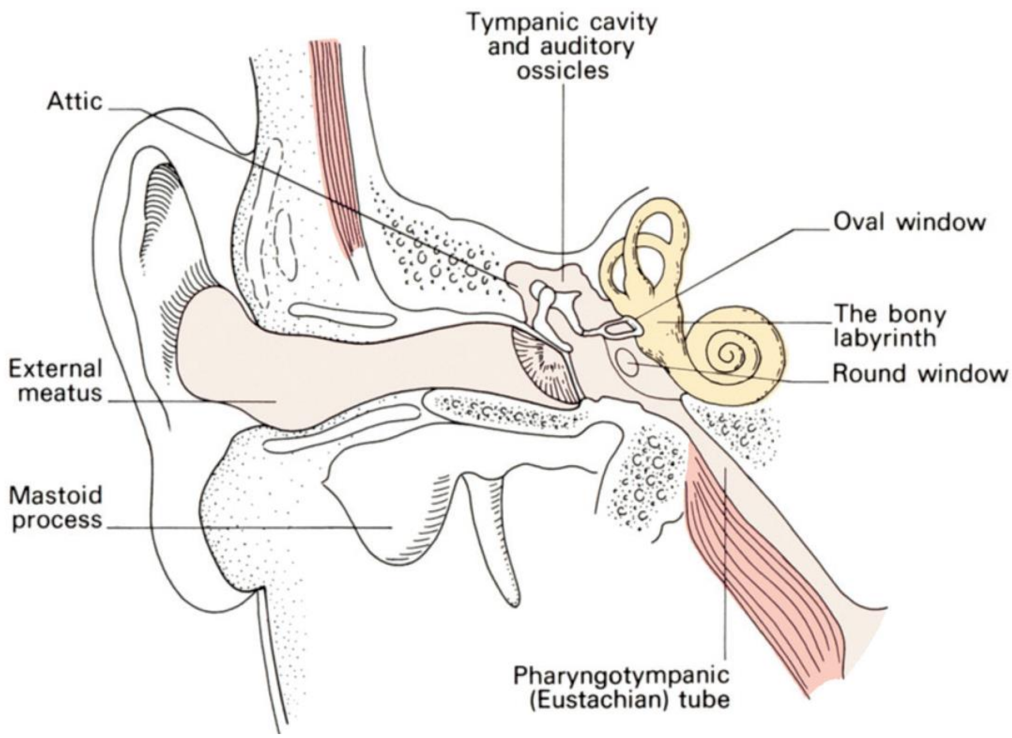

Figure 8. General Anatomy of the Ear (adapted from Ellis & Mahadevan, 2013)

The handle of the malleus is in direct contact with the interior surface of the membranous TM and moves in response to TM pulsation. In turn, the malleus articulates with the incus, stimulating it in a lever-like motion. Movement of the incus exerts pressure on the stapes. Magnification of the pressure exerted from the wide TM terminally to the narrow stapes focally amplifies the force by which the stapes stimulates the oval window of the cochlea. This system thereby functions as an additional resonator for received sounds.

Two miniscule muscles, the tensor tympani and the stapedius, stabilize and maintain the position of the ossicles. When noise exceeds 80 dB, these muscles contract to protect the delicate structures of the inner ear. This mechanism, known as the aural reflex, does not occur rapidly enough to protect against impulse or blast noises. Additionally, the reflex does not have the capability to protect the inner ear when exposed to sustained high levels of noise (OSHA, 2011).

The oval window serves as an entry point for the transmission of signals from the ossicles to the cochlea, a fluid-filled organ resembling a snail's shell. The cochlea contains three chambers: the scalas vestibuli, tympani, and media, where the organ of Corti is located. The organ of Corti is lined with minute hairs known as stereocilia which are suspended in endolymph (Ellis & Madahevan, 2013; pg. 422). Piston-like stimulation from stapes contact with the oval window results in a wave-like motion of the fluid that causes mechanotransduction, a pulsatile movement of the stereocilia. As the hairs bend to and fro, ion channels open, allowing the efflux of potassium to facilitate a positive membrane potential. The resulting action potential stimulates cranial nerve VII, the vestibulocochlear nerve (Stephens, 1986; Ellis & Madahevan, 2013; pg. 412) which carries sensory information to the auditory cortex of the brain. Figure 9 schematically depicts the acoustic pathway from the outer ear to the cochlea and the process of mechanotransduction via the structures of the middle ear.

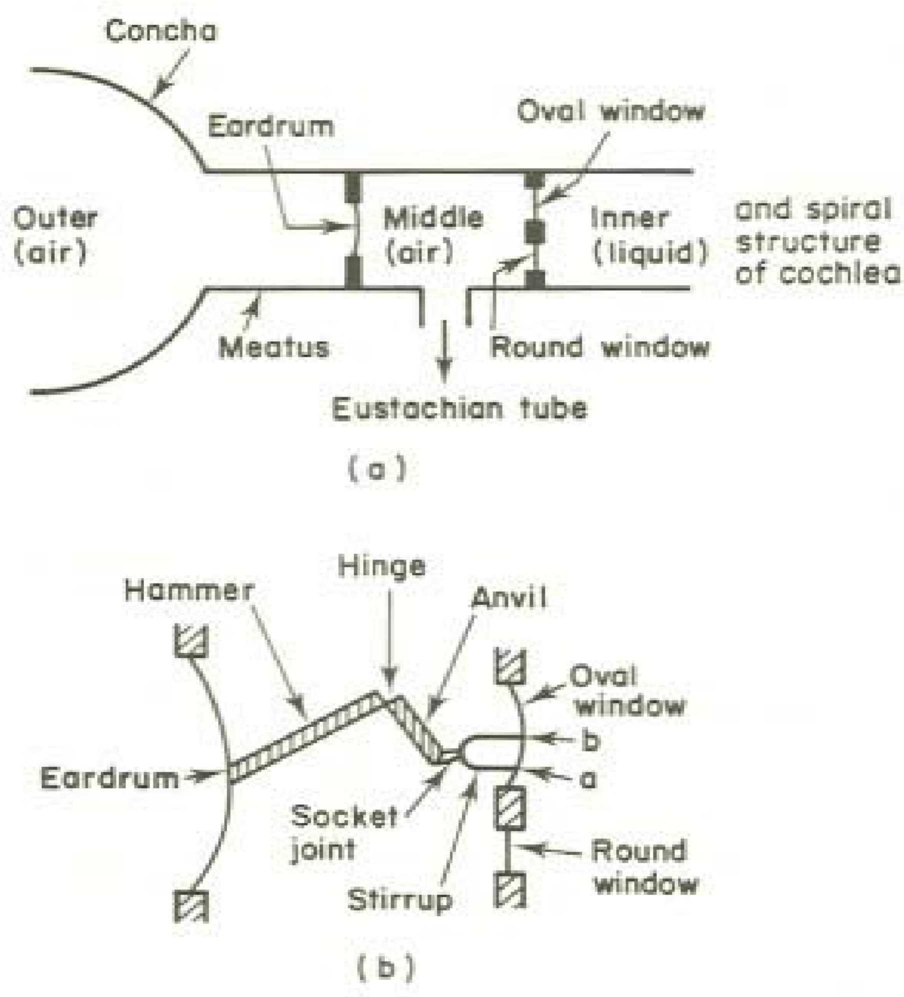

Figure 9. The Acousto-mechanical Pathway of the Ear: (a) From outer receptor to cochlea; (b) Schematic of middle ear structures (Stephens, 1986)

Relationships between the gross anatomy, structures and functions of the components of the external, middle and inner ear are delineated in Table 6.

Table 6. Functional Anatomic Components of the Ear

Gross anatomy	Structures	Function
External ear (pinna, auricle)	Auricular cartilage: tragus, antitragus, helix, anthelix, concha, lobule	Sound funnel; collects and directs sound towards the external auditory meatus and through the canal
	External auditory meatus/auditory canal	Resonator for sound; increases by 10-15 dB from originating source
	Tympanic membrane (eardrum)	Stimulates movement of the ossicles via transmission of sound wave vibration
Middle ear (tympanic cavity)	Ossicles: incus, malleolus, stapes	Transmits and intensifies vibration from the TM to the cochlea
	Muscles: tensor tympani, stapedius	Support ossicles; contract (aural reflex) during extreme noise conditions
Inner Ear	Cochlea Organ of Corti	Mechanotransduction of endolymph-bathed cilia increases membrane potential, stimulates CN VII which signals auditory cortex of the brain

The Physiology of Hearing

Sound (and noise) produces rapid pressure variations in elastic substances such as air, water or solids. These oscillating vibrations create a sine wave pattern (Fig. 10).

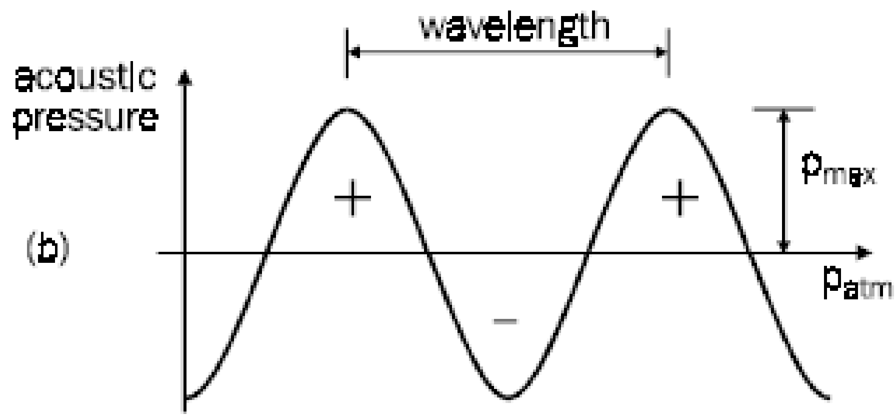

Figure 10. Representation of a Sound Wave (Hansen, 1995)

Pure tonal sound waves can be graphically depicted by the amplitude of pressure changes within the flexible medium through (P_{max}), frequency (*f*), wavelength (ʎ) and velocity (Hansen, 1995). The amplitude or height of the positive sine wave produced by acoustic pressure is a measure of power, correlating to the production of sound. Lower amplitude corresponds to softer sound while increased amplitude parallels intensified sound such as noise. With the transmission of sound waves through air, the P_{max} represents the increase in pressure above atmospheric pressure (P_{atm}).

The tonal quality or pitch of sound is related to the frequency of acoustic oscillations (Fig. 11). Undulations produced by sound are measured by wavelength (peak to peak in meters [m]) and frequency (rate of occurrence in hertz [Hz])[6]. Slower, low frequency wavelengths produce low-pitched, bass sound while high frequency oscillations result in higher-pitched treble sounds (Hansen, 1995).

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[6] One Hertz (Hz) equals 1 vibration (cycle) per second

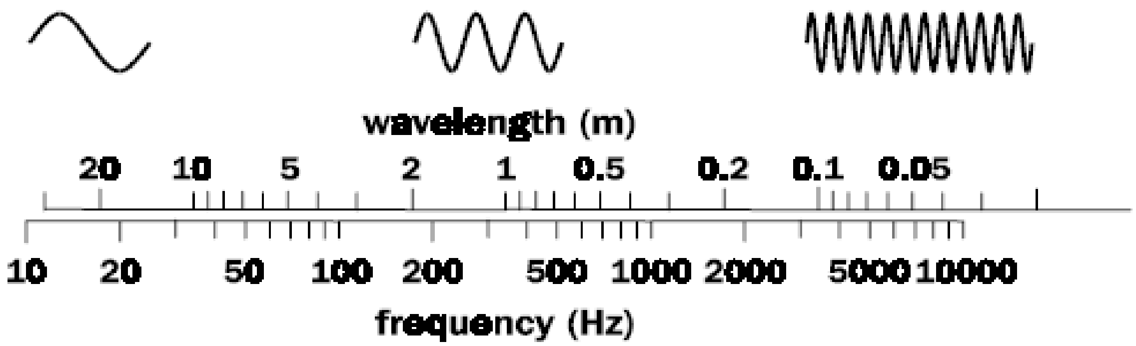
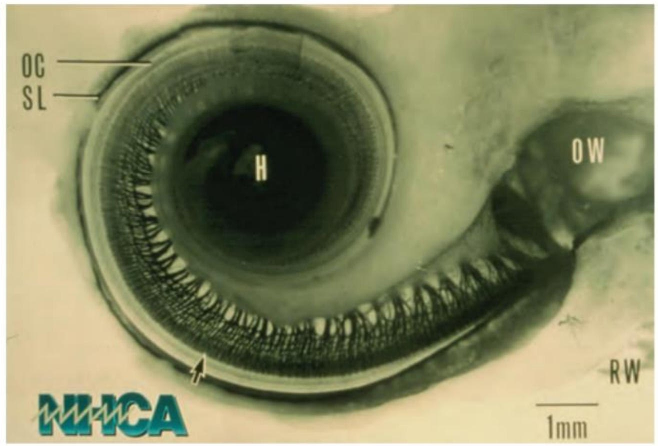
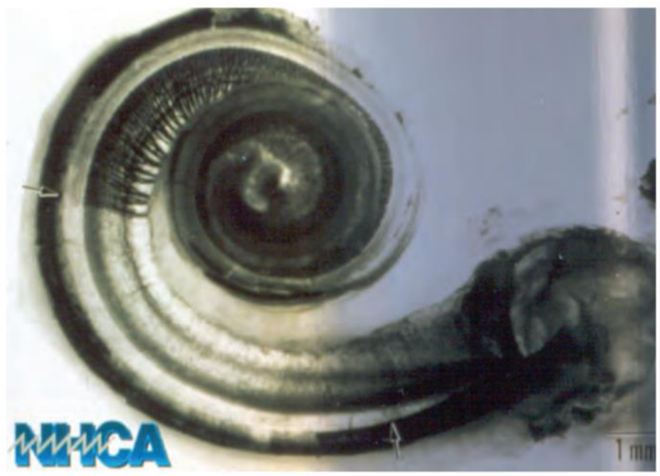


Figure 11. Relationship between Sound Wavelength and Frequency (Hansen, 1995)

Auditory Effects of Chronic Noise Exposure. Human exposure to basal quantities of noise is beneficial as it stimulates the ability of the inner ear to detect discrete sounds. This effect is referred to as stochastic resonance (Kosko, 2006; pg. 54). However, repeated or sustained contact with increased levels of noise has been shown to damage the structural components of the ear, particularly the microcilia located in the organ of Corti. Due to the delicate nature of these minute hair cells lining the cochlear whorls, repeated stimulation over the long-term causes overstimulation of mechanotransduction, ultimately resulting in damage. Stereocilia that detect sound at higher frequencies are located at the base of the cochlea and appear to be affected initially by noise-related damage. This manifests as an inability to perceive treble or higher-pitched sounds, an early symptom of hearing impairment. Hair cells that detect lower-frequency sounds reside in the inner apex of the cochlea and are affected by noise damage at a later time. Figure 12 compares a healthy cochlea, fully lined with stereocilia to one that is damaged from sustained exposure to high sound pressure levels (Kosko, 2006; pp. 52-53; OSHA, 2011).



Healthy inner ear lined with cilia, tiny hair cells that help you hear.



Inner ear showing damage to the cilia.

Graphics courtesy of National Hearing Conservation Association

Figure 12. Normal and Damaged Inner Ear (OSHA, 2011)

Minute hearing loss is expected as a result of the aging process, a condition known as presbycusis. Exposure to a loud blast or sustained high levels of environmental noise accelerates the process of noise-induced hearing loss. Individuals may initially perceive a high-pitched tone in the ears, either unilaterally or bilaterally. This condition, known as tinnitus, may signify the onset of cochlear damage (Kosko, 2006; pg. 53; OSHA, 2011). Hyperacusis, a disorder wherein an individual senses commonplace sounds more acutely and Paracusis Willisii, intensification of sound in the presence of amplified background noise, may also be premonitory symptoms of the onset of conductive hearing loss (Carroll et al., 2017). At present, hearing loss is considered the third most frequently occurring chronic malady in the US (OSHA, 2011), exceeded only by cardiac and pulmonary diseases and twice as prevalent as diabetes and cancer (Carroll et al., 2017). In extreme cases, hearing loss may proceed to complete deafness. Unfortunately, once underway, this damaging process is untreatable and irreversible. Because intact auditory function is integral to physical and psychological and social wellbeing, early recognition of risk factors and preservation is of the utmost importance. Hearing loss may ultimately lead to depression, social isolation and loneliness, and cognitive dysfunction if left untreated (Carroll et al., 2017).

Patients in the hospital setting may be exposed to untenable levels of environmental noise. This may lead to sleep deprivation, stress, increased requirement for pain medication**,** impaired wound healing, stimulation of the SNS and potentially an increase in surgical site infections (SSIs) (Dholakia, 2015; Kurmann, 2011). Because the ill effects of sustained elevated noise on patients and healthcare workers have been well documented, the World Health Organization (WHO) has suggested standards for limiting levels of ambient noise in the healthcare environment. The WHO suggests that sound levels not exceed 35 dBA in patient rooms and acute care areas such as the intensive care units and OR, and 45 dBA in other care areas. Due to the presence of continual background noise from hospital HVAC systems, this optimistic goal may be nearly impossible to achieve.

Additionally, sustained exposure to elevated levels of noise may lead to long-term untoward health effects in the anesthetist secondary to repeated provocation of stress-related symptoms (Broom et al., 2011; Murthy et al., 1995). Table 7 summarizes the various issues attendant with increased and sustained environmental noise levels in the OR.

Table 7. Effects of Elevated Ambient Noise Levels in the OR

Untoward Effects of Increased Noise Levels
Effects on anesthetist
Impaired mental efficiency
Impaired short-term memory
Decreased concentration
Decreased vigilance/situational awareness
Attenuated performance
Impaired auditory processing
Deleterious long-term health effects
Effects on OR team
Impaired communication between members
Increased distraction
Effects on patient population
Increased discomfort
Interruption of care
Sleep deprivation
Increase in surgical site infections
Decreased patient safety

Noise Sensitivity and Annoyance

Human perception of and response to noise are highly variable, and have not been reliably correlated with covariates such as age, sex and socioeconomic factors (Öhrström et al., 1988). While some individuals seem unaffected by the presence of elevated ambient noise, others may lose focus, exhibit annoyance (Ramirez et al., 2002), become agitated or, in the case of misophonia, become irrationally violent. Noise annoyance may vary in the same individual based on the context of exposure. For example, the person may be unaffected by loud music in a social setting but may become agitated if comparable noise is heard while attempting to concentrate on a task or sleep.

Mood, fatigue, and overall health status may also impact perception of noise contextually. In a project produced for the Danish Ministry of Science, Technology and Innovation, Danish Electronics, Light and Acoustics Group (DELTA) developed the Genlyd[7] Noise Annoyance Model (2007). The Genlyd model is a simplistic schematic that aptly represents potential contributors to and confounding variables of noise annoyance (Fig. 13). Noise annoyance is the result of three main factors: the level and quality of the noise, the context in which the noise is perceived, personality traits and pre-existing sensitivity to and attitude regarding noise (Pedersen, 2007).

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[7] A contraction of *annoyance* and *sound* in Danish (“gene” and “lyd”, respectively)

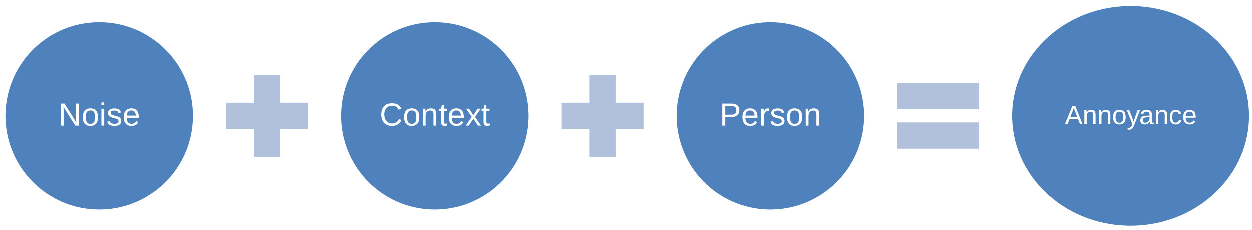

Figure 13. Components of Noise Annoyance (Genlyd Project, 2007)

Noise sensitivity and annoyance has long been a focal point in the environmental sciences. In his seminal research project, Weinstein (1978) studied the affective reaction of dormitory noise on college students and the phenomenon of noise adaptation. Using a repeated-measures design, he surveyed 155 subjects at three junctures: prior to arriving on campus, at the commencement of the school year and 7 months later. Weinstein noted individual differences in noise tolerance that paralleled specific personality traits and a predilection towards noise intolerance. Students who were prior identified as noise-sensitive exhibited marked annoyance to ambient dormitory noise ($p < .0001$) that further increased at the 7-month re-evaluation point ($p < .01$). Extroverts were more tolerant of extraneous noise throughout the course of the study while introverts expressed sensitivity and increased annoyance over time to its presence. Interestingly, noise sensitivity was also correlated with lower scholastic ability (Weinstein, 1978). These research findings culminated in the design of the Weinstein

Noise Sensitivity Scale (Appendix A), a validated and reliable tool for assessing inherent pre-disposition to noise annoyance.

Ramirez and associates (2002) reported that approximately 67% of the urban population is impacted by environmental noise exceeding 65 dB on a daily basis. Their research focused on the anger reaction to noise in 234 adolescents, aged 15-19 years. Inherent noise sensitivity was measured by responses to the Sensitivity to Noise Test (SENSIT), a tool formulated by the researchers for this project. Anger was assessed by the pre-validated State-Trait Anger expression inventory (STAXI). The researchers found a statistically significant relationship between sensitivity to noise and anger ($p < .01$). Males had a greater tendency towards anger than did females ($p = .02$), a finding not supported by previous research. Increasing age also correlated with increased anger scores ($p = .036$); results that had been elicited prior to this study. The researchers concluded "…*noise may act as a stressor causing unwanted aversive changes in an affective state, such as anger*" (Ramirez et al., 2002; pg. 0). These findings may have serious ramifications in the OR work environment, particularly as it relates to provider gender, age and interprofessional collaboration.

Early work by Öhrström and colleagues (1988) focused on noise annoyance, comparing it to physiological sensitivity to heat, cold, bright light and noise. They found that heart rate remained stable while subjects endured heat, cold, bright light and continuous white noise. Heart rate increased with exposure to loud intermittent noises. The researchers concluded that the only correlational marker of noise sensitivity was subjects' predisposition to and attitude about noise (Öhrström et al., 1988).

In her doctoral dissertation, Heinonen-Guzejev (2009) postulated a relationship between noise sensitivity as a contributing precursor to cardiovascular (CV) disease. Figure 14 depicts the effects of sustained noise on the sympathetic nervous system. Heinonen-Guzejev hypothesized that these effects may be further exacerbated in noise-sensitive individuals, placing them at increased risk for cardiovascular derangements. Other contributions to the development of CV disease emanated from stress, sleep deprivation, annoyance, genetic predisposition to CV disease and lifestyle choices.

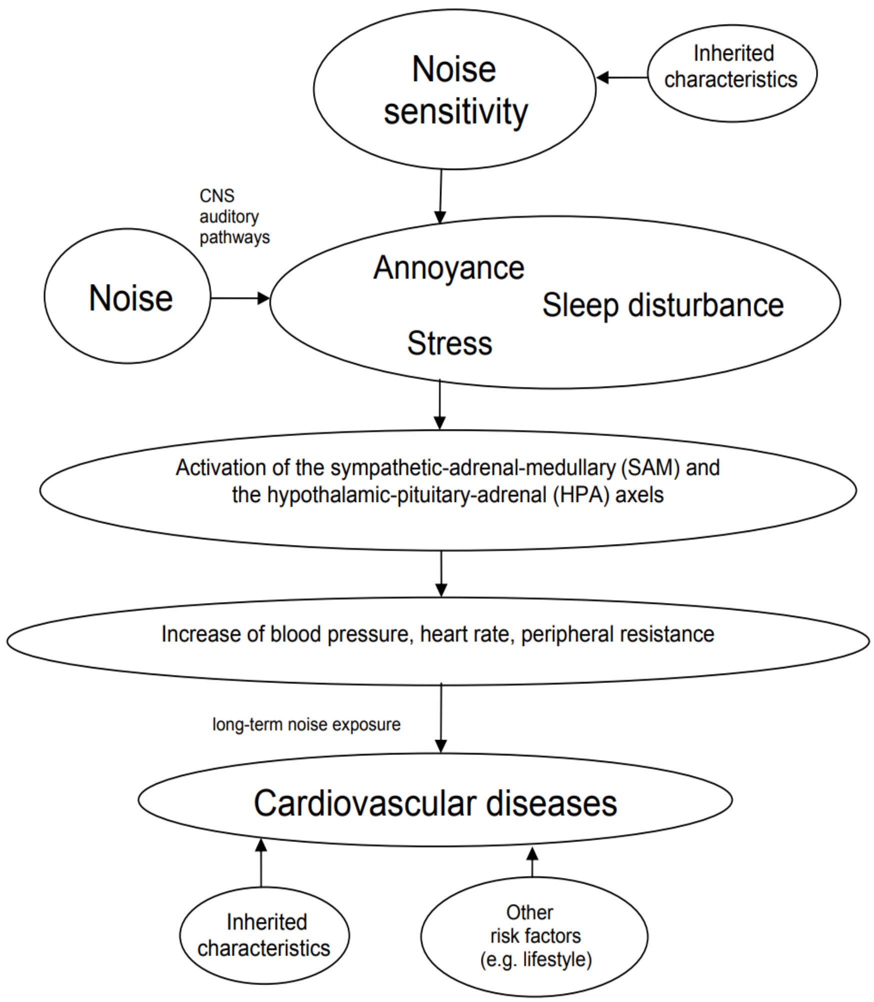

Figure 14. Proposed Relationship of Noise Sensitivity and CV Diseases (Heinonen-Gusejev, 2009)

Jastreboff & Jastreboff (2014) postulated that a significant portion of the population experiences from some form of noise annoyance and intolerance. In their work with patients suffering from decreased sound tolerance (DST), researchers observed a number of negative reactions to particular types of noise. These responses included irritation, annoyance, anger, tension, frustration, inability to concentrate, emotional distress, uneasiness, worry and stress (Jastreboff & Jastreboff, 2014). Formulating specific definitions for hyperacusis and misophonia, they proposed a treatment plan consisting of conditioning to the inciting noise(s), pink noise therapy and, in extreme cases, pharmacological intervention with anti-depressants and anxiolytics (Jastreboff & Jastreboff, 2014). A detailed list of sounds that evoke negative reactions as reported by their patients was formulated. Table 8 provides a selection of identified sounds from their work, specifically chosen due to their similarity to or representation of sounds that may be heard in the OR milieu during the intraoperative period.

Table 8. Comparison of Sounds that Evoke Negative Reactions (Jastreboff & Jastreboff, 2014) with Sounds Common to the OR Environment

Sounds that Evoke Negative Reactions	**Similar Sounds: OR Environment**
Loud rings (phone, doorbell)	Monitor alarms
Warning sounds (sirens, car horns, beepers)	Beepers, equipment alarms
Slamming doors	Multiple entrance/egress to/from OR
Sudden sounds (object dropped on a hard surface)	Surgical instrument manipulation/breakdown
Sounds of surgical instruments in an operating room	Same: orthopedic and neurologic procedures
Drilling	
Power tools	
Mechanical/motor sounds	
A musical instrument	Presence of background music
Other people singing	
Specific type of laughter	Non-essential conversation by staff
High-pitched voices	
Hum of electricity	Background electrical equipment noise (e.g. forced air heater; HVAC system)
Hum of computer	

The Effect of Noise on Human Performance

Numerous works concerning the effect of noise on human performance exist in the literature. Research emanates from multiple domains, specifically the environmental sciences, the armed forces and medicine. However, the effect of noise on performance remains a complex and controversial topic (Nassiri et al., 2013; Suter, 1989; Yoshida, 1991). Covariates such as environmental factors, fatigue, mood, inherent noise sensitivity and task complexity may confound individual performance in the presence of elevated noise. Certain types of noise may impede performance while others improve it. For example, intermittent, treble noise may deter performance whereas continuous "white" noise may actually enhance performance of simple or monotonous tasks (Dalton & Behm, 2007; Suter, 1989). Yoshida (1991) found that reaction time was best preserved within a sound range of 55 dBA. However, it was equally prolonged in both quiet (45 dBA) and noisy (75 dBA) conditions. Yoshida concluded that low-level noise may improve performance to a degree.

Helton and colleagues (2002) found that simulated jet engine noise actually increased vigilance and task performance relative to a quiet control state (Hancock & Szalma, 2008; pg 130). Dalton & Behm (2007) studied the effects of music on driving performance. Their results, although inconclusive, suggested that the presence of music relieved driver stress and aggressive behavior, possibly facilitating driver skill. However, loud volume and music with quicker tempos encouraged speeding (Dalton & Behm, 2007). In the OR environment, research dealing with the effects of music on performance remains inconclusive (Katz, 2014). Prior studies support the notion that, in some individuals, music relieves stress and may potentially enhance performance; however, Katz (2014) reports that music has the potential to increase the baseline ambient OR noise level by approximately 87 dBA. The effect on providers may be varied, ranging from soothed to productive to feelings of annoyance.

D.E. Broadbent produced seminal research regarding the effects of noise on human performance. Initially, he focused on the effects of noise on paced performance and vigilance tasks (1953). In this study, Broadbent tested subjects' ability to maintain attention and respond to changes with a light board designed to simulate a watchfulness task akin to the job of naval radar operators. His findings supported the following comment:

"As far as noise is concerned, it will be realized that the presence of an intense competing stimulus during a period of continuous performance is likely to increase the frequency of failures in attention to the task portion of the surroundings" (pg. 301).

In a subsequent study, *Effect of Noise on an "Intellectual" Task* (1958), Broadbent found that sustained exposure to elevations in noise (70 and 100 dB for 30 minutes) significantly slowed subjects' ability to perform simple mathematic subtraction. In his conclusion, Broadbent stated:

"These results suggest firstly that intellectual work as well as simple sensory tasks must be regarded as endangered by noise" (pg. 824).

Broadbent also posited that enduring sustained levels of noise could impart "harmful aftereffects" to an individual. Broadbent's influential work provides an important framework for the potential effect of noise on the anesthesia provider. Vigilance, response time and ability to perform cognitive tasks on a continuous basis are crucial factors while administering an anesthetic. As a result of Broadbent's early findings, it is clear that noise may significantly negatively impact these markers of performance.

Smith (1989) provided a thorough meta-analysis of the effects of various types of noise on performance. He speculated

"Any task involving auditory information is likely to be impaired by the presence of noise" (pg. 185).

Furthermore, listening in noise conditions could impair performance due to the requirement for additional attentional demand for auditory perception. Performance in noise conditions was found to be task-specific. Simple tasks were not found to be adversely affected, nor was reaction time. However, vigilance tasks requiring sustained attention and cognitive tasks such as short-term memory formation and retrieval were significantly adversely affected by noise (Smith, 1989). Smith also delineated effects of continuous and intermittent noise and music on performance. Table 9 summarizes Smith's meta-analysis of prior research related to noise and its effects on performance. Noise effects that may directly impact nurse anesthetist performance and/or OR team dynamics have been asterisked.

Table 9. Smith's Meta-Analysis: Key Points

Smith's Meta-Analysis: Key Points
• Loud noise (> 90 dB) produces deafness, interferes with communication*
• Moderate intensity noise (70-85 dB) increases rate of errors after sustained exposure (2 vs. 5 hours)
• Visual acuity, motor performance and simple/clerical tasks are minimally affected by noise
• Vigilance tasks are impaired during sustained exposure to noise > 95 dB*
• Irrelevant speech (55-95 dBA) impairs memory formation and disrupts complex mental tasks *
• Vocal music interrupts tasks to a greater degree than instrumental music*
• Intermittent noise produces disruption of tasks while being performed; effects are sustained after occurrence*
• Noise duration exceeding 30 minutes impairs performance*
• High frequency (treble) noise engenders error at high noise levels (100 dB)
• Noise-related errors are reduced when subjects have perceived control over the noise*
• Work-related accidents decrease and productivity is increased when ear protection is used

- Noise increases self-report of everyday errors (failures of attention, memory and action)*
- Noise inhibits cognitive ability and motivation; increases distraction and blood pressure in children
- Introverts are more susceptible to effects of noise than extraverts; extraverts may prefer higher noise levels
- Individuals prone to neuroticism and anxiety exhibit impaired recall ability in the presence of noise
- Noise slows performance in adults as compared to children; older adults exhibit increased impairment in performance as compared to younger adults*
- Noise may impair performance in inherently noise sensitive individuals; may improve performance in noise insensitive individuals (controversial)
- Noise masks acoustic cues; may mask "internal speech"[8]*
- Noise leads to increased use of lower level memory mechanisms dependent on ordered information*
- Noise increases attention to dominant sources of information; impairs recall of information from irrelevant sources
- Noise reduces helpful behavior, increases aggression, and may influence the judgment of others*

In summary, Smith's pivotal theorem was that response to noise is variable and multifactorial. Like Broadbent, Smith agreed that noise has a definitive effect on performance; however, it is variable and contingent upon the quality of the noise and the actual task performed. "*Changes in the difficulty of the task, subjects' prior experience, and changes in other task parameters may abolish or even reverse certain*

[8] Internal dialogue which aids in cognitive tasks, memory retrieval and decision-making

effects (of noise)" (Smith, 1989; pg. 200). Of the variety of noise conditions discussed, intense, sudden noises and irrelevant speech appeared to have the greatest negative impact on performance. This was of particular importance when the subject was involved in the continuous intake of new information or tasked to recall verbal cues.

Smith's points are well taken and it is acknowledged that the ability to accurately capture the effects of noise on performance in the OR is prone to confounding by multiple factors. However, key points of his analysis have been noted as they may have specific application to the population of interest in this research project. Tasks most affected by noise such as vigilance and retrieval of short-term memory closely mirror those that are carried out by the CRNA during the administration of an anesthetic in the OR milieu. Additionally, sudden noises and irrelevant speech, both of which occur frequently during the intraoperative phase, may have deleterious effects on anesthetist performance.

Noise as a Stressor. Noise has been defined as a stressor (Hancock & Warm, 1989; Kosko, 2006). Intuitively, this form of stress would inevitably constitute a detriment to performance. Yet, according to Hancock and Warm (1989), performance may actually be enhanced in the presence of low to moderate levels of stress (Fig. 15).

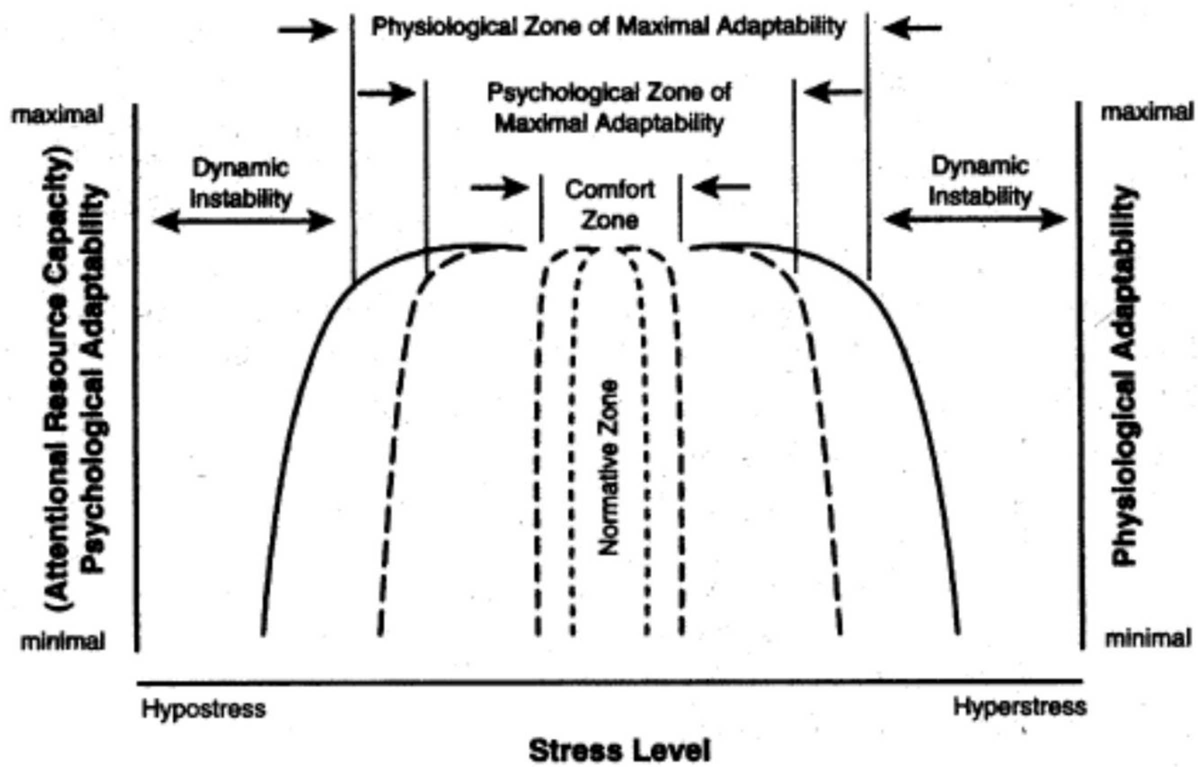

Figure 15. A Model for the Prediction of Stress Events (Hancock & Warm, 1989)

In the *Model for the Prediction of Stress Events*, stress level is depicted as an inverted "U". Psychological adaptability, A.K.A. attentional resource capacity (ARC), is used as an indicator of performance. Both psychological and physiological adaptability are at their peak when the individual functions in a state of eustress, as noted by the normative and comfort zones. However, performance during marginal hypo or hyper stress states may decline at a much earlier time than physiological adaptability. It is hypothesized that noise represents a stressor, and as such, may cause performance as operationalized by ARC to wane initially. As noise persists and/or increases, detriments to ARC are followed by deleterious effects on the individual's physical state (Hancock & Warm, 1989). Since ARC is vital to intact situation awareness and therefore performance, stress in the form of noise may initially arouse attention and increase performance. However, noise will ultimately adversely affect both psychological and physiological adaptability (Hancock & Warm, 1989).

Following Smith's seminal work, Suter (1989) completed a meta-analysis, outlining the effects of noise on various indicators of performance for the US Army Engineering Laboratory. Although she concluded that the study of noise on performance was multifaceted secondary to several impactful covariates, Suter noted that performance in many areas consistently declined when noise levels exceeded 95 dBA. Furthermore, she concluded that sustained exposure to noise conditions may produce a "reduced tolerance for frustration" and may place the individual at risk for increased anxiety states, decreasing the incidence of helpful behavior while increasing the propensity towards hostile behavior (Suter, 1989). Since the care of the patient in the OR is a collaborative effort between anesthetist, surgeon, nursing and other ancillary staff, this particular effect of noise, previously discussed by Smith, may engender poor team dynamics and SA and could potentially impact outcomes in a negative way. In the often variable and frenetic OR environment, the ability to withstand stress, control anxiety and emotions, exhibit mutual respect and cooperate with all members of the perioperative team is crucial to the success of the procedure and preservation of patient safety.

Hancock and Szalma (2008) discussed the effects of battlefield noise on military personnel. In their book *Performance Under Stress*, they focused on military troops who typically function in intense noise environments. Recurrent themes emerged when subjects were repeatedly exposed to forceful noise: communication was attenuated, performance was adversely affected and risk for permanent hearing loss was a reality. Stress from exposure to sustained levels of noise, either continuous or “battle blast” was shown to cause both physiologic and psychological debilitation (Hancock & Szalma, 2008, pg. 24). This is particularly true when noise is unexpected, a state which engages the neuroendocrine response, momentarily distracts the individual, and limits attentional resources. Unfortunately, the aural reflex cannot respond to unexpected noises in a timely manner so the propensity towards permanent hearing loss is greater when repeated exposure to intense noise occurs (Katz, 2014).

Increased stress from exposure to high levels of noise may also impact subject perception of mental workload. Warm, Dember and Hancock (1996) used NASA’s Task Load Index scale to ascertain subjects’ perceptions of workload while performing a vigilance task under varied conditions. They found that, during a basic card-sorting exercise simulating a vigilance task, subjects’ perception of workload increased in the presence of increased acoustic noise. Furthermore, vigilance waned, thereby decreasing overall performance (Hancock & Szalma 2008, pg. 119).

Nassiri and colleagues (2010) sought to find a relationship between noise and performance. Utilizing a 3 x 3 x 2 design for independent factors, they subjected 40 healthy male college students to noise conditions of varying intensity, frequency and quality during performance of simple manual tasks. Noise levels were dispersed into three groups of independent factors. Sound pressure levels were defined as 75, 85, and 95 dBA. Noise schedule was described as continuous, intermittent or fluctuating. Noise harmonic index was delineated as positive (bass) or negative (treble) frequencies. Subjects were observed for skill and speed in performing manual and tool dexterity, hand steadiness and two-arm coordination tasks during exposure to various combinations of noise conditions. Student's T test demonstrated an increased amount of time to complete the four separate tasks in the presence of noise in all skill categories: intermittent/treble/95 dB, continuous/treble/95 dB, continuous/treble/85 dB and intermittent/treble/95 dB respectively. Additionally, a decrement in hand steadiness, manual and tool dexterity, and two-arm coordination was noted across all domains. A statistically significant effect of noise on performance was elucidated with exposure to intermittent treble noise at the 95 dBA level ($p = .01$). The researchers concluded that loud, higher pitched, intermittent noise worsens environmental conditions during simple task performance. They posited that the unexpected nature of the sporadic noise caused distraction, limiting the subjects' ability to concentrate, thereby reducing human performance significantly (Nassiri et al, 2013).

Molesworth (2015) studied the effects of noise on functionality essential for workplaces requiring higher-level skills. Thirty-two subjects were subjected to simulated aircraft in-cabin noise at 75 dB. Cognitive skill was assessed by three tests: 1) recognition memory, 2) working memory, and 3) reaction time. Tests were repeated in noise conditions and after application of noise-cancelling headphones. Although working memory and reaction time were marginally impacted by the presence of noise, recognition memory was significantly negatively impacted. Scores for test item recall were increased by 26% during noise-cancelling headphone use as compared to those obtained in noise conditions ($p \leq .001$). (Molesworth, 2015).

Effects of Noise on Performance in Healthcare. The effects of noise on performance have been studied in the surgical realm. Franken et al. (2008) described the effect of noise and distraction on 12 surgical residents engaged in performing laparoscopic surgery. Subjects were trained to proficiency in the execution a simple ring transfer task prior to exposure to increased noise, visual and tactile distractions[9]. Performance was assessed subjectively via hand tool movement, proficiency, number of cognitive errors made and time taken to complete the exercise. Findings from this research demonstrated statistically significant decrements in both performance and cognitive function when laparoscopic manipulation tasks were performed in the presence of noise (Franken et al. 2008).

Siu and colleagues (2010) studied the effects of noise on twelve medical students while performing 3 surgical tasks using the daVinci® surgical system. Participants were exposed to pre-recorded OR noise and observed for skill precision via instrument tip movement, muscle activation and time taken to complete the surgical exercise. Noise was found to adversely affect time taken to complete surgical tasks ($p = .046$), increase surgical instrument distance traveled ($p = .011$) and muscle activation ($p = .015$). The researchers concluded that noise adversely affected performance, particularly during the execution of more difficult surgical maneuvers (Siu et al., 2010).

Suh et al. (2015) also studied the effects of noise distraction on proficiency in robotic surgery. Fifteen subjects were asked to perform a suture knot-tying task using the daVinci® robotic surgical system. Performance under 3 distracting noise and conversation conditions was observed: 1) passive distraction (noise: constant heart rate tone from monitor), 2) active distraction (noise: heart rate tone with subject identification

[9] Pager vibration

of changes), and 3) interactive distraction (conversation: answering math questions). Electromyography of the forearm muscles, the NASA Task Load Index[10] and Fundamentals of Laparoscopic Surgery scores were used to assess subject performance under all conditions. Statistically significant negative effects of distraction on performance of robotic surgery skills were noted across all 3 conditions for EMG measures ($p < .05$). Statistically significant adverse effects of distraction on subjective measures of surgical skill were also noted. The researchers concluded that passive, active and interactive noise distraction impaired surgical skill performance and increased muscle work while performing surgical tasks (Suh et al., 2015).

Effects of Noise on Anesthesia Provider Performance. The effects of noise on performance have also been studied in anesthesia providers. Through a series of measurements obtained within 25 cm of the anesthetist's station, Murthy and associates (1995) derived a mean baseline operating room decibel level of 77.32 dBA. They subsequently exposed 20 anesthesia residents to the predetermined noise conditions in a simulated environment over a period of 90 minutes. During exposure, subjects were administered three assays: The Trail Making Test (TMT) and Digit Symbol Test (DST) to evaluate mental efficiency and the Benton Visual Retention Test (BVRT) to assess short term memory. Their findings demonstrated that all scores evaluating mental efficiency (TMT and DST) and short-term memory (BVRT) worsened in a statistically significant fashion during exposure to noise ($p < .05$). In their conclusion, the researchers aptly stated: "*Administration of anesthesia is a task where even a*

[10] Self-assessment for mental, physical and temporal demands, effort, frustration and performance

momentary inefficiency can result in serious consequences to the patient" (Murthy et al., 1995; pg. 610). They recommended that efforts be made to reduce operating room noise.

In her doctoral dissertation, Hogan (2014) studied the effects of noise on student registered nurse anesthetists (SRNAs) undergoing computer-based anesthetic simulations. Twenty-four SRNAs were subjected to computerized scenarios of anesthetic induction and unanticipated bronchospasm. While noise adversely affected SRNA efficiency, findings were not significant. However, statistically significant deleterious effects on accuracy were noted, particularly in relation to simulated induction sequence scores ($p = .007$). When queried in a post-hoc analysis, SRNAs reported that noise interfered with mental processing and retrieval from memory, increased stress, and caused distraction (Hogan, 2014).

Enser et al. (2017) found a relationship between noise and anesthesiology residents' ability to exhibit clinical reasoning skills as measured by script concordance tests (SCTs). Forty-two anesthesia residents with differing experience levels[11] were enrolled in the study. SCTs were used to assess subjects' critical thinking and decision-making skills when confronted with various clinical vignettes. The researchers reported a statistically significant decrement in SCT scores when 1st and 2nd year residents were exposed to noise vs. quiet conditions ($p = .04$). Scores decreased only marginally in 3rd and 4th year residents, thereby failing to achieve statistical significance ($p = .60$). The researchers posited that, with increased clinical experience, the brain eventually adapts

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[11] Years 1 through 4

to noise. Enser and colleagues suggested efforts be made to mitigate noise in the OR, particularly in the presence of less experienced practitioners. Of interest, they suggested that, since the prevention of noise to produce a silent OR is an unrealistic goal, the acclimatization of anesthesia providers to noise conditions during training could offer a potential benefit (Enser et al., 2017).

McNeer and colleagues (2016) studied the effects of intraoperative noise on anesthesiology residents using a simulation-based, randomized, repeated-measures design. After the development of a "NOISE"[12] simulator, researchers subjected 20 first-year residents to quiet conditions versus a simulated clinical soundscape at a level of 76.5 dB. The soundscape was comprised of various noises commonly encountered during the intraoperative period, including monitor alarms, surgical instrument handling, pager alerts and conversation. Subjects were given the Perceived Stress Scale (PSS) prior to the start of observation sessions to ascertain their basal stress and fatigue levels; no significant differences were found between test conditions. Study participants were asked to give lunch breaks during a simulated anesthetic in both quiet and noise conditions, encountering both stable and complicated scenarios. Upon conclusion of the simulation, subjects were asked to report their impressions regarding task load during exposure to quiet and simulated clinical soundscape. The NASA Task Load Index (NASA-TLX) and the Swedish Occupational Fatigue Inventory[13] (SOFI) were used as instruments to assess residents' perception of the effects of elevated ambient noise.

[12] Noisy OR Immersive Simulation Environment
[13] Self-assessment for lack of energy and motivation, physical exertion and discomfort and sleepiness

Statistically significant increases were noted with summation of NASA-TLX and SOFI scores for noise vs. quiet conditions (p = .003). Additionally, temporal demand (via NASA-TLX) and lack of energy (via SOFI) were both statistically significantly increased (p = .0004; p = .001, respectively) in the presence of increased levels of noise. Although differences in subject self-perception of performance (via NASA-TLX) in quiet vs. noise conditions did not reach significance (p = .264), the authors concluded that noise in the intraoperative period could increase perceptions of stress (McNeer et al., 2016).

Noise and Communication

The Joint Commission cites loss of communication as a critical patient safety problem, causing the majority of medical errors that occur (Katz, 2014; Way, 2013). In the Commission's report regarding the cause the prevention of sentinel events (2005), it was estimated that 60% of serious adverse issues were the result of inadequate communication between healthcare providers (Elks & Riley, 2009). Effective communication is critical to efficient teamwork; therefore, impeding issues such as high levels of ambient noise may be linked to poor surgical outcomes (Wadhera, 2010). Additionally, noise creates a distraction resulting in diversion of provider attention. This may result in grave consequences as it has been shown to increase the incidence of human error and potentially critical incidents (Biddle, 2009; Broom et al., 2011; Endsley, 1995; Gaba, 2000; Oliviera, 2012; Wadhera, 2010).

The Lombard Effect. "*One of the first casualties of noise is conversation*" (Keizer, 2010; pg. 7). This statement aptly summarizes the effect of noise on communication between individuals. The human voice has been measured at approximately 55-60 dB during normal conversation (Keizer, 2010; pg. 7). In evolutionary terms, humans (and non-humans) have adapted to increases in ambient noise by virtue of a mechanism known as the Lombard effect. This reflex increases the amplitude of vocalization by approximately 10 dB above the surrounding sound level, in an effort to assure intact communication to the receiver of the verbal message (Hotchkin & Parks, 2013). Recalling the fact that decibels are a logarithmic manifestation of sound pressure, the 10 dB increase in vocal tone produced by the Lombard effect essentially doubles the increase in sound pressure (Kosko, 2006). Due to the presence of increased levels of ambient noise in the OR from multiple sources, the need for communication among team members is vital. In the OR, the Lombard effect has a dual impact. It can help to secure transmission of information between team members but it also introduces additional sound pressure to the already noise-laden OR environment.

The Shannon-Weaver Model of Communication. The Shannon-Weaver Model of Communication (1948) represents a simplified relationship between the sender of a message and its receiver; this may exemplify basic communication which occurs between OR staff members during the course of a surgical procedure. Information sent from the transmitter is encoded into language and transferred to the receiver. The receiver must decode the message to comprehend its meaning. Interference may occur during message transmission via the introduction of extraneous noise, thereby distorting the communication ("…*the received signal is not necessarily the same as was transmitted*." [Shannon, 1948; p.19]) and impeding the receiver's auditory processing of the message.

Although the original application of this theory was formulated for the telecommunication domain, the simplistic design of the Shannon-Weaver Model may be applied to the communication that transpires between individuals in the OR (Fig. 16).

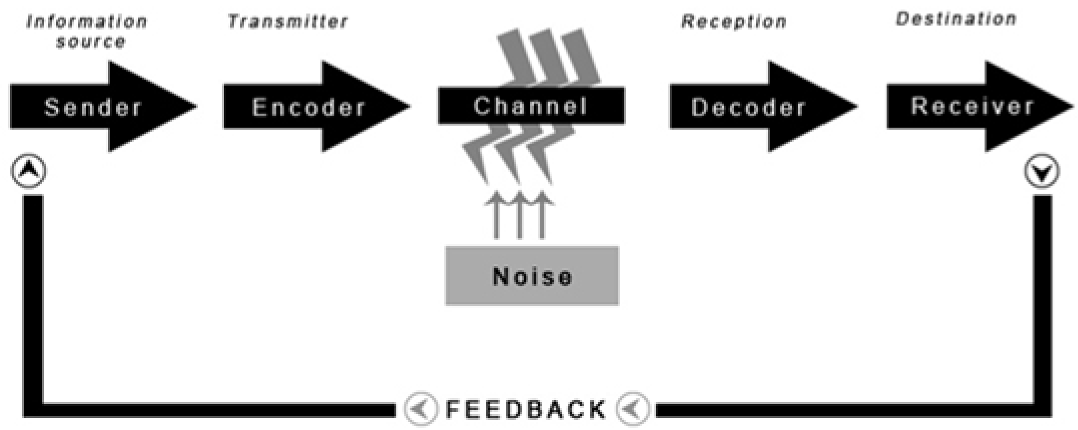

Figure 16. Shannon-Weaver Model of Communication (Shannon, 1948)

Error in transmission may be mitigated in two distinct ways. First, message integrity may be preserved via a decrease in ambient OR noise. Second, the repetition of the initial directive by the sender will increase the chance for successful transmission of the message from source to destination (Shannon, 1948; p. 22). Once decoded, response to and clarification of the sent message by the receiver may support the use of closed-loop communication in the OR, particularly in high-noise situations.

Because it is well known that miscommunication accounts for the majority of errors occurring in the healthcare domain (Katz, 2014; Way, 2013), it stands to reason that any factor which impedes communication amongst caregivers may engender error and jeopardize patient safety. In a highly dynamic environment such as the OR, interference through increased levels of ambient noise, particularly during task-dense phases of the case such as patient induction, emergence and unforeseen critical events, may lead to miscommunication and error.

Effect of OR Noise on Auditory Processing. Way and associates (2013) observed the effects of noise on auditory processing in the OR. They postulated that untenable levels of ambient noise during surgical procedures posed a threat to patient safety by engendering miscommunication amongst members of the perioperative team. Additionally, authors emphasized the loss of visual cueing that normally aids human auditory perception from obstruction of mouth movement by surgical masks in the OR. This consequence was posited to further magnify the decrement in discernment of auditory signals in the noisy OR (Way et al., 2013). In a prospective, experimental project, Way and researchers observed the ability of providers to comprehend verbal cues while encountering noisy conditions. Fifteen surgeons, ranging in operative experience from 1 to 30 years, were examined for normal peripheral hearing sensitivity prior to the study. The Speech in Noise Test-Revised (SPIN-R) was utilized to assess participants' ability to comprehend and repeat words while exposed to four contextual sound conditions: quiet, filtered noise[14], and filtered background OR noise with and without the addition of music. Research findings were statistically significant for decreases in auditory processing in noise conditions, particularly when the subject was tasked with surgical work vs. during an untasked situation ($p < .003$). SPIN-R performance was noted to be highest in quiet, unfiltered conditions ($p < .001$).

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[14] Verbal cues transmitted through a surgical mask

Researchers concluded that increased ambient noise posed a danger in the OR due to its untoward effect on communication vis à vis diminished auditory perception. This finding was of particular importance when visual cues were impeded by the presence of a surgical mask and during performance of tasks (Way et al., 2013).

Noise in the Operating Room

The presence of noise in the OR continues to be an inescapable problem. The overall effect of increased noise in the OR is hypothesized to cause attenuated vigilance, increased attentional demand and decrease SA of the provider. Therefore, these disruptions are posited to attenuate patient safety. Due to the stressful and task-dense nature of the anesthetist's role, carried out in a highly dynamic environment (Fig. 1), error and potential critical incidents may result from any issue that causes distraction. This includes the presence of extraneous noise (Gaba et al., 1994; Katz, 2014).

Environmental noise in the OR has two etiologies. The first type is unavoidable (A.K.A. essential) noise. This emanates from the use of power tools and other noise-emitting surgical equipment, ventilation (HVAC) systems, phones, pagers, computers, monitor alarms and crucial verbal communication between team members. The second type is avoidable (A.K.A. non-essential) noise. This noise is fundamentally human-driven, produced by non-critical conversation, background music, frequent entrance into and egress from the OR, and the presence of extraneous personnel (Choiniere, 2012; The Joint Commission, 2017; Katz, 2014; Way, 2013). Intraoperative noise levels also correlate to the type of procedure performed. Surgeries reliant on the use of nitrogen-driven power tools such as saws, drills and hammers yield the highest sound levels.

Noise may also originate from unintended mishaps during the manipulation of surgical equipment. Dropped instruments or rushed handling of metal pans produce sudden noise that has been shown to distract and annoy providers through stimulation of the startle response. The repercussions of this disturbance are twofold: excessive stimulation of the SNS and an inability to immediately re-engage in the task at hand (Broom, 2011; Giv et al., 2017; Smith, 1989).

It has been demonstrated through a myriad of research studies that noise has the capacity to negatively impact human performance. This is particularly true when work is carried out in a demanding environment where intact allocation of attention, vigilance, critical thinking skills, rapid decision-making, short- and long-term memory recall and sound integration and communication with team members are requisite and vital to the success of the procedure (Endsley, 1995).

There is a paucity of prior studies specifically regarding the negative effects of noise on situation awareness, an elemental metric of performance. However, functioning in the presence of excessive environmental noise has been postulated to reduce situation awareness (SA), decrease performance and negatively impact health over the long term (Endsley, 1995; Oliviera, 2012). Distraction from noise may result in grave consequences as it has been shown to increase the incidence of human error and potentially critical incidents (Biddle, 2009; Broom et al., 2011; Endsley, 1995; Gaba, 2000; Oliviera, 2012; Wadhera, 2010). The Joint Commission cites loss of communication as a critical patient safety problem, causing the majority of medical errors that occur (Katz, 2014). Effective communication is essential to efficient team dynamics; therefore, it may be impeded by factors such as high levels of ambient noise.

Similarly, teamwork is jeopardized and can ultimately lead to annoyance, frustration, team incompatibility, missed auditory cues and poor surgical outcomes (Wadhera, 2010; Way, 2013). Occupational exposure to noise in the OR may present a detriment to the health of both providers and patients alike.

Edwards (1988) proposed an ergonomic-based classification that delineated human and physical factors contributing to anesthetist workload. Constructs were divided into software (scheduling), hardware (equipment dependability and ease of use), environment and liveware (individual and team condition) domains. Noise was prominently featured as a distinct contributor to anesthetist workload in the environmental category (Leedal & Smith, 2005).

A number of studies exist concerning levels of noise in the operating room. Kracht et al. (2006) studied noise levels in the ORs of Johns Hopkins Hospital in Baltimore, MD. Researchers measured ambient noise levels, noise frequency and peak noise events, correlating them to a variety of surgical procedures. Study findings revealed that orthopedic procedures were associated with the highest average sound pressures (~66 dBA), followed by neurosurgery, urology, cardiac and gastrointestinal surgeries (~62-65 dBA). Peak sound levels were found to exceed 100 dBA. These values, comparable to the noise produced by a jackhammer at 30 meters distance, were most highly associated with orthopedic and neurosurgical procedures. Peak levels were estimated to occur during 40% of the total case duration in both procedural domains (Kracht et al., 2006).

Tsiou et al. (2008) measured ambient noise levels in the operating rooms of nine Greek Hospitals. Using a mixed-methods approach, the researchers quantified sound pressure levels from 43 surgical procedures while delineating the major etiologies of noise. Concurrently, a survey was distributed to 684 multidisciplinary members of the OR team: 391 surgeons, 74 anesthetists and 219 OR nurses. The intent was to garner opinions regarding levels and sources of ambient noise levels in the OR as well as impact on workload and performance. Methodological issues were apparent in that there was no mention of prior validation of survey items via piloting.

Noise was measured at pre-surgical, surgical and post-surgical intervals in both orthopedic and non-orthopedic procedures. The pre- and post-surgical phases appeared to coincide with induction and emergence phases of anesthesia. Maximum average sound levels were measured at 71.9 dBA across all procedures. Mean sound pressures obtained in orthopedic settings far exceeded those measured in non-orthopedic cases (68.31 vs. 63.86 dBA; $p = .000$). This statistically significant trend persisted between orthopedic and non-orthopedic cases for the majority of interval measurements ($p = .000$). The authors attributed antiquated ORs lacking sound insulation, the practice of leaving OR doors ajar to alleviate increased room temperature, machinery, surgical tools and number of people in the OR to be key contributory factors to the production of excessive ambient OR noise (Tsiou et al., 2008). Interestingly, the researchers did elicit a statistically significant difference in perceptions of ambient OR noise between surgeons, anesthetists and nursing staff, with anesthetists exhibiting the highest sensitivity to this background noise.

With regards to maximum instantaneous sound pressure level of noise in the OR, researchers reported connection and disconnection of gas supply as a major source of sudden noise. Peak levels for nitrogen cord disconnection/depressurization were measured at 106 dBA, followed by displacement of furniture (100 dBA), tools (94.8 dBA) and objects falling on the floor (94.5 dBA). These elements were deemed the four leading causes of sudden, unanticipated noise. Human-generated factors in the form of loud voices, talking or laughter were recorded at 90.2 dBA.

The qualitative arm of this research project garnered opinions from a range of OR personnel regarding the noise pollution in the OR. The survey consisted of eight items (Appendix B) assessing the presence of noise in the OR, the impact of noise on respondent work, whether noise was disturbing and perceptions of main sources of noise in the OR. Figure 17 depicts survey results. There were statistically significant differences in opinions regarding intraoperative noise pollution between the various roles of respondents. Anesthetists affirmed the presence of noise in the OR (85.1%) and sensitivity to the negative impact of noise on their work (84.1%) to a greater degree than their surgeon and nurse counterparts. Surgeon affirmation of the presence of noise in the OR and negative impact of noise on work was 65.6% and 65.8%, respectively. These views were statistically significantly different from anesthetist opinions ($p = .000$; .006). Louder conversations, machine operation and air-conditioning systems were significantly confirmed as major sources of OR noise.

Tsiou and associates concluded that noise was present in ORs and suggested application of ear protection for the noisy and often longer orthopedic procedures. They also postulated that anesthetists' magnified perception of noise in relation to their OR team peers reflected the need for their constant presence in the OR for the entirety of procedures as well as their close proximity to noise-emitting anesthesia equipment. Finally, efforts to contain conversation, adjustment of monitor alarm volume and modernization of outdated ORs to mitigate noise and facilitate communication among staff members were interventions to be considered (Tsiou et al., 2008).

TABLE I. Different opinions of surgeons, anaesthetists, and nursing personnel regarding noise pollution in the operating room. This study used 391 surgeons, 74 anaesthetists, and 219 operating room nursing personnel.

	Affirmative answers			
Questions	Surgeons[a] %	Anaesthetists[b] %	Nursing personnel[c] %	*p* value
Is there any noise in the operating room?	65.6	85.1	78.2	0.000
Do you feel that noise has a negative impact on your job?	65.8	84.1	71.8	0.006
Does noise in the operating room disturb you?	53.0	54.0	53.9	0.100
Which are the main sources of noise in the operating room?				
Conversation?	74.2	81.1	68.5	0.082
Louder conversation (such as arguments)?	30.4	60.8	48.4	0.000
Machines being operated?	21.5	41.9	57.1	0.000
External noise?	33.0	29.7	22.4	0.021
Air-conditioning systems?	16.4	25.7	30.1	0.000

[a]Consisting of surgeons and nonspecialist surgeons.
[b]Consisting of anaesthetists and nonspecialist anaesthetists.
[c]Consisting of operating room nurses or assistants.

Figure 17. Results of Greek OR Staff Opinions Regarding Noise Pollution (Tsiou et al., 2008)

A similar study by Broom et al. (2011) focused on the issues of ambient noise and misdirected attention of OR staff during critical phases of a typical anesthetic course. They examined the mean sound level during the induction, maintenance and emergence phases of 30 anesthetics, equating them to flight takeoff, cruising at altitude and landing. Their findings revealed a statistically significant increase in ambient noise levels from the induction to the emergence phases of the anesthetic (induction 46.4 dB; emergence 58.3 dB; $p < .001$). Sound pressure levels averaged 52 dB during the maintenance phase of the procedures. Researchers also drew attention to unanticipated loud noises, measured in excess of 70 dB. These distracting sounds occurred 34 times during emergence when compared with induction (9 times) and maintenance (13 times). Staff entrance into and egress from the OR was also monitored. Movement to and from the OR suite occurred 0, 6 and 10 times during induction, maintenance and emergence phases, respectively. Most significantly, conversations unrelated to the case or patient occurred during 93% of all anesthetic emergences studied. These findings induced the researchers to suggest the application of a mechanism such as the FAA's sterile cockpit rule[15] during every case, with a focus on the critical induction and emergence phases of the anesthetic (Broom et al., 2011).

Giv and colleagues (2017) evaluated the level of noise pollution in ten Iranian operating rooms. Their results closely mirrored prior studies: OR noise levels well exceeded advised standards. The highest levels of noise emanated from orthopedic procedures with maximum levels reaching 93 dBA, and the lowest noise pollution occurred during cardiac surgery and laparoscopic procedures. The most important sound sources were equipment (69 ± 4.1 dBA), trolley movement (66 ± dBA) and personnel conversation (64 ± 3.9 dBA). They concluded that increased ambient noise

[15] Limiting non-essential conversation during takeoff, landing or below altitude of 10,000 feet

posed a significant problem, particularly owing to its interference with intact, necessary communication between providers. Though equipment and trolley movement were noted as unavoidable, unnecessary dialogue between team members was cited as avoidable and a key factor in the production of extraneous noise (Giv et al., 2017).

A survey-based study by Australian researchers Elks and Riley (2009) queried anesthesiologists' perspectives on communication between OR team members. Their findings suggested that anesthetists' self-perception of communication skills ranged from average to very good (39-52% respectively). Fifty-seven percent of anesthetists agreed that good communication led to improved patient outcomes and an overwhelming 89% agreed that intact communication between OR team members decreased provider stress. Noise was briefly mentioned as impedance to good communication but was not explored further within the study.

Padmakumar and associates (2017) questioned varied members of the OR healthcare team using six simplistic, open-ended survey questions. The queries focused on the perceived effect of noise on ability to perform tasks and overall stress load. Eighty-three percent of respondents agreed that noise in the OR contributed to errors. However, this study exhibited attenuated generalizability and lack of internal consistency, validity and power. Factors contributing to these issues included a relatively small sample size, a mixed population sample of perioperative professionals, survey items that appeared to be somewhat biased and leading, and no evidence of pre-validation measure of the survey tool via piloting.

Noise Control in Healthcare. The World Health Organization (WHO) specifies that environmental noise has the capability to cause major adverse effects on communication, speech intelligibility and provider hearing. As a result, suggested guidelines for maximal noise levels for hospitals have been proposed. With respect to ambient noise in patient care areas, it has been recommended that sound pressure not exceed 35 dBA, particularly in critical care areas where patients may be increasingly vulnerable to the ill effects of noise. These include the intensive care units and operating rooms (WHO, 2014). Although a lofty goal, this level may be difficult to achieve. This researcher has measured baseline sound pressures in quiet, empty OR suites ranging from 41-46 dBA using the Sound Level Meter (SLM; NIOSH, 2018), a handheld decibel meter application for iPhone (2018). Kardous & Shaw (2014) established face validity and reliability of this handheld iOS application, finding it to be the most accurate in measuring A-weighted decibels when compared to similar handheld applications. Using a high-quality microphone and sound meter as a reference, they found the SLM accurately measured ambient sound level with a precision level of ± 2 dBA. They concluded "*for A-weighted data, the SoundLevel is the app best suited for occupational and general-purpose noise measurements*" (Kardous & Shaw, 2014; pg. EL190).

Adopting guidelines for ambient noise levels from the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA) proposes that hospitals maintain basal noise levels at 45 dBA (The Joint Commission, 2017). The National Institute for Occupational Safety and Health (NIOSH) recommends that sustained exposure to noise in the workplace be controlled below a level equivalent to

85 dBA for eight hours to minimize occupational noise-induced hearing loss (Katz, 2014; NIOSH, 2013). Despite these recommended metrics, sustained mean ambient OR noise levels have been reported to range from 40-130 dBA (Hasfeldt, 2010; The Joint Commission, 2017; Katz, 2014). Forty percent of surgical cases will reach 100 dBA due to the use of noise-emitting equipment and sounds produced by OR air exchange systems. Staff conversation and the presence of music will likely further exacerbate elevated background noise. Peak sound levels of 120 dBA, mirroring the decibel level of an ambulance siren at close proximity, have been documented in the OR due to the addition of these extraneous factors (Hasfeldt, 2010; Katz, 2014). During extreme noise conditions, sound reaches the level of discomfort at 120 dBA, a level referred to as uncomfortably loud: the threshold of pain for noise (Keizer, 2010; pg. 275; Kosko, 2006; pg. 50; NIOSH, 2018).

Theoretical and Conceptual Framework

The Importance of Situation Awareness. The ability to function in the stimulating, highly complex and ever-changing operating room environment requires adaptability and the possession of both technical and non-technical skills (Fletcher et al., 2003; Flin et al., 2010; Gaba, 2015; Leedal & Smith, 2005). Distractions such as elevated ambient noise levels may negatively impact anesthetist situation awareness (Ford, 2015). Application of the Theory of Situation Awareness provides a framework that may help to illustrate the potential adverse effects on anesthesia provider performance, particularly in the presence of external factors such as increased ambient noise levels in the OR.

Situation awareness is a cognitive construct that is crucial to the safe and effective practice of anesthesia providers as well as other individuals who function in highly dynamic settings. It is defined as the individual's perception of the events that are occurring in the environment, the capability to respond appropriately to them, and an understanding of the impact of events and interventions in the future (Endsley, 1995; Schultz et al., 2013). Within the domain of anesthesia, SA may be divided into three distinct levels (Table 10).

Table 10. The Three Levels of Anesthetist Situation Awareness (Schulz, 2014)

SA I	Knowledge and perception of current events and variables as they transpire (i.e. recognition of a change in patient status)
SA II	Comprehension of variables and their effects (i.e. appropriate treatment or intervention in response to patient change in status)
SA III	Projection of the future status of the situation based on the events that are transpiring (i.e. knowledge of potential impact of patient status if left untreated)

In addition to its application to the individual provider, SA also may be present in teams. Team situation awareness explains the relationship between team member awareness of environmental conditions, maintenance of effective communication and responsiveness, not only to the situation at hand, but also to individual and shared goals (Fig. 18). Additionally, a construct known as distributed situation awareness (DSA) further explains the team SA model with the inclusion of a non-static environment in which individuals receive input from both human (team member) and non-human (monitor) sources (Stanton, 2006).

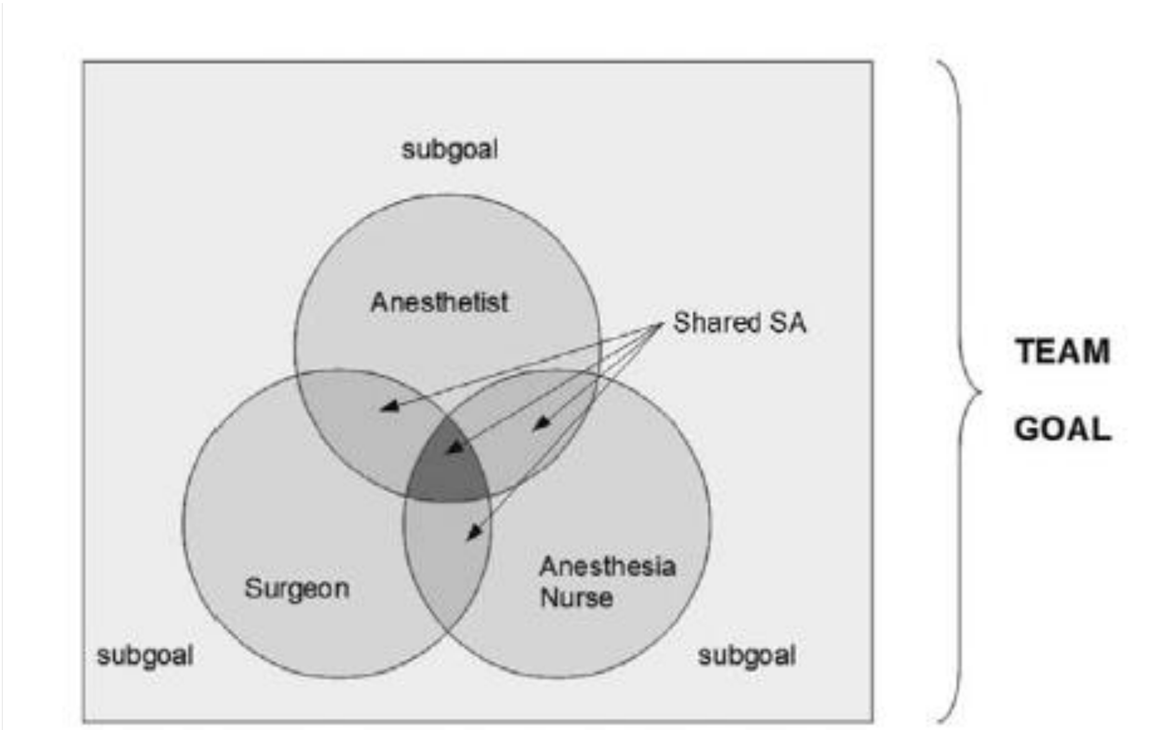

Figure 18. Team Situation Awareness in the OR (Schultz, 2013)

Application of the Theory of Situation Awareness is appropriate for this research project as it characterizes an integral element of anesthesia provider performance. All models of SA require that the anesthetist maintain intact attention, responsiveness, prior knowledge, short- and long-term memory and critical thinking skills. Issues such as high levels of noise cause a distraction that may attenuate attentional allocation and concentration to the task at hand. In turn, this will limit provider SA, representing a precursor to error that ultimately leads to critical incidents and patient injury.

According to the U.S. Coast Guard (1998), two key barriers to situation awareness are task overload and poor communication. Both issues may be the result of excessive ambient noise in the OR and can adversely affect the anesthetist's capacity to perceive urgent issues and respond to them appropriately. Distribution of attention may be diverted away from the patient and workload may increase as the anesthetist deals with additional sources of input from the environment. Furthermore, for SA to be maintained in the team model, it is imperative that the aforementioned factors coexist with preservation of audible essential discourse between members. As illustrated in the opening case study, excessive ambient OR noise has the capacity to negatively impact team communication and performance, resulting in grave consequences. In addition to the importance of anesthetist situation awareness, team integration and functionality is contingent upon intact communication between members.

Figure 19 (Endsley, 1995) depicts the relationship between CRNA situation awareness (SA) and factors that influence it. This graphic fittingly illustrates the importance of situation awareness to the practice of anesthesia. Central to the construct of SA as it relates to live-time, "working" memory are its three pillars: perception, comprehension and projection. Key to the preservation of SA is the continuous evaluation of the situation and of self-performance. If interventions are found to be inadequate, alternative solutions must be sought.

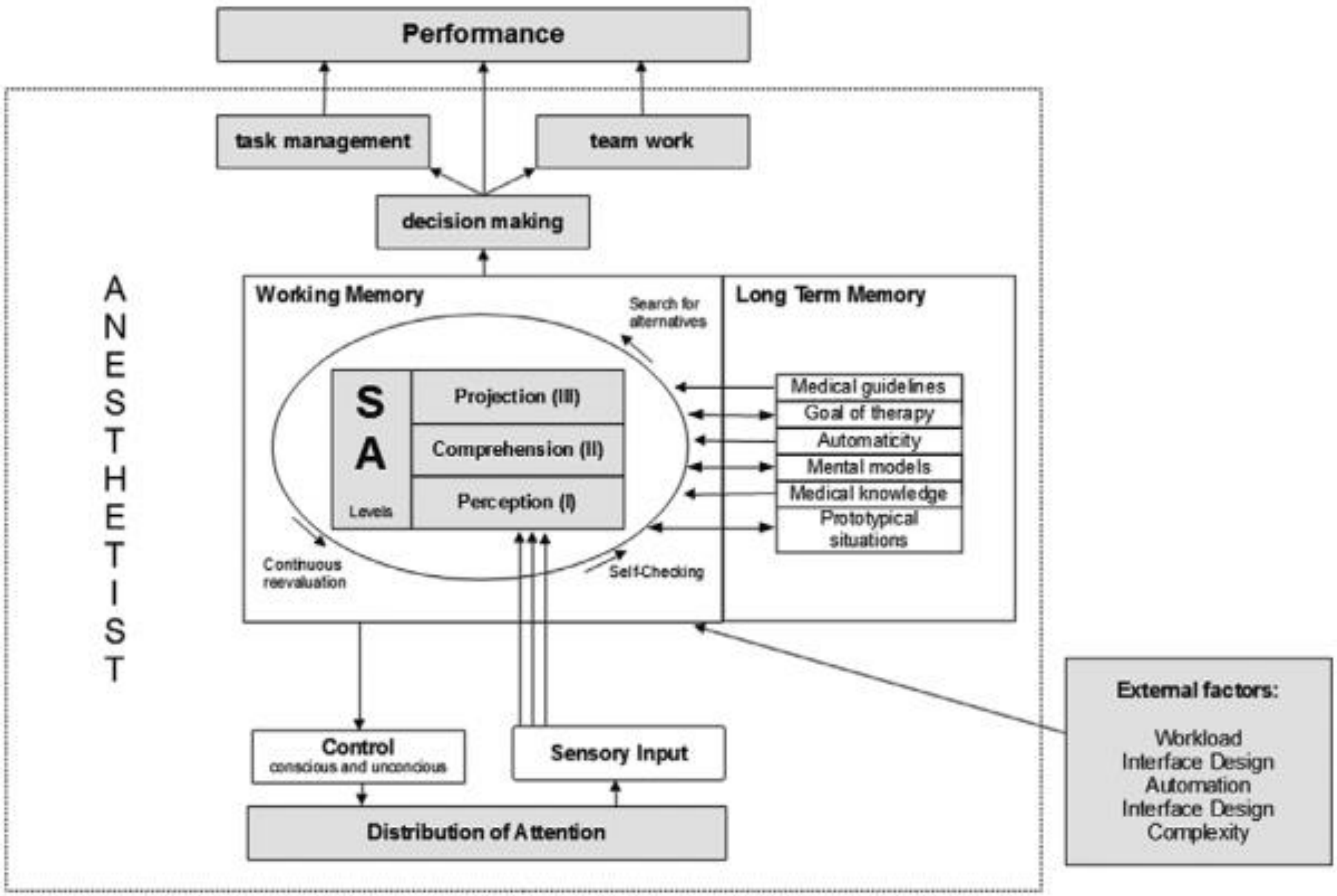

Figure 19. Anesthetist SA and Influential Factors (Endsley, 1995)

It is clear that all models of SA require that the anesthetist have appropriately distributed attention, responsiveness to events, prior knowledge, working and long-term memory and critical thinking skills. Issues such as elevated noise may be negatively impactful in a multitude of ways as it poses the following:

- Additional sensory input
- Increased mental workload
- Attenuated and/or misallocated attention
- Inadequate concentration to the task at hand
- Inability to retrieve information from long term memory
    - Disruption of mental models
    - Lack of automaticity
- Magnification of external factors
    - Workload
        - Complexity

Anesthetist performance, the pivotal concept in this framework, is ultimately operationalized by three critical factors: decision making, task management and teamwork. Since these components are tightly coupled with integral SA, it is postulated that each aspect will be negatively affected by the presence of elevated ambient noise in the OR. It has been shown that both short (working) and long-term memory, features which are an integral part of SA, are adversely affected by the presence of noise. While noise has not been consistently shown to reduce automaticity in performing simple tasks, disruption of mental models through cognitive interference does occur (Broadbent, 1958; Smith, 1989). External factors such as workload and complexity may also be affected. It is postulated that noise may potentially add to workload secondary to the increase in attentional demand of the anesthetist. Additionally, the presence of noise may hypothetically increase task complexity, again from diversion of attentional resources to increased environmental stimuli.

Application of Bacharach's Framework

Samuel Bacharach (1989) proposed a graphic representation of the relationships between the integral components of a theory: constructs, variables, propositions and hypotheses. Adaptation of Bacharach's theoretical framework to the central elements of this research project, noise, anesthetist performance and patient safety, aims to illuminate the relationship between increased levels of ambient noise in the OR, attenuation of anesthetist performance and overall impact on patient safety (Fig. 20). This underpinning is provided to support the presumption that there is an integral relationship between constructs: the OR milieu and patient safety and variables: ambient noise in the OR and CRNA performance. Through application of this framework, it is proposed that the state of the OR environment may directly influence patient safety. Likewise, the presence of noise in the OR may significantly impede CRNA performance. The construct of patient safety is tightly coupled with anesthetist performance, which may be evaluated through intact situation awareness as previously discussed.

The OR environment is subject to changes based on variations in ambient noise levels. In the presence of increased noise, anesthetist performance may be impaired through diminished situation awareness. Likewise, patient safety is integrally dependent on both the condition of the OR environment and proficient anesthetist performance.

The overall result of the presence of elevated levels of ambient noise in the OR is hypothesized to be a decrease in patient safety, with constructs and propositions bound together, interconnecting and generalizable to all OR domains. The association between the OR environment and patient safety is graphically depicted and integrated with the potential negative effect that increased levels of ambient noise are posited to have on anesthetist performance (Fig. 20).

Subjective measurement of both variables depicted, the presence of ambient noise in the OR environment and anesthetist performance, are achieved through the survey responses eliciting feedback regarding the anesthetists' perception of noise on their performance. Respondents are queried as to the presence of excessive noise in the OR and whether it diminishes performance through a self-assessment of key anesthetist attributes: execution of tasks and procedures, memory retrieval, communication with OR team members, and concentration and distractibility. The construct of patient safety is also captured via survey item as perceived by CRNA respondents.

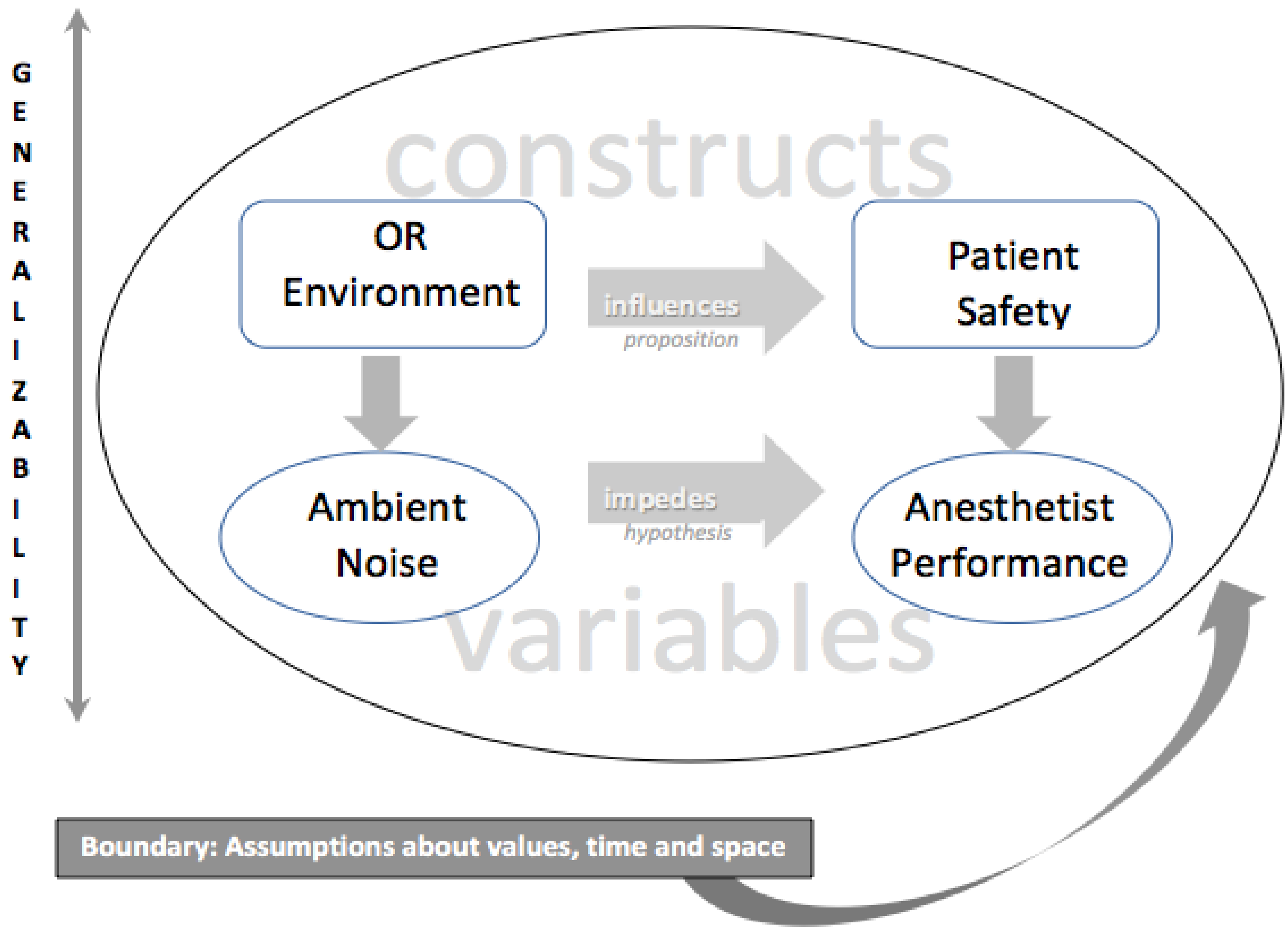

Figure 20. Project Theoretical Framework (Cosgrove, 2018; Adapted from Bacharach, 1984)

Summary

This critical review of the literature provides a comprehensive summary of noise. Noise is redefined, it is examined from an environmental and historical perspective, and its effects on human health and performance are discussed. Although it is clear that noise constitutes a definitive health problem in humans, effects on performance remain controversial. Individual response to noise is also variable and may be linked to personality traits, preconceived notions, health status or mood at the time of exposure.

Relationships between the OR environment, noise, anesthetist performance and patient safety are also outlined as a theoretical underpinning for the project with the aid of Bacharach’s framework. This model serves as the impetus for the project at large.

Chapter Three follows with a thorough review of the research project design and methodology. Survey construction and piloting will be discussed with a focus on thematic factors framing the queries. A description of data handling and review follows with the plan for tallying of results and correlation of survey questions to demographic covariates and items regarding underlying proclivity towards noise sensitivity. Finally, the non-parametric statistical analysis of data will be discussed.

Chapter 3: Research Design and Methodology

Overview

The focus of this chapter is to outline the research project design and methodology. This inquiry will be carried out via a survey of currently practicing CRNAs residing in the US regarding their perceptions of ambient noise in the OR. Survey development and design is reviewed with an emphasis on four overarching themes that provide a framework for specific query content. A description of the target population, independent and dependent variables related to the research question regarding effect of noise on performance, sampling procedure, inclusion and exclusion criteria, survey administration, statistical analyses and study limitations are discussed.

The goal of this non-experimental, quantitative, descriptive study is to contribute to the body of knowledge surrounding ambient noise in the OR and its impact in that environment. Although elevations in OR ambient noise and the effects of noise on human performance and health have been well-documented, it is uncertain whether CRNAs perceive the presence of noise in the OR to be excessive or perceive noise to be problematic in their practice, adversely affecting their individual job performance and health status. This represents a significant gap in knowledge pertaining to this issue and provides an underpinning for this investigation.

Institutional Review Board (IRB) Considerations

Permission to engage in the research project was obtained via the approval of the Institutional Review Board (IRB) through the Office of Research and Innovation at Virginia Commonwealth University in Richmond, VA. Subject permission to participate was garnered after initial questions regarding satisfaction of inclusion criteria were met.

Population of Interest: Certified Registered Nurse Anesthetists

Certified registered nurse anesthetists (CRNAs) are highly skilled advanced practice nurses who receive specialized training in the administration of all types of anesthesia. CRNAs work in a wide array of practice settings, providing services to patients across the lifespan for all procedures requiring anesthesia (AANA, 2018). The profession of nurse anesthesia originated during the Civil War. Catherine S. Lawrence was recorded as the first nurse to provide anesthesia, administering chloroform to wounded soldiers in 1861 (Ray & Desai, 2016). At present, CRNAs administer roughly 45 million anesthetics each year and are the primary anesthesia caregivers in rural America and in the US Armed Forces (AANA Practice Profile, 2018). As of August 31, 2017, the National Board of Certification & Recertification for Nurse Anesthetists (NBCRNA) quoted the population of newly certified and recertified CRNAs at 49,746 practitioners. Of these anesthesia professionals, 20,144 (40%) were male and 29,602 (60%) were female. The average overall age of currently practicing CRNAs was reported at 47.40 years with an average age of 32.76 years at the start of their career as nurse anesthetists (NBCRNA, 2018).

Sampling Procedure

An accessible convenience sample representative of the target population of CRNAs was obtained with the aid of the AANA Foundation. Through their research arm, the Foundation disseminated a pre-authorized survey instrument on behalf of the investigator to a maximum of 3000 CRNAs engaged in current clinical practice. Stratified sampling was achieved via the researcher's request for equal representation of subjects from the seven geographic regions of the US as delineated by the AANA (AANA, 2018). This uniform distribution of members garnered subjects originating from the Northeast, Midwest, South and West regions of the US. The aim of this stratified sampling scheme was to increase generalizability of findings to the CRNA population at large. In addition, it served as a comparative indicator of distribution of the sample to the overall population of CRNAs.

Sample Size

Cochran's Formula. In fiscal year 2017, the National Board of Certification and Recertification for Nurse Anesthetists (NBCRNA) reported the population of practicing certified and recertified CRNAs in the US at 49,746 (NBCRNA, 2018). Because the population of CRNAs currently practicing in the US approaches 50,000 members, survey dissemination to the entire population would be time consuming, costly and impractical. Based on the NBCRNA's current population report, the sample size was calculated via use of Cochran's formula for populations equal to or greater than 50,000.

Approximation of the sample size using Cochran's formula for estimation of a sample size offers a more feasible approach to garnering study samples as it reduces time and cost necessary to obtain data, thereby increasing overall efficiency. Sampling may also increase the accuracy of survey results (Cochran, 1953). Cochran's formula is well-suited to sample size estimation of the CRNA population at large as the data is both categorical and ordinal. Figure 21 depicts Cochran's formula for sample size estimation of categorical data.

$$n_0 = \frac{Z^2pq}{e^2}$$

n	Sample size
Z	A.K.A. Z score: the abscissa of the normal curve that cuts off a desired α level at the tails. 95% level of confidence = α 0.05 = Z 1.96
p	Estimated proportion that is an attribute of the population: 0.5 assures greatest variability
q	1-p
e	The desired level of precision or error margin. α 0.05 = 0.5

Figure 21. Cochran's Formula for Sample Size with Definitions (Cochran, 1953)

Establishment of an *a priori* alpha level of 0.05 corresponds to a precision level[16] of 5%: the frequency of response within a range of ± 5 responses. This value, coupled with a proposed confidence interval of 95%, produces an estimated sample size of 382 from the population of interest.

[16] A.K.A. margin of error

It is postulated that the *a priori* metrics will reduce the risk of violation of internal validity of the research method while increasing generalizability to other OR environments. Initial calculations utilizing Cochran's formula were subsequently verified by the use of an online calculator offered by Qualtrics (2018).

According to the AANA Foundation, the current rate of return of Internet-based surveys may range from 8-10% (AANA Foundation, 2018). Appendix C displays an email communication between the researcher and Lorraine Jordan, PhD, CRNA, Executive Director of the AANA Foundation, regarding expected Internet survey response rates. With a sample size of 382 required for generalizability, robust statistical power and a comprehensive analysis of the presence and effects of elevated noise in the operating room, the desired number of surveys to be distributed ranges between 3802 -13,000. The researcher requested a total of 3000 surveys to be disseminated which is the maximum allowable quantity as specified by the AANA Foundation.

Variables

Theoretical constructs, research project independent and dependent variables specific to research question 4 regarding CRNA perception of the effects of ambient OR noise on performance, covariates and their operationalization are delineated in Table 11.

Table 11. Constructs, Variables and their Measurement: Research Question 4

Constructs	Variables	Measured via:
OR Environment	**Independent (IV)** Ambient OR noise	CRNA perception of ambient noise in the OR: presence, level, sources and control
Patient Safety	**Dependent (DV)** CRNA performance	CRNA self-assessment of performance: memory retrieval, execution of tasks/procedures, communication with OR team, distractibility/concentration
	Covariates Respondent demographics	Respondent age/generation Years of work experience; Gender Geographical location in the US

The Survey

Function and Objective. The function of a survey is to obtain information regarding "prevalence, distribution, and interrelations of a phenomena within a population" (Polit and Beck, 2012; pg. 264). Scheuren (1997) simply describes the survey as a "method of gathering information from a sample of individuals" (pg. 9). The objective of the survey instrument developed for this research project is to assess the presence and perceived impact of intraoperative noise levels by currently practicing CRNAs in the US. Survey questions were written with several key elements in mind: simplicity, specificity, clarity and non-bias. Survey questions sought to elicit perception of various factors related to elevated ambient noise in the OR and were framed by four core themes described in the existing literature: 1) the presence of elevated levels of ambient noise in the OR; 2) the effect of elevated levels of ambient noise in the OR; 3) the source(s) of elevated levels of ambient noise in the OR and 4) the control of elevated levels of ambient noise in the OR.

Construction and Content. An exhaustive review of the literature was performed to ascertain the availability of pre-existing surveys regarding perceptions of noise. No specific survey regarding the perceptions of OR noise by CRNAs was found; therefore, the researcher designed the instrument to be utilized in this study. Prior research studies regarding perceptions of noise in healthcare yielded few directly applicable questions for use in the survey design. In one instance, survey questions distributed to members of the OR staff were found to be rudimentary multiple-choice questions which were construed as leading and biased by this author. In addition, internal consistency and validity of the survey tool was not established by the researchers prior to its use (Padmakumar, 2017).

In an alternative study, surveys were disseminated to emergency department (ED) registered nurses (RNs) to garner their opinions related to the presence and effects of ambient noise levels in the emergency room. The survey question "*Do you believe the noise in the emergency department is louder than it should be?*" was transformed from a "yes/no" query into survey item 2, a statement concerning the OR milieu: "*Elevated levels of noise are present in the operating room (OR) during the intraoperative period*." The remaining questions were not applicable to the CRNA population or germane to the OR setting. Interestingly, researchers reported wide variations in perceptions of noise and its effect on work and cognitive function as self-reported by ED RNs. Ambient noise in the ED was generally perceived as low and found not to significantly impact nursing workload, cognitive function or patient healing. However, a clear relationship between perception of frequency of excessive noise in the ED and increasing years of RN work experience was elicited. Experienced RNs consistently rated noise in the ED as occurring Frequently or Always louder than it should be (Graneto & Damm; 2013).

These findings contrast the work of Morrison et al. (2003) who studied the effects of ambient noise on RNs in the pediatric intensive care unit (PICU). Higher levels of ambient noise in this setting were shown to increase RN heart rate (p = .014). The Specific Rating of Events Scale assessed feelings of annoyance and stress[17]. This instrument, developed for use by the US Army, rates potential stress-provoking events on a scale of 1 to 100: “not at all stressful/annoyed” to “most stress/annoyance possible”. Both annoyance and stress were reported by PICU RNs to be significantly increased in noisy environments (p = .016, .021 respectively). However, increased years of nursing experience correlated with decreases in heart rate, even when measured in noisy conditions (Morrison et al., 2003). Of note, the Events Scale was examined for potential survey questions for this study. None were found to be applicable. However, the delineation of respondent age and years of work experience as covariates were included in the survey demographic information.

An additional survey entitled *Noise Pollution: A Health Hazard*? was elicited from the literature search. This instrument was designed to assess respondents’ comprehension of noise pollution in the home and neighborhood environment; thus, items were deemed non-applicable to this research project. Two pre-validated surveys, the Weinstein Noise Sensitivity Scale (Weinstein, 1978; Appendix A) and the NoiSeQ Scale (Schutte, 2007; Appendix D), did inform the development of survey questions

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[17] A.K.A. the Impact of Events Scale (IES)

regarding tendency towards noise annoyance. Survey item 7, "*I am normally sensitive to noise*", was garnered directly from the Weinstein Scale. The Situation Awareness Rating Tool (SART) (Taylor, 1990; Appendix E) was examined for questions dealing with workload, task performance and attentional demands. Survey items regarding the effect of noise on memory, task performance and communication were modeled after pre-validated SART items.

The final survey tool developed for this project consisted of the following:

- One query establishing inclusion criteria regarding identification as a CRNA and engagement in current clinical practice in the OR,
- Nineteen rank scaled thematic questions,
- One open-ended question,
- Four demographic questions (Appendix F).

Sixteen queries were posed as definitive statements. One question sought a comparative rating of the importance of four potential contributors to avoidable noise in the OR. One question aimed to identify CRNA perception of the quality of ambient noise typically encountered on a daily basis in the OR. One question was open-ended, requesting additional comments from survey respondents related to the construct of interest. The intent of this question was to allow for further elaboration on and inclusion of detailed perceptions regarding ambient noise in the OR. It was posited that remarks garnered will provide deeper insight beyond the scope of the predetermined survey questions and a potential framework for future research.

The statement questions were designed for use of a Likert scale for responses. The Likert Scale, developed by Rensis Likert in 1931, is described as "*a set of items, composed of approximately an equal number of favorable and unfavorable statements concerning the attitude object…*" (Gliem & Gliem, 2003; pg. 82). For this research project, the construct or "attitude object" is operationalized as noise and the Likert scale was well suited to aptly depict both positive and negative responses to the survey items. Although this study sought qualitative answers regarding the presence and effects of intraoperative noise, evaluation through frequencies and bivariate correlation of specific quantitative responses was planned to report findings. Mean values of rankings are not used in correlational analyses; however, they are reported with frequencies to provide directionality to survey item response.

The response scale consists of five possible rank choices: 1-5. A rating of 1 corresponds to a response of Never while the rating of 5 corresponds to a response of Always. Rather than allow the middle integer to represent a non-committal, neutral rating, the rating of 3 will be labeled as *Sometimes* (Table 12).

Table 12. Likert-type Ratings and Corresponding Answers (from Sullivan & Artino, 2013)

1	**2**	**3**	**4**	**5**
Never	Rarely	Sometimes	Often	Always

Integration of Survey Items and Themes. The survey tool design aims to elucidate four central themes garnered through a systematic literature review regarding noise in the OR:

1) The presence and perception of elevated levels of ambient noise in the OR
2) The effect of elevated levels of ambient noise in the OR (on health and performance)
3) The source of elevated levels of ambient noise in the OR
4) The control of elevated levels of ambient noise in the OR

An additional query regarding the perception of the category of ambient OR noise was included using the OSHA guidelines for noise exposure as a reference point for descriptors (Fig. 4; pg. 36). Table 13 depicts the overarching themes operationalized through a series of corresponding survey questions.

Table 13. Survey Questions and Corresponding Themes

Survey Question Theme	Survey Questions (Q)
The presence of elevated levels of ambient noise in the OR	1) Elevated levels of ambient noise are present in the operating room (OR) during the intraoperative period 2) Elevated levels of ambient noise in the OR are consistent throughout the course of the anesthetic. 3) Elevated levels of ambient noise in the OR are highest during the induction phase of the anesthetic. 4) Elevated level of ambient noise in the OR are highest during the emergence phase of the anesthetic. 5) Elevated levels of ambient noise in the OR are a problem.
The effect of elevated levels of ambient noise in the OR on health and performance	6) I am normally sensitive to noise 7) I am adversely affected by elevated levels of ambient noise in the OR 8) I find it difficult to perform tasks and procedures in an environment where ambient noise exists

	9) I find it difficult to remember things in the presence of elevated levels of ambient noise in the OR 10) Elevated levels of ambient noise in the OR limit my ability to effectively communicate with members of the OR team 11) Elevated levels of ambient noise in the OR cause a distraction which limits my ability to concentrate 12) Elevated levels of ambient noise in the OR negatively impact my health 13) Elevated levels of ambient noise in the OR pose a threat to patient safety 14) Elevated levels of ambient noise in the OR contribute to adverse patient outcomes
Control of elevated levels of ambient noise in the OR	15) Elevated levels of ambient noise in the OR are controllable 16) Efforts should be made to control levels of ambient noise in the OR
Avoidable (A.K.A. Contributory) sources of elevated levels of ambient noise in the OR	17) On a scale of 1 to 4, rank these potential contributory sources of ambient noise in the OR from the MOST (4) to the LEAST (1) impactful: Presence of music; OR; Number of bodies in the OR; Non-essential conversation; Multiple entries and exits to and from the
Perception of quality of ambient noise in the OR	18) My perception of the typical level of ambient noise in the operating room is: (select one) Barely audible __ Very quiet __ Quiet __ Moderately loud ___ Very loud ___ Uncomfortably loud ___ Painfully loud ___

Research Questions and Hypotheses

The following research questions and hypotheses provide an underpinning for survey elements:

1) Are levels of ambient noise in the operating room perceived as excessive by certified registered nurse anesthetists (CRNAs)?

$\mathbf{H_0}$: Levels of ambient noise in the operating room will not be perceived as excessive by CRNAs.

H_1: CRNAs will report excessive levels of ambient noise in the operating room.

2) Is excessive ambient noise in the operating room perceived as problematic by CRNAs?

H_0: Excessive ambient noise in the operating room will not be perceived as problematic by CRNAs.

H_1: CRNAs will perceive excessive levels of ambient noise in the operating room as problematic.

3) Do CRNAs perceive levels of ambient noise in the operating room to be inappropriately elevated during the critical induction and/or emergence phases of the anesthetic?

H_0: Levels of ambient noise in the operating room will not be perceived as being inappropriately elevated during the critical phases of the anesthetic by CRNAs.

H_1: Levels of ambient noise in the operating room will be perceived as being inappropriately elevated during the critical phases of the anesthetic by CRNAs.

4) Do CRNAs perceive that ambient noise in the operating room adversely affects self-performance?

H_0: CRNAs will not perceive ambient noise in the operating room as having an adverse effect on self-performance.

H_1: CRNAs will perceive ambient noise in the operating room as having an adverse effect on self-performance.

5) Do CRNAs perceive that exposure to ambient noise in the operating room over the long term adversely affects personal health?

H_0: CRNAs will not perceive exposure to ambient noise in the operating room over the long term to have an adverse effect on personal health.

H_1: CRNAs will perceive exposure to ambient noise in the operating room over the long term to have an adverse effect on personal health.

6) Are there variations in response to increased levels of ambient noise based on CRNA age/generation and years of work experience?

H_0: CRNAs will not vary in their response to elevated ambient noise in the OR regardless of age/generation and/or years of work experience.

H_1: CRNAs will report varying responses to elevated ambient noise in the OR based on age/generation and/or years of work experience.

7) Do CRNAs support the institution of noise abatement modalities in the operating room?

H_0: CRNAs do not support noise abatement modalities in the operating room.

H_1: CRNAs support noise abatement modalities in the operating room.

8) Does inherent noise sensitivity correlate with CRNA perceptions regarding the presence and effects of ambient noise in the operating room?

H_0: Inherent noise sensitivity does not correlate with CRNA perceptions regarding the presence and effects of ambient noise in the OR.

H_1: Inherent noise sensitivity correlates with CRNA perceptions regarding the presence and effects of ambient noise in the OR.

Association between survey items and corresponding research questions is depicted in Table 14: Crosswalk: Research Questions and Assessment Modalities.

Table 14. Crosswalk: Research Questions and Assessment Modalities

Research question	**Assessment via**
1) *Are levels of ambient noise in the operating room perceived as excessive by certified registered nurse anesthetists (CRNAs)?*	Survey items 2, 18
2) *Is excessive ambient noise in the operating room perceived as problematic by CRNAs?*	Survey items 5, 13, 14
3) *Do CRNAs perceive levels of ambient noise in the operating room to be inappropriately elevated during the critical induction and/or emergence phases of the anesthetic?*	Survey items 3, 4
4) *Do CRNAs perceive that ambient noise in the operating room adversely affects self-performance?*	Survey items 7, 8, 9, 10, 11
5) *Do CRNAs perceive that exposure to ambient noise in the operating room over the long term adversely affects personal health?*	Survey items 7, 12
6) *Are there variations in response to increased levels of ambient noise based on CRNA age/generation and years of work experience?*	Correlation #1: Survey items 2-16 with covariates
7) *Do CRNAs support the institution of noise abatement modalities in the operating room?*	Survey items 15, 16
8) *Does inherent noise sensitivity correlate with CRNA perceptions regarding the presence and effects of ambient noise in the operating room?*	Correlation #2: Survey item 6 with items 2-16

Demographics

Demographic data will be collected from respondents with two overarching goals: 1) To assess whether the sample is representative of the overall population (gender and geographic location) and 2) To elicit potential relationships between perceptions of noise in the OR and the group queried (age, years of work experience). The research question and hypotheses for these queries are as follows:

Goal 1: *Does the sample of respondents adequately represent the population of CRNAs with regard to gender and geographic location in the US?*

$\mathbf{H_0}$: The sample of respondents adequately represents the population of CRNAs with regard to gender and geographic location in the US.

$\mathbf{H_1}$: The sample of respondents does not adequately represent the population of CRNAs with regard to gender and geographic location in the US.

Goal 2: *Does age/generation and/or years of work experience correlate with perceptions of ambient OR noise?*

$\mathbf{H_0}$: There will be no relationship between age/generation and/or years of work experience of CRNAs and perceptions of OR noise.

$\mathbf{H_1}$: There will be a relationship between age/generation and/or years of experience of CRNAs with perceptions of OR noise.

Covariates. The following covariates will be elicited from survey responses:

Respondent gender: Requesting this demographic marker is purely exploratory and aims to elicit whether the sample of respondents is adequately representative of the

CRNA population as reported by the NBCRNA (2018). Queries for gender include "*Male,*" "*Female*" or "*Other.*" Survey participants will be given the option to opt out of answering this question with the inclusion of response choice "*Would prefer not to answer*."

Respondent geographic region in US. Information garnered through this question is simply exploratory as it aims to assess the degree of distribution of respondents throughout the US. Responses received from a wide distribution would best represent the CRNA population and potentially increase generalizability of results. Regions of the US and corresponding states as delineated by the American Association of Nurse Anesthetists (AANA) are depicted in Table 15. Puerto Rico (PR), located in AANA Region 1, will be excluded from this study as it is considered an unincorporated territory of the US. Issues regarding possible language barriers with item misinterpretation and/or the inability of respondents to comprehend survey queries will also be avoided with this exclusion.

Table 15. AANA Geographic Regions of the US (AANA, 2018)

AANA Region	**States Included in Region**
1	CT, MA, ME, NH, NJ, NY, RI, VT (PR)
2	GA, KY, NC, SC, TN, VA, WV
3	IL, IN, MI, WI
4	AR, IA, KS, MI, MN, OK, NE, ND, SD
5	AK, AZ, CA, CO, HI, ID, MT, OR, NM, NV, UT, WA, WY
6	DC, DE, MD, OH, PA
7	AL, LA, FL, MS, TX

***Respondent age**:* Age will be matched to a corresponding generational group with the intent of eliciting relationships between perceptions of intraoperative noise and age and generation. Age ranges matched with generational groupings are depicted in Table 16.

Table 16. Survey Age Ranges and Generations (adapted from Zickuhr, 2011)

Age Range (years)	**24-34**	**35-46**	**47-56**	**57-65**	**> 65**
Generation	Millennial	Generation X	Young Baby Boomer	Older Baby Boomer	Silent Generation

***Respondent years of experience as a CRNA**:* Eliciting this demographic information aims to correlate perception of noise with years of practice experience. Categories of years of experience are detailed in Table 17.

Table 17. Years of Experience as a CRNA: Categories

Years of Experience as a CRNA	0-5	6-10	11-15	16-20	21-25	> 25

Survey Piloting

Prior to formal launch, a pretest of the survey instrument was achieved by dissemination to a focus group of 30 CRNAs. The objective of this exercise was to identify potentially ambiguous questions and other unanticipated problems that may arise with the survey design. Furthermore, piloting provides a means to ascertain quality as operationalized through face, content and construct validity as well as measurement reliability and practicality of survey items. Potential redundancy of questions may also be uncovered through pre-launch piloting.

According to Perneger et al. (2014; pg. 1), "*small samples (5-15) participants that are common in pre-tests of questionnaires may fail to uncover even common problems. A default sample size of 30 participants is recommended*." Guided by Perneger's recommendation, the researcher utilized a convenience sample of 30 CRNAs currently engaged in clinical practice throughout the state of Connecticut. Practice locations included the Yale New Haven Hospital York Street and St. Raphael campuses in New Haven, CT, St. Francis Hospital and Hartford Hospital in Hartford CT, and St. Mary's Hospital in Waterbury, CT. Prospective candidates were initially contacted via email, direct phone call or in-person communication to garner permission to participate in piloting of the survey. Focus group members, considered experts in the field of nurse anesthesia, met two inclusion criteria: 1) consent to participate in the pilot and 2) current engagement in clinical practice in the OR. An email with the link to access the survey followed when both inclusion criteria were met.

Since the final survey instrument was planned for delivery to participants via the Internet, the pilot utilized SurveyMonkey, Inc. (San Mateo, CA, 2019), a readily available and relatively inexpensive online survey service. SurveyMonkey, founded in 1999 and ranked as #13 on the Forbes Cloud 100 list (Konrad, 2018), is well known for its dependability, clear and visually pleasing graphics and ease of utilization by both survey designer and end-user. This platform was chosen for this project for those reasons and the ability to customize the survey page header with the VCU logo and export data directly into a variety of statistical analysis software platforms (i.e. Excel and SPSS).

Incidentally, SurveyMonkey is the same Internet-based service used by the AANA Foundation to deliver their surveys.

Piloting of the survey garnered 30 completed responses from the panel of experts. The estimated time to complete the survey was 5 minutes, 51 seconds. This information prompted an increase in estimated time to complete to 6 minutes on the survey invitation. Notably, two respondents' email addresses were tagged as having provided incomplete submissions. Upon further inspection, response data for all survey items had been logged for both subjects; however, both failed to click on the "DONE" button at the conclusion of the survey. This potential problem prompted the inclusion of the following message on the last screen of the finalized survey:

***Don't forget to click the "DONE" button below before exiting as your responses will not be received! ***

Cronbach's Alpha. For the survey items ranked using the Likert scale, Cronbach's alpha (Cronbach, 1951) was employed as the parametric test for survey item internal consistency, reliability, construct, content and face validity. Alpha is expressed as a value ranging from 0 to 1; acceptable values for uniformity of questions range from 0.7-0.95 (Tavakol & Dennick, 2011). Values below 0.7 are regarded as questionable and < 0.5 as unacceptable (Hulley, 2013; pg. 230). Table 18 delineates the relationship between Cronbach's alpha values and corresponding levels of internal consistency.

Table 18. Cronbach's Alpha and Levels of Internal Consistency (Statistics Solutions, 2018)

Cronbach's alpha	Internal consistency
α ≥ 0.9	Excellent
0.9 > α ≥ 0.8	Good
0.8 > α ≥ 0.7	Acceptable
0.7 > α ≥ 0.6	Questionable
0.6 > α ≥ 0.5	Poor
0.5 > α	Unacceptable

Low values may depict heterogeneity of survey constructs, poor interrelatedness of survey items or an inadequate number of items examined. Although higher values may indicate consistency of survey questions, construct and face validity, they may occasionally indicate item redundancy (Tavakol & Dennick, 2011). Table 19 provides a review of the four overarching survey themes ranked through Likert scaling and number of items in each category.

Table 19. Survey Item Thematic Categories and Number of Items

Survey Item Themes	Number of Survey Items (Likert scale)
The presence of elevated levels of ambient noise in the OR	5
The effect of elevated levels of ambient noise in the OR on health and performance	8
Avoidable (A.K.A. Contributory) sources of elevated levels of ambient noise in the OR	1
Control of elevated levels of ambient noise in the OR	2

Since the *avoidable (contributory) sources* and *control of elevated levels of ambient noise in the OR* categories possessed an inadequate number of survey questions to be reliably tested thematically by Cronbach's alpha, the assessment was performed initially for 2 latent variables: the *presence of elevated levels of ambient noise* (5 survey items) and *effects of elevated levels of ambient noise in the OR* (8 survey items). All Likert-rated survey items were ultimately tested with the overarching construct of perception of ambient OR noise. Statistical analyses for Cronbach's alpha for both thematic groups and all Likert-ranked questions were performed with IBM SPSS Statistics for Windows, Version 25.0. (IBM Corp., 2018).

Survey Pilot Results

The presence of elevated levels of ambient noise. Survey items Q1, Q2, Q3, Q4, Q5 (Table 13; pg. 102) regarding the presence of elevated ambient OR noise were assessed for internal consistency. Cronbach's alpha yielded the following results:

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.557	.549	5

The resulting alpha, .557, indicated poor internal consistency for this thematic category. Removal of survey Q2: *Elevated levels of ambient noise in the OR are consistent throughout the course of the anesthetic* increased alpha to .584; however, this value remained unacceptable. It was unclear if the limited number of thematic questions yielded the low alpha value; there is little consensus in the statistical literature as to the minimum number of items to be reliably tested by Cronbach's. Pallant (2007; pg. 95) suggests that when validating internal consistency of less than 10 survey items, use of the mean inter-item correlation may be employed for further assessment. A mean inter-item correlation of .2-.4, would indicate an acceptable internal consistency of survey items tested. Upon further inspection, this value for the presence of noise factors thematic category was .35672, deeming those items acceptable for retention in the final survey.

The effects of elevated levels of ambient noise. Survey items Q7, Q8, Q9, Q10, Q11, Q12, Q13, Q14 (Table 13; pg. 100) regarding the effects of elevated of ambient noise were assessed for internal consistency. Cronbach's alpha yielded the following results:

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.882	.888	8

This thematic assay yielded an alpha of .882, indicating excellent internal consistency. Cronbach's increased to .891 with the removal of Q12: *Elevated levels of ambient noise in the OR negatively impact my health*. However, since the initial alpha value was deemed to be adequate, this survey item was retained to provide an additional exploratory data point.

Finally, all Likert items (Q1 through 16) were tested for Cronbach's alpha with the *perception of ambient OR noise* as the latent variable. Reliability statistics for this overarching construct of the research project were as follows:

Reliability Statistics

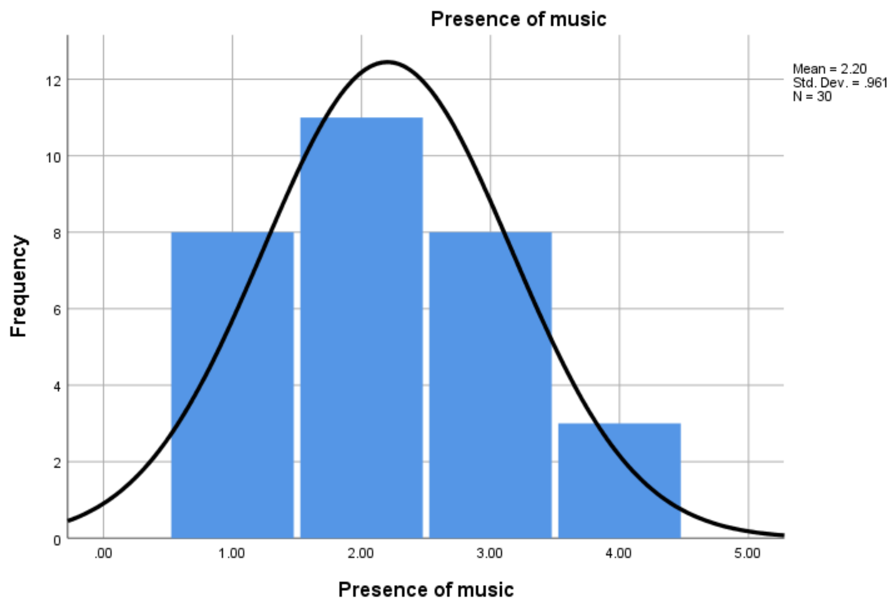
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.857	.851	16

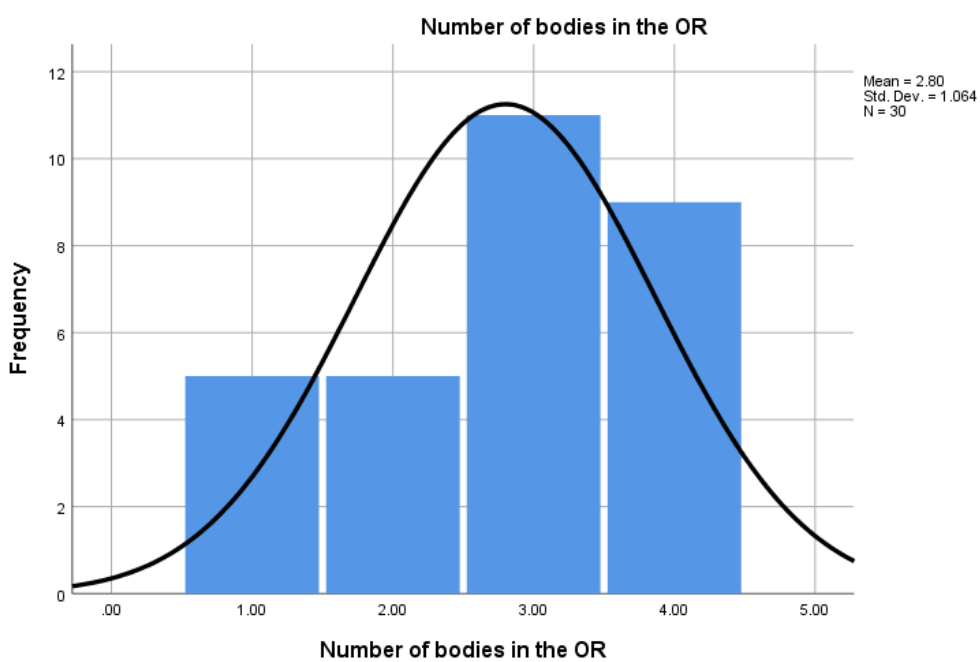
Removal of Survey Q2: *Elevated levels of ambient noise in the OR are consistent throughout the course of the anesthetic* subsequently resulted in an increase in alpha to .873. Since removal of this item was prior identified as improving alpha in the *presence of elevated levels of noise* thematic category, it was ultimately eliminated from the final survey.

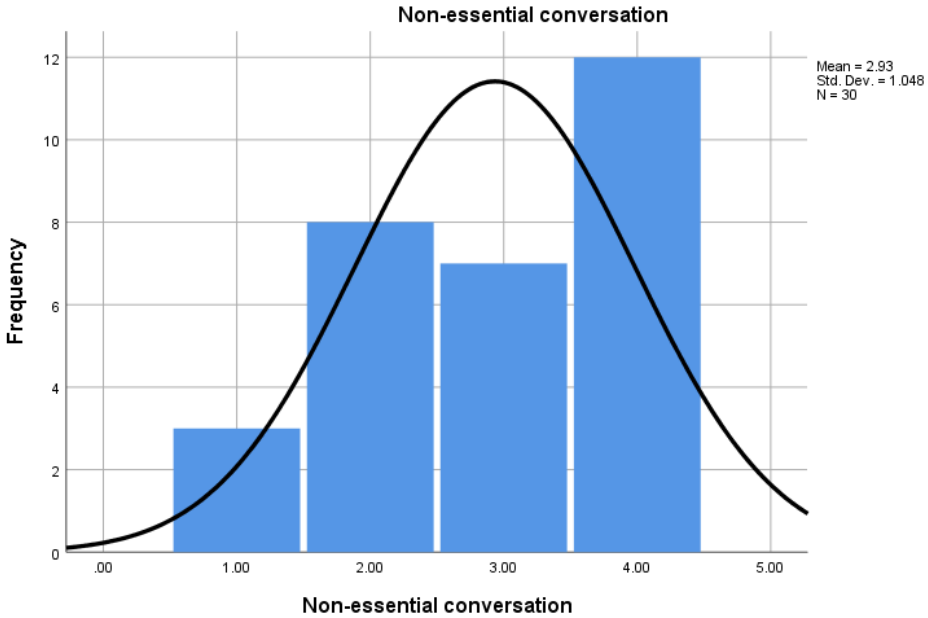
In addition to the initial query assessing inclusion criteria and items depicting demographic variables, the following survey questions were excluded from reliability testing due to the use of alternative scoring mechanisms:

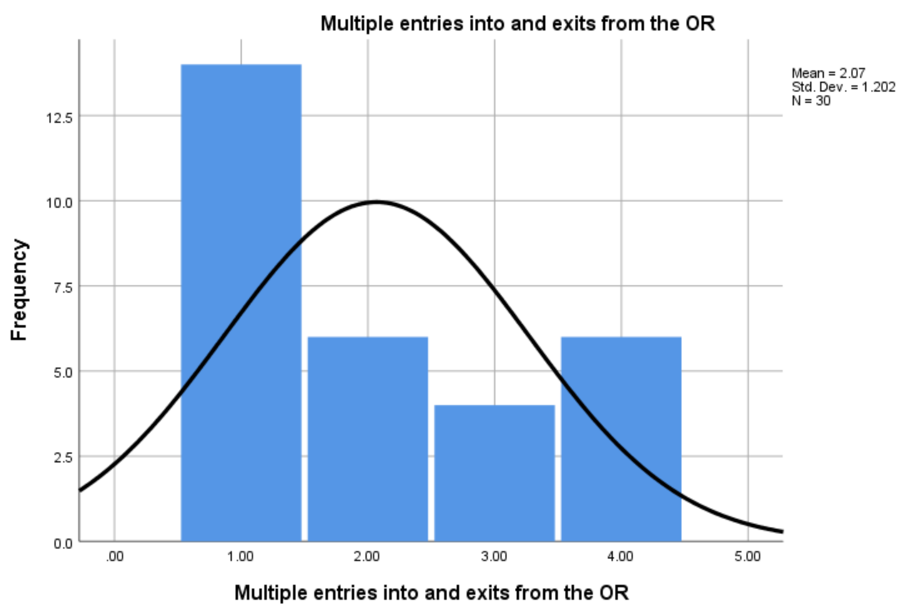
- *Q17: Rank these potential contributory sources of ambient noise in the OR from the MOST (4) to the LEAST (1) impactful:* Presence of music, Number of bodies in the OR, Non-essential conversation, Multiple entries into and exits from the OR.
- Q18: *My perception of the typical level of ambient noise in the operating room is: (*select one*)* Barely audible, Very quiet, Quiet, Moderately loud, Very loud, Uncomfortably loud.

Histograms of responses to both queries were performed to assess normalcy of distribution of responses. Regarding the ranking of potential contributory sources of ambient OR noise (Q17), presence of music was normally distributed while number of bodies in the OR and non-essential conversation were slightly negatively skewed. The multiple entries into and exits from the OR category was bimodal and slightly positively skewed.

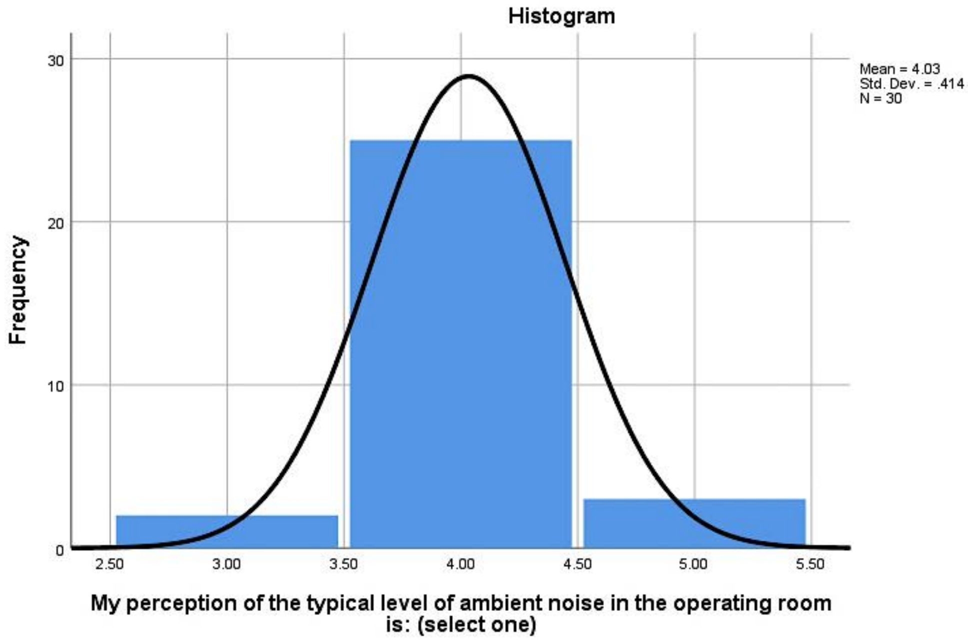








With regards to the perception of the typical level of OR noise encountered by CRNAs, responses ranging from barely audible to painfully loud were normally distributed.



The final survey question was open-ended, included to elicit free-texted comments from respondents regarding additional perceptions of ambient OR noise that may not have been adequately captured within the constraints of pre-designed survey items. Therefore, it was not eligible for inclusion in analysis by Cronbach's alpha.

Although a Cronbach's α level of ≥ 0.8 suggests excellent internal consistency, questions garnering values of ≥ 0.7 would have been deemed as acceptable retained in the survey instrument. Those items garnering alpha of < 0.7 were scheduled for removal from the survey completely. In the event that a large number of survey items were indicated for removal, a Delphi technique would have been employed to establish validity of the items in question. This technique employs dissemination of survey questions to experts in the field of the constructs studied and collating their judgments regarding the validity of the items (Polit and Beck, 2012; pg. 267). In the case of this research project, content experts include CRNAs engaged in current clinical practice.

Benefits of application of the Delphi technique include eliciting group consensus from a panel of experts which demonstrates the validity of survey questions that may have garnered a substandard Cronbach's alpha. However, there are major drawbacks associated with use of this technique. Repeated rounds of enquiry as to survey item strength may potentially result in the attrition of recruited experts. To date, there is no consensus as to the acceptable number of experts for review. Finally, consensus-building through multiple rounds of questioning can be laborious and time consuming. (Polit & Beck, 2012; pg. 268; Hsu & Sandford, 2007). Fortunately, for this research project, construct, face, and content validity and internal consistency were supported by robust Cronbach's alpha.

Sampling Strategy

Inclusion and Exclusion Criteria. Figure 22 outlines the varied eligibility criteria for inclusion in or exclusion from the study. The AANA Foundation emailed prospective research participants an invitation to participate in the project on behalf of the researcher (Appendix G). This document clearly states the rights of the participant, the description and intent of the research, the approximate time that the survey will take to complete, and the opportunity for the respondent to opt out and close the survey at any time should they decide not to proceed. With survey item 1, respondents were prompted to verify an introductory statement regarding inclusion criteria before entry into the survey tool:

"I am a Certified Registered Nurse Anesthetist in the US currently engaged in active clinical practice."

Active membership in the AANA was tacit knowledge as all prospective subject emails were accessed through the AANA active member database by the Foundation. Likewise, consent to participate is evident with subject entry into the survey tool. In the event that a “no” response was logged after survey item 1, this indicated that inclusion criteria were not met. Through the application of survey item skip logic, the potential respondent was directed to the exit screen and thanked for their time in participating.

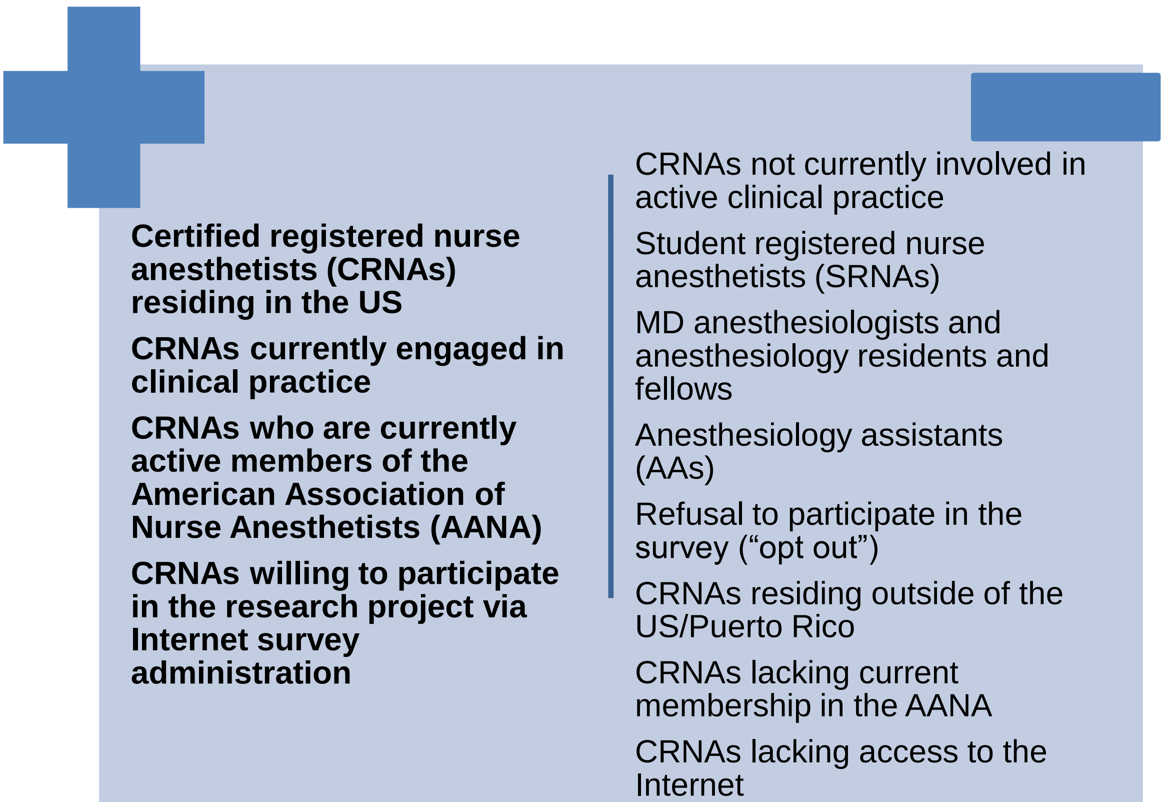


Figure 22. Study Inclusion and Exclusion Criteria

Incentivization. In an effort to increase response rate through participation in the study, an incentivization method was employed. According to the Incentive Theory of

Motivation[18] (Locke, 1968), individuals will be more inclined to participate in an activity if presented with the possibility of positive feedback through an external incentive or reward. Potential subjects were offered the opportunity to enter into a sweepstake by providing their email address at the conclusion of the session. Upon survey completion, voluntary submission of email addresses were requested through a separate survey page and provided directly to the researcher at cosgrovems@vcu.edu. Using this tactic, de-identification of subjects from their survey responses was assured. Subsequent to submission, addresses were logged into a numbered Excel spreadsheet and randomly assigned numbers 1 through 20 to choose contest winners.

Data Cleaning and Measurement

It is widely accepted that surveys administered by an interviewer via face-to-face interaction typically communicate responses of better quality. However, in an effort to reach a broader sample of the CRNA population, delivery of the survey instrument via the Internet provides a viable alternative (Polit and Beck, 2012; pg. 265). In this project, survey responses were de-identified. All surveys were received as completed as final submission was predetermined to occur only upon successful completion of every survey item. Data resulting from responses were examined for a phenomenon known as "straight lining." Straight lining, or entering the same response repetitively for all questions may indicate a respondent's boredom, lack or loss of interest in the survey, or rushing to complete the survey (Jamieson, 2004). It may also signify a non-human,

[18] A.K.A. Reward Motivation Theory

automated Internet robot[19] response. Since the mailing list was provided directly from the AANA Foundation, the likelihood of response by "bots" was improbable.

Likert values impart a degree of magnitude to the perceptions garnered from respondents. For this research project, Likert scale responses were handled as discrete and ordinal data. Frequency of response was obtained for survey questions 2 through 16. Survey questions 17 and 18 were examined separately as neither used Likert ratings. Survey question 19 was designed to be open-ended; responses were recorded, grouped and quantified thematically for analogous or repeated comments, and reported verbatim in Appendix H (pg. 227) *Thematic Catalog of Open-ended Responses by CRNAs*.

Associations between two demographic covariates and perceptions of noise was sought through the application of bivariate correlational statistical analyses. The intent of this investigation was to delineate potential relationships between CRNA age/generation and years of work experience with the dependent variable: perception of ambient noise in the OR (Fig. 23).

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[19] Commonly referred to as "bots".

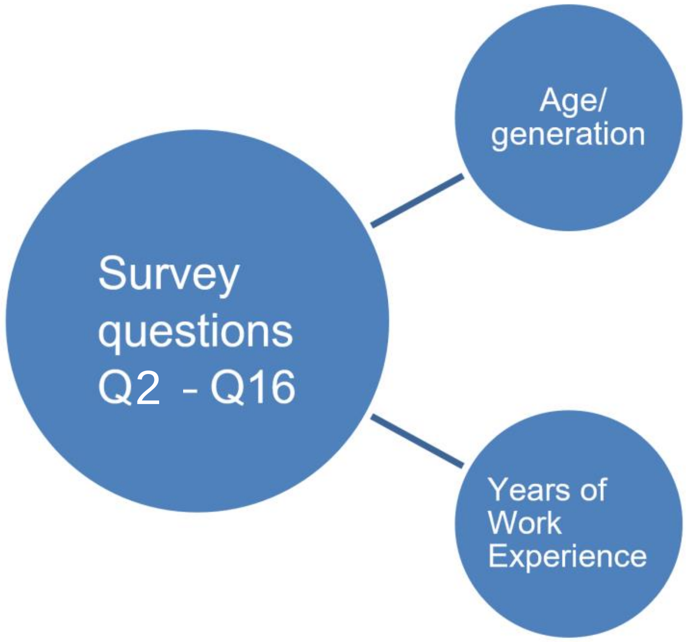

Figure 23. Schematic: Bivariate Correlational Analysis of Demographic Data Points

In addition, questions belonging to the "*Effects of ambient noise in the OR/noise sensitivity*" thematic category were correlated within the group to delimit associations and directionality between responses. Since underlying tendency towards noise sensitivity of respondents may skew responses towards more negative perceptions of the effects of noise, this correlational data may aid the researcher in uncovering such relationships. Figure 24 illustrates the schematic for survey question correlation with the "I am normally sensitive to noise" question.

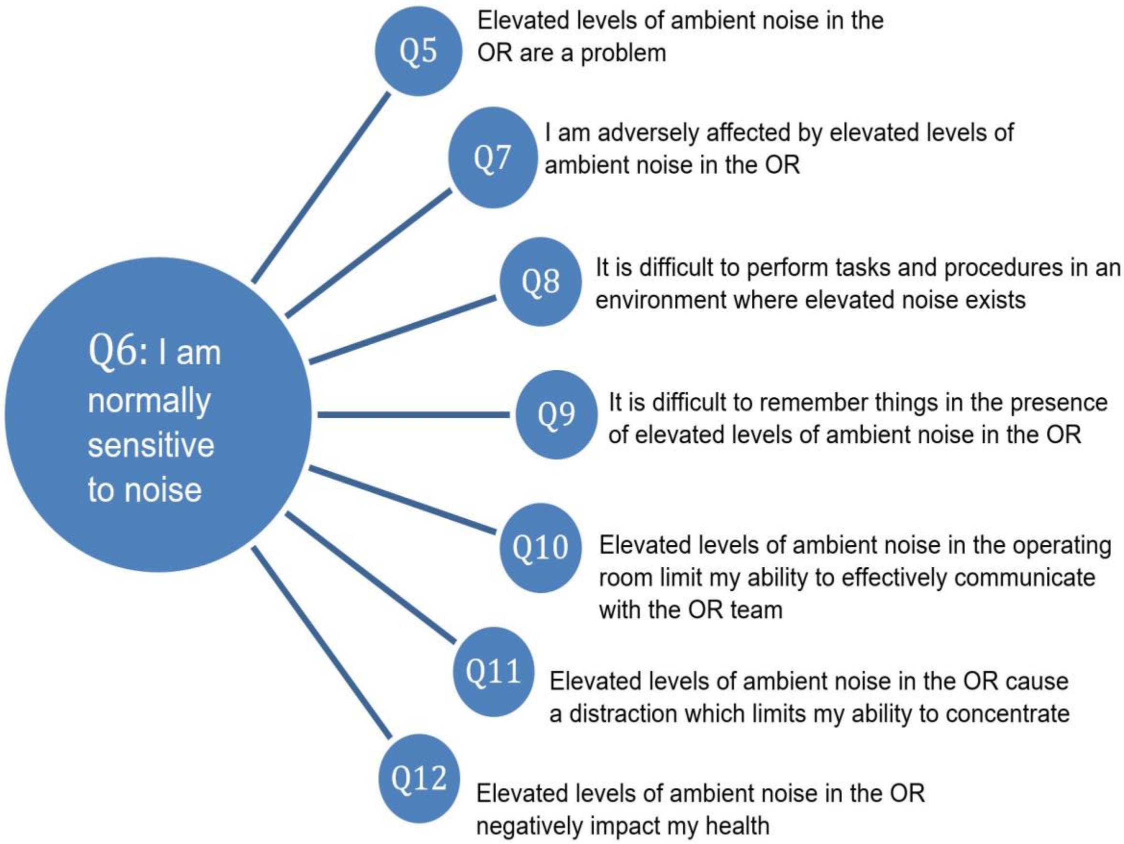

Figure 24. Schematic: Correlational Analysis of Inherent Noise Sensitivity with Thematic Questions

Statistical Analyses

In addition to quantifying frequency of responses to all Likert-scaled questions, a descriptive report of the relative ranking of non-essential sources of OR noise and adjuvant comments offered by survey participants was developed.

Data garnered from Likert scale responses elicit attitudes regarding a certain topic on an agreement to disagreement continuum. Data are non-parametric, ordinal and may not be assumed to have a normal distribution (Polit & Beck, 2010; pg. 301). The practice of summating rating scales via obtaining mean values for Likert scores is controversial, as the data produced should most probably not be construed as interval. For example, the difference between *Always* and *Frequently* ratings cannot be equally tabulated for every respondent (Jamieson, 2004). Bearing this in mind, correlations of the perceptions of noise with demographic information will maintain Likert scores purely as ordinal rankings of attitudes. However, mean values of rankings are reported with frequencies as weighted averages to provide directionality of responses.

Somers' delta was employed as the statistical test for measurement of association of selected Likert data points. Somers' *d*, a non-parametric measure of the strength and direction of association between ordinal variables, is well suited for the comparison of sets of ordinal independent and ordinal dependent variables. Application of Somers' *d* is appropriate provided that the data meet two central assumptions: 1) There is one independent variable and one dependent variable and 2) There is a monotonic relationship between variables to be compared (Laerd Statistics, 2019). Correlation coefficients resulting from Somers' *d* range from -1 to 1 with a value of zero indicating no relationship between tested variables.

Since the data elicited from this project meet both assumptions, Somers' *d* is appropriate for analyses of the strength and directionality of association between selected survey items. This analysis was applied to the noise sensitivity thematic queries, assessing the data output for potential relationships between survey Q6 delineating respondent predisposition towards noise aversion with questions related to the various perceived effects of noise (Fig. 23). Somers' *d* was also employed as the measure of association between age/generational group and years of work experience demographic groups with survey items 2-16.

Limitations

Potential methodological limitations of this research project include the following:

Use of a non-experimental design. Although the use of non-experimental research design predominates in the social sciences and is most applicable to this particular project, it may be construed as a “lesser” technique as compared to a more rigorous experimental design. Variables cannot be manipulated and there are no control or intervention groups. Non-experimental research is generally descriptive, exploratory, or correlational, obviating the capability to discern causal relationships (Reio, 2016; Polit & Beck, 2012; pg. 228). Bearing this limitation in mind, studies concerning the impact of ambient OR noise within the CRNA population are scarce and development of evidence-based research will be initiated by this project. The baseline information to be garnered via the non-experimental approach is necessary as a foundation to inform subsequent research efforts regarding this important topic.

While the non-experimental approach aims to elicit associations between variables, assumptions regarding links in hypothesized relationships should be introduced carefully. Imprecise or erroneous reporting of results and misrepresentation of pivotal relationships may ultimately represent a threat to external validity (Reio, 2016). Furthermore, results may not truly be generalizable to the population of interest.

Use of a non-probability, convenience sample. Demographic stratification was achieved through the researcher’s request to the AANA Foundation to garner an even distribution of surveys across the seven AANA Regions. However, there is a risk that certain email addresses used by the Foundation may be invalid or duplicative (Wright, 2005). The use of a convenience sample is inherently flawed in that may introduce an element of sampling bias in that the population of interest may be either over- or under-represented (Polit & Beck, 2012; pg. 275). The application of a convenience sample also introduces the possibility of selection bias in that the subjects were not randomly chosen for the research study. This would precipitate a threat to external validity and generalizability to the population of interest.

Use of an Internet-based survey. Due to the ubiquitous use of the Internet by a large proportion of individuals, Internet-based surveys allow for a broader reach and dispersion of a population sample. Access is more convenient and may be less expensive than traditional mail-based paper-and-pencil surveys. Furthermore, respondents may be more comfortable with and truthful in responding to survey questions online, versus a face-to-face interaction with an interviewer (Wright, 2005). However, there are specific problems inherent in this type of research inquiry. Firstly, there is an inability to assure respondent identity secondary to use of an Internet-based versus face-to-face survey. Despite affirmation that the subject is a practicing CRNA, respondents may fall into the exclusion criteria category, unbeknownst to the researcher. This would engender a threat to face validity in that an invalid respondent would misrepresent the population studied. In addition, credibility of the quantitative results would be in jeopardy (Polit & Beck, 2012).

In addition, Internet-based surveys cannot guarantee that the respondent is truly a member of the population of interest. Because participants respond to the survey in a private environment, some may be motivated to fabricate responses. Subjects may become bored and lose interest in lengthy online surveys. This may lead to the practice of “straight lining” to rush to survey conclusion (Jamieson, 2004). Finally, despite the fact that the Internet is widely used among medical professionals such as CRNAs, there may still be a subset of individuals who do not have access to the Internet or who prefer to respond using a conventional paper- and pencil-formatted survey. Therefore, these potential respondents may be lost in the sampling process, further introducing the threat of bias (Polit & Beck, 2012; pg. 276).

Self-directed opt out is the decision by a prospective respondent to decline participation at the outset or abort the survey before completion. This may also decrease the number of potential survey respondents. In the event of low rate of responses, the sample may not adequately reflect the generalized demographic of the population of CRNAs. These effects may be offset by population interest in the focus of the research (Jordan, 2018; Appendix C). Finally, although every effort has been made by the researcher to construct survey questions that are clear, non-ambiguous and non-leading, there remains the risk of demand bias by the participant solely due to participation in the study. Respondents may be consciously or subconsciously be inclined to respond in a certain way because they understand the intent of the study; a phenomenon is known as response bias. Despite the construct being examined in each query, there may be the tendency towards agreement leading to a higher frequency of positive responses. This may engender acquiescence response set bias from “yea-sayers” (Polit & Beck, pg. 313) and represent a threat to construct validity.

Incentivizing study participants. Incentivizing study participants may help to alleviate the “opt out effect” and has been found to substantially increase subject participation (Polit & Beck, pg. 287). However, the resultant higher response rate may come at the risk of survey credibility (Wright, 2005), thereby endangering face and construct validity as well as generalizability. Additionally, this practice may possibly engender response bias, particularly through an increase of “yea-sayer” contributors.

Imposed limitation on access to subjects. The AANA Foundation provides the researcher with indirect access to the email addresses of all current members of the American Association of Nurse Anesthetists. However, a finite limit of 3000 addresses has been imposed by the Foundation. In the event of a high rate of survey opt out or loss of potential participants to exclusion criteria, the resulting sample may fall well below 382 respondents, the quantity established *a priori* to achieve adequate power and precision. Fincham (2008) states that response rates to Internet-based surveys continue to decline steadily since the 1980s. With the AANA Foundation’s estimated response rate for e-mailed surveys ranging between 8-10% (Jordan, 2018; Appendix C), the study may ultimately not achieve power, even with the proposed 1-2% increase in response rate resulting from incentivization. Low response rate would cause nonresponse bias and threaten external validity, generalizability and reliability (Fincham, 2008).

Summary

This chapter serves as a guide to the methodological plan for the research project *Perceived Impact of Ambient Operating Room Noise by Certified Registered Nurse Anesthetists*. Survey instrument design and execution is discussed with emphasis on four key themes elicited in the literature review. Plan for survey piloting is reviewed including the application of Cronbach’s alpha to assess item validity and reliability. The population of interest, sampling scheme to acquire ample stratification, inclusion and exclusion criteria, and demographic information is described. Potential limitations in the planned methodology are discussed at length, with a focus on the problems inherent in research performed via an online survey.

Research questions delineated in this chapter are systematically reviewed and answered with a discussion of survey response frequencies and mean response values. Correlational relationships and their statistical significance are delineated between two distinct groupings: 1) presence of inherent noise sensitivity and the noise annoyance-themed questions and 2) the "*Noise is a problem in the OR*" survey item with provider age/generational group and years of work experience. Results gained from survey responses are discussed in detail in Chapter Four: Research Results.

Chapter 4: Research Results

"Of all the varieties of modern pollution, noise is the most insidious."

--Robert Lacey, 2000

Overview

This chapter provides a comprehensive report of the results of the Internet survey *Perceived Impact of Ambient Operating Room Noise by Certified Registered Nurse Anesthetists*. First, sample demographics are described. Survey item one, establishing inclusion criteria for participation in the research project is discussed. Survey items two through nineteen are delineated and frequency of responses and mean rank values are detailed for the individual queries. Mean rank values are reported as weighted averages: the addition of all rank category selections divided by n (502). Weighted averages are reported for each Likert item providing additional data points to indicate directionality of response. Since assigned Likert scale values were *Never* (1) to *Always* (5), weighted averages approaching 5 indicate a stronger tendency towards the impact of the factor tested.

Survey Q17 ranks four possible etiologies of increased ambient OR noise. The order of magnitude is reported from most to least impactful contributory factor. Mean values of the overall ranks for each element are compared to determine if statistically significant differences exist within the group. Correlations between Likert-scaled items

Q2 through 16 with age/generational group and years of work experience are designated. Associations between survey Q6: "*I am normally sensitive to noise*" and survey items 5, 7, 8, 9, 10, 11, and 12 describing perceptions of the effects of noise by CRNAs are reported. Finally, open-ended responses resulting from the request for comments (Q19) are sorted into thematic groups and cataloged in Appendix H. Table 20 outlines all survey questions and their statistical analyses.

Table 20. Survey Items and Statistical Analyses

Survey Item	**Statistical Analysis**
Demographics (Q 20, 21, 22, 23)	Frequency of response
Q1	Establishment of inclusion criteria Frequency of response
Q2-18	Frequency of response Weighted average
Q19	Review/thematic sorting/report of verbatim comments
Q17	Comparison of mean ranks of potential contributory sources of ambient OR noise for statistically significant differences (Friedman all pairs exact test)
Q6: Q5-12	Correlations between "*I am normally sensitive to noise*" (Q6) with presence/effects of noise questions (Somers' *d*)
Q20, 22: Q2-16	Correlations between respondent age/generational group and years of work experience with presence/effects/control of noise questions (Somers' *d*)

The Survey

The survey was deployed on April 14, 2019 by the AANA Foundation on behalf of the researcher. Following survey instrument review and approval, the Foundation distributed a letter via email to potential participants with an invitation to participate (Appendix G). The letter contained a direct hyperlink to the survey. SurveyMonkey was the platform used to administer the survey to a convenience sample of CRNAs across all 7 AANA Regions of the US. Puerto Rico, a member of AANA Region 1, was excluded from the dispersion as a predetermined exclusion criterion. Email and Internet Protocol (IP) addresses were not collected from respondents, assuring anonymity.

The survey remained active for a period of four weeks. A reminder email was sent by the Foundation to all invited participants on May 5, 2019, 24 days after initial launch. The intent of this email was to garner additional completed responses and data points. Due to an extremely low survey response rate at this juncture (~5%:169 valid responses/3000 email invitations), the research project was announced by the researcher on social media to the Facebook group "CRNAs and SRNAs," a second convenience sample. The survey link was posted at the request of multiple members of the group interested in participating in the research project. In addition, the survey link was provided to all CRNAs practicing at the Yale New Haven Hospital York St. and St. Raphael campuses in New Haven, CT, comprising a third and final convenience sample.

The survey closed on May 12, 2019 with 534 responses received. Survey completion rate was 94%. The average time to take the survey was 5 minutes. Only 502/534 surveys were fully completed. Six respondents answered "*No*" to survey item 1 and were disqualified from participation. The survey was entered by 26 respondents; however, questions 2 through 19 were skipped, excluding those entries due to incompletion. The remaining 502 responses were uploaded into SPSS Version 25 (IBM Corp, 2017) and data were closely examined for evidence of homogeneity of responses[20] by the primary researcher. No examples were found; therefore, all residual responses were deemed valid and retained for statistical analyses.

SurveyMonkey was used for computation and graphical depiction of survey items 1-18 and 20-23 frequency of responses. R statistical programming (R Core Team, 2013) was used for comparison of mean rankings resulting from responses to Q17 and for both correlational analyses. Associations between inherent noise sensitivity (Q6) and presence and effects of ambient OR noise were computed (Q2 through 16) using Somers' delta (*d*). Likewise, age in years/generational group (Q20) and years of work experience (Q22) were examined for associations with Q2 through 16; these were also computed with Somers' *d*. Because data obtained from Q17 ranking potential contributory sources of ambient noise in the OR from most to the least impactful appeared closely approximated, mean ranks were compared for statistically significant differences using the Friedman all pairs exact test. Both Somers' d and Freidman's test were specifically designed for comparison of ordinal data; therefore, both statistical assays were well-suited to the project's correlational and comparative computations.

Seventy-five participants requested to be entered into the sweepstake for Amazon gift cards. Email addresses were logged by the researcher into an Excel

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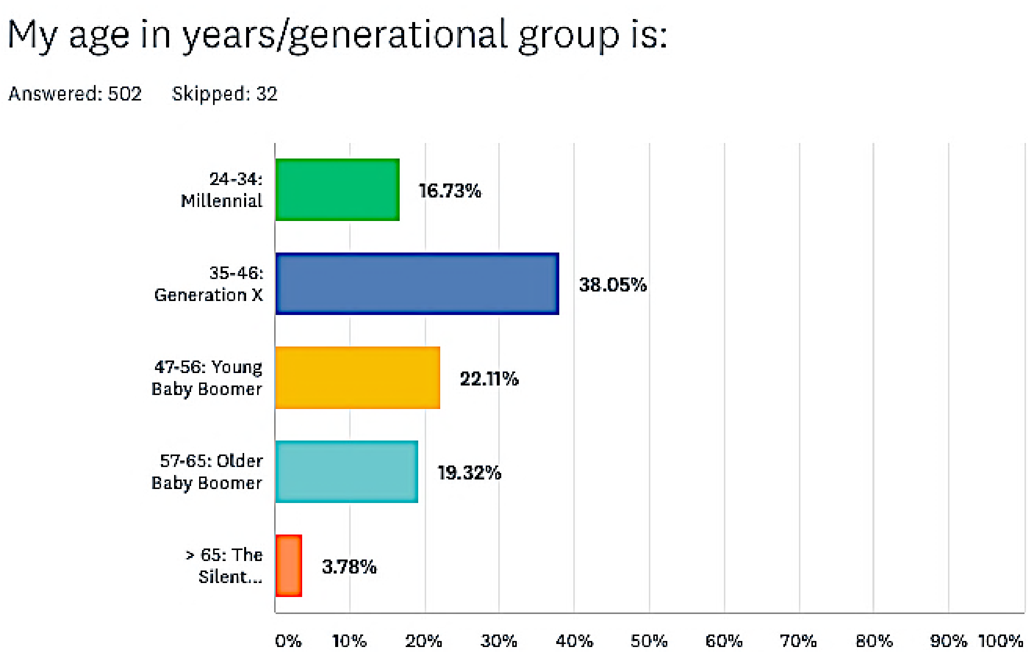
[20] A.K.A. "Straight-lining"

spreadsheet numbered 1 through 75 in the order that contestant entries were received. Pretty Random© (Fox Bytes, 2016), a random number generator application for iPhone, was used to randomly select 20 winners. Each recipient received a $25 Amazon gift e-card. The remaining contestants were contacted via email to inform them of sweepstake results and thanked once more for their participation in the research project.

Demographics of Sample

Age in Years/Generational Group. Survey question 20 (Q20) sought to describe the ages and generational group designations of participants to provide an additional data point in delineating CRNA perceptions of noise. Of the 502 respondents, the largest proportion were members of Generation X, ranging in age from 35-46 years (191; 38.05%). This group was followed by the Young Baby Boomers (47-56 years of age: 111 [22.11%]), Older Baby Boomers (57-65 years of age: 97 [19.32%]) and Millennials (24-34 years of age: 84 [16.73%]). The Silent Generation, > 65 years of age, was represented by the least number of respondents (19 [3.78%]). As of August 31, 2018, the mean age of CRNAs in the US was reported at 47.5 years (NBCRNA, 2019). Results of this demographic were essentially congruous with the current population of AANA members. Frequency of responses to Q20 "*My age in years/generational group*" is graphically depicted in Figure 25.



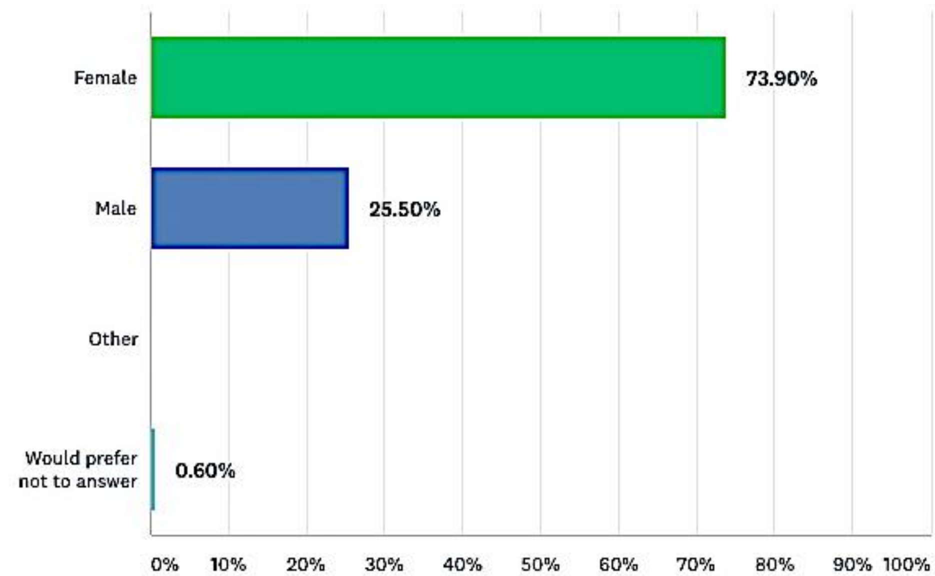
ANSWER CHOICES	RESPONSES	
24-34: Millennial	16.73%	84
35-46: Generation X	38.05%	191
47-56: Young Baby Boomer	22.11%	111
57-65: Older Baby Boomer	19.32%	97
> 65: The Silent Generation	3.78%	19
Total Respondents: 502		

Figure 25. Frequency of Responses: Age in Years/Generational Group

Gender. Survey question 21 (Q21) delineated the gender designation of participants. Although gender was not used as a variable in correlational assays, this demographic provides an additional data point for comparison of the sample to the overall population of CRNAs in the US. The majority of survey participants were female (371 [73.90%]). Males accounted for 128 (25.50%) of all respondents. Three participants responded, *Would prefer not to answer* (.60%). There were no responses to the *Other* category (Fig. 26). As of August 31, 2018, the population of CRNAs was comprised of 59% females and 41% males (NBCRNA, 2019). Therefore, this demographic data point does not precisely describe the current population of practicing CRNAs in the US.

My gender is:

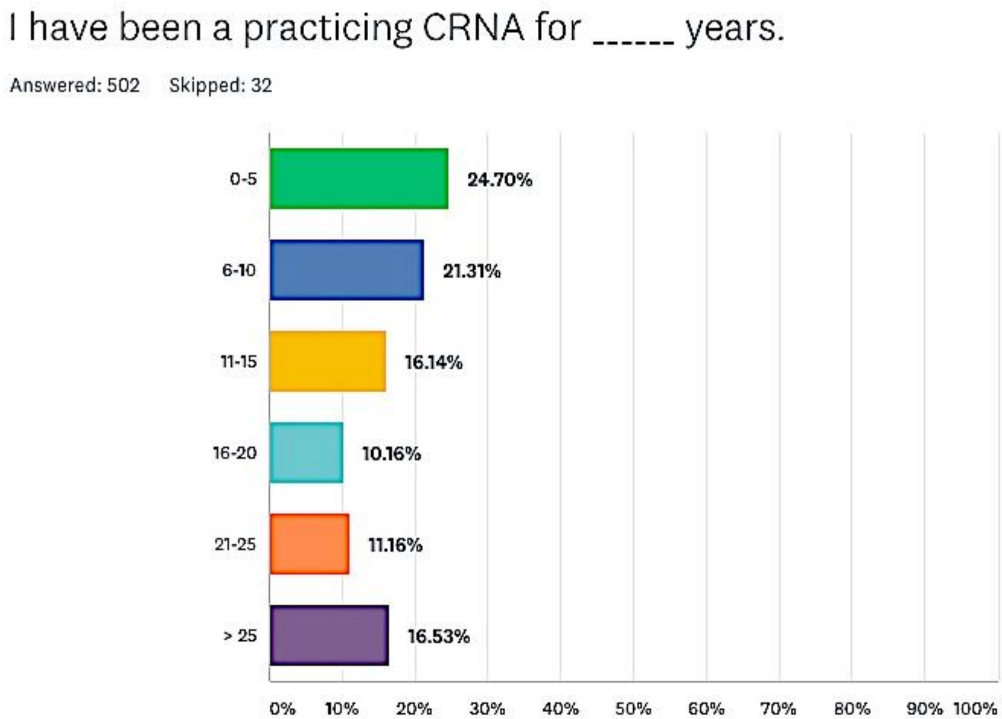
Answered: 502 Skipped: 32



ANSWER CHOICES	RESPONSES	
Female	73.90%	371
Male	25.50%	128
Other	0.00%	0
Would prefer not to answer	0.60%	3
Total Respondents: 502		

Figure 26. Frequency of Responses: Gender

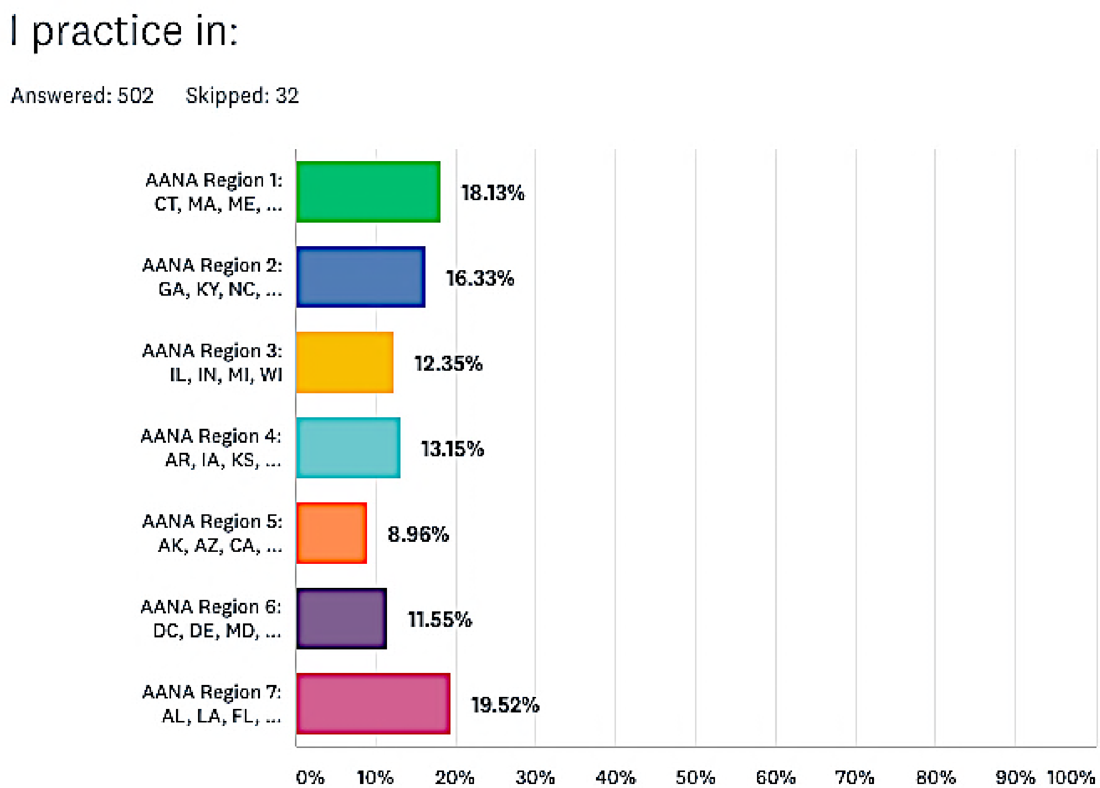
Years of Experience as a CRNA. Survey question 22 (Q22) aimed to elicit the length of time participants were engaged in clinical practice as CRNAs. The impetus for garnering this data point was to correlate years of work experience with perceptions of ambient OR noise. The largest group of respondents reported 0-5 years of work experience (124 [24.70%]), followed by 6-10 years of experience (107 [21.31%]), > 25 years of experience (83 [16.53%]), 11-15 years of experience (81 [16.14%]), and 21-25 years of experience (56 [11.16%]). The lowest frequency of years of work experience reported by survey participants was 16-20 years (51 [10.16%]) (Fig. 27). According to the NBCRNA Annual Report (2018), the average duration of work experience of CRNAs was estimated to be 14.8 years. Therefore, this sample demographic did not aptly represent the population of CRNAs at large.



ANSWER CHOICES	RESPONSES	
0-5	24.70%	124
6-10	21.31%	107
11-15	16.14%	81
16-20	10.16%	51
21-25	11.16%	56
> 25	16.53%	83
Total Respondents: 502		

Figure 27. Frequency of Responses: Years of Work Experience as a Practicing CRNA

Geographical Location. Question 23 (Q23) explored the geographic distribution of CRNA survey participants. The largest group of respondents originated from AANA Region 7 (98 [19.52%]), followed by AANA Region 1 (91 [18.13%]), Region 2 (82 [16.33%]), Region 4 (66 [13.15%]), Region 3 (62 [12.35%]) and Region 6 (58 [11.55%]). AANA Region 5 had 45 members, comprising 8.96% of all survey participants (Fig. 28). According to the NBCRNA's most recent Annual Report (2018), the five states containing the highest number of practicing CRNAs were Florida (4196), Texas (4107), Pennsylvania (3583) North Carolina (2772) and Ohio (2470). In this survey, AANA Region 7 (FL, TX) yielded the highest response rate. Therefore, this data point aptly describes the dispersion of CRNAs in the US. However, responses garnered from AANA Region 6 (PA, OH) and Region 2 (NC) may not have accurately represented the population of CRNAs in the US at present due to underrepresentation of survey participants from those regions.

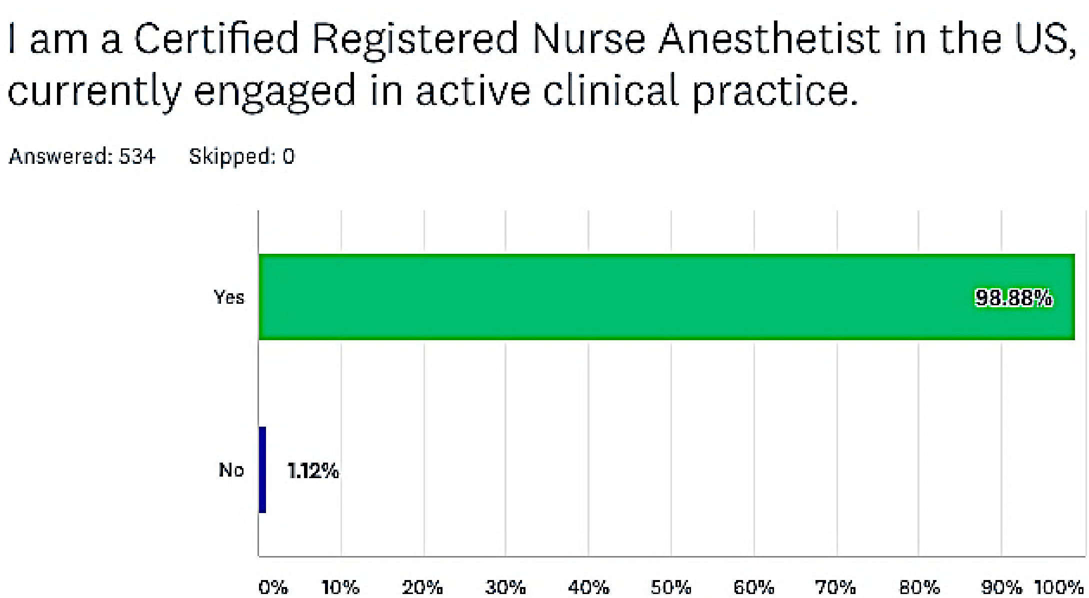


ANSWER CHOICES	RESPONSES	
AANA Region 1: CT, MA, ME, NH, NJ, NY, RI, VT	18.13%	91
AANA Region 2: GA, KY, NC, SC, TN, VA, WV	16.33%	82
AANA Region 3: IL, IN, MI, WI	12.35%	62
AANA Region 4: AR, IA, KS, MN, MO, OK, NE, ND, SD	13.15%	66
AANA Region 5: AK, AZ, CA, CO, HI, ID, MT, OR, NM, NV, UT, WA, WY	8.96%	45
AANA Region 6: DC, DE, MD, OH, PA	11.55%	58
AANA Region 7: AL, LA, FL, MS, TX	19.52%	98
Total Respondents: 502		

Figure 28. Frequency of Responses: Geographical Location of CRNA Respondents

Survey Items

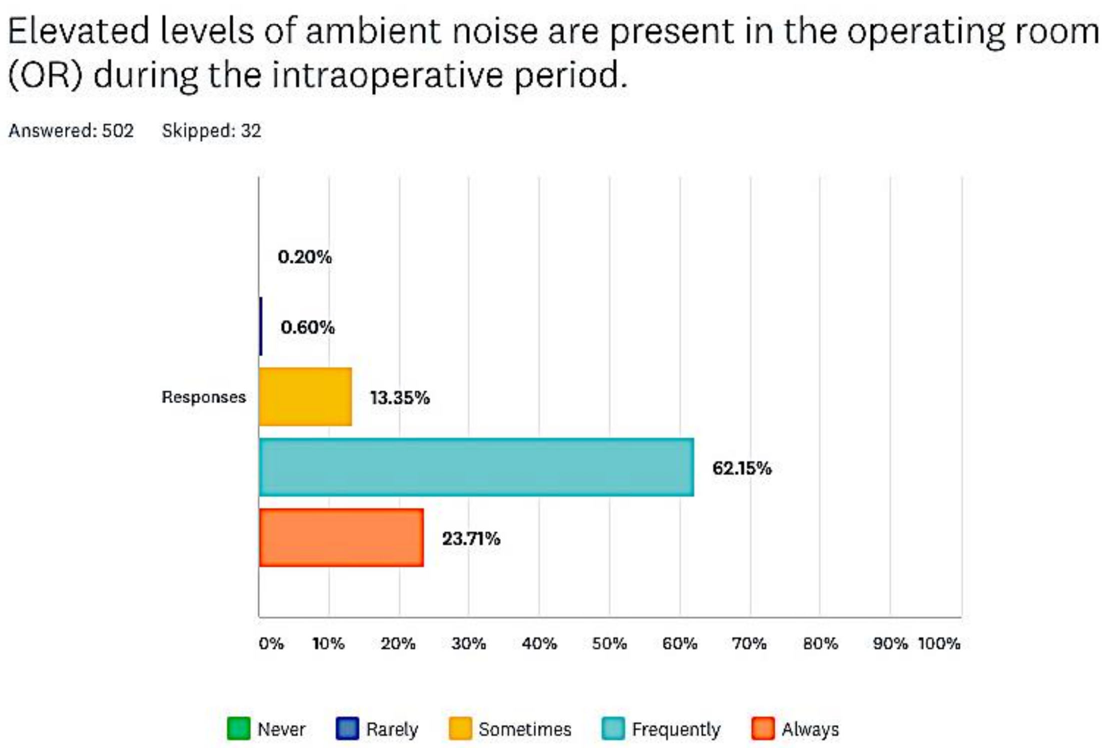
Survey Item 1. *I am a Certified Registered Nurse Anesthetist in the US, currently engaged in active clinical practice.* This initial survey item (Q1) sought to establish inclusion/exclusion criteria for potential respondents. Of the 534 original participants, 528 responded *Yes* and 6 responded *No* to the query (Fig. 29). All *Yes* responses were examined for completeness; 26 were found to be incomplete due to failure in answering survey items 2 through 23. The remaining 502 responses were examined by the primary researcher for evidence of homogenous responses indicating straight-lining. None of the completed surveys yielded this effect, a result of a bored respondent or potential Internet “bot” participation. Consequently, 502 responses were considered valid and retained for statistical analyses.



ANSWER CHOICES	RESPONSES	
Yes	98.88%	528
No	1.12%	6
Total Respondents: 534		

Figure 29. Frequency of Responses: Survey Q1

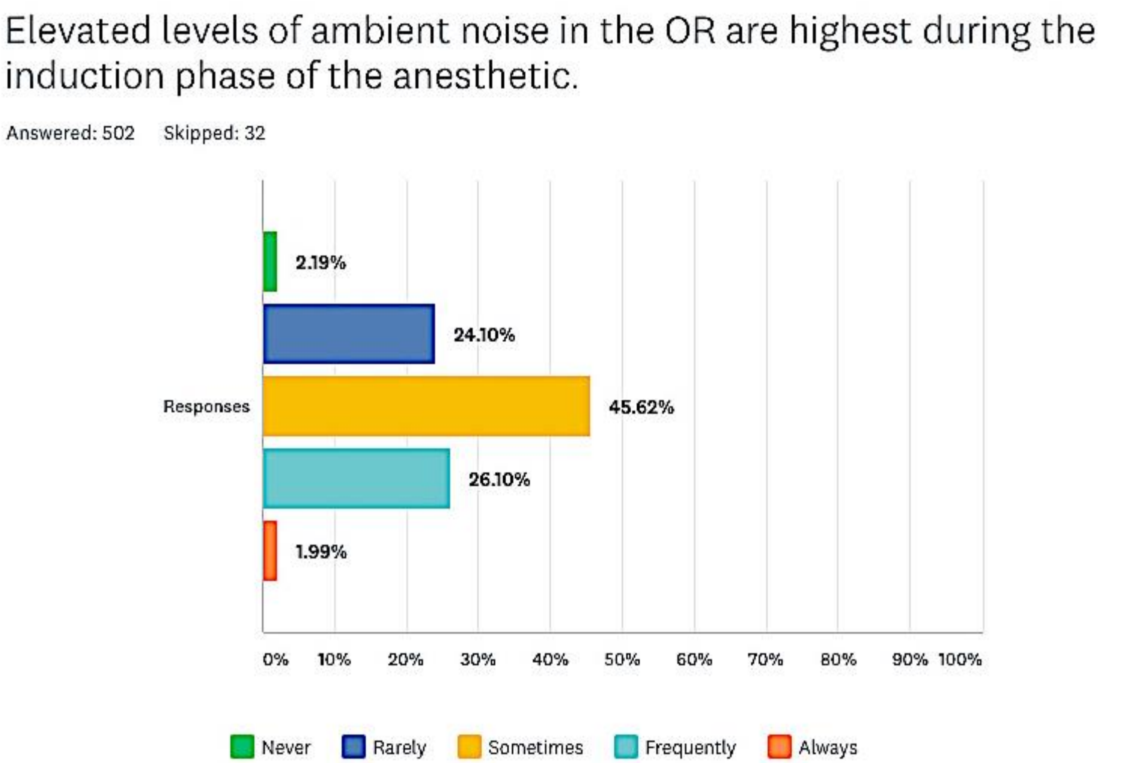
Survey Item 2. *Elevated levels of ambient noise are present in the operating room (OR) during the intraoperative period.* This survey item sought to elicit CRNA perceptions of the presence of elevated levels of ambient noise in the OR. The majority of participants responded *Frequently* (312 [62.15%]), followed by *Always* (119 [23.71%]), *Sometimes* (67 [13.35%]) and *Rarely* (3 [.60%]). One participant (.20%) responded *Never* to survey Q2. The weighted average of all rankings was 4.09/5 indicating a more positive direction of response. This finding supports the perceived presence of elevated ambient noise levels in the OR during the intraoperative period by CRNAs (Fig. 30).



	NEVER	RARELY	SOMETIMES	FREQUENTLY	ALWAYS	TOTAL	WEIGHTED AVERAGE
Responses	0.20% 1	0.60% 3	13.35% 67	62.15% 312	23.71% 119	502	4.09

Figure 30. Frequency of Responses: Survey Q2

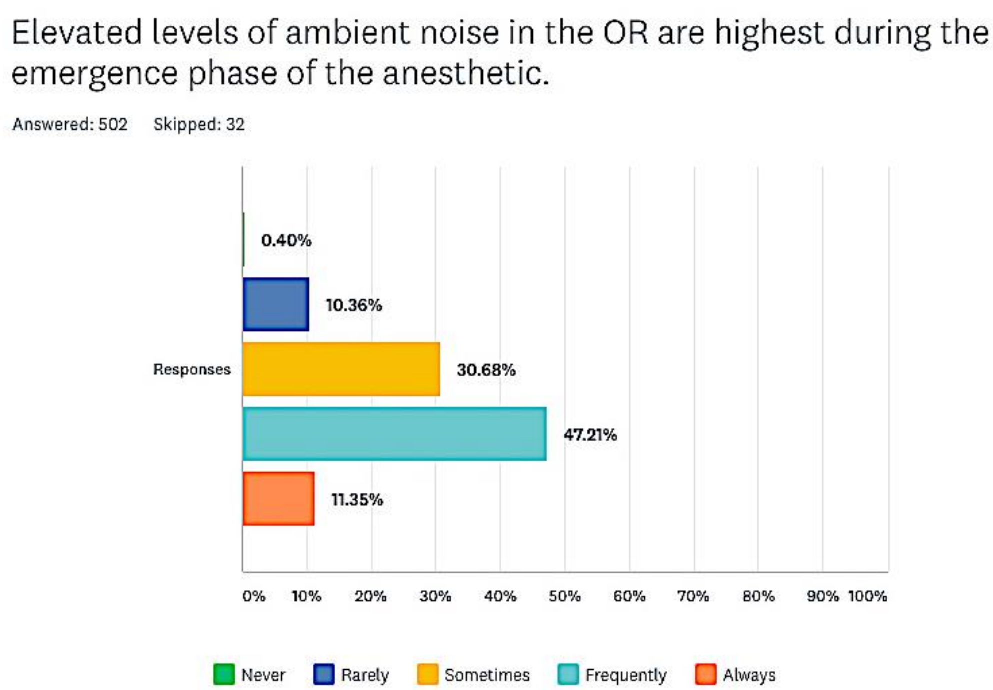
Survey Item 3. *Elevated levels of ambient noise in the OR are highest during the induction phase of the anesthetic.* Survey Q3 sought to draw CRNA perceptions of the presence of high levels of ambient noise during the induction phase of the anesthetic. Roughly 46% of participants responded *Sometimes* (229), followed by *Frequently* (131 [26.10%]), *Rarely* (121 [24.10%]), and *Never* (11 [2.19%]). Ten participants (1.99%) responded *Always.* The weighted average of all rankings was 3.02/5 indicating a relatively neutral direction of responses (Fig. 31).



	NEVER	RARELY	SOMETIMES	FREQUENTLY	ALWAYS	TOTAL	WEIGHTED AVERAGE
Responses	2.19% 11	24.10% 121	45.62% 229	26.10% 131	1.99% 10	502	3.02

Figure 31. Frequency of Responses: Survey Q3

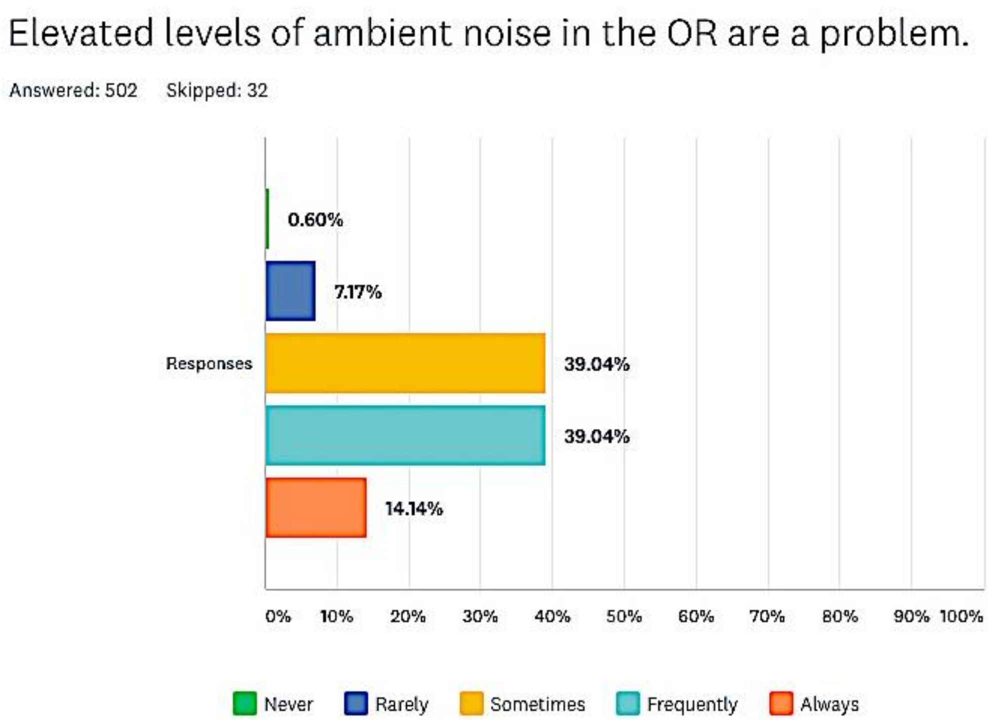
Survey Item 4. *Elevated levels of ambient noise in the OR are highest during the emergence phase of the anesthetic*. Survey Q4 elicited perceptions of the presence of increased levels of ambient OR noise during the critical emergence phase of the anesthetic. Forty-seven percent responded *Frequently* (237), followed by *Sometimes* (154 [30.68%]), *Always* (57 [11.35%]), and *Rarely* (52 [10.36%]). Two respondents (.40%) answered *Never.* The weighted average of all rankings was 3.59/5 indicating a more positive direction of response. This finding supports the perceived presence of elevated levels of ambient noise during the emergence phase of the anesthetic by CRNAs (Fig. 32).



	NEVER	RARELY	SOMETIMES	FREQUENTLY	ALWAYS	TOTAL	WEIGHTED AVERAGE
Responses	0.40% 2	10.36% 52	30.68% 154	47.21% 237	11.35% 57	502	3.59

Figure 32. Frequency of Responses: Survey Q4

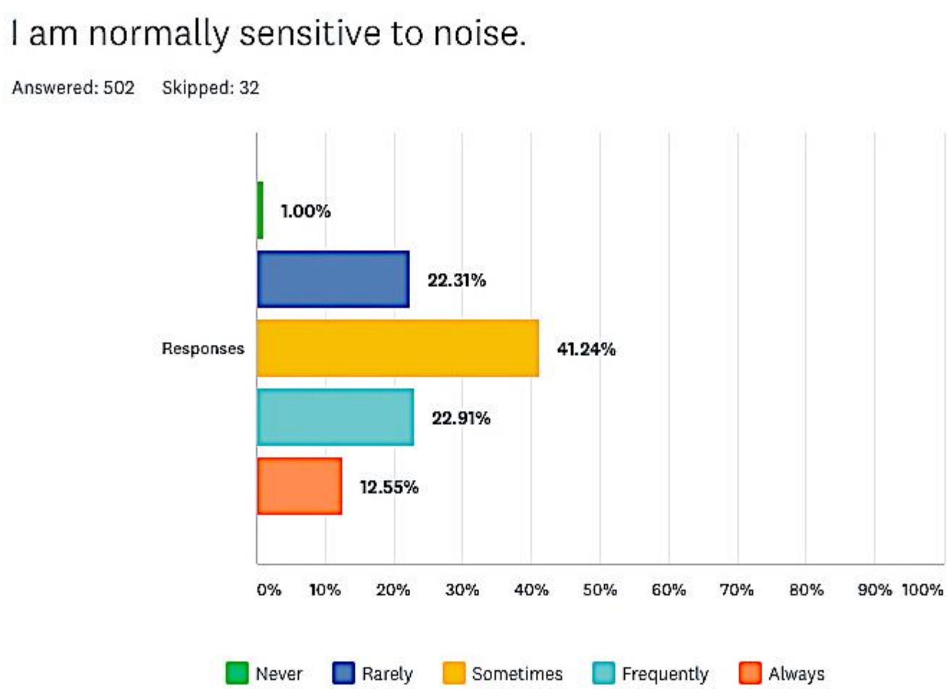
Survey Item 5. *Elevated levels of ambient noise in the OR are a problem.* Survey Q5 was included to identify CRNA feelings regarding the presence of elevated levels of ambient OR noise as problematic. Both rankings *Sometimes* and *Frequently* garnered an equal number of responses (196 [39.04%]), followed by *Always* (71 [14.14%]) and *Rarely* (36 [7.17%]). Three respondents (.60%) answered *Never* to survey Q5. The weighted average of all rankings was 3.59/5 indicating a more positive direction of response.This finding supports the notion that elevated levels of ambient noise in the OR are perceived as problematic by CRNAs (Fig. 33).



	NEVER	RARELY	SOMETIMES	FREQUENTLY	ALWAYS	TOTAL	WEIGHTED AVERAGE
Responses	0.60% 3	7.17% 36	39.04% 196	39.04% 196	14.14% 71	502	3.59

Figure 33. Frequency of Responses: Survey Q5

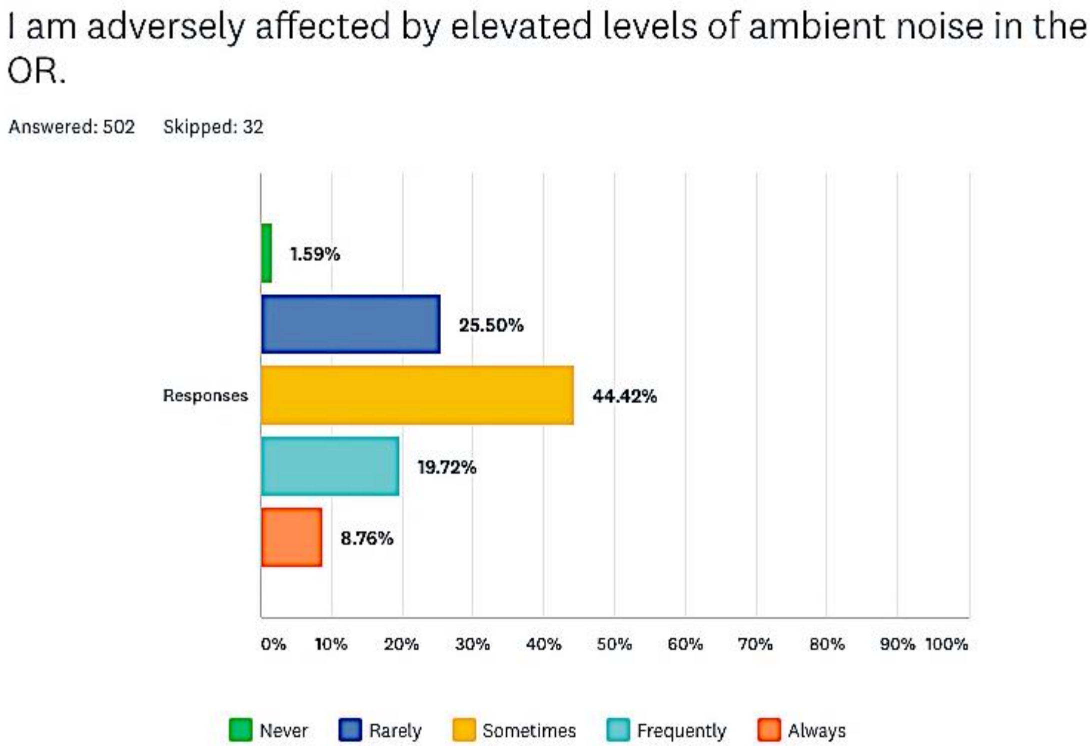
Survey Item 6. *I am normally sensitive to noise.* This survey question aimed to elicit respondents' inherent predilection to noise sensitivity, producing data for correlation with survey questions regarding the presence and effects of elevated levels of ambient OR noise. Forty-one percent (207) responded *Sometimes*. Rankings of *Frequently* and *Rarely* (115 [22.91%]; 112 [22.31%] respectively) were nearly equal. Sixty-three CRNAs (12.55%) reported *Always* while 5 (1.00%) responded *Never* being sensitive to noise. The weighted average of all rankings was 3.24/5 indicating a relatively neutral direction of responses (Fig. 34). These findings appear to support a degree of variability in noise sensitivity amongst CRNAs.



	NEVER	RARELY	SOMETIMES	FREQUENTLY	ALWAYS	TOTAL	WEIGHTED AVERAGE
Responses	1.00% 5	22.31% 112	41.24% 207	22.91% 115	12.55% 63	502	3.24

Figure 34. Frequency of Responses: Survey Q6

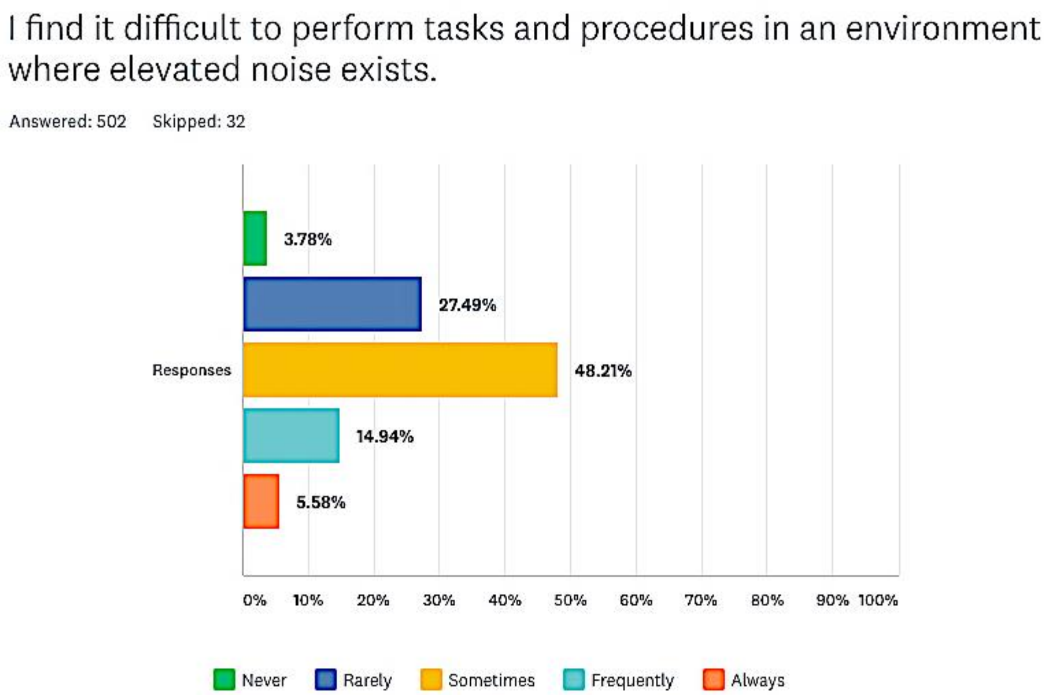
Survey Item 7. *I am adversely affected by elevated levels of ambient noise in the OR.* Question 7 sought to elicit perception of negative effects of elevated ambient noise in the sample of CRNAs queried. Forty-four percent (223) of respondents replied *Sometimes* followed by responses of *Rarely* (128 [25.50%]), *Frequently* (99 [19.72%]) and *Always* (44 [8.76%]). Eight CRNAs (1.59%) responded *Never* when asked about the adverse effects of elevated levels of ambient noise in the OR. The weighted average of all rankings was 3.09/5 indicating a neutral direction of response (Fig. 35).



	NEVER	RARELY	SOMETIMES	FREQUENTLY	ALWAYS	TOTAL	WEIGHTED AVERAGE
Responses	1.59% 8	25.50% 128	44.42% 223	19.72% 99	8.76% 44	502	3.09

Figure 35. Frequency of Responses: Survey Q7

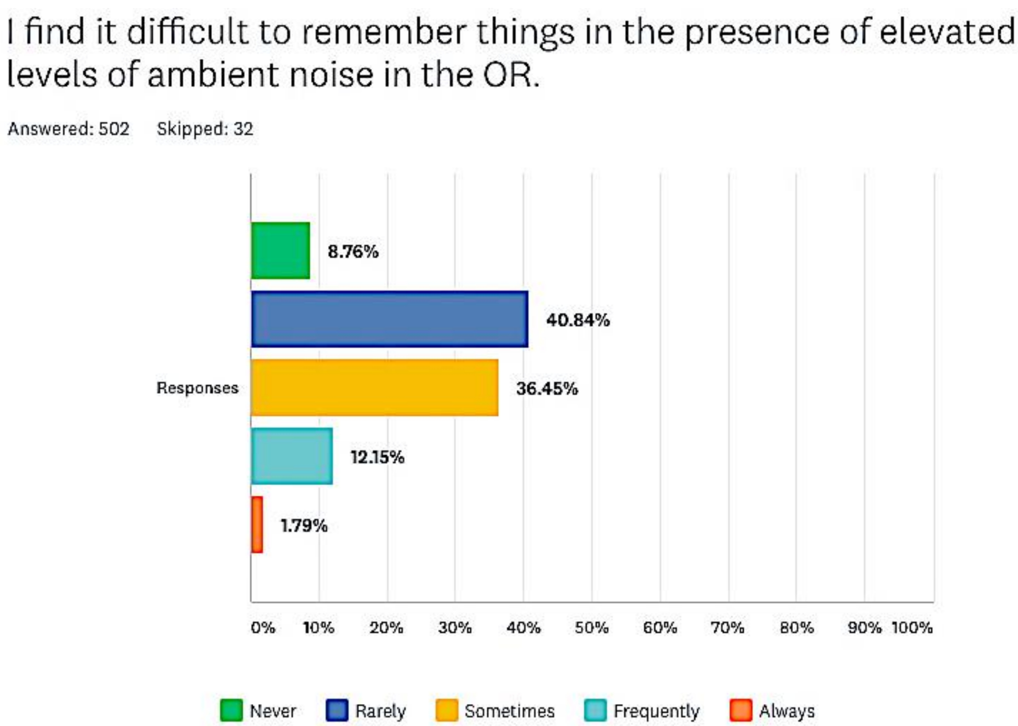
Survey Item 8. *I find it difficult to perform tasks and procedures in an environment where elevated noise exists.* This survey item sought CRNA perceptions regarding the impact of elevated ambient noise in the OR on key markers of performance: the ability to execute tasks and procedures. Nearly half of all CRNA participants responded *Sometimes* (242 [48.21%]). Responses of *Rarely* (138 [27.49%]), *Frequently* (75 [14.94%), and *Always* (28 [5.58%]) followed in descending order. Nineteen respondents (3.78%) replied *Never* to survey Q8. The weighted average of all rankings was 2.91/5 indicating a marginally negative direction of responses (Fig. 36). These findings may represent the adaptability of CRNAs to their surroundings, despite non-optimal conditions.



	NEVER	RARELY	SOMETIMES	FREQUENTLY	ALWAYS	TOTAL	WEIGHTED AVERAGE
Responses	3.78% 19	27.49% 138	48.21% 242	14.94% 75	5.58% 28	502	2.91

Figure 36. Frequency of Responses: Survey Q8

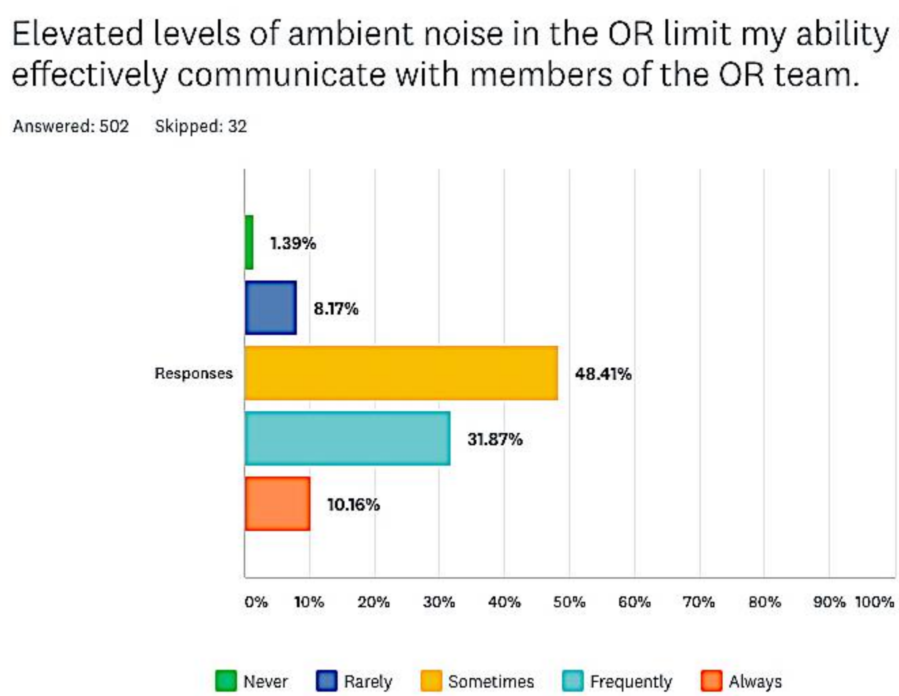
Survey Item 9. *I find it difficult to remember things in the presence of elevated levels of ambient noise in the OR.* This question elicited respondents' perceptions of the effect that elevated ambient OR noise has on their ability to recall information. Forty-one percent of CRNAs (205) responded *Rarely* to this query, closely followed by responses of *Sometimes* (183 [36.45%]). Replies of *Frequently* (61 [12.15%]) and *Never* (44 [8.76%]) followed. Nine participants (1.79%) responded *Always* regarding the negative impact of elevated ambient OR noise on memory retrieval. The weighted average of all rankings was 2.57/5 indicating a more negative direction of responses (Fig. 37). These findings further support the probable adaptability of CRNAs to their surroundings.



	NEVER	RARELY	SOMETIMES	FREQUENTLY	ALWAYS	TOTAL	WEIGHTED AVERAGE
Responses	8.76% 44	40.84% 205	36.45% 183	12.15% 61	1.79% 9	502	2.57

Figure 37. Frequency of Responses: Survey Q9

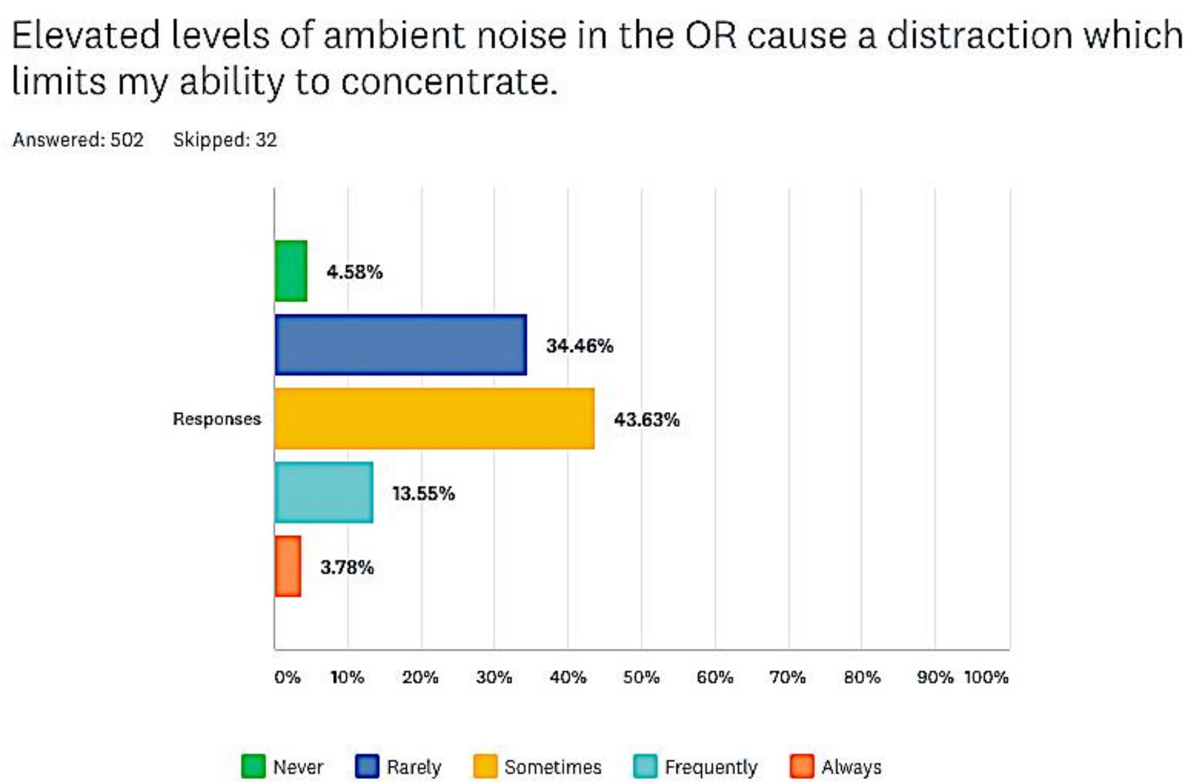
Survey Item 10. Elevated levels of ambient noise in the OR limit my ability to effectively communicate with the OR team. The aim of this survey query was to elicit CRNA perception of the impact of elevated levels of ambient OR noise on their ability to communicate with members of the perioperative team. Surprisingly, despite reports of increased levels of ambient noise in the OR during the intraoperative period (Fig. 30), almost half of respondents replied Sometimes (243 [48.41%]) to Q10. Other responses followed in descending order: Frequently (160 [31.87%]), Always (51 [10.16%]), Rarely (41 [8.17%]) and Never (7 [1.39%]). The weighted average of all rankings was 3.41/5 indicating only a marginally positive direction of responses regarding the deleterious effect of elevated ambient noise on OR team communication (Fig. 38).



	NEVER	RARELY	SOMETIMES	FREQUENTLY	ALWAYS	TOTAL	WEIGHTED AVERAGE
Responses	1.39% 7	8.17% 41	48.41% 243	31.87% 160	10.16% 51	502	3.41

Figure 38. Frequency of Responses: Survey Q10

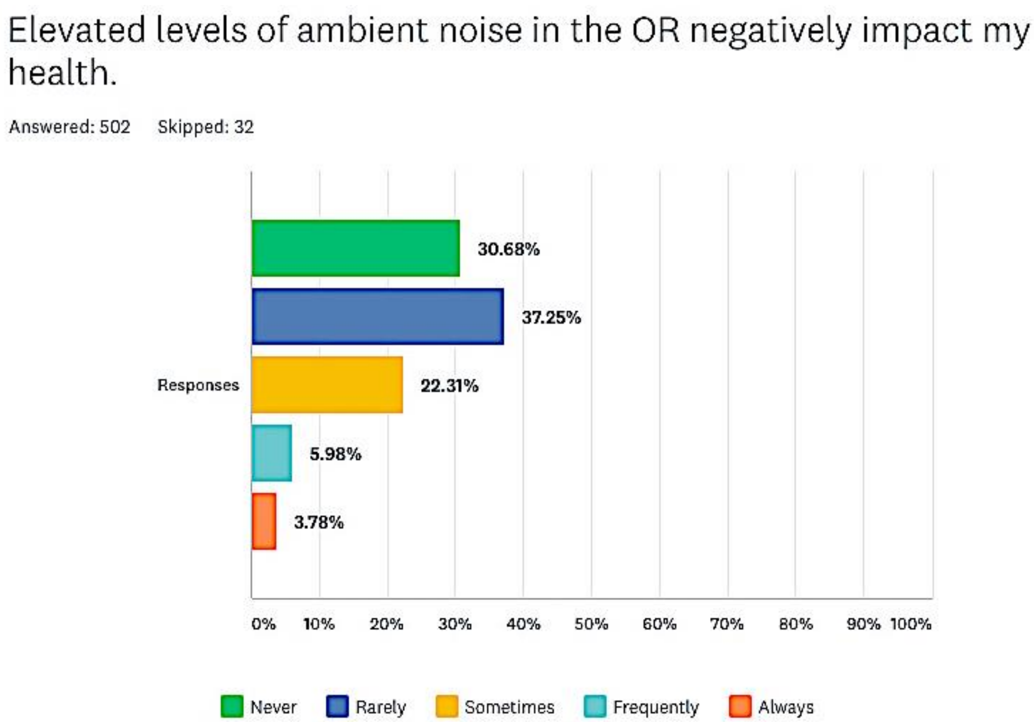
Survey Item 11. *Elevated levels of ambient noise in the OR cause a distraction which limits my ability to concentrate.* This survey item attempted to elicit the potential distracting effect that elevated levels of ambient OR noise may have on CRNAs. Forty-four percent (219) respondents answered *Sometimes*, followed by *Rarely* (173 [34.46%]), *Frequently* (68 [13.55%]), and *Never* (23 [4.58%]). Nineteen participants (3.78%) responded *Always*. The weighted average of all rankings was 2.77/5 indicating a slightly negative direction of responses (Fig. 39).These findings may further support the concept of increased adaptability in the CRNA.



	NEVER	RARELY	SOMETIMES	FREQUENTLY	ALWAYS	TOTAL	WEIGHTED AVERAGE
Responses	4.58% 23	34.46% 173	43.63% 219	13.55% 68	3.78% 19	502	2.77

Figure 39. Frequency of Response: Survey Q11

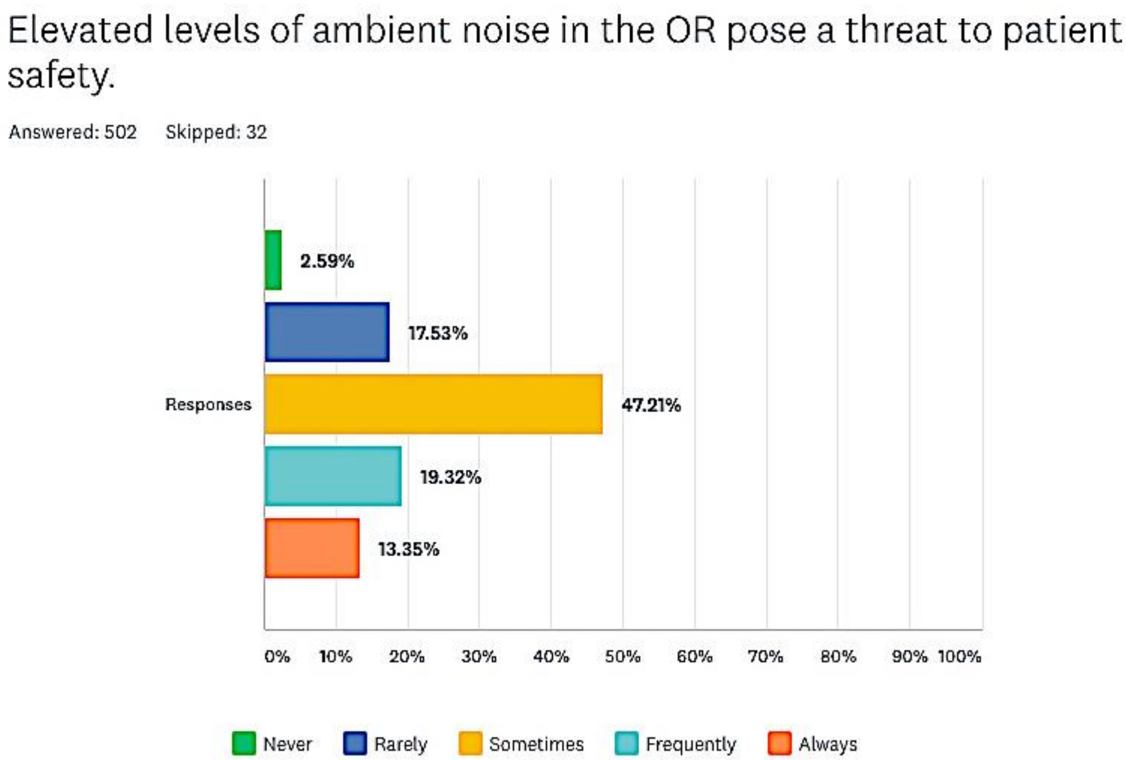
Survey Item 12. *Elevated levels of ambient noise in the OR negatively impact my health.* The intent of this survey question was to garner perceptions of the effect that elevated levels of ambient OR noise may potentially have on anesthesia provider health. Interestingly, thirty seven percent of CRNA participants (187) responded *Rarely,* followed by *Never* (154 [30.68%]), *Sometimes* (112 [22.31%]), *Frequently* (30 [5.98%]) and *Always* (19 [3.78%]). The weighted average of all rankings was 2.15/5 indicating a largely negative direction of responses (Fig. 40).



	NEVER	RARELY	SOMETIMES	FREQUENTLY	ALWAYS	TOTAL	WEIGHTED AVERAGE
Responses	30.68% 154	37.25% 187	22.31% 112	5.98% 30	3.78% 19	502	2.15

Figure 40. Frequency of Responses: Survey Q12

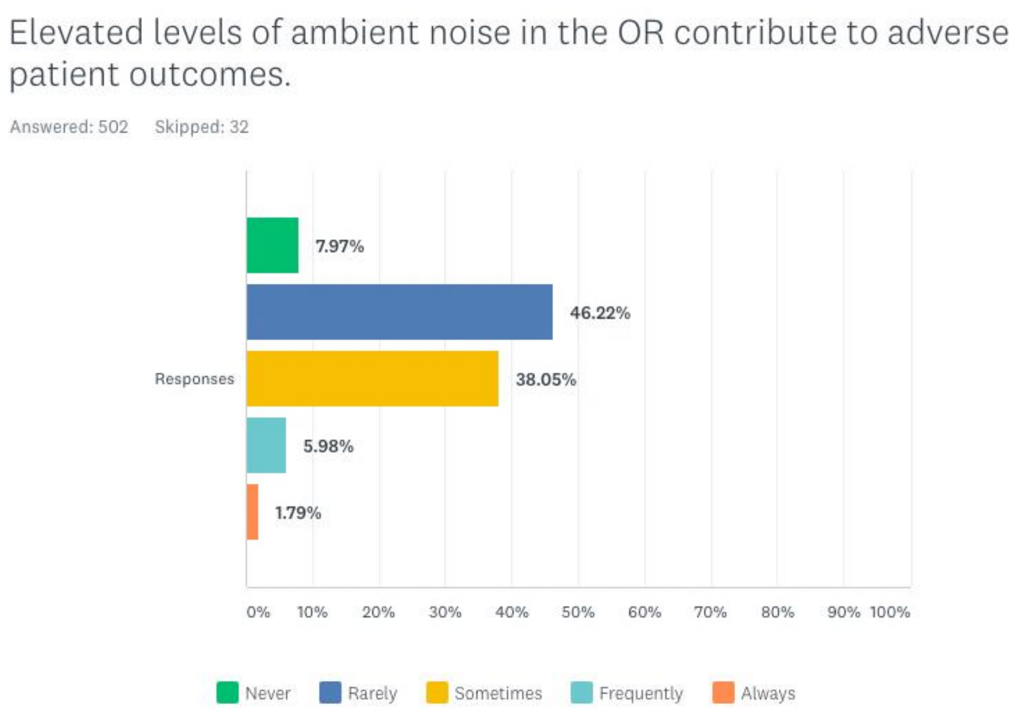
Survey Item 13. *Elevated levels of ambient noise in the OR pose a threat to patient safety.* The intent of survey question 13 was to elicit perceptions of the potential deleterious effect that elevated levels of ambient OR noise may have on patient safety. Remarkably, despite support of the presence of elevated levels of ambient OR noise, nearly half of CRNA respondents answered *Sometimes* (237 [47.21%]). Responses of *Frequently* (97 [19.32%]), *Rarely* (88 [17.53%]), *Always* (67 [13.35%]) and *Never* (13 [2.59%]) followed distantly in order of decreasing magnitude. The weighted average of all rankings was 3.23/5 indicating only a slightly positive direction of responses (Fig. 41).



	NEVER	RARELY	SOMETIMES	FREQUENTLY	ALWAYS	TOTAL	WEIGHTED AVERAGE
Responses	2.59% 13	17.53% 88	47.21% 237	19.32% 97	13.35% 67	502	3.23

Figure 41. Frequency of Responses: Survey Q13

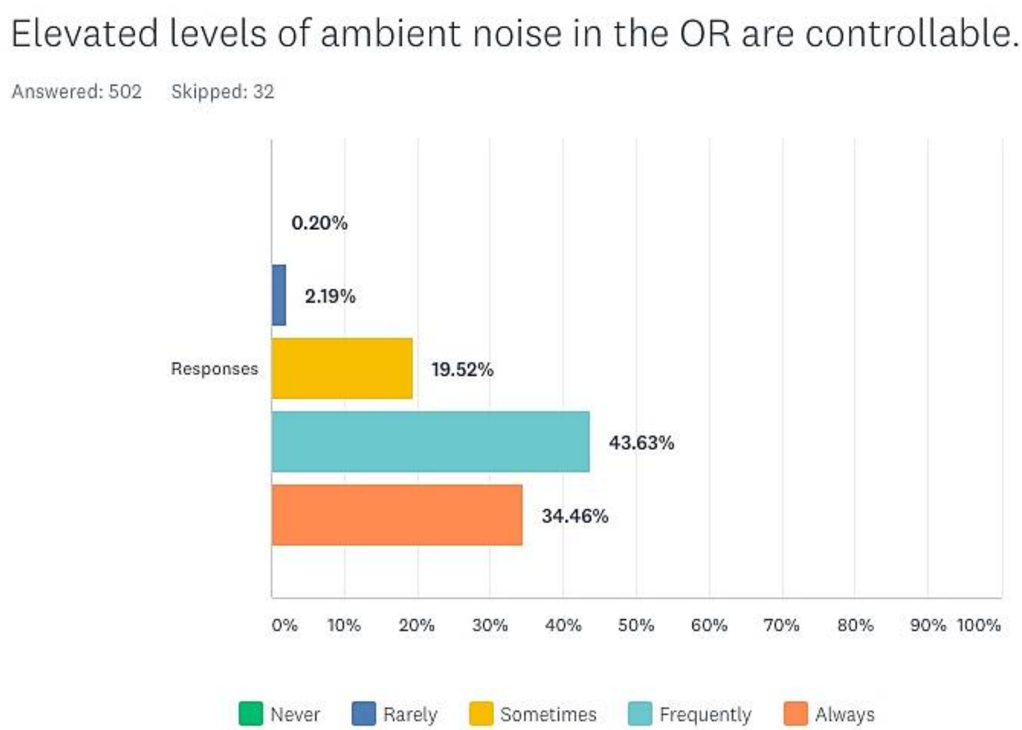
Survey Item 14. *Elevated levels of ambient noise in the OR contribute to adverse patient outcomes.* The inclusion of this survey question sought to elicit perceptions from CRNAs regarding the potential contribution that elevated levels of ambient noise in the OR have on untoward patient outcomes. Forty-six percent of respondents (232) answered *Rarely*. The response of *Sometimes* followed closely (191 [3.05%]). Responses of *Never* (40 [7.97%]), *Frequently* (30 [5.98%]) and *Always* (9 [1.79%]) followed distantly in order of descending response rate. The weighted average of all rankings was 2.47/5 indicating a more negative direction of responses (Fig. 42). This data point demonstrates that CRNAs do not particularly perceive elevated levels of ambient OR noise as a threat to patient safety.



	NEVER	RARELY	SOMETIMES	FREQUENTLY	ALWAYS	TOTAL	WEIGHTED AVERAGE
Responses	7.97% 40	46.22% 232	38.05% 191	5.98% 30	1.79% 9	502	2.47

Figure 42. Frequency of Responses: Survey Q14

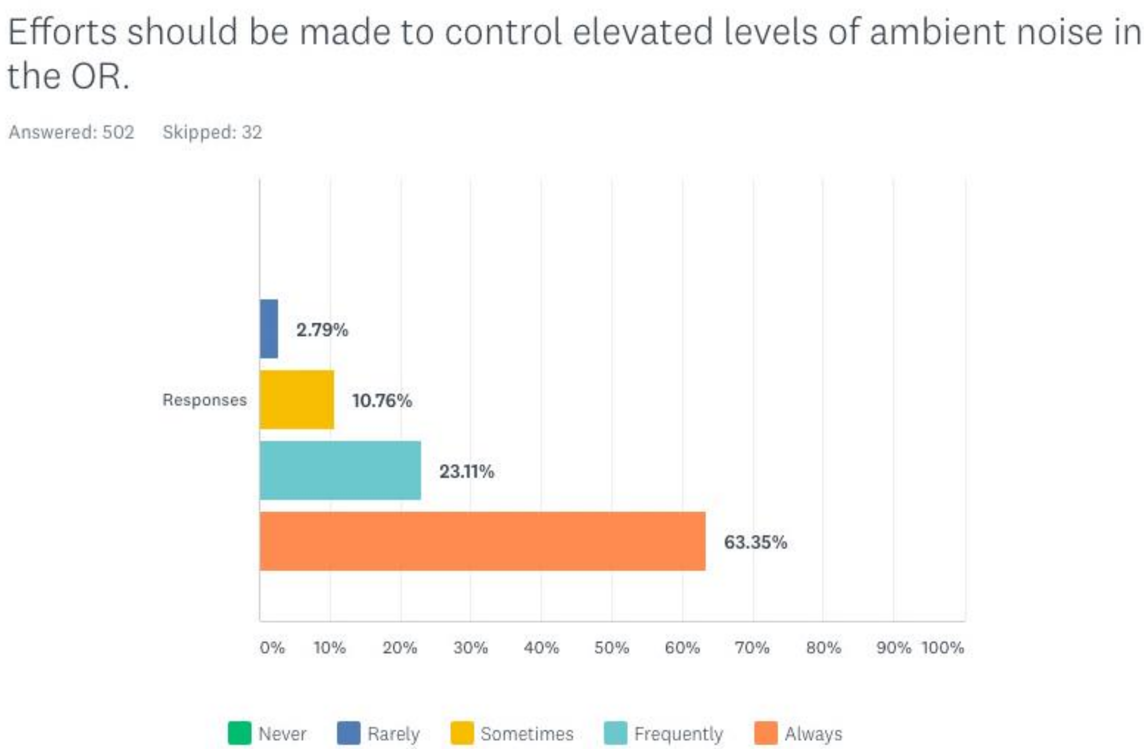
Survey Item 15. *Elevated levels of ambient noise in the OR are controllable.* The purpose of this survey item was to ascertain CRNA opinions regarding the ability to control excessive levels of ambient noise in the OR environment. Forty-four percent of participants (219) responded *Frequently,* followed by *Always* (173 [34.46%]). Responses of *Sometimes* (98 [19.52%]) and *Rarely* (11 [2.19%]) followed distantly. Only 1 respondent (.20%) answered *Never* to survey Q15. The weighted average of all rankings was 4.10/5 indicating a more positive direction of responses (Fig. 43). This finding supports the notion that elevated levels of ambient noise in the OR are perceived to be controllable by CRNAs.



	NEVER	RARELY	SOMETIMES	FREQUENTLY	ALWAYS	TOTAL	WEIGHTED AVERAGE
Responses	0.20% 1	2.19% 11	19.52% 98	43.63% 219	34.46% 173	502	4.10

Figure 43. Frequency of Responses: Survey Q15

Survey Item 16. *Efforts should be made to control elevated levels of ambient noise in the OR.* This survey item sought to elicit CRNA opinions as to the necessity for control of ambient noise levels in the OR during the perioperative period. The majority of respondents replied *Always* (318 [63.35%]), followed distantly by *Frequently* (116 [23%]), *Sometimes* (54 [10.76%]), and *Rarely* (14 [2.79%]). Zero responses for the *Never* ranking were received for survey Q16. The weighted average of all rankings was 4.47/5 indicating a significantly positive direction of responses (Fig. 44) and validation of CRNA perceptions that elevated levels of ambient noise in the OR should be controlled.



	NEVER	RARELY	SOMETIMES	FREQUENTLY	ALWAYS	TOTAL	WEIGHTED AVERAGE
Responses	0.00% 0	2.79% 14	10.76% 54	23.11% 116	63.35% 318	502	4.47

Figure 44. Frequency of Responses: Survey Q16

Survey Item 17. On a scale of 1 to 4, rank these potential contributory sources of ambient noise in the OR from the MOST (4) to the LEAST (1) impactful: Presence of music; non-essential conversation; number of bodies in the OR; multiple entries into and exits from the OR. The intent of survey Q17 was to elicit perceptions of the magnitude of contribution of four specific sources of ambient OR noise during the intraoperative period: non-essential conversation, number of individuals in the OR, background music and entries into and exits from the OR. Respondents ranked these elements in order of MOST (4) to LEAST (1) impactful. Order of ranking was based on average (mean) ranking scores from highest to lowest (Table 21).

Table 21. Magnitude of Impact of Potential Sources of Ambient OR Noise

Magnitude of Impact		**Mean values**
MOST	Non-essential conversation	2.71
	Number of bodies in the OR	2.56
	Presence of music	2.52
LEAST	Multiple entries into and exits from the OR	2.22

As depicted in Table 21, respondents ranked non-essential conversation as the most impactful contributor to increased ambient noise in the OR. Number of bodies in the OR and the presence of background music were nearly equal in rank. Multiple entries into and egresses from the OR was regarded as the least impactful factor in the production of increased ambient OR noise. Graphic depiction of this factor yielded a bi-modal distribution of responses (Fig. 45). This variance in responses may have signified the difference in OR environments of survey participants (i.e. proximity of anesthesia station to the OR door, patency of door, noise produced by physical manipulation/opening/closing of OR door).

Friedman all pairs exact test was used as the omnibus statistical assay to elicit significant differences between the ranks of all four tested noise contributory factors. The Friedman test replaces the traditional analysis of variance (ANOVA) for data that is ordinal, such as the ranked values emanating from Likert scales. Likert rating averages were utilized only to illustrate directionality of responses. However, data from comparison of the four noise-producing variables in Q17 was maintained as ordinal rankings. Therefore, Friedman was most appropriate for this analysis.

Entries/exits had a statistically significantly lower average rank than all other potential sources of increased ambient noise (music: p = .00112; number of bodies: p = .00017; conversation: p = 1.20E-08). Comparison of non-essential conversation to music indicated a marginally significant trend for conversation as a more impactful contributor to ambient OR noise than background music (p =.05859). Number of bodies in the OR and presence of music were closely approximated (means 2.56, 2.52, respectively). Freidman all pairs exact test elicited no statistically significant difference between the two factors (p = .61636) (Table 22).

Table 22. Friedman all pairs exact test p-values, Comparing Average Ranks per Item

Impact of:	Music	Number of Bodies	Conversation
Number of Bodies	0.61636		
Conversation	**0.05859**	0.13711	
Entries and Exits	**0.00112**	**0.00017**	**1.20E-08**

**Bolded values are significant or marginally significant*

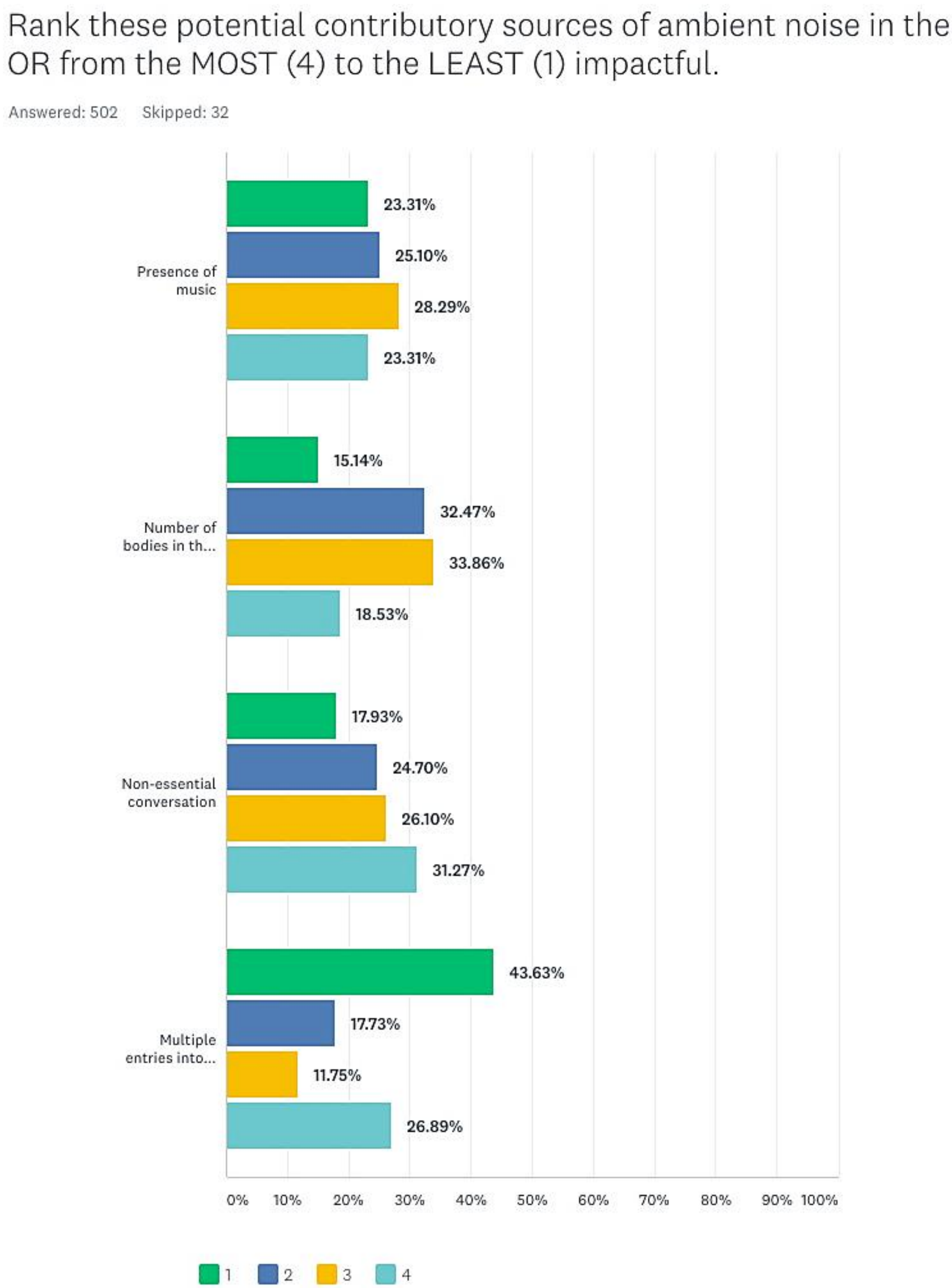


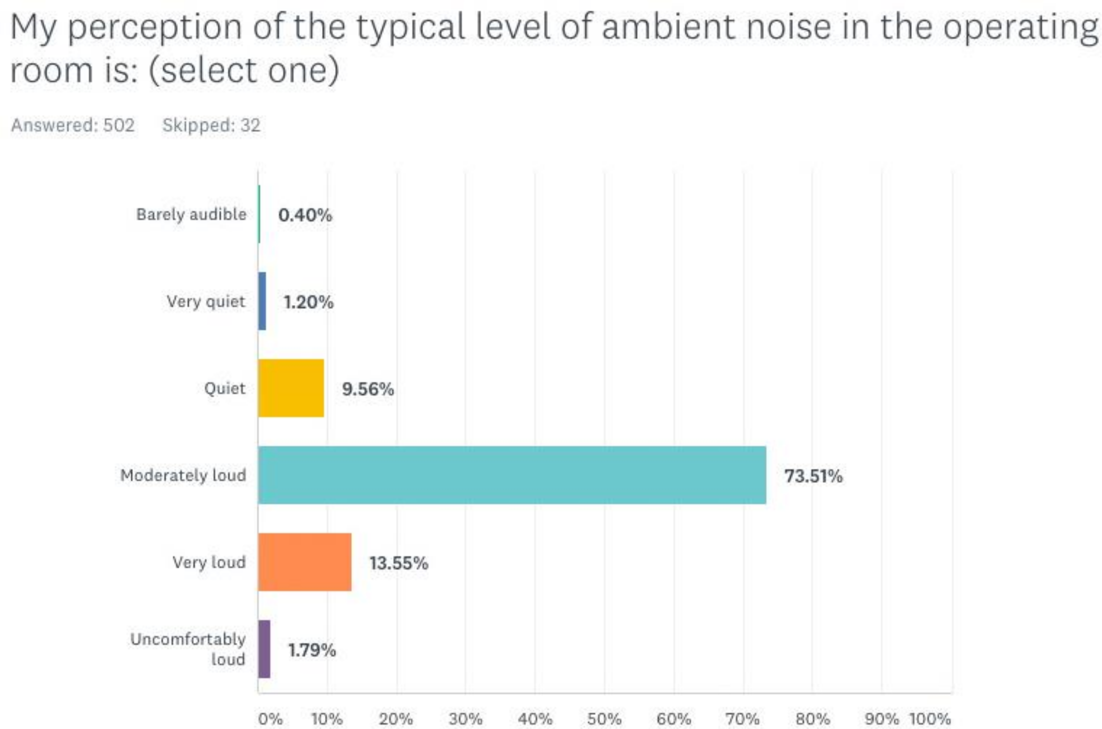
Figure 45. Contributory Sources of Ambient OR Noise: Survey Q17

	1	2	3	4	TOTAL
Presence of music	23.31% 117	25.10% 126	28.29% 142	23.31% 117	502
Number of bodies in the OR	15.14% 76	32.47% 163	33.86% 170	18.53% 93	502
Non-essential conversation	17.93% 90	24.70% 124	26.10% 131	31.27% 157	502
Multiple entries into and exits from the OR	43.63% 219	17.73% 89	11.75% 59	26.89% 135	502

BASIC STATISTICS

	MINIMUM	MAXIMUM	MEDIAN	MEAN	STANDARD DEVIATION
Presence of music	1.00	4.00	3.00	2.52	1.09
Number of bodies in the OR	1.00	4.00	3.00	2.56	0.96
Non-essential conversation	1.00	4.00	3.00	2.71	1.09
Multiple entries into and exits from the OR	1.00	4.00	2.00	2.22	1.26

Survey Item 18. *My perception of the typical level of ambient noise in the operating room is: (select one): Barely audible; Very quiet; Quiet; Moderately loud; Very loud; Uncomfortably loud; Painfully loud.* The intent of this survey item was to explore CRNA perceptions of the quality of noise they are regularly exposed to in the OR environment. Descriptions of noise intensities were garnered from *Comparison of Sound Levels in the Environment* (CA EPA, 2000; Fig. 6, pg. 34). An overwhelming majority of respondents perceived typical levels of ambient noise in the OR as *Moderately loud* (369 [73.51%]). Of note, this sound designation ranges from approximately 48 dBA, approximating the sound of normal conversation, to 78 dBA similar to the sound of a vacuum cleaner. CRNA perceptions of alternate noise characteristic selections in order of descending frequency of responses were *Very loud* (68 [13.55%]), *Quiet* (48 [9.56%]), *Uncomfortably loud* (9 [1.79%]), *Very quiet* (6 [1/20%]) and *Barely audible* (2 [.40%]) (Fig. 46).



ANSWER CHOICES	RESPONSES	
Barely audible	0.40%	2
Very quiet	1.20%	6
Quiet	9.56%	48
Moderately loud	73.51%	369
Very loud	13.55%	68
Uncomfortably loud	1.79%	9
TOTAL		502

Figure 46. CRNA Perceptions of Typical Ambient Noise Quality in the OR: Survey Q18

Survey Item 19. *Please share any comments that you may have regarding levels of ambient noise in the OR.* Multiple interesting and insightful remarks were offered in response to Q19. Three hundred and nine comments were examined by the researcher for completeness; 32 containing the following responses were eliminated: N/A, none, no comment, 0000, and (.). Although responses to Q1-18 were not used from the pilot survey in the final analyses, 19 valuable comments were elicited from participants, reported and designated as pilot responses by an asterisk. Observations with similar themes were consolidated into seven descriptive categories:

- Control of Intraoperative Ambient Noise
- Effects of Ambient Intraoperative Noise
- Phase of Procedure Related to Ambient Intraoperative Noise
- Prevalence of Noise during the Intraoperative Period
- Sources of Ambient Intraoperative Noise
- Variability in Ambient Intraoperative Noise
- Positive Aspects of Ambient Noise/Coping Mechanisms

Verbatim responses elicited from Q19 are displayed in Appendix H: Thematic Catalog of Open-ended Responses by CRNAs.

Correlational Analyses

Age/Generational Group and Years of Work Experience with Survey Q 2-16. Responses to survey questions Q2 through 16 were compared to CRNA age/generational group and years of work experience. The purpose of this inquiry was to identify potential associations between dependent variables: perceptions of the presence and effects of noise with independent variables: covariates age and years of work experience. As described in Chapter 2, Graneto and Damm (2013) elicited a positive concordant relationship between perception of noise and work experience in ER RNs. Ambient noise was perceived as excessive by nurses with increased years of practice. However, Morrison (2003) reported a conflicting effect among PICU RNs. Nurses with increased work years exhibited lower heart rates in high noise conditions in contrast to their younger counterparts. Correlations of CRNA age/generational group and years of work experience sought to uncover similar associations within this population of providers.

Marginal relationships between age and generational group with the impact of noise survey questions were elicited through the Somers' *d* correlation coefficient. Because multiple relationships were simultaneously analyzed for associations, stringent 99% confidence intervals (CI) were applied to control the overall error rate.

Those CRNAs who were older displayed a stronger influence, although the relationship was relatively weak and significant for only 5 of the 15 dependent variables tested. *Noise should be controlled* (*d* .088; CI .003-.173) was minimally associated with age/generational group followed by *Noise is a problem* (*d* .097; CI .005-.190). Moderate positive relationships existed between age and survey queries regarding difficulty in performing tasks and procedures (*d* .129; CI .034-.223), inherent sensitivity to noise (*d* .144; CI .055-.234), and adverse effects of noise (d .156; CI .065-.246) in ascending order of importance.

Regarding years of work experience, Somers' *d* with 99% CI again revealed only minimal relationships with the impact of noise survey questions. Statistically significant associations were elicited for the survey questions regarding inherent noise sensitivity (*d* .121; CI .037-.206), adverse effects of noise (*d* .119; CI .033-.204), noise as a problem (*d*. 096; CI .013-.180) and the presence of noise during induction (*d* .090; CI .004-.175) in descending order of importance.

Tables 23 and 24 delineate the Somers' *d* coefficients predicting the relationship of respondent age/generational group and years of work experience to survey items 2 through 16 (respectively). Values in bold print denote statistically significant differences from zero.

Table 23. Somers' *d* Coefficients Predicting Survey Q2-16 from Age/Generational Group (CI 99%)

Survey Items re: Noise	**Somers' *d***	**Lower CI**	**Upper CI**
Q2: Present during intraoperative period	0.003	-0.079	0.085
Q3: Present during induction	0.091	0.000	0.183
Q4: Present during emergence	0.012	-0.079	0.103
Q5: Is a problem	**0.097**	**0.005**	**0.190**
Q6: I am sensitive	**0.144**	**0.055**	**0.234**
Q7: I am adversely affected	**0.156**	**0.065**	**0.246**
Q8: Difficult to perform tasks	**0.129**	**0.034**	**0.223**
Q9: Difficult to remember things	-0.027	-0.123	0.069
Q10: Difficult to communicate	0.018	-0.074	0.110
Q11: Difficult to concentrate	0.088	-0.005	0.181
Q12: Negative impact on health	0.005	-0.090	0.100
Q13: Threat to patient safety	0.046	-0.049	0.140
Q14: Contributes to adverse patient outcomes	-0.049	-0.137	0.039
Q15: Is controllable	-0.003	-0.094	0.089
Q16: Should be controlled	**0.088**	**0.003**	**0.173**

**Bolded values are significantly different from zero*

Table 24. Somers' *d* Coefficients Predicting Survey Q2-16 from Years of Work Experience (CI 99%)

Survey Items re: Noise	Somers' *d*	Lower CI	Upper CI
Q2: Present during intraoperative period	0.023	-0.057	0.102
Q3: Present during induction	**0.090**	**0.004**	**0.175**
Q4: Present during emergence	0.007	-0.079	0.092
Q5: Is a problem	**0.096**	**0.013**	**0.180**
Q6: I am sensitive	**0.121**	**0.037**	**0.206**
Q7: I am adversely affected	**0.119**	**0.033**	**0.204**
Q8: Difficult to perform tasks	0.087	0.000	0.175
Q9: Difficult to remember things	-0.020	-0.112	0.072
Q10: Difficult to communicate	0.007	-0.078	0.091
Q11: Difficult to concentrate	0.055	-0.031	0.141
Q12: Negative impact on health	0.031	-0.056	0.118
Q13: Threat to patient safety	0.055	-0.030	0.141
Q14: Contributes to adverse patient outcomes	-0.049	-0.134	0.037
Q15: Is controllable	0.024	-0.065	0.112
Q16: Should be controlled	0.054	-0.027	0.135

**Bolded values are significantly different from zero*

Inherent noise sensitivity with Survey Q 5, 7-12. Responses to survey questions Q5 and 7 through 12 were compared to CRNA perception of inherent noise sensitivity (Q6*: I am normally sensitive to noise*). The aim of this correlational analysis was to elicit any potential effect that pre-existing sensitivity to noise might have on CRNA perception of the effects of excessive ambient OR noise. It was posited that a respondent's innate aversion to noise might precipitate negative bias towards ambient noise in the OR. Not surprisingly, Somers' *d* demonstrated a moderate to large association between all survey questions tested: Q6 with Q5 and Q7 through 12 (Table 25). These findings support the hypothesis that tendency towards noise aversion positively impacts perceptions of the adverse effects of increased levels of ambient OR noise in CRNAs. This association must be taken into account when considering responses to these questions from all participants.

Table 25. Somers' *d* Coefficients Predicting Survey Q 5, 7-12 from Inherent Noise Sensitivity (CI 99%)

Survey Items re: Noise	**Somers' *d***	**Lower CI**	**Upper CI**
Q5: Is a problem	**0.274**	**0.180**	**0.369**
Q7: I am adversely affected	**0.482**	**0.400**	**0.563**
Q8: Difficult to perform tasks	**0.359**	**0.268**	**0.451**
Q9: Difficult to remember things	**0.162**	**0.059**	**0.266**
Q10: Difficult to communicate	**0.185**	**0.092**	**0.277**
Q11: Difficult to concentrate	**0.304**	**0.210**	**0.398**
Q12: Negative impact on health	**0.319**	**0.225**	**0.413**

**Bolded values are significantly different from zero*

Summary

This chapter serves as a review of the survey results garnered from *Perceived Impact of Ambient Operating Room Noise by Certified Registered Nurse Anesthetists*. Sample size was described, data inspection and cleaning were discussed, and tabulation and review of specific survey items was undertaken. Correlational analyses were generated, and open-ended comments were thematically arranged and reported verbatim in Appendix H.

Chapter 5 will briefly restate the motivation for this research project: the problem, the aim of the study, and the methodology used to carry out the investigation. Research questions will be reviewed with a discussion of findings and possible explanations for results; hypotheses will be accepted or disproved. Dialogue regarding perceived threats to both external and internal validity will ensue. Finally, suggestions for the mitigation of elevated levels of ambient OR noise and focal areas for continued research on this pervasive and problematic phenomenon will be offered.

Chapter 5: Discussion and Conclusion

Summary and Overview of the Problem

Purpose of the Study. The operating room is one of the most complex and dynamic environments found across all healthcare domains. No two surgical cases are alike and no two patients are alike. Due to the intense nature and volume of the work carried out during the perioperative period, variables such as increased levels of unnecessary noise may produce unsafe conditions for both patients and healthcare professionals (AORN, 2014). Anecdotally, health care providers have had longstanding issues with elevated levels of ambient noise occurring during the intraoperative period, particularly at the induction and emergence phases of the anesthetic. Complaints regarding the presence of untenable levels of noise in the OR proliferate amongst anesthesia providers, having the potential to draw attention away from the patient. A thorough review of the literature, however, yields a paucity of formal research projects that explore these subjective perceptions. This represents a significant gap in knowledge pertaining to this paradigm. In particular, the issue of increasing noise levels and inattention of OR team members to events surrounding patient emergence from anesthesia, widely regarded as an extremely critical phase, (Atchabahian in Chu, pg. 27, 2012; Hatzakorzian et al., 2006), has been noted to be pervasive and to negatively affect anesthetists. This effect is not entirely understood; thus, it represents one of the core themes of this research project.

On June 25, 2015, an informal query posted in the Facebook *CRNAs and SRNAs* group feed posed the following question:

> *"Anyone else have a problem with noise at induction and/or emergence?"*

The question garnered 168 responses. Although the majority of respondents suggested noise during the critical phases of the anesthetic was a significant problem in their practice, a small proportion of respondents denied having any difficulty with the issue. Some practitioners expressed the ability to "tune it out." Other CRNAs sensed that they had a modicum of control over the situation. Where noise levels were perceived as excessive during critical times, these CRNAs felt comfortable alerting the team and requesting quieter conditions. Most agreed that this was an effective tactic; however, others reported fear of alienation of OR team members when calling for quieter surroundings. This poses a potential for compromised patient safety.

In an age where patient safety in health care is the highest priority, there is still so much to learn about the impact of noise on outcomes. Elevated levels of ambient noise in the operating room have long been recognized as a persistent, ongoing problem, but which confounding factors might influence the individual's perception of environmental noise? Does time spent functioning in a noisy environment facilitate habituation, an eventual adaptation of the anesthesia provider to the setting? Since elevations in OR noise occur regularly, do anesthetists eventually accept its presence? Does this normalization of deviance (Prielipp et al., 2010) inadvertently provoke potentially dangerous conditions? Are covariates such as noise sensitivity and annoyance, provider age/generation, and/or years of work experience related to the impact of excessive ambient noise on concentration, situation awareness, technical skills and overall performance? What is the origin of this unwanted sound? Are elevations in ambient noise in the OR inevitable? Are there methods to control excessive ambient OR noise?

This exploratory research project was undertaken with the aim of answering these questions, thereby filling a significant gap in knowledge regarding the perceptions concerning the presence of untenable levels of noise in the operating room by CRNAs. The short-term goal was to add to the existing body of knowledge and to direct further inquiry regarding this intriguing construct. However, the overarching meta-objective was and is to contribute towards the continued improvement of patient safety.

Review of Methodology

The purpose of this project was to explore CRNA perceptions of the presence, quality and potential detrimental effects of excessive ambient noise in the OR. To that end, a 20-item survey was devised after a thorough review of the literature regarding this subject matter. There were no studies that explicitly examined noise awareness and perception of noise in anesthesia providers. Survey items were derived through appraisal of prior surveys related to the construct of noise and from earlier research in the noise aversion domain.

After receiving IRB approval from VCU, the original survey was piloted to a convenience sample of CRNAs from the state of Connecticut engaged in current clinical practice. Cronbach's alpha was performed on the 16 Likert-scaled survey items as reported in the Methods section of this document. While the overall results supported good internal consistency and reliability, one thematic category regarding the presence of elevated ambient noise in the OR yielded an unacceptable alpha when examined alone. This was likely due to an inadequate number of group items tested or a redundancy within items regarding noise levels during specific phases of the anesthetic. Removal of the question "*Elevated levels of ambient noise in the OR are consistent throughout the course of the anesthetic*" resulted after an improved alpha was elicited both within the thematic category and with overall testing of all Likert-based items.

Statistical analyses of survey results included frequency of responses of Likert values and the description of typical levels of ambient OR noise questions. Weighted averages were added to inform general directionality of responses. Four potential sources of ambient OR noise were examined and reported in order of impact. These included non-essential conversation, presence of background music, number of bodies in the OR and entries into and exits from the OR. Not surprisingly, non-essential conversation was elicited as the most impactful contributor to ambient OR noise. CRNA perceptions of the typical ambient OR noise levels were also examined; noise was perceived as moderately loud the majority of the time.

The Effects of Noise on Human Performance

The widespread and varied effects of noise on human performance, behavior and health have been well established. However, conflicting reports of noise sensitivity and adaptation exist. For example, studies purporting the negative effects of noise on performance abound; however, the results of this research project via CRNA perceptions of the impact of ambient OR noise did not wholly support this notion. As described in Chapter 4, 62% of CRNAs surveyed did perceive moderately loud noise as characteristically present in the OR; however, only 39% felt that it was frequently problematic. CRNAs did not perceive described noise as a distraction or as provoking a negative impact on their performance or health. Smith (1989; pg. 191) reported significant "individual differences in the effects of moderate intensity noise" while the work of Weinstein (1978) elicited an eventual adaptation to noise conditions. Helton et al. (2002) reported that loud jet engine noise actually *increased* both vigilance and task engagement relative to a quiet control condition, an unexpected and curious finding (Hancock & Szalma, 2008; pg.130).

Despite the majority of CRNA participants reporting frequently elevated levels of ambient OR noise, particularly at the critical emergence phase of the anesthetic, outcomes from this research project suggest that CRNAs perceive only marginal negative impacts resulting from exposure to noise. Occurrence of adverse patient outcomes and elements of performance such as the ability to carry out tasks and procedures were perceived to be affected only *Rarely* (46%) and *Sometimes* (48%), respectively. The ability to retrieve information from short- and long-term memory was again perceived as rarely impacted by noise (41%). Additionally, situation awareness vis-à-vis anesthetist distractibility and fidelity of team communication was not perceived to be significantly negatively impacted by the presence of increased levels of ambient OR noise. The majority of ratings for both factors was *Sometimes* (44%; 48%, respectively). Anesthetists did not perceive noise to negatively affect their health. Perhaps most remarkably, CRNAs felt that adverse patient outcomes were a rarity and that diminution in patient safety occurred only occasionally. Whereas this research project does illuminate a variety of concerning issues surrounding elevated levels of ambient noise in the intraoperative period, many of the findings were inconsistent with the ideation that noise poses a problem for CRNAs in the OR.

It remains unclear whether the reported perceptions of the effects of noise are the result of an anesthetist's high degree of adaptability, the ability to discern critical information in the midst of interference (Figs. 1, 16) or the phenomenon of habituation. Habituation, a fundamental form of learning, is the individual's ability to become less aroused by a stimulus after repeated exposure to that stimulus (Thompson, 2001). Perhaps recurrent contact with intraoperative noise over the long term becomes commonplace. CRNAs learn to "tune it out" and adjust their practices accordingly.

Given the knowledge that noise may diminish patient safety and a reported agreement that noise should be controlled, are CRNAs engaging in the normalization of deviant behaviors by functioning in noisy conditions? There is an unsaid pressure to conform to the culture of the OR, a culture that can be dynamic, even chaotic at times, and one that lacks well-defined social norms. Glew (2012) refers to the "person-environment fit" as being elemental to sound team dynamics in the workplace. Characteristics of the individual must meld with certain attributes of the work environment; compatibility with the work team is a key factor. Henceforth, it may be easier to maintain good relationships, "keep the peace" with OR team members, and conform to the culture than to advocate for patient safety by requesting quiet conditions during the intraoperative period. This represents a thought-provoking area of focus for future research in this field.

Recently, Keller et al. (2018) examined the effect of noise pollution on members of the surgical team. Members of the intraoperative team were questioned as to their distractibility (1= *ability to work in a concentrated way*; 7= *very distracted*) and the difficulty of the procedure (1= e*asy*; 7= *very difficult*). Analogous to earlier research findings, researchers found that global ambient noise levels well exceeded 55 dBA 50% of the time, predominantly during the intraoperative and closing phases of the procedure. Furthermore, noise levels were deemed to be the highest during the closing phase, further corroborating previous findings in this regard. Of the healthcare providers studied, those who were most vulnerable to the untoward effects of increased noise were resident surgeons and anesthetists. In these two subsets, perceptions of increased distractibility and difficulty of procedure were noted during periods of increased task demand and complexity. Not surprisingly, anesthetists were most adversely affected during closure phase (Keller et al., 2018).

Findings related to the impact of noise on anesthetists do not wholly corroborate with the results of this study regarding the perceptions of noise by CRNAs. Whereas CRNAs did report elevated levels of ambient noise in the OR during the task-dense emergence phase, they did not strongly perceive noise as adversely affecting their concentration, ability to perform tasks and procedures or recall vital information. This outcome mirrored the response of the surgeons and scrub technicians studied and may be the result of individual variations in noise sensitivity, greater work experience and/or a heightened capability of these providers to focus during intense phases of the procedure.

Another topic warranting further research in the general area of noise is the effects of music in intraoperative period on outcomes. The results of this study revealed paradoxical information regarding music in the OR. Contradictory reviews exist regarding the acceptability of background music during the intraoperative period as well as the effects of music on performance. For example, Dalton & Behm (2007) proposed that music has the capacity to impact human performance both positively and negatively. Similarly, Moorthy et al. (2004) found that laparoscopic performance appeared to be unchanged between quiet, loud and music conditions. Regarding the effect of music on patients, Ayoub et al. (2005) found that music decreased the requirement for ancillary sedation with propofol infusions during spinal anesthesia. Joseph and Ulrich (2007) reported therapeutic effects of environmental music on hospitalized patients as evidenced by increased relaxation and a reduction in anxiety.

CRNA respondents in this study ranked music as the third of four most impactful contributors to ambient OR noise, exceeded by non-essential conversation and number of bodies in the room. In the open-ended comments, many claimed that music in the OR was enjoyed, acceptable and easily controllable. Other comments spoke to the type of music played; loud, "pulsating" music was deemed as unacceptable. Despite ongoing contradictions surrounding this issue, background music is present in an estimated 62% of surgical procedures (Bosquanet et al., 2014). Suffice it to say that if music is to be played in the OR, consideration should be given to an appropriate volume along with the consent of all members of the intraoperative team and the safety of the patient in mind (Shambo et al., 2015).

Summary of Findings: Research Questions and Hypotheses

Research Question 1. *Are levels of ambient noise in the operating room perceived as excessive by Certified Registered Nurse Anesthetists (CRNAs)?* The results of this research revealed that the majority of CRNAs queried perceive ambient OR noise to be excessive. Roughly 86% of respondents replied either *Frequently* or *Always* to this query (62.15% and 23.71%, respectively). This finding is congruent with and further substantiates existing literature regarding levels of noise in the OR. Therefore, the null hypothesis is rejected.

Research Question 2. *Is excessive ambient noise in the operating room perceived as problematic by CRNAs?* Responses were mixed; divided equally between *Frequently* and "*Sometimes*." This dichotomy may reflect the difference in CRNAs' inherent sensitivity to noise or variations in OR cultures, milieus or surgical services. In light of the relatively equal distribution of responses between the two main rankings, use of the weighted average of rank means was employed and elicited an overall response which was slightly positive from neutral. Although it is acknowledged that this represents a minor effect, this finding does support the rejection of the null hypothesis.

Research Question 3. *Do CRNAs perceive levels of ambient noise in the operating room to be inappropriately elevated during the critical induction and/or emergence phases of the anesthetic?* CRNAs perceived ambient noise levels to be inappropriately elevated to a greater degree during the emergence than the induction phase of the anesthetic. Although the majority of CRNAs implied that elevations in noise occurred Sometimes during induction, most indicated that noise levels are highest at emergence "*Frequently*." The issues surrounding these perceived high levels of noise exist on two fronts: effects on the provider and effects on the anesthetized patient. For example, high levels of noise, acutely during the emergence period, produce a stimulating environment which may intensify surgical pain, anxiety and recurrence of post-traumatic stress syndrome (PTSD) in susceptible patients (Lovestrand et al., 2013). There is evidence that patients' perceptions of OR noise may be negative, and its presence may ultimately diminish patient satisfaction (Hasfeldt et al., 2014). Notably, in addition to the responses received for the survey items regarding noise during induction and emergence, multiple open-ended comments were received from CRNAs in reference to this issue (Appendix H: "*Phase of Procedure*" thematic group). Overall, the results from this inquiry support rejection of the null hypothesis.

Research Question 4. *Do CRNAs perceive that ambient noise in the operating room adversely affects self-performance?* As established in Chapter 2, CRNA performance may be aptly understood by Endsley's Theory of Situation Awareness (SA). To reiterate, SA is tightly linked to elements of performance of the CRNA on three key levels: the ability to assess the current situation, the ability to respond appropriately to events and the ability to predict potential future events base on the current situation (Endsley, 1995). Figure 20 depicts the research hypothesis that increased ambient OR noise adversely affects anesthetist performance. Oddly, perceptions of self-performance by CRNAs alluded that this factor was not significantly impacted by the presence of increased noise. Survey questions related to effects of elevated noise on markers of performance (task and procedure execution [Q8] and the ability to concentrate ([Q11]) were answered the majority of the time with "*Sometimes*." Memory retrieval, an additional marker of performance and SA, was rarely affected by increased levels of ambient OR noise. This may be explained by the following factors: sound educational preparation and simulation training, continued education in evidence-based practice, habituation to non-optimal environmental conditions, and/or years of work experience. Although CRNAs did not strongly uphold noise as a distraction or a factor which diminished performance and communication, prior research in this area has repeatedly proven this to be an issue. Due to the tendency towards negativity in the weighted values for responses to survey questions regarding performance, the null hypothesis is accepted.

Research Question 5. *Do CRNAs perceive that exposure to ambient noise in the operating room over the long term adversely affects personal health?* The majority of CRNA respondents indicated that chronic exposure to elevated levels of OR noise did not adversely affect their personal health. This was an unanticipated finding since habitual exposure to noise has been associated with hearing loss and sustained cortisol secretion engendering Type II diabetes and cardiovascular disease. Fatigue, stress and anger may also result from prolonged noise exposure, predisposing the practitioner to an immunocompromised state. This, in turn, may provoke frequent illnesses such as colds, GI disturbances and influenza. Responses to this query may reflect a potential gap in knowledge amongst CRNAs of the negative health effects resulting from chronic exposure to elevated levels of ambient noise. Consideration should be given to including this important health information in the training and educational programs of nurse anesthetists. For this query, the null hypothesis is accepted.

Research Question 6. *Are there variations in response to increased levels of ambient noise based on CRNA age/generation and years of work experience?* The results of the correlational assays did not support a relationship between CRNA age/generational group or years of work experience with perceptions of noise. Increasing age has been associated with negative perceptions regarding noise and in this study, this association was elicited in 1/3rd of the survey questions examined. Noise was perceived as more problematic, the cause of adverse effects, and an impedance to task performance as CRNA age increased. An increased tendency towards noise sensitivity and agreement that noise should be controlled was also noted with increasing CRNA age.

Regarding years of work experience, statistically significant relationships were shared in three of the same survey items with 'increasing age of the CRNA'. With a higher number of years of work experience, noise was considered problematic and to cause adverse effects. Similarly, increased inherent noise sensitivity corresponded to years of work experience. Given these statistically significant relationships, it is likely that the main influence on responses could be age itself rather than years practicing, the latter conceivably denoting an imperfect proxy for the former variable. It is reasonable to expect that older CRNAs have more years of work experience and an increased sensitivity to noise.

An association between noise as a distraction and years of work experience was not found. Work by Enser et al. (2017) upholds these findings. Researchers found that anesthesiology resident performance was diminished in noise conditions. However, this effect was only identified in 1st and 2nd year residents. Third and 4th year residents were not significantly affected by noisy conditions. Due to only weak correlations between age/generational group and years of work experience with a small percentage of the survey items examined, the null hypothesis is accepted.

Research Question 7. *Do CRNAs support the institution of noise abatement modalities in the operating room?* The results of this research project confirmed that even though CRNAs do not unanimously appear to feel negatively impacted by the presence of increased levels of ambient noise in all conditions, they seem to support the institution of noise abatement modalities in the OR. This may be explained by a difference between individual feelings and an overall understanding that noise is generally accepted as being associated with diminished performance and adverse outcomes. While some CRNAs may not personally feel affected, they may support abatement strategies with knowledge that decreased noise probably doesn't negatively impact these factors. In other words, it is common sense to believe the benefit of abating noise outweighs the costs. Therefore, the alternate hypothesis is accepted.

Research Question 8. *Does inherent noise sensitivity correlate with CRNA perceptions regarding the presence and effects of ambient noise in the operating room?* Intuitively, there was a definitive relationship between predisposition to noise aversion and survey questions dealing with the presence and adverse effects of noise. Therefore, the alternate hypothesis is accepted.

Project Limitations

Threats to External Validity. *Sample demographics misrepresentative of the CRNA population at large.* As demonstrated by the demographic results, age of respondents was largely congruous with the current population of practicing CRNAs within the US. Also, the largest geographical group of respondents did parallel the national distribution of CRNAs. However, neither the gender nor the years of work experience designations of CRNA respondents aptly illustrated the current population of CRNAs at large. These may have somewhat limited the generalizability of the research findings to the population of interest.

The use of an Internet-based survey. As mentioned in Chapter 3, it is impossible to verify respondent identity when survey research is performed in an online environment. Although CRNAs were the only individuals who received invitations to participate in the research project, participants may have been unknowingly represented by other anesthesia providers. Additionally, SurveyMonkey restricted the ability of respondents to re-enter and take the survey repeatedly from the same IP address. However, there is no guarantee that participants did not enter more than one survey from different computers. Although this event is likely improbable, it is not outside of the realm of reason and must be entertained as a limitation.

The use of a convenience sample. The original sample of CRNA participants was derived through the acquisition of 3000 email addresses from the AANA Foundation. As prior explained in Chapter 3, the use of convenience samples may not be optimal at baseline. At day 24 of the 30-day survey duration and despite incentivization of respondents, a mere 169 responses had been received, representing a 6% survey response rate. This left the requirement for an additional 213 valid responses to achieve power. At this juncture, in an effort to increase response rate, a reminder letter was sent to the original 3000 email addresses. Additionally, the researcher posted a brief note to the Facebook group “CRNAs and SRNAs” to alert CRNAs to the potential presence of the survey in their email inboxes. A link to the survey was posted on the group page and provided individually to members upon request. Finally, the link was distributed to CRNAs employed at the 2 campuses of Yale New Haven Hospital (YNHH) in New Haven CT. Although these maneuvers did succeed in garnering enough responses to achieve power, it is recognized that the alternate convenience samples may have led to response bias. This is particularly true of the respondents from YNHH who know the researcher personally and had prior knowledge of her interest regarding the paradigm of ambient noise in the OR.

Threats to Internal Validity. *Spurious findings based on individual differences in sensitivity to or auditory perception of noise*. Perception of noise is fundamentally subjective and is related to individual sensitivity and the context of the noise (Hasfeldt et al., 2014). There is also some controversy regarding the relationship that exists between perception and reality. Is perception truly reality? This underlying variability in noise sensitivity represents a major confounding factor in this research. Even with the addition of the query regarding pre-existing noise sensitivity and the correlational data produced by comparing noise aversion to responses regarding the ill-effects of noise in the OR, variability in response to the effects of noise was evident through the wide use of the Sometimes response, particularly for survey items regarding the untoward effects of noise on performance and health. Perhaps future researchers might consider eliminating noise-averse participants at the outset with the application of noise sensitivity as a criterion for exclusion. Though this would provide a more homogenous sample, it would not accurately describe the overall population of practicing CRNAs. Therefore, this maneuver would most probably be impractical.

Spurious findings based on varying OR environments and/or culture. Responses may have been confounded by CRNA environment. Services such as plastic surgery are associated with lower noise intensity than orthopedic and neurosurgery procedures (The Joint Commission; 2017). CRNA perception of ambient noise is thereby potentially biased by the service in which they habitually work. In addition, the cultural norms of OR may vary based on surgical specialty and possibly geographic location.

Spurious findings based on respondent physical status/mood on the day of response. Noise intensity may be magnified in respondents who are fatigued, ill, anxious or stressed. Any one of these conditions has the capacity to alter the CRNA perception of ambient OR noise and cause sensitivity in practitioners who are not normally noise-averse. While it is impossible to know participant physical status or mood while responding to survey queries, it is acknowledged that any alteration may skew research results.

The presence of extraneous (unavoidable) sources of noise in the OR impacting CRNA perceptions of noise. Heating, ventilation and air conditioning (HVAC) systems, nitrogen-operated power tools, traditional suction canisters, automated suction devices (e.g. Neptune), warming equipment (e.g. Bair Hugger) and other noise-emitting equipment all contribute to the overall noise load in contemporary ORs. Accidental dropping of instruments and metal pans cause sudden “impulse” noise, an unforeseen but highly disruptive and stimulating addition to ambient OR noise. Since there is a limited ability to control these noise-producing elements, they were not included in the survey items. However, many of the open-ended comments spoke to the level of noise emanating from these inescapable sources.

Issues with comprehension of specific survey items. Survey item 17 asked respondents to rate 4 sources of ambient noise in order of greatest to least importance. The structure of this item may have lent itself to problems with discernibility and technical difficulty with manipulating ordered answers. Although the item was designed to be answered using either a traditional numeric fill in or “drag-and-drop” approach, two separate email messages were sent to the researcher claiming an inability to enter all 4 answers or manipulate the order of the responses. These communications suggested participant difficulty in comprehending the directions. This, in turn, may have led to inaccurate results for the survey item rating important sources of noise in descending order of impact. In addition, the terms ‘problem’ (Q5) and ‘adversely affected’ (Q7) may have been too broad, leading to diverse interpretation by survey respondents. Future surveys may seek to enhance these descriptors to include actual examples of problems or adverse effects related to excessive noise.

The presence of survey question bias. Survey items focused principally on the negative effects of increased levels of ambient noise in the OR. Consequently, the overall tone of the survey design may have contained an intrinsic element of bias, potentially leading subjects to respond more negatively towards their perceptions of noise. This could have been a subconscious effect and/or the result of “yea-saying.”

Modalities for Noise Control in the Operating Room

The Joint Commission and AORN have published position statements related to minimizing noise and potential distractions in the OR. Table 26 lists recommendations from both organizations for the mitigation of sources of distraction and extraneous noise in the OR.

Table 26. Suggestions for Noise Control and Limiting Distractions in the OR (adapted from AORN, 2014; the Joint Commission, 2017)

Modalities for Noise Control and Limiting Distractions in the OR
▪ Employ a multidisciplinary team approach in limiting extraneous noise and distractions in the OR ▪ Create no-interruption zones (A.K.A. sterile cockpit, zone of silence, red zone) during critical phases of the procedure (Broom, 2011; Wright, 2016) ▪ Regularly measure noise levels in the OR to provide evidentiary proof that elevated levels of noise exist ▪ Gather empirical data supporting the efficacy of noise-reduction strategies ▪ Provide staff education as to sources of excessive noise and methods to mitigate its occurrence ▪ Consider the OR environment when playing music or breaking down instruments; limit volume from both sources ▪ Buy Quiet (NIOSH, 2015); choose equipment with low-level noise emission when possible ▪ Consider simulation scenarios to enhance attention skills; practice strategies for noise reduction and closed-loop communication ▪ Foster a culture of safety among perioperative staff members, empowering all members to speak up when noise conditions are non-optimal ▪ Enhance collegiality and communication skills between perioperative staff members ▪ Establish policies regarding personal electronic devices, pagers and telephones; create a code of conduct regarding music volume and overall noise levels in the OR ▪ Minimize monitor tones and alarms appropriately whenever possible (Doyle, 2016) ▪ Minimize distractions and noise that do not serve a clinical function

NIOSH acknowledges that chronic exposure to noise in the workplace can cause long-term health effects, specifically hearing loss. This research project did elucidate two open-ended comments from CRNA respondents claiming that years of working in the OR environment have caused them to sustain hearing loss. Four others mentioned the risk of hearing loss associated with chronic exposure to noisy OR conditions. The recommendation that sustained noise levels not exceed 85 dBA (NIOSH, 2015) may be difficult to achieve in the OR environment, especially in services where power-driven equipment is used. Figure 47 depicts the Hierarchy of Controls, a strategy to limit exposure to hazardous noise conditions in the workplace (NIOSH, 2015).

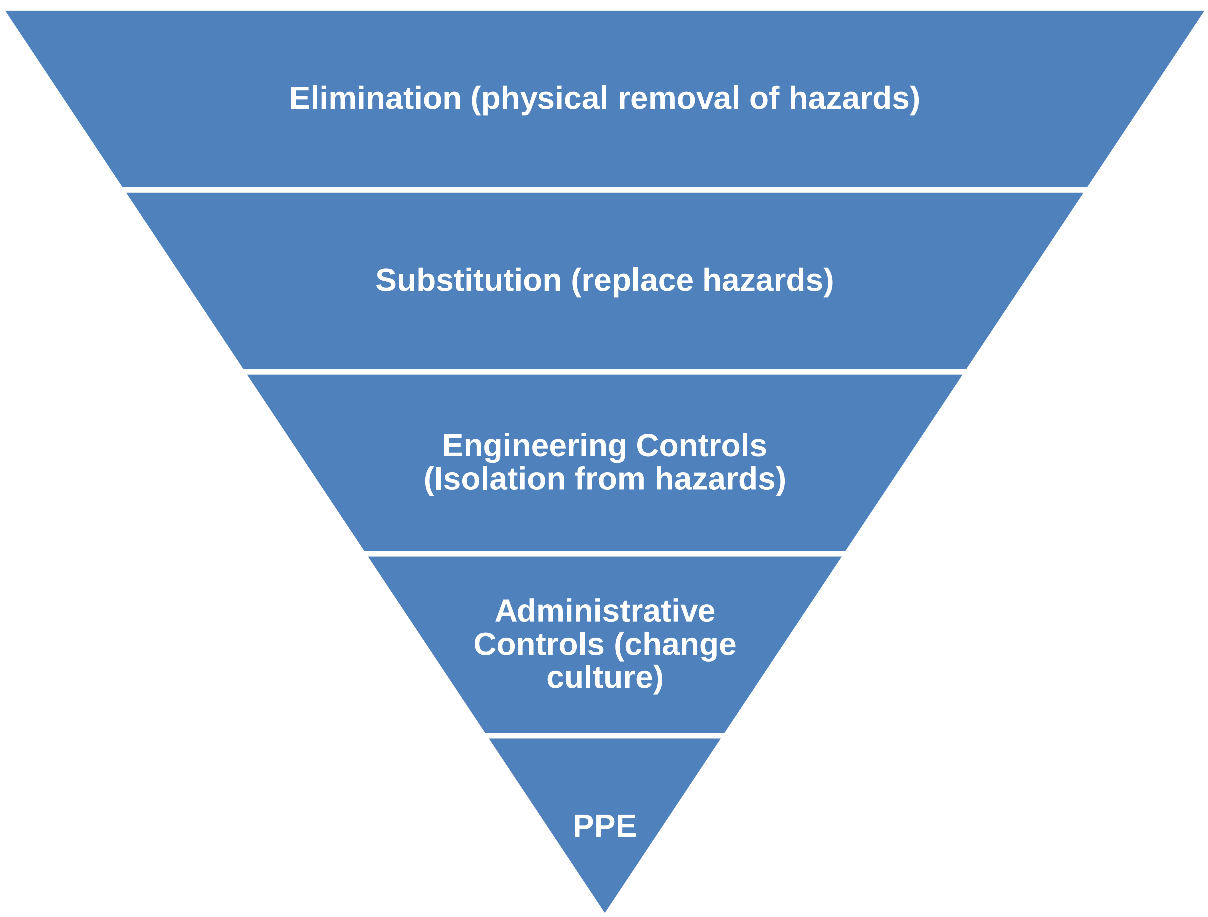


Figure 47. NIOSH Hierarchy of Controls from Most to Least Effective (NIOSH, 2015)

In examining this hierarchy, it is evident that its application in the OR environment may be useful. Elimination of hazards, the most effective intervention in the hierarchy, may be achieved by limiting non-essential conversation, loud music, rushed handling of metal surgical tools and pans, number of bodies in the OR, overhead pages, telephone calls, beeper tones and entry into and egress from the OR. Substitution, related to choosing machinery which emit lower levels of noise in the OR, is improbable at the end-user lever. However, feedback regarding the noise produced by various equipment should be shared with hospital administrators in an effort to raise awareness and potentially steer more thoughtful purchasing habits (*Buy Quiet*). In the OR milieu, isolation of staff from the hazard is unfeasible; however, administrative controls may be achieved through staff education and collaboration and formulation of noise-reducing policies and protocols. Finally, the application of personal protective equipment (PPE) is unlikely in OR staff as ear protective devices may be expensive, unwieldy and may further limit essential communication between team members. Nonetheless, application of PPE to patient ears may be entertained as a strategy to mitigate noise-related injury in this vulnerable population. Modalities such as the insertion of soft foam ear plugs, placement of headphones or blankets gathered around the patient's ears may help to mitigate the deleterious effects of high noise levels during surgery. This is particularly relevant to those patients undergoing orthopedic or neurosurgical procedures and who are receiving neuromuscular blockade.

The Physical Plant. In a research project funded by the Robert Wood Johnson Foundation, Joseph & Ulrich (2007) illustrate the variety of loud noise sources present in hospitals. These sources are ubiquitous in the OR environment, which is chiefly comprised of sound-reflecting versus sound-absorbing materials. Sound-reflecting surfaces such as metal walls and tables are typically utilized in ORs to achieve and maintain a germ-free environment (Ford, 2015). However, these materials may actually magnify and transmit sound over long distances through reverberation and echoing. Modalities for the reduction of noise in OR architecture may include the use of high-performance sound-absorbing ceiling tiles. This tactic, coupled with soundless pager systems and minimization of non-essential conversation may significantly reduce the overall noise burden in the OR milieu (Joseph & Ulrich, 2007). Softer flooring materials such as carpet have also been suggested to mitigate transmission of sound and improve the acoustical environment. However, use of these materials in the OR environment are impractical due to the difficulty in disinfection after contamination with blood or other body fluids.

Staff Education. It is postulated that elevated levels of ambient OR noise may be somewhat mitigated with provision of a pointed curriculum for all members of the perioperative staff. Engelmann et al. (2014) piloted the application of a noise-reduction curriculum in pediatric ORs in Germany. Sound levels were obtained in 156 surgical procedures prior to and after the institution of staff education, implementation of a noise reduction policy and signage in the ORs. In conjunction with these interventions, a visual cueing device was installed in ORs to notify staff of rising or excessive ambient noise levels.

OR staff was divided into two groups: control and intervention. Mean noise levels collected initially in 40 cases served as a baseline reference point for comparison. Researchers found that post-intervention noise levels decreased from an average of 63 vs 59 dBA ($p < .001$) between control and intervention groups; significant decreases in non-essential noise was also noted in the intervention group. Due to the logarithmic nature of dB measures, this drop represented a 50% decrease in the overall sound level. More importantly, the incidence of post-operative complications was reduced in patients associated with the intervention group (n = 10/56 vs. 20/58 control; $p < .05$) (Engelmann et al., 2014).

Similarly, Hogan & Harvey (2015) instituted a quality improvement project intended to decrease ambient noise in the OR. Employing a pre-test/post-test design in two separate hospitals, researchers first obtained baseline measurement of sound pressures concomitant with the induction and emergence phases of 118 anesthetics. Prior to re-measurement of ambient OR noise at these critical points in the cases, researchers introduced a staff education module and placed both signage and decibel meters in the ORs. Of note, staff members were unaware of the presence of sound monitors as they were concealed from view. This approach aimed to lessen the possibility of the Hawthorne effect which could hypothetically skew post-test results, causing in a Type I error.

Results demonstrated a statistically significant decline in OR noise levels during both the induction and emergence phases of the anesthetic ($p < .05$) after noise reduction strategies were introduced. In addition, noise events exceeding 70 dBA were decreased significantly after interventions ($p = .000$).

Clearly, prior training that highlights the potential untoward effects of excessive ambient OR noise and a review of the critical phases of the anesthetic appear to be efficacious and are suggested for noise mitigation and potential culture change in ORs. Educational modules could describe the concept of the sterile cockpit and suggest the possibility of its application to two of the critical phases of the anesthetic course: induction and emergence. In addition, a review of potential noise-inducing factors which exacerbate elevated ambient noise in the OR and suggested modalities for their mitigation should be included. Perioperative staff attention to non-essential conversation, volume of background music and careful handling of surgical pans and instruments could significantly reduce sound levels. However, organizational culture change may take 2-3 years to achieve (Fajak, 2018), and sustainability may be difficult.

A logical theoretical underpinning for the prior education of OR staff arises from Knowles' Adult Learning Theory (Western Region Training Consortium, 2011). This theory of andragogy is operationalized when the pertinent material is presented in a framework that preserves five vital aspects of instruction: respect, safety, immediacy, relevance and engagement. This model is of particular importance when educating staff members as it may serve to maintain collegiality and foster personal and professional growth.

It has been proposed that the problem of unacceptable levels of OR noise be dealt with using a systems-centered approach rather than a person-centered approach (Broom et al., 2011; Van Beuzekom et al., 2010). Presenting the training in this global manner, with leaders adopting noise-reduction practices first, may facilitate acceptance and foster teamwork by all staff members involved in the educational endeavor. In addition, delineation of specific "noise champions" within the OR community may be employed to lead others to be cognizant of ambient noise levels, especially during critical portions of the case. This tactic may further foster positive interprofessional relationships, facilitate engagement in and ownership of the initiative, and result in eventual culture change and sustainability of noise-reduction strategies (Walker & Soule, 2017).

The Sterile Cockpit. There are distinct similarities between the domains of anesthesia and aviation such as the use of technologically advanced equipment coupled with human interfacing and decision-making, and rigorous safety-promoting procedures. As a result, researchers in anesthesia reference the aviation industry for modalities to improve efficacy and enhance a culture of safety (Gaba, 2000; Leape, 1994).

In 1981, after multiple root-cause analyses revealed that diversion of attention or loss of communication was central to the majority of airline misadventures. As a result, the Federal Aviation Administration (FAA) promulgated the concept of the "sterile cockpit." The sterile cockpit rule specifically prohibits crew members from engaging in non-essential activities, including speaking, while the aircraft is involved in taxi, take off, landing or during any period except cruise flight that occurs below an altitude of 10,000 feet (Ludovic, 2019; Sumwalt, 1993). Interestingly, despite the prevalence of this rule since the early 1980's, a review in 2009 of 63 critical incidents transpiring while in flight revealed that the most habitually cited offense was non-essential conversation between crew members. That same year, a flight crew ignored air-traffic control for 90 minutes and inadvertently steered a passenger carrier 110 miles off-course, citing use of laptops in the cockpit (Maynard & Wald, 2009). This ultimately led to the introduction of the FAA Modernization and Reform Act in 2012. This amendment of the original sterile cockpit rule was expanded to forbid the use of "*any personal wireless communications device or a laptop computer for personal use while at their duty station on the flight deck while the aircraft is being operated*" (FAA via U.S. Federal Register, 2014).

Because the course of an anesthetic may be likened to specific procedures occurring during a typical flight, similarities may be drawn between the two events. Table 27 aligns the three phases of an anesthetic course with those of a routine flight. Plane takeoff is akin to anesthetic induction; anesthetic maintenance may be associated with time in-flight and emergence to landing of the aircraft (Broom et al., 2011). With regards to cognitive load, task density and necessity for anesthetist SA and optimal performance, induction and emergence are often regarded as the most precarious phases of the anesthetic course (Atchabahian, 2014; Hatzakorzian et al., 2006). Therefore, the potential application of this comparative modality and utilization of the sterile cockpit rule during critical phases such as anesthetic induction and emergence may direct the attention of anesthesia caregivers and operating room (OR) personnel to patient and anesthetist needs during critical phases of the anesthetic. Likewise, limitation of noise-provoking non-essential activities such as superficial chatter, presence of background music in the OR suite and multiple entrances and egresses into and from the OR coupled with engaging the attention of ancillary OR staff during critical phases of the anesthetic course may decrease anesthetist distraction and division of attention. This may potentially mitigate the occurrence of error and resultant critical incidents.

Table 27. Critical Phases of Flight as Compared to a Typical Course of Anesthesia

Aviation	Takeoff	In-flight	Landing
Anesthesia	Induction	Maintenance	Emergence/extubation

Wadhera and associates (2010) examined the application of the sterile cockpit concept to critical phases of open-heart surgery, specifically during the cardiopulmonary bypass phase. Along with attention to non-essential communication during this critical phase of the procedure, they employed a structured communication protocol. Their findings indicated that frequency of case-specific communication increased (p = .06) and miscommunication events decreased significantly (p = .008) after the intervention.

Lastly, although the concept of the sterile cockpit in the OR during critical phases of the anesthetic may be a viable one, Keller and associates (2018) recommend alternating periods of silence with appropriately timed periods of “relaxing and chatting,” especially during longer surgical procedures. Attention to nuances such as these may help to re-energize the team, thereby preserving staff morale, positive interpersonal relationships and a collegial climate.

Conclusion and Recommendations for Future Research

Elevated levels of intraoperative noise were identified in this research but its effects on performance require further inquiry. Until that time, the application of interventions to mitigate excessive OR noise could potentially decrease anesthesia provider distraction, increase patient safety, and improve quality measures. Regarding practical significance, it is hoped that the results of this research will inspire an increased appreciation for the presence of unacceptable noise levels and their association with anesthetist distraction and OR staff inattention during key phases of the anesthetic, particularly emergence. Additionally, since healthcare is not only a service but a business, attention to patient perception of ambient noise levels is imperative to assure not only patient safety, but satisfaction.

Future research may focus on the identification of variations in ambient OR noise during critical phases of the anesthetic; these findings may be shared with members of the perioperative staff to substantiate the presence of ambient noise and engender initiatives to decrease it. Delineation of significant contributors to noise levels may inform further development of novel modalities for noise mitigation. These include a more focused attention to OR design, the development and use of quieter machinery and instruments, and the installation of sound-reducing ceiling panels. Although adjustments to physical plant factors may be more of a long-term goal, education of the perioperative staff as to the negative effects of excessive noise in the OR, and the implementation of a pause to raise staff awareness during the critical induction and emergence phases of the anesthetic may be employed more expeditiously.

The Council on Accreditation of Nurse Anesthesia Programs offers established policies and procedures designed to steer nurse anesthesia programs in a way that produces the most effective and prepared health care providers possible. The inclusion of education on the effects of ambient noise could conceivably be included in the educational standards given the importance of this work environment hazard in operating rooms around the country. When graduate nurse anesthesia students are trained with such safety principles, they are more likely to incorporate them into their professional practice where such strategies will have the greatest impact.

This author envisions the eventual inclusion of an anesthetic emergence protocol as an integral component of the perioperative course, similar to the “Time Out” implemented before procedure initiation. A rubric specifically focusing on the precarious phases of the case with attention to control of ambient levels of noise may ultimately parallel the blueprint of the sterile cockpit rule. Additionally, the use of visual cueing via a device such as the SoundEar© may be efficacious in moderating noise levels and may ultimately become more commonplace in OR suites. It is anticipated that the potential establishment of these or similar interventions will represent a critical step towards the pivotal end goal: to improve outcomes through the facilitation of increased patient safety.

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Appendix A: Weinstein's Noise Sensitivity Scale (1978)

Items

1) I would not mind living on a noisy street if the apartment I had was nice
2) I am more aware of noise than I used to be
3) No one should mind much if someone turns up his stereo full blast once in a while
4) At movies, whispering and crinkling candy wrappers disturbs me
5) I am easily awakened by noise
6) If it is noisy where I am studying, I try to close the door or window or move somewhere else
7) I get annoyed when my neighbors are noisy
8) I get used to most noises without much difficulty
9) How much would it matter to you if an apartment you were interested in renting was located across from a fire station?
10) Sometimes noises get on my nerves and get me irritated
11) Even music I normally like will bother me if I am trying to concentrate
12) It would not bother me to hear the sounds of everyday living from neighbours (footsteps, running water, etc.)
13) When I want to be alone, it disturbs me to hear outside noises
14) I am good at concentrating no matter what is going on around me
15) In a library, I do not mind if people carry on a conversation if they do it quietly
16) Often, there are times when I want complete silence
17) Motorcycles ought to be required to have bigger mufflers
18) I find it hard to relax in a place that is noisy
19) I get mad at people who make noise that keeps me from falling asleep or getting work done
20) I would not mind living in an apartment with thin walls
21) I am sensitive to noise*

**Survey item*

Appendix B: Survey Items: Noise in the Operating Rooms of Greek Hospitals
(Tsiou et al., 2008)

Questions
Is there any noise in the operating room?*
Do you feel that noise has a negative impact on your job?*
Does noise in the operating room disturb you?*
Which are the main sources of noise in the operating room?
Conversation?*
Louder conversation (such as arguments)?
Machines being operated?
External noise?
Air-conditioning systems?
**Survey items*

Appendix C: Letter from Lorraine Jordan, PhD, CRNA documenting AANA Foundation current survey response rates.

LJ

Lorraine Jordan <ljordan@aana.com>
Fri 7/27, 10:01 AM
Cosgrove, Marianne

Reply all

Dear Ms. Cosgrove

The typically response rate for AANA electronic surveys is 8-10%. Sometime incentives help with the response rate, however, it may increase your response rate 1-2%. The topic is one of the most impactful elements regarding the response rate.

Good luck with your doctoral work. Please feel free to reach out to me if I can be of further help.

Sincerely,

Lorraine Jordan, PhD, CRNA, CAE, FAAN
AANA Chief Research, Quality and Policy Officer and AANA Foundation CEO

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Appendix D: NoiSeQ Scale (Shutte, 2007)

No	Rating scale: **0**: Strongly disagree **1**: Slightly disagree **2**: Slightly agree **3**: Strongly agree
1	I find it hard to relax in a noisy environment
2	I need peace and quiet to do difficult work
3	For a quiet place to live I would accept other disadvantages
4	I am very sensitive to neighborhood noise
5	I find it hard to communicate while it is noisy
6	I have no problems to do routine work in a noisy environment
7	I become very agitated if I can hear someone talking while I am trying to fall asleep
8	When I am absorbed in a conversation I do not notice if it is noisy around me
9	I can fall asleep even when it is noisy
10	My performance is much worse in noisy places
11	Listening to loud music helps me relax after work
12	In a restaurant I cannot concentrate well on my conversation when people are talking loudly at other tables
13	I need quiet surroundings to be able to work on new tasks
14	When people around me are noisy I don't get on with my work
15	I need an absolutely quiet environment to get a good night's sleep
16	Even the slightest noise can prevent me from falling asleep
17	When I am at home, I become accustomed to noise quickly
18	In the cinema, I am annoyed by other people whispering and by rustling paper
19	I think music interferes with conversations
20	I find it very hard to follow a conversation when the radio is playing
21	If my workplace was noisy I would always try to find a way for me to change this
22	When dancing I don't mind how loud the music is
23	It would not bother me to live in a noisy street
24	When other peoples' children are noisy I would prefer that they should not play in front of my house
25	At weekends I prefer quiet surroundings
26	I do not feel well rested if there has been a lot of noise the night before
27	When I am at home I find it uncomfortable if the radio or TV is left on in the background
28	Loud music in a restaurant makes me stop my conversation
29	I can do complicated work even when background music is playing
30	I wake up at the slightest noise
31	I avoid leisure activities which are loud
32	I don't like noisy activities in my residential area
33	Noises from neighbours can be extremely disturbing
34	The sound of loud thunder does not usually wake me up
35	High noise levels make it hard for me to concentrate on my conversation

**Survey items/like themes Q2, 4, 5, 6 (inverse), 10, 13, 14, 19, 20, 21, 29 (inverse), 35*

Appendix E: Situation Awareness Rating Technique (SART) (Taylor, 1990)

Instability of Situation (AD)
How changeable is the situation? Is the situation highly unstable and likely to change suddenly (High) or is it very stable and straightforward (Low)?
Complexity of Situation (AD)
How complicated is the situation? Is it complex with many interrelated components (High) or is it simple and straightforward (Low)?
Variability of Situation (AD)
How many variables are changing within the situation? Are there a large number of factors varying (High) or are there very few variables changing (Low)?
Arousal (AS)
How aroused are you in the situation? Are you alert and ready for activity (High) or do you have a low degree of alertness (Low)?
Concentration of Attention* (AS)
How much are you concentrating on the situation? Are you concentrating on many aspects of the situation (High) or focused on only one (Low)?
Division of Attention* (AS)
How much is your attention divided in the situation? Are you concentrating on many aspects of the situation (High) or focused on only one (Low)?
Spare Mental Capacity (AS)
How much mental capacity do you have to spare in the situation? Do you have sufficient to attend to many variables (High) or nothing to spare at all (Low)?
Information Quantity (U)
How much information have you gained about the situation? Have you received and understood a great deal of knowledge (High) or very little (Low)?
Familiarity with Situation (U)
How familiar are you with the situation? Do you have a great deal of relevant experience (High) or is it a new situation (Low)?

Rating scale 1-7; 1 = Low; 7 = High
AD = Attentional Demand **AS** = Attentional Supply **U** = Understanding
Situation **A**wareness = **U**nderstanding – (Attentional **D**emand – Attentional **S**upply)
**Survey theme*

Appendix F: Survey Instrument

VCU

Perceived Impact of Ambient Operating Room Noise by Certified Registered Nurse Anesthetists

Survey Instrument

Ambient noise in the OR describes background noise that is present throughout the perioperative period. Please respond to this brief survey by answering each question with your *initial* impression.

The estimated time to complete this survey is approximately 6 minutes. Your contribution will add greatly to the body of knowledge regarding the presence and effects of ambient noise in the OR.

At the end of the survey, you will be invited to enter a raffle for a $25 Amazon gift card. Twenty respondents will be randomly selected to receive this gift.

Many thanks for your time in participating in this research project!

1. I am a Certified Registered Nurse Anesthetist in the US, currently engaged in active clinical practice.

☐ Yes

☐ No

1

Perceived Impact of Ambient Operating Room Noise by Certified Registered Nurse Anesthetists

2. Elevated levels of ambient noise are present in the operating room (OR) during the intraoperative period.

Never	Rarely	Sometimes	Frequently	Always
○	○	○	○	○

3. Elevated levels of ambient noise in the OR are highest during the induction phase of the anesthetic.

Never	Rarely	Sometimes	Frequently	Always
○	○	○	○	○

4. Elevated levels of ambient noise in the OR are highest during the emergence phase of the anesthetic.

Never	Rarely	Sometimes	Frequently	Always
○	○	○	○	○

5. Elevated levels of ambient noise in the OR are a problem.

Never	Rarely	Sometimes	Frequently	Always
○	○	○	○	○

6. I am normally sensitive to noise.

Never	Rarely	Sometimes	Frequently	Always
○	○	○	○	○

2

7. I am adversely affected by elevated levels of ambient noise in the OR.

Never	Rarely	Sometimes	Frequently	Always
○	○	○	○	○

8. I find it difficult to perform tasks and procedures in an environment where elevated noise exists.

Never	Rarely	Sometimes	Frequently	Always
○	○	○	○	○

9. I find it difficult to remember things in the presence of elevated levels of ambient noise in the OR.

Never	Rarely	Sometimes	Frequently	Always
○	○	○	○	○

10. Elevated levels of ambient noise in the OR limit my ability to effectively communicate with members of the OR team.

Never	Rarely	Sometimes	Frequently	Always
○	○	○	○	○

11. Elevated levels of ambient noise in the OR cause a distraction which limits my ability to concentrate.

Never	Rarely	Sometimes	Frequently	Always
○	○	○	○	○

12. Elevated levels of ambient noise in the OR negatively impact my health.

Never	Rarely	Sometimes	Frequently	Always
○	○	○	○	○

13. Elevated levels of ambient noise in the OR pose a threat to patient safety.

Never	Rarely	Sometimes	Frequently	Always
○	○	○	○	○

14. Elevated levels of ambient noise in the OR contribute to adverse patient outcomes.

Never	Rarely	Sometimes	Frequently	Always
○	○	○	○	○

15. Elevated levels of ambient noise in the OR are controllable.

Never	Rarely	Sometimes	Frequently	Always
○	○	○	○	○

16. Efforts should be made to control elevated levels of ambient noise in the OR.

Never	Rarely	Sometimes	Frequently	Always
○	○	○	○	○

17. Rank these potential contributory sources of ambient noise in the OR from the MOST (4) to the LEAST (1) impactful.

- Presence of music
- Number of bodies in the OR
- Non-essential conversation
- Multiple entries into and exits from the OR

18. My perception of the typical level of ambient noise in the operating room is: (*select one*)

○ Barely audible

○ Very quiet

○ Quiet

○ Moderately loud

○ Very loud

○ Uncomfortably loud

19. Please share any comments that you may have regarding levels of ambient noise in the OR:

20. My age in years/generational group is:

- ☐ 24-34: Millennial
- ☐ 35-46: Generation X
- ☐ 47-56: Young Baby Boomer
- ☐ 57-65: Older Baby Boomer
- ☐ > 65: The Silent Generation

21. My gender is:

- ☐ Female
- ☐ Male
- ☐ Other
- ☐ Would prefer not to answer

22. I have been a practicing CRNA for ______ years.

- ☐ 0-5
- ☐ 6-10
- ☐ 11-15
- ☐ 16-20
- ☐ 21-25
- ☐ > 25

23. I practice in:

- ☐ **AANA Region 1:** CT, MA, ME, NH, NJ, NY, RI, VT
- ☐ **AANA Region 2:** GA, KY, NC, SC, TN, VA, WV
- ☐ **AANA Region 3:** IL, IN, MI, WI
- ☐ **AANA Region 4:** AR, IA, KS, MN, MO, OK, NE, ND, SD
- ☐ **AANA Region 5:** AK, AZ, CA, CO, HI, ID, MT, OR, NM, NV, UT, WA, WY
- ☐ **AANA Region 6:** DC, DE, MD, OH, PA
- ☐ **AANA Region 7:** AL, LA, FL, MS, TX

Perceived Impact of Ambient Operating Room Noise by Certified Registered Nurse Anesthetists
THANK YOU!

Thank you for your participation in this survey! If you would like to be entered into a raffle to win a $25 Amazon gift card, please indicate this by providing your email address and the message "Raffle Contestant" to the following address:
cosgrovems@vcu.edu
At the conclusion of the study, 20 winners will be randomly selected from entries received. Gift cards will be delivered electronically to the email address provided by the contestant upon entry to the raffle.
****Don't forget to click the "DONE" button below before exiting as your responses will not be received!****

7

Appendix G: Email Inviting Prospective Survey Participants

Subject: Invitation to participate in a research study: "*Perceived Impact of Ambient OR Noise by CRNAs"*

Dear CRNA Colleague:

You are invited to participate in a research study titled "*Perceived Impact of Ambient Operating Room Noise by Certified Registered Nurse Anesthetists*". This study is being conducted by Marianne Cosgrove, CRNA, DNAP, PhD(c) and her research committee from the College of Allied Health Professions and the Department of Nurse Anesthesia at Virginia Commonwealth University (VCU) in Richmond, VA.

Presently, pre-existing research regarding the issue of exposure to noise in the operating room (OR) raises multiple concerns regarding provider performance and health and potential adverse impact on patient safety. The purpose of this study is to gather and assess perceptions as to the presence and effects of ambient noise in the OR from currently practicing CRNAs. Since no prior research has been identified with reference to this group of anesthesia providers, this study aims to fill a current gap in knowledge regarding this matter.

In this study, you will be asked to complete an electronic survey. Your participation in the research is entirely voluntary and *you are free to withdraw your participation from this study at any time*. The survey is brief and should take only 6 minutes to complete. This survey has been approved by the Institutional Review Board of VCU. The research is considered minimal risk and participation in the survey will be kept confidential.

Upon successful completion of the survey, you will be invited to submit a current email address for entry into a sweepstakes. Twenty randomly selected respondents will be notified of their win at the conclusion of the research project and will each receive an Amazon gift card valued at $25. Please note that entry into the lottery is completely voluntary. Email addresses supplied for contest entry are de-identified, sent directly to the researcher, separated from prior submitted survey responses.

Information collected in this study may benefit the profession of nurse anesthesia in the future by enhancing understanding regarding the phenomenon of noise in the OR and its potential impact on CRNA performance and patient safety. If you have any questions regarding the survey or this research project in general, please contact Marianne Cosgrove or her advisor Dr. Suzanne Wright at cosgrovems@vcu.edu or smwright@vcu.edu.

If you have general questions about your rights as a participant in this or any other research, or if you wish to discuss problems, concerns or questions, to obtain information, or to offer input about research, you may contact:

Virginia Commonwealth University Office of Research 800 East Leigh Street, Suite 3000, Box 980568, Richmond, VA 23298 (804) 827-2157.
https://research.vcu.edu/human_research/volunteers.htm

By completing and submitting this survey, you are indicating your consent to participate in this study. Your contribution to this important project is so very appreciated. Thank you for your generosity in participating!

Marianne Cosgrove, CRNA, DNAP, PhD(c), Doctoral Candidate, Virginia Commonwealth University

Advisor Dr. Suzanne Wright, PhD, Department of Nurse Anesthesia, Virginia Commonwealth University

Please click on the survey link below and provide us with your feedback no later than **May 12, 2019**.

https://www.surveymonkey.com/r/3FMQSHT

This invitation does not imply any endorsement of the survey research and/or its findings by the AANA. The survey contents and findings are the sole responsibility of the individual conducting the survey.

Click **here** to unsubscribe

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Appendix H: Thematic Catalog of Open-Ended Responses by CRNAs

Control of Intraoperative Ambient Noise

It is the CRNA's responsibility to call out high levels of ambient noise and seek to control it.

Staff have all been trained that induction and emergence are quiet.

It can be controlled but with the goal of fast in and fast out, personnel scramble to get things done.

Levels of noise are completely controllable by the team. If the noise level is deemed inappropriately loud by any team members, they must voice this concern so corrective actions may be taken.

It can and should be controlled by the CRNA.

As a practitioner for many years I can and do control ambient noise when needed.

It is only a problem if one allows it to be a problem. Most of the OR staff will comply if/when you tell them to quiet down for the patient during induction/emergence.

Noise levels should be dictated by those providers in the room and on a case by case basis. We are all professionals, not children.

I find people in the OR feel you are a "$%RT^R" when you ask to keep the noise down. Oh well, I still ask and feel it is essential that we all do this.

I frequently ask "Could I have quiet in the room for induction, please" as I start preoxygenation, and that request is usually met with laughter, scorn, and no decrease in noise level. People think I'm uppity to even ask. If I ask that music volume be lowered, usually my request will not be granted. The surgeon's request for quiet is ALWAYS respected.

Constant communication with the staff and surgeons facilitates lower noise levels.

I always turn it down if needed.

The volume of conversation/music is typically decreased when requested.

Need to communicate need for lowered volumes at crucial times is a must.

You can always control the noise level during induction and emergence. At some point in your career, you reach a level where you can hear changes in heartrate and pulse ox instinctively. This makes ambient noise less of a problem.

Ambient noise is controlled by setting expectations. It also helps to communicate with team members when noise is at a distracting level.

Loudest ambient noise in ORs at my institution seem to be during orthopedic procedures, where the presence of music in addition to loud equipment and surgical procedures are most common.

If it's so loud that you can't hear monitors or excessive suction or if the surgeon is asking you something or you have to yell... speak up and ask that the noise be reduced.

Need to communicate need for lowered volumes at crucial times is a must.

A gentle reminder to keep voices down during induction is always a good idea.

I think it is very important to limit ambient noise, especially during induction and emergence.

Each individual provider has control over the noise levels in the OR. If his or her preference is to tone down the noise, this can be managed with a simple spoken request to do so. My experience has been that any request coming from the head of the bed has been well received and respected.

Staff need more education as to the impact of noise.

I like it when surgeons like it quiet, makes it better to concentrate and be vigilant.

Am always asking people to be quiet, especially on emergence. They just don't get it and now since I have asked so much at least people say shhh, she likes it quiet for wake up. We are educating all staff on why this is important.

Everyone in the OR should be more aware of how they are contributing to un-necessary noise.

When music is loud and I cannot concentrate, I just go over and reduce the volume. Most of time, no one even knows.

Emergence is the only time I ask for the noise level to decrease or comfort of the patient. Unless communication is inhibited.

I work in plastic surgery offices, where we all know how much to talk and when to keep quiet. Music is played lightly.

Needs to be made a priority not only for patient safety but for patient satisfaction also.

I control the ambient noise (music and talking) during induction and emergence. I request the music to be turned down and for people to cease any conversation that does not relate directly to the care of this patient.

I frequently need to remind or staff to quiet down in the environment especially during emergence. As soon as the surgery is over everyone starts chatting about non-essential and not patient related things. This is a constant source of frustration in my career. Surgery is not over until the patient has woken up and left the operating room which is a concept that most of our staff do not understand.

The level of noise in the OR is controllable as persons can be quiet and do their tasks quietly, no need for conversation, random conversation about nonessential things.

Ambient noise level should be controlled in the intraoperative period.

As long as I can hear the team and we can communicate effectively, then I am fine with the level of noise. Ambient noise varies case to case and some is controllable, so I control what I can.

Usually I just have to tell staff to quiet down. They tend to listen.

I believe it is important to speak up and control the amount and volume of noise in the OR especially at critical patient care periods.

If it gets too loud, I have no problem telling folks to cut it out. In 22 years, I have only had one surgeon turn the music up louder when asked to tone it down.

I will take action during critical times to limit noise.

I try to limit noise especially during induction and emergence.*

I control the music, and we are a small OR crew. Everyone is very respectful, thankfully!

Ambient noise is definitely present at all time in the OR. I think that there are certain times that the noise needs to be controlled, and staff does not appreciate the importance of this. For example, during induction, time out, incision and emergence. Other noise not mentioned in the survey that should be included is clean up (trays clashing, garbage being maneuvered, etc.).

The anesthesia provider must, at critical times, exert control over the level of ambient noise in the room. This is necessary but not always well-received.

Sometimes it is difficult to hear members of the OR team when they need assistance because the music is so loud. It would be nice if we had a noise check of some sort, rather like the time out but ensuring that we can hear one another before starting the case.

When I ask for noise reduction, it is viewed as being “bitchy” rather than focused on patient care.

Although I believe it’s all personnel in the OR ‘s responsibility to be mindful of ambient noise in the OR, I believe anesthesia providers should take the lead in insuring noise levels are kept to a minimum as we are often looked upon to generally take charge of the OR.

I regularly have to ask OR staff to “quiet the room” during induction and emergence. During loud procedures such as orthopedic surgical drilling/sawing, I often cover my patient’s ears with a blanket to protect their hearing.

(Noise) should be kept to a minimum.

I always say something if people or music are too loud. I have little or no control over entry/exits into OR.

Annoying. We have the opportunity to set the tone/make requests to change it. Politely!

On many occasions I have asked the OR staff to turn down the music or to stop talking- Can’t hear the surgeon or more importantly my monitors.

I address the noise issue during induction and emergence the radio is off and I quiet the room of conversations.

In the past have “shooshed” team members during induction and emergence because the noise level was too loud.

I am incredibly sensitive to ambient conversations and incessant noise in the OR when going to sleep and emerging a patient. I often demand pure silence during this time, and my staff has become accustomed to it, and will make sure absolute silence is achieved during induction and emergence.

It is necessary to speak up as Anesthesia providers to let others know the level of noise is too high.

Particularly important to control or be aware of these during induction, emergence, and critical points in the surgery.

OR should be ready to receive patient and not opening and clanking trays /instruments while patient is awake and monitors are applied. I feel compelled to explain extraneous noises and assure patient I am concentrating on them before induction.

I always intervene and ask for quiet on induction and emergence.

Frequently noise levels can get out of control when multiple people in the room. When entering the room and preparing for induction, multiple staff may be present leading to side conversations and increased noise. Not only can anesthetist not hear monitors well, but this can be unsettling for patient to have a chaotic environment. It is important for the anesthetist to take control and insist on a quiet room until induction complete. Once asleep, I feel a small amount of noise, music, discussion is tolerable, as long as monitors are audible.

Ambient noise should be kept to a minimum during critical times (i.e. induction and emergence). OR staff should be mindful of the importance of decreased ambient noise and be respectful of an anesthesia provider's request for quiet.*

Effects of Ambient Intraoperative Noise

The major effect that loud ambient noise has for me, is the inability to clearly understand what other members of the team are saying.

Creates a patient danger in stage 2.

Music and non-essential talking contribute adversely to patient caregiving.

Neptune suction machines and music limit ability to hear important communication, plus may contribute to long term hearing loss.

I really hate the loud music one surgeon plays. Heavy metal. Totally unnecessary. No one can communicate if they need something. Distraction because it causes more people to become casual and lose vigilance.

I do not believe surgeon or circulating nurse considers anesthesia's ability to hear communication across blue drape, such as bed position changes, and emergent HR BP changes that has to be yelled for them to hear.

It is imperative to follow the "repeat back verification" of any communication. Too easy to misunderstand.

Noise may be well tolerated by most under normal circumstances but, during crisis or critical situations this noise can be extremely detrimental and pose an increased risk for errors.

Music selection effects OR concentration also, volume and genre.

After 30 years in the operating room my hearing is terrible and, per my ENT, I need hearing aids.

My biggest concern for ambient noise in the OR is limited ability to hear the surgical team and vice versa. Also, it would be interesting to know the effect on staff hearing over time, if any.

I am a pediatric CRNA and I think noise has the potential to cause emergence delirium in the pediatric population.

I can't stand loud music in the OR. I have no problem speaking up and asking them to turn it down. I can't concentrate or hear my monitors.

In our OR the layout is designed so the Bair Hugger, Neptune suction machine, and cautery are all to my left of my workspace for plenty of procedures. Those combined with music make it very hard to hear surgeons or anyone for that matter when they are talking to me. It is one of my biggest irritations.

Loud machinery is awfully loud! Retina machine, phaco machine, Bovie, Neptune suction. Too loud, causes progressive hearing loss!

It’s very distracting and probably not the best thing for a patient to hear when going to sleep or waking up aside from the possible lack of or miscommunication that can occur due to music and or non-essential conversation.

It’s very distracting and makes me always have to turn up my monitors even more creating even more noise.

Many times, people don’t even recognize how loud equipment is until it’s turned off. A perfect example of this is the Bair Hugger. I also think people don’t realize the potential damage they’re doing to their hearing until much later in their career when the damage is in fact already done.

It is starting to affect my hearing.

Phase of Procedure Related to Ambient Intraoperative Noise

Noise level increases during the most critical times in the anesthetic (induction, emergence). Times when the rest of the team is not focusing on the patient.

The most frequent and easiest to change cause is personal conversations that are not necessary, especially during induction/emergence!

Especially detrimental during induction or emergence.

Only time it really aggravates me is during induction and emergence. I get really frustrated if music is up loud or people are talking loudly when I’m trying to calmly put a patient to sleep or wake them up.

Most bothersome at end of case, especially when techs and reps taking care of trays and slamming into case carts. Everyone acts as if case is over, cleaning and picking up.

Very difficult to concentrate at a very critical time-emergence.

Emergence tends to be the loudest time.*

Loud music, banging of case carts during emergence.

Noise is most often noted during induction of anesthesia and emergence from anesthesia - two critical parts of any anesthetic where a provider's attention to detail is critical.

Ambient noise should be kept to a minimum during critical times (i.e. induction and emergence). OR staff should be mindful of the importance of decreased ambient noise and be respectful of an anesthesia provider's request for quiet.

Noise is very common during induction and emergence.*

Emergence is difficult due to the level of noise in OR.*

I find that the levels of ambient noise are highest during emergence immediately after drapes are taken down.*

Non-essential conversation and the clearing of equipment and instruments during induction and emergence creates a potentially dangerous level of distraction for the anesthesia provider, as well as a negative experience for the patient. Both mentioned can adversely affect patient outcomes. Thank you for your attention and efforts in this matter.

I find high levels of ambient noise in the OR on a daily basis. It is something I had complained about since I started working in the OR. During emergence seems to be the most frequent time I heard obnoxiously loud noise. I find it to be unprofessional and increases the potential for an adverse event to occur because the staff isn't paying attention during important intraoperative procedures. The OR staff seems to get easily distracted. Also, it's concerning for the patients because they may feel the music and conversation are more important than their procedure. I wouldn't want to hear this noise if I was undergoing a surgical procedure.*

It would be helpful to have members of the OR team refrain from excess noise during induction and emergence of anesthesia.*

I often have to specifically ask other members of the OR team to limit their noise upon emergence, as this is the time it can be most problematic. Particularly if we have an expected difficult emergence or a known patient with PTSD who would specifically benefit from a quiet room upon emergence.

Staff are repeatedly asked to keep noise down at induction and emergence. I feel that people respond initially and the noise eventually gets back to it's original level or louder. It's so frustrating.

Non-essential conversations are distracting in the OR especially during emergence.

Critical times to be quiet for me are induction, timeouts and emergence.

During emergence/extubation, staff cleaning up and banging pans, whipping trash bags around and not paying attention to the patient.

Most often if I have to ask for quiet it is during induction.

Most often loud talking laughing at beginning and end of case. Is increased when reps and additional team members present.

At my institution no one pays attention to quiet during induction and emergence.

I like music playing during surgery but not during induction nor wake up. Typically, the more people the louder the room.

I frequently have to tell people not to talk during induction and not to slam equipment during emergence.

I have frequently asked the circulator to turn music down or off on emergence and I find it helps everyone (including me) focus on the patient more and his/her safety.

When the staff starts gabbing and being disgracing during induction, emergence, or difficult situations I tell them to Shut. Up.

I feel strongly about quiet during induction and emergence. These are both crucial to good outcomes.

I just ask the personnel in the room to please keep it quiet especially on emergence.

Ambient noise doesn't personally affect me, but it can serve as a distraction for learners in the OR (residents/fellows, SRNAs). I ALWAYS ask for people to be quiet during emergence for the sake of my patients.

It would be helpful if conversations would stop during induction.

Non-essential conversations during induction are annoying. It is hard to obtain the help of the circulator during induction frequently.

Noise levels are the highest during induction and emergence due to everyone being focused on their job specific roles -- such as opening trays, counting instruments, vendors enter/exiting the room, etc. As we all know, times during induction and emergence, are the most critical for patient safety in anesthesia. Therefore, noise should be the controlled the most during these times.

I personally feel like the OR staff does not realize the importance of being quiet during induction and emergence. It is really disrespectful to our patients because the conversations are the last thing they hear when going to sleep and when waking from anesthesia.

Often during induction and emergence the noise level is much higher and the most inconvenient. Many staff members do not respond kindly when asked to minimize their discussion and noise level to optimize patient safety.

Beginning of room turn-over during emergence is one of the biggest problems.

Surgeons that insist on very loud music to the point that it is difficult to hear monitors and alarms are an occasional problem.

The noise level is highest on induction and emergence. If it is at an unsafe level it is the responsibility of the anesthetist to control the noise level. There are times that it is difficult to hear monitors because the volume of the music is so loud. I will ask to have the volume decreased. I almost gave the wrong antibiotic because the music volume was so loud that I misunderstood the drug request.

I agree that conversation that is not essential to patient care frequently occurs by staff during induction and emergence in particular...I find that it is not appropriate ...especially in the presence of an awake patient at the beginning of an anesthetic case. Music is also played very loud intraoperatively which makes it difficult to hear monitors even when turned up to five and six level.

I found that the OR staff is not professional, but don't realize it, during induction and emergence of anesthesia. I believe that all staff in the OR should learn the importance of maintaining professionalism throughout the entire surgical phase ie from preop, introp and recovery.

Production pressure and room turnover at the end of the case contribute to high noise levels during emergence. Leadership rarely wants to address this issue because it delays turnover and noise is not seen by leadership as having an effect on patient care or safety.

Frequently, when surgery is done, it sounds like a party has started while I am still waking the patient.

Important to have a quiet OR during induction, especially with pediatric or special needs patients e.g. neuroatypical/sensory processing disorder.

Can be problematic especially during critical periods of anesthesia/case. All OR staff should feel comfortable about speaking up if they perceive the level of noise to be distracting and compromising the conduct of the case.

Often noise comes from medical students and residents because they are not taught to be quiet; music can be too loud; banging of surgical trays on emergence a huge problem.

There is a disconnect between providers as to what constitutes the “end” of a case. We need to be better at educating the OR staff that the case is not over because the incision(s) is closed. The case is over when the patient is moving out of the OR. This time period between the closing of the incision and moving out the operating room should be valued by everyone as a highly vulnerable time for errors.

Surgeons should NOT be allowed to play music beyond a certain volume For MAC patients the elderly patients do not like loud music It should be mandatory music is shut off at induction AND emergence Often extraneous talking from OR staff at emergence as though all is finished for that particular case when in actuality a very significant part of the case remains i.e. the wake up.

It takes the focus off of patient care. It can be upsetting to the patient prior to induction and during/after emergence.

I’m most concerned during emergence. Frequently the OR staff is distracted and not dialed into what I’m doing.

I really have a problem with conversations going on during induction and emergence--there should be no talking during this time every one should be focused on the patient. I can't count the times i have had to ask everyone to be quiet!

I am extremely sensitive to ambient noise during induction and emergence.

I continually remind staff to refrain from the party-like atmosphere during induction and emergence.

Seems that induction and emergence is the worst as other staff are talking and joking among themselves. In cases turned 180 degrees, it’s hard to hear the surgeons past the Bair Hugger noise, the monitors and the music.

Induction and emergence should be times for a quieter room atmosphere. I often feel that the room personnel are completely disconnected from the potential complications during these times - especially emergence.

Almost always too noisy on emergence

This is definitely an issue, it's crazy how many people think the case is over when the surgeon is finished and how loud conversation and music get especially during emergence

I have had OR nurses mock me and throw me the finger when I have politely asked for noise reduction w emergence.

Hospitals should have better policies about noise during induction and emergence. Most of the time people are talking about the next patient and could be a HIPAA violation.

Induction and emergence are vital times where noise is dangerous.

Music is usually too loud, instruments are banged around during emergence.

It is often very difficult to hear my monitor alarms over conversations and music. Induction and emergence is NOT appreciated and often ignored by non-anesthesia staff.

Induction and emergence are the most critical times for quietness in the OR.

At times I find it almost unbelievable that the rest of the OR staff is so loud, and involved in their own conversations during my most important times during the case, induction and emergence, where a lot can go wrong. It feels rude.

CRNAs use ALL senses to pick up on changes in patient status and equipment function- OR staff do not understand this. Also, emergence tends to be the loudest room time. I always try to keep a calm controlled voice even when an emergence is concerning...frequently, an MDA and I are busy together and communicating well through a difficult emergence while others in the room may be totally oblivious to the situation.

Music is ok if it is kept at a reasonable level and is not chaotic in nature. However, many staff will turn up the music at the end of the case during the most critical time of emergence. Staff conversations can and cannot contribute to negatively regarding ambient noise depending on several factors. HOWEVER, staff conversations during emergence ALWAYS results in their own distraction and loss of situational awareness when anesthesia emerges patients. Their lack of focus can be a contributing factor to patient safety.

OR staff including surgeons and reps should not need to be reminded to tone it down especially during induction and emergence.

Personally, the most distracting noise in the OR involves the surgical tech and equipment ... Counting, sorting, organizing, turnover help coming into the room. These are things that often occur during induction and emergence and I frequently have to remind others to be aware of the noise they are creating. Often times they are under pressure for quick turnover so are rushing to get things done and forget there is a patient on the table. It's a daily frustration.

I find it problematic for patents during induction and emergence more from scrubs and circulators getting equipment ready and cleaning up i.e. metal instrument pans being crashed around.

Tearing down the room while the patient is still waking up I feel is one of the biggest culprits. Those pans are so noisy and the amount of people that show up is a big part of the problem.

Induction and Emergence are times I struggle most. I feel bothered for a patient who is about to go to sleep and all they hear are conversations and loud noises.

Noise in the OR during induction and emergence is something that is important to control. Most people are receptive to asking for quiet but otherwise it is a common time for people to be loud. During the surgery I usually leave the noise level up to the surgeon unless it is impacting my ability to deliver a safe anesthetic which is rare.
It's always controllable but no one respects the CRNA's request to minimize the level of noise during induction and emergence.

Ambient noise during induction and emergence are the most difficult to control.

Continuing education to staff regarding noise limitation should be done frequently.

Noise during intubation is the most distracting.

Prevalence of Noise during the Intraoperative Period

This is a huge problem at the large university hospital I work in. Some EB information would be great to begin to tackle this issue.

It seems to be a greater issue in the OR now than it ever was in the past.*

It is always more than it needs to be. It can also contribute to patient anxiety.*

There are teams who knowingly and willingly resist decreasing levels of noise in the OR despite my asking for the sake of patient safety.

OR nurses were once the advocates of a quite surgical environment (1970s-1980s). This is no longer the case and it must not be taught in nursing school anymore. It makes me feel like the "bad-guy" when I have to ask for quiet and induction and emergence.

At times it's difficult to hear the monitors or the surgeon's instructions because the music is too loud.

This is a great survey topic that directly affects patient safety!

I have been a CRNA for almost 25 years. It occurs to me that in the earlier years, there was much more attention paid to controlling ambient noise throughout cases but especially during inductions and emergences. Today, the OR team seems to have lost a patient centered focus and all too often, behavior and noise become a free for all. When the CRNA requests quiet, the request is all too often met with an unapologetic disdain and scowl.

I have to make an effort every case to quite the room down. I have taken this issue to OR director and have seen some improvement. I work in Midland, Texas and have felt this is the loudest OR I've ever experienced. It is an issue and I address it head on every day.

I've complained numerous times to OR Director about to many OR employees coming in to help "turn over a room," nothing changes. Recently counted 9 people in my room while the patient is waking up.

Staff and surgeons have no idea what is going on at the head of the table nor do most care, despite their actions being a detriment to the patient.

It seems to be less noisy if the attending surgeon is present.

There is a huge need for this problem to be addressed and dealt with. Even when asked to be quiet, requests are ignored.

This is a very pertinent subject - I often have to ask for quiet, especially at the end of cases when staff is preparing for turnover/ clean up.

At my facility, there is a large number of newer (0-3 yr. experience) staff. There has not been proper education of the impact of noise in the OR on adverse patient outcomes due to noise.

Ambient noise levels that are excessive typically occur with a couple surgeons on a consistent basis.

Some surgeons play extremely loud, raucous music in the OR. They also mumble and wear hoods, which makes them very difficult to hear. That's my greatest source of noise-related frustration.

It's such a problem no matter which institution I work in! It's disrespectful to anesthesia providers particularly on induction and emergence, and a threat to patient safety. Thank you for so much for doing this study! Hopefully we can use your findings to implement culture change.

Reps from equipment companies are frequently loud and disrespectful. Many surgeons play their music too loud and then complain about the beeping of the SpO2 monitor. Once the operation is over ancillary staff seem to think it's party time. Just because their job is essentially finished, they forget that ours (anesthesia providers) has just begun, it's called emergence and they don't respect that. I had a surgeon tell me he didn't believe any studies that showed a quiet environment is better. Where do we start?!!!

It has become more of a problem over the last 5 years.

It's unnecessary and unprofessional.

Insidious.

I usually ask for the music to be turned off and for quiet during critical phases or when I feel it is out of control.

Staff should be educated on the problems no how operating room noise affects patients' safety.

Noise is a great issue impacting our patients.

I sometimes find noise to be a problem in the OR. When I do reduce it usually isn't a problem.

I have measured the noise level with a decibel reader and while the insensity (? presence) of ambient noise is found to be relatively low, I have found that a combination of unnecessary ambient noise contributes to my inability to function to my fullest potential during cases.

I wish staff would be more cognizant of unnecessary conversations during induction and emergence.

One of the biggest issues can be the staff's perception of anesthesia when we ask them to be quiet. All of a sudden, we are labeled as angry and mean for asking staff to stop talking. Despite education.

Number 1 unrecognized, untreated hazardous condition to safe Anesthesia care

Sources of Ambient Intraoperative Noise

Much of the ambient noise that adversely affects my practice comes from the convection warming blankets. We have Level 1 brand convection warmers which are louder than other brands such as Bair Hugger.

Suction sounds are the main (source of noise).

Sometimes there is very loud conversation.

Unnecessary talking is the worst problem.

Power equipment and music are the two biggest contributors.

Contributions to ambient noise are often the buildup of sounds that on their own individually would be innocuous, i.e. surgical field suction, anesthesia suction, forced air warmer, and music. In orthopedic cases just the operative noise itself is often uncomfortably loud.*

The worst is too many people with non-important conversations.*

I find loud music and unnecessary conversation the most disturbing.

Talking is the major noise at both start and end.

Suction is also a big part of it.

Unnecessary chatter is the biggest problem.

Mostly between nurses and techs and is unnecessary conversation.

Non anesthesia staff frequently create unnecessary noise and generally are completely unaware of the disruption

Noise of machines, suction, Bair Hugger, Bovie, is sometimes controllable. This is the largest contributor of ambient noise. While I am not usually bothered by music in the OR, there are times when the type of music or the volume of music makes it difficult for me to hear the monitors and concentrate. When I become aware that I am having trouble filtering I always ask to turn the volume down and or change the music. If there is too much push back, I would ask to turn it off. I have never had to turn it off. I feel that I have the power to veto that type of noise or any other unnecessary noise as do other members of the team.

Music can be a distraction depending on the type and volume. I'm my hospital setting anesthesia controls the music so we are able to regulate both content and volume. What is more challenging is controlling conversations which increases in amount and difficulty to control as the number of people in the room increases.

Multiple electrical devices in use, suction, Bair huggers, drills, or loud orthopedic noises contribute to ambient noise.

It seems that younger surgeons believe that they are disc jockeys in the OR and that it is "cool" to play very loud music, many times with offensive language.

Neptune suction sits near the top of bed. Constant noise.

The biggest contributor to ambient noise is usually the giant Neptune suction beast.

Unnecessary conversation is BY FAR the most distracting noise concern.

The younger the staff the louder the radio, nonessential conversations and decibels of conversations are. Basically, a lack of professionalism.

Sales reps (Ortho, Neuro, etc.) are very distracting.

In addition to number of people, music, there is also equipment such as Bair hugger and suction.

The operating team opening metal trays as we are doing induction and slamming them into a metal cart, as well as housekeeping staff cleaning the room as we are waking up the patient.

Levels of noise seem to correlate with maturity level of surgical team members, i.e. young immature residents and fellow prefer a club-like loud, pulsating environment.

It’s worse with PCAs coming in prior to emergence to help clean room. No concept of noise level. Also, residents aren’t taught or expected to be aware.

The new OR air handler & the smoke evacuator on the Neptune suction device are by far the worst offenders when it comes to noise!

Worst controllable contributor is the Neptune suction systems.

Conversation and background noise during induction while tasks are being performed by the surgical tech and RN can be loud at times. I will inform them to quiet it down if it becomes too loud.

Usually music.

If you add music with loud power tools and then the surgeon is in full orthopedic gear, who can understand what they are saying?! Also, nonsensical talking is annoying; ignoring patients when this happens before induction is awful!

Nurses and techs sometimes talk constantly regardless of induction and emergence. We have an X-ray tech in the pain room who virtually never stops talking, and we do 24 pain patients sometimes. It's just sedation but very distracting- exp towards end of day. It's never ever about the patient and usually about her kids! Drives me crazy!

Talking among personnel during induction and emergence are the chief distractions in my opinion.

Neptune suction has been one of the most annoying contributors to ambient room noise. Few realize the noise can be avoided by shutting the Neptune off and hooking the Neptune up to “wall suction”.

Equipment noise is often a factor.

If you add music with loud power tools and then the surgeon is in full orthopedic gear; who can understand what they r saying!! Also, nonsensical talking is annoying, ignoring patients when this happens before induction is awful!

Some voices are extremely loud and/ or irritating such as loud talkers, baby voices, vocal fry...

Radio being on when patient enters the room is very unprofessional in my opinion. Equipment reps tend to talk too much also.

Primarily music in my practice environment.

You left out all the machine noises such as suction and Bovie. They can be worse than the music and talking. But when there is all of it, that's when it becomes intolerable.

Generally, people that have no "indoor voice" and music that is too loud.

The loudest is the noise coming from all the equipment. Bair hugger, Neptune, weird sounds from the vents, construction, normal machine sounds, etc.

Scrub techs laugh and talk too loudly. Music is played entirely too loud by several surgeons. No one controls these actions.

Suction machines (not wall suction) are the most detrimental. They are extremely loud and cause everyone more stress.

There is a lot of equipment that contributes to this problem also!

Loud music that disables me from hearing pulse oximetry tones is not acceptable.

Chit chat and music are the two leading causes of noise in the OR.

Neptune suction is so loud.

I would've added the Bair Hugger that I sit next to all day as the number 1 irritating noise and the most likely to negatively affect my hearing in the future.

For me the most dangerous ambient noise in the OR to the patient is non-essential conversation and banging of used trays, equipment at emergence.

The OR staff when turning over rooms or upon entry to the OR is often unaware of how loud they are being and with unnecessary conversations.

Certain doctors bring their own loud music. Most don't. When the OR nurse controls it, it is at a tolerable level. It is only sometimes when the doctors choose to turn it up. But they are usually cooperative if I asked to turn it down. Softer background music is not distracting. But loud music or too much chatter from the personnel can be distracting, especially during emergence.

Loud music is the highest contributing factor to communication issues.

Suction and the revolving door are the most distracting.

The Neptune and Bair hugger are some of the most (significant) contributors of noise as are opening of trays and cleaning up.

Ambient noise to me can also be the beeping of our machines which contribute to the ambient noise in the room, also the air warming machine can be specifically to anesthesia. I realize this study is about other noise specifically but this can be loud for patients as well in my opinion and can contribute to safety issues with not hearing what is being said by the surgical team at times.

Sometimes even soft music is too much to hear the surgeon when they ask for certain things.

Too much talking when vendors are in the room. Many times, I have to ask to turn down radio. People talking loud during induction and extubation.

Big problems for ambient noise in outback facility is our Neptune auction machines which are almost always placed within 3 feet of where I sit. The Bair hugger, also usually by anesthesia, makes a lot of constant noise as well.

It's often the scrub techs and cleaning crew who show no knowledge of how loud they are talking and how dangerous it is when the patient is going to sleep and waking up. Suction, especially Dornoch machines and HVAC are the most intrusive in terms of ambient noise.

The Dornoch is too loud and approaches unsafe decibel levels in the OR.

When music is on so loudly, I just have to increase the volume of my monitor so I can hear. Noise in the OR needs to be addressed in promoting safety and quality care to patients.

Conversations among different parties talking over each other.

Radio being on when patient enters the room is very unprofessional in my opinion. Equipment reps tend to talk too much also.

Reps are infamous for contributing to the ambient noise in proportion to the surgeon.

Cautery & suction (especially with smoke evacuators) are exceptionally loud.

Huge problem with people who are unconcerned with loud banter or music especially during critical times.

We usually have music going, conversation with multiple reps, plus monitors and suction. It gets quite loud at times.

The noise that seems to bother me most is that coming from my area and it is usually not controllable. The ventilator, the monitor, the suction, the Bair hugger.

The worst situation I have now is a young GI doc who plays head-banger rock music at volume 7++ when I'm trying to do MAC Generals on an over 50 y/o patient population. Other instance is people talking during induction/emergence (but I always ask them to be quiet- and they comply).

Bair hugger and surgical suction is big contributor of noise.

Music is played too loud, too much non-essential conversation, it's more like a social hour than an operating room.

Music main contributor.

The more people in the room elevates the noise levels tremendously; add music and the white noise from equipment and levels can be very high.*

Top offenders of ambient noise in my practice: surgical suction on but not in use, improper function smoke evacuation tubing, compression boot beeping, surgical resident cell phone ring tones.*

If I had to list the number one cause of loud ambient noise that if difficult to control, I would say equipment. Especially suction machines (free standing machines especially) and cautery. More effort should definitely be made to decrease those noises by companies. Music volume should also should also be decreased... but again that is more controllable.*

Variability in Ambient Intraoperative Noise

Each room and situation is unique.

Depending on who you're working with or which sub specialty you're in, the noise level is extremely variable.*

Very dependent on surgeon, staff and case.

It varies on Room, Service, Surgeon, Staff, etc...*

Noise levels are directly related to surgical case being performed and the surgeon's preference/tolerance of noise levels.

Ambient noise really differs depending on the type of case (i.e. ortho vs. general).

Higher noise levels are rare and so are inconsistent. There may be moments of high volume. But it is usually a combination of factors. Multiple people and music. Again, this is acute and periodic, not consistent.

I find that there are different types of ambient noises that are bothersome. Equipment: for example, a badly placed smoke evacuator machine (close to me). I frequently ask for it to be moved, if bothersome. Badly timed conversations while the patient is going to sleep or waking. For example, the surgeon discussing set up with staff or teaching a student. Ironically, the severity of noise often increases with the complexity of the case and I frequently find myself reminding others to quiet down or directing the nurse to quiet them down. This chatter and activity increases patient's anxiety and impairs my ability to communicate with essential staff if there is a problem. At times, music...the type (motor metal) or when it is played. I prefer no music when we enter the room until the patient is under anesthesia and I deem they are stable to precede. Music during the case is normal fine unless I have any difficulty hearing my equipment. I often have them turn down the speakers over my area. I have staff turn off the music before emergence as well. We are lucky to have a good amount of turn over help, however they need to be reminded that their activity noise needs to be minimal with emergence as well.

The noise level varies, but if anyone - surgeon or anesthesia- states a need for quiet, the noise level diminishes. Cooperation has become much better in the last 5-10 years.

This is always a tricky issue to address in the OR, because you want everyone to be able to perform their specific duties but don't want to have it negatively impact your patient.

The type of surgeon you work with often dictates the type of music you will endure all day. For instance, ortho docs are usually into rap or heavy metal; vascular surgeons usually rap or hip-hop. Rarely, is there ever NO music. And rarer still is it ever classical music, out of 3 hospitals I've worked in I've only worked with one surgeon who chooses classical music. I've also worked with several who listen to Christian or light pop and generally I find the room less chaotic with these choices. These musical choices seem to influence a state of mind, being, and presence to others and tasks on hand in the operating environment.

It's a problem that is commonly addressed, improves slightly for a while and then regresses back to being a big problem.

Type of music played...soothing / quiet melodies more acceptable than loud obnoxious inappropriate rap type music.

Varies with the procedure and especially the surgeon.

It is amazing how many sources of ambient noise exist. This varies depending on surgeon/OR. It is certainly distracting and draws attention away from essential noises like the pulse oximeter.*

It was difficult to answer many of these questions with an absolute score because as anesthesia providers we can ask that the noise level be reduced at certain periods during the case. For me I will ask that the noise be reduced during emergence.

Positive Aspects of Ambient Noise/Coping Mechanisms

Ambient noise is frequently present in the OR. Having done this job for many years I block most of it out. If it becomes problematic, I address it immediately. Otherwise, I'm fine with music and conversation.

Non-issue.

The music helps me stay awake and I am able to not pay attention to the music. I do find that other people don't listen to me when emergencies are happening when there is music playing.

Why didn't you do any research about the positive effects of some noise? Music can help in the OR. Looks like your research is pretty negatively biased towards any unnecessary noise.

Not a problem in my practice.

Usually not an issue for me, and when it is, a simple statement can reduce the room to dead quiet.

Noise has no perceived effect on my comfort, performance, or patient care outcomes.

Doesn't usually affect me.

I am normally not at all bothered by conversation, music, etc. Clanging instruments is probably the most annoying.

I have learned in 28 years of practicing anesthesia to tune out ambient noise and trained myself to only put my attention to the patient. The OR personnel are also mindful if I asked that noise be contained.

I can tune it out pretty well.

Often times there is a perception of music in the OR being detrimental to quality of patient care and safety. However, in my experience, low level generally pleasurable "background music" is well received by patients arriving in the OR, and staff seem to be more engaged with interactions being more balanced amongst all OR staff.

You can always control the noise level during induction and emergence. At some point in your career, you reach a level where you can hear changes in heartrate and pulse ox instinctively. This makes ambient noise less of a problem.

Is not a problem for me personally. I work better in an environment with ambient noise. Music often helps me focus.

I work in Ophthalmology so patients are sedated but awake. They prefer conversation over quiet. Quiet makes them more nervous.
Ambient noise keeps me alert.

Sound of business.

Prefer music in the OR. Low volume.

Suction noise is the most disturbing to me. I don't notice ambient noise when I am working i.e. induction, emergence, etc.

Don't mind music but it doesn't have to be very loud.

Staff are usually in tune to when noise levels should be altered.

Sometimes too loud but mostly ok.

Most times I am able to function without adjusting the noise level. If needed I tell everyone to be quiet and turn the music down.

It is part of the job, and listening for direction is a skill that has to be learned over time. Novices might find it difficult to “hear” over the suction, counts, Bovie, pulse ox, but over time this becomes an adaptation to the job.

I like music in the OR.

I usually can tune it out when focused on my patient.

Music in the OR is nice, but level should be controlled and moderated depending on case progress.

Ambient noise is frequently present in the OR. Having done this job for many years I block most of it out. If it becomes problematic, I address it immediately. Otherwise, I'm fine with music and conversation.*

**Indicates comments retrieved from pilot survey*

Vita

Marianne Scarpati Cosgrove was born on February 17, 1962, in Delaware County, Pennsylvania, and is an American citizen. She graduated from Daniel Hand High School, Madison, Connecticut in 1979. She received her Bachelor of Science in Nursing from Salve Regina University, Newport, Rhode Island in 1984 and worked as a registered nurse and transport team member in the Newborn Special Care Unit at Yale New Haven Hospital for four years. She received a certificate in nurse anesthesia from the Yale New Haven Hospital School of Nurse Anesthesia in 1990 and a Master of Science in Biological Sciences: Anesthesia from Central Connecticut State University, New Britain, Connecticut in 1993. She received a Doctor of Nurse Anesthesia Practice from Virginia Commonwealth University, Richmond, Virginia in 2011. She has been a practicing certified registered nurse anesthetist since 1990 and is currently employed as the Program Director of the Yale New Haven Hospital School of Nurse Anesthesia and as a practicing CRNA at YNHH. She was a clinical instructor in anesthesiology at Yale University from 2014 to 2019 and is an adjunct faculty member of the Department of Biology at Central Connecticut State University. She is on the editorial board of the International Student Journal of Nurse Anesthesia and is a journal reviewer for the AANA Journal. She is the co-owner of Core Concepts Anesthesia Review, LLC.