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## **A Science Education Study Using Visual Cognition and Eye Tracking to Explore Medication Selection in the Novice Versus Expert Nurse Anesthetist**

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A SCIENCE EDUCATION STUDY USING VISUAL COGNITION AND EYE TRACKING  
TO EXPLORE MEDICATION SELECTION IN THE NOVICE VERSUS EXPERT NURSE  
ANESTHETIST

A Dissertation

Submitted to the Graduate Faculty of the  
Louisiana State University and  
Agricultural and Mechanical College  
in partial fulfillment of the  
requirements for the degree of  
Doctor of Philosophy

in

The School of Education

by

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## **Abstract**

The purpose of this science education study is to explore visual cognition and eye tracking during medication selection in the student nurse anesthetist (first year and second year students) and the expert nurse anesthetist. The first phase of this study consisted of the selection of a specific medication (target) from an array of medications via computer simulation. Various dependent variables were recorded to examine performance (reaction time and accuracy), and the allocation of visual attention was measured with eye tracking (dwell proportion, verification, and guidance). The second phase of this study included the administration of a demographic and post experiment questionnaire to capture additional quantitative and qualitative data. Results demonstrate that similar distractors attract attention during search as evidenced by longer reaction times when similar distractors are present, most significantly in expert participants. Additionally, all participants spent a greater amount of time looking at the similar distractor as compared to randomly chosen non-similar distractors when a similar distractor was present. However, the presence of similar distractors in target present trials increased performance in experts, decreased performance in second year students, and had no effect on first year students' performance. Expertise effects were further demonstrated, as expert participants were significantly slower than both first and second years during target verification. The post experiment questionnaire included both open-ended and close-ended questions, to allow for themes to emerge related the participants' beliefs related to visual search and medication selection. The results reinforced the eye tracking results reported above, with most participants identifying "color" and "medication label" as the most difficult medication features to distinguish during visual search. Additionally, the majority of participants who responded they

had committed a medication error, identified “similarity” as the most common factor that led to the medication error.

## **Chapter 1. Introduction**

Medication-related errors occur frequently in the hospital setting, although not all of those that occur will cause patient harm. However, when there is harm, it is costly; a recent study at two prestigious teaching hospitals found that almost two percent of admissions experienced a preventable adverse drug event resulting in an average increased cost of \$2.8 million annually for a 700-bed teaching hospital (Kohn, Corrigan, & Donaldson, 2000). It has been reported that medication errors account for one out of 131 outpatient deaths and one out of 854 deaths (Kohn et al., 2000). These errors potentially cause physical, emotional, and financial harm to all those involved. While these numbers are staggering, they likely underestimate the true number of medication errors that occur because many go undocumented or unreported (Kohn et al., 2000). A medication error can occur in any phase of the medication process, including prescribing, dispensing, administering, and monitoring. And while most medication errors are preventable, decreasing medication error rates significantly will require multiple interventions at various stages (Kohn et al., 2000).

The problem of medication errors is multi-faceted in nature and is not unique to one particular group of healthcare professionals (Leufer & Cleary-Holdforth, 2013). Medication errors occur at several points in the medication administration process and are multidisciplinary in nature. Wolf (1989, p. 9) provides a comprehensive description of what constitutes a medication error, defining it as “mistakes associated with drugs and IV solutions that are made during the prescription, transcription, dispensing and administration phases of drug preparation and distribution”. This clearly demonstrates that errors can and do happen at any point in the medication process and can be effected by pharmacists, physicians, nurses, nurse anesthetists, and by the patient themselves, in the case of self-administration (Leufer & Clearly-Holdforth,

2013). Because the process of medication administration is multidisciplinary (medicine, nursing, and pharmacy) it is therefore collaborative in nature. This collaborative approach has the potential to enhance patient safety, but only when each group scrutinizes its own contribution to the problem of medication errors. Nursing, like other healthcare groups, plays a role in contributing to this problem, but reciprocally, nursing is integral to the solution (Leufer & Cleary-Holdforth, 2013). The opportunity to address medication errors presents itself within both nursing education and in nursing practice. Nursing education in medication administration must ensure competence to effectively reduce medication errors (Leufer & Cleary-Holdforth, 2013). This education must have its foundation in undergraduate nursing, but must also continue beyond graduation and throughout the nurse's career, to not only include continuing education for the registered nurse but also during graduate nursing education.

The administration of medications is a vital and valued aspect of nursing practice (Cheek, 1997). Early in nursing education programs, nursing students learn about medication administration via multiple nursing and pharmacology courses. The nursing students often solve medication dosage problems in various courses until their skills are deemed acceptable by programmatic standards (Wolf, Hicks, & Serembus, 2006). Nursing students will often then practice these tasks in a simulation setting and then perform medication administration tasks in supervised clinical experiences.

Nursing faculty teach and emphasize safe medication administration practices to nursing students and challenge the students to develop the necessary skills to calculate drug dose and solve intravenous flow rate problems (Wolf et al., 2006). However, despite these efforts, student nurses make medication errors. Currently, limited research is available on the attributes of student-made medication errors and effective teaching strategies that help students avoid them

(Wolf et al., 2006). Areas that have been identified in the literature as contributing factors include interruption on medication rounds, poor mathematical skills, pharmacological knowledge deficit and teaching and learning strategies employed within the nurse education field (Leufer & Cleary-Holdforth, 2013). Many reasons exist as to why limited information regarding medication errors and nursing students is available. Organizations and systems that collect information about medication errors may not be willing to publicly share such reports for reasons of legal liability (Wolf et al., 2006). Additionally, Kohn et al. (2000) suggest that even if the organization were willing to publically share these reports, very few reports may exist within a single organization. Additionally, some errors are considered rectified by being reported with no follow up analysis performed. Consequently, undergraduate-nursing education needs to consider the educational preparation that is required to promote medication safety (Leufer & Cleary-Holdforth, 2013).

Armitage and Knapman (2003) suggest clinical nurses spend as much as 40% of their time in the clinical setting administering medications. In a recent literature review of individual and systems factors that contribute to medication errors in nursing practice by Brady, Malone, and Fleming (2009), 26 studies were included to illuminate the complexity of factors involved in medication errors. From this review, key themes identified by the authors include: level of knowledge and skills, deviation from procedure, workload, medication reconciliation, drug distribution systems and barriers to reporting (Brady et al., 2009).

In 2000, the Centers for Medicare and Medicaid Services sponsored the report by the Institute of Medicine (IOM), *Preventing Medication Errors: Quality Chiasm Series* with the aim of developing a national agenda for reducing medication errors based on estimates of the incidence of such medication errors and evidence on the efficacy of various prevention strategies (Aspden, Wolcott, Bootman, & Croenwett, 2007). During this study, the IOM identified

significant gaps in the knowledge base regarding medication errors (Aspden et al., 2007). The IOM cited both the methods used to generate and communicate information about medication errors as inadequate and as contributing factors to the incidence of errors (Aspden et al., 2007).

Recently, human factors have been considered a viable intervention for the prevention of errors in health care. Human factors are “the study of the interrelationships between humans, the tools they use, and the environment in which they live and work” (Kohn et al., 2000, p.63). By focusing on human factors, health care can begin to understand when, where and why systems and processes break down, thus preventing error. According to Marcucci (2008), as compared to other health care fields, anesthesia has been at the forefront of focusing on human factors in healthcare for a number of years by adopting safety initiatives and making continuous process improvements. This is essential as it is estimated that nurse anesthetists deliver approximately 65 percent of all general anesthetics in the United States, with over four million anesthetics being administrations being performed a year. However, while there has been improvement in patient safety in recent years, there is still much to be learned in the realm of human factors, even by the anesthesia care team, as the field of human factors is multidisciplinary and thus can be approached from many domains (Dekker, 2006).

While numerous articles have been published regarding medication errors (nursing’s contribution to errors, human factors related to medication errors and nursing education) very few studies have examined medication errors in the field of nurse anesthesia. During a search to locate information related to medication errors in anesthesia only three research studies were found. These studies by Cooper, DiGiovanni, Schultz, Taylor, and Nossaman (2012), Llewellyn et al. (2009), and Webster, Merry, Larsson, McGrath, and Weller (2001), provide little insight into the incidence and types of medication errors committed in the field of nurse anesthesia and

the educational practices employed to decrease the incidence of medication-related errors. Therefore, student learning of medication safety specific to nurse anesthesia is virtually an unexplored territory for science education. There is a need for a study that examines medication error prevention strategies in the field of nurse anesthesia education while exploring strategies to decrease the incidence of medication-related errors in the operating room.

Mintzes and Wandersee (1998) outline five promising areas of future research in science education, which include: (a) critical junctures in learning, (b) comparative knowledge structures of experts and novices, (c) knowing and feeling, (d) metacognition and, (e) intervention strategies.

This research study addresses two of these areas in the context of learning about medication selection in nurse anesthesia students. The study will use metacognition and comparative knowledge structures of experts and novices during medication selection. Metacognition is the “ability to think about thinking, to be consciously aware of oneself as a problem solver, and to monitor and control one’s mental processing” (Bruer, 1993, p. 61). Bruer (1993) suggests that metacognition is a general skill that can be used to improve novice performance across domains with an “intelligent novice” differing from the typical novice based solely on the ability to utilize such metacognitive skills. Each participant completed a post experiment questionnaire that questioned the participant’s use of metacognition during the medication selection process.

This science education research study uses visual cognition, specifically visual search, to identify those features that guide attention during medication selection in the novice and expert anesthetist, thus comparing the knowledge the knowledge structure of novice versus expert participants. Although the checking of medications is often conducted through visual



confirmation prior to medication administration, there has been no research on the visual search patterns of student nurse anesthetists or nurse anesthetists prior to medication selection (Kataoka, Sasaki, & Kanda, 2011). In order to better understand medication-related errors during medication selection, it is necessary to understand those cognitive and visual processes that occur during the medication selection. Cognitive processing studies have been conducted in various health care fields including dermatology, radiology, and pathology (Norman, Rosenthal, Brooks, Allen & Muzzin, 1989; Beck, Martin, Smitherman, & Gaschen, 2013; Crowley, Naus, Stewart, & Friedman, 2003). Experts in these perspective fields examine an image often first looking at larger areas then typically searching for any notable abnormalities prior to making a diagnosis. Visual scanning during medication selection is similar in that the nurse anesthetist must search for specific characteristics within the medication vial and label but then select the correct medicine rather than making a “diagnosis” upon completing the visual search task (as is the case for other health care fields).

The researcher theorizes that by exploring visual scanning patterns in expert nurse anesthetists, a common effective and efficient search process will be revealed in those practitioners who do not commit medication selection errors. Previous eye movement studies, (Castelhano, Pollatsek, & Cave, 2008; Malcolm & Henderson, 2009; Spotorno, Malcolm, & Tatler, 2014) have divided visual search into three distinct phases: initiation, guidance and verification as show in Table 1. *Search Initiation Time* is defined as the time from the appearance of the stimuli (photograph search array) until the first saccade away from the initial fixation point (Malcolm & Henderson, 2009). *Guidance Time* is defined as the elapsed time between the first saccade (the end of initiation) to the first fixation on the target, and is representative of the actual search process (Castelhano et al., 2008; Malcolm & Henderson,

2009). *Verification time* is defined as time from the first fixation on the target until a correct response is elicited (Malcolm & Henderson, 2009). The current study will separate visual search into two distinct phases: guidance and verification. Guidance time will be defined as the time from the appearance of the stimuli until the first fixation on the target. Verification time will be defined as the time from fixation on the target until a correct response is elicited.

Ultimately, this study will establish a foundation for research related to visual search and scanning patterns during medication selection in nurse anesthesia. The sum of these three traditional phases will be reported as reaction time, the typical measure reported in visual search studies. The researcher hypothesizes that by segmenting the reaction time into these two distinct phases, guidance and verification, effects of target similarity will be more clearly elucidated.

Table 1  
Visual Search: Division of Three Phases

		Reaction Time		
Initiation Time		Guidance Time	Verification Time	
Stimulus Appears	First Saccade	Target Fixation		Response

## Research Questions

To guide this study, the following research questions are posited:

### Main Research Question

How does visual search differ in the novice versus expert nurse anesthetist?

### Sub-Questions

1. What are the visual search strategies deployed during medication selection in the novice and expert anesthetist?

2. What features guide attention during medication selection in the novice and expert nurse anesthetist?

The researcher hypothesizes:

1. Similar distractor medications will attract attention away from the target medication and dissimilar distractor medications during visual search.
2. Because similar distractor medications attract attention during visual search, reaction time will increase when similar distractor medications are present, while accuracy will decrease across all participant groups.
3. When similar distractors are present, expert participants will have an increased reaction time overall as compared to novice participants. However, while expert participants will have an increased reaction time compared to novice participants, expert participants will be more accurate as compared to novice participants.

## **Chapter 2. Literature Review**

The literature review focuses on concepts salient to this study: nurse anesthesia, human error, medication-related error, attention, visual cognition, and expertise.

### **Nurse Anesthesia Practice**

A certified registered nurse anesthetist (CRNA), commonly referred to as a nurse anesthetist or an anesthetist in the United States, is a state licensed registered nurse who is educationally prepared and competent to engage in the practice of anesthesiology (Foster & Jordan, 1994). According to Foster and Callahan (2011), anesthesiology is defined as the art and science of rendering a patient insensible to pain by the administration of anesthetic agents and related drugs. Anesthesia and anesthesia-related care represents those services that anesthesia professionals provide upon request, assignment, and referral by the patient's physician or other health care provider authorized by law, most often to facilitate diagnostic, therapeutic, and surgical procedures (Foster & Jordan, 1994). Additionally, services may include a referral or request for consultation or assistance for the management of pain associated with obstetrical labor and delivery, management of acute and chronic ventilation problems, or management of acute or chronic pain through the performance of selected diagnostic and therapeutic nerve blocks (American Association of Nurse Anesthetists, 2010a). According to the American Association of Nurse Anesthetists, "education, practice and research within the specialty of nurse anesthesia promote competent anesthesia care encompassing the diversity of patient populations, age, ethnicity and gender" (American Association of Nurse Anesthetists, 2010b).

Nurse anesthetists are recognized in all 50 states by state regulatory (licensing) bodies, primarily state boards of registered nursing, and as such, the practice of nurse anesthetists is a recognized role within the profession of nursing and is not delegated by the board of medical

examiners within each state (Foster & Callahan, 2011). Nurse anesthetists are responsible and accountable for their individual professional practice and are capable of exercising independent judgment within the scope of their education, demonstrated competence and licensure (American Association of Nurse Anesthetists, 2010b).

### **History of Nurse Anesthetists**

Many are surprised to learn that nurse anesthetists have provided anesthesia services in the United States since the 19<sup>th</sup> century (Nagelhout & Plaus, 2011). The use of ether for surgical anesthesia by dentist William Morton in 1846 allowed patients to undergo dental and surgical procedures without pain and was a critical step leading to the practice of modern anesthesia and surgery (Foster & Callahan, 2011; Nagelhout & Plaus, 2011). It was after this discovery of ether that a need was soon realized for a healthcare provider to assume the responsibility for the safety of the patient, as ether rendered the patient not only pain free but also unconscious (Foster & Jordan, 1994). By the late 1880s, nurses began to specialize in anesthesia and became known as nurse anesthetists, becoming the first professional group to provide anesthesia in the United States (Bankert, 1989). However, nurse anesthetists' work was not recognized publicly until the 1953 publication of *The History of Nurse Anesthesia, with Emphasis on the Nurse Specialist* by Virginia Thatcher.

The profession of nurse anesthesia developed in response to surgeon's request for anesthesia services. In the 19<sup>th</sup> century, surgeons turned to nurses as the providers best suited and available to specialize in the field of anesthesia (Thatcher, 1953). In 1877, Sister Mary Bernard of St. Vincent's Hospital in Pennsylvania, became the first identifiable nurse anesthetist in the United States (Thatcher, 1953). From this time until the early 20<sup>th</sup> century it was the religious

orders of sisters in the profession of anesthesia that documented the role of nurse anesthesia providers (Bankert, 1989).

Currently, more than 44,000 nurse anesthetists administer approximately 32 million general anesthetics to patients in the United States each year (Foster & Callahan, 2011). According to the American Association of Nurse Anesthetists, nurse anesthetists are the primary anesthesia providers in rural America (American Association of Nurse Anesthetists, 2010c). Nurse anesthetists practice in every setting in which anesthesia is delivered including traditional hospital surgical suites and obstetrical delivery rooms, critical access hospitals, ambulatory surgery centers, the offices of specialized health care providers, such as dentists, and United States military facilities, working in collaboration with surgeons, physician anesthesiologists and other health care professionals (American Association of Nurse Anesthetists, 2010c). Regardless of the practice setting and practice model, numerous studies have confirmed the safety record of nurse anesthetists (American Association of Nurse Anesthetists, 2010c).

### **Educational Programs for Nurse Anesthetists**

The first educational programs for nurse anesthetists were established in 1909, prior to the development of anesthesiology as a role for physicians (Bankert, 1987). Throughout the next 90 years, the education of nurse anesthetists changed drastically from certificate training programs to degree-granting programs. Currently, the educational preparation for certified registered nurse anesthetists is conducted in more than 100 accredited educational programs in the United States and Puerto Rico (American Association of Nurse Anesthetists, 2010d). The Council on Accreditation of Nurse Anesthesia Educational Programs (COA) has mandated that all students entering an educational program on or after January 1, 2022, must graduate with a doctoral degree related to the field of anesthesia (American Association of Nurse Anesthetists,

2010d). The COA is the sole accrediting agency for all nurse anesthesia programs and is recognized by both the United States Department of Education and the Council of Higher Education Accreditation (American Association of Nurse Anesthetists, 2010d).

Currently, Masters-level nurse anesthesia programs range from 24 to 36 months and are composed of both academic and clinical study. The length of the current masters-level programs will increase as programs transition to the doctoral-preparation for nurse anesthetists to a minimum of 26 months, as required by the COA (Council on Accreditation of Nurse Anesthesia Educational Programs, 2015). The academic curriculum of nurse anesthesia programs are specific to anesthesia and consists of subjects such as anatomy, physiology, pathophysiology, chemistry, biochemistry, advanced pharmacology, basic and advanced principles of anesthesia practice, research methodology and statistical analysis. In addition, academic content related to the degree being conferred (such as nursing) is required (American Association of Nurse Anesthetists, 2010d). The clinical component of the nurse anesthesia educational program provides supervised patient care experience for students during which time the students are able to develop clinical competency.

### **Certification and Recertification**

Upon graduation from an accredited nurse anesthesia educational program, graduates must meet all the requirements as set forth by the National Board of Certification and Recertification of Nurse Anesthetists (NBCRNA) in order to write the National Certification Exam (American Association of Nurse Anesthetists, 2010d). Those students who pass this rigorous exam are designated as “certified” and are qualified to practice as a CRNA.

Recertification is granted through the NBCRNA with the purpose of advancing the quality of nurse anesthesia care provided to patients by assuring that nurse anesthetists maintain

their skills and are current with scientific and technological developments (National Board of Certification and Recertification of Nurse Anesthetists, 2013). Recertification is granted for a period of two years but cannot be a guarantee of competency to perform all anesthetic procedures. Recertification is at the national level in that the CRNA may practice in all 50 states, as long as advanced practice licensure is obtained within the state. The NBCRNA also strives to ensure that appropriate limitations are placed on those nurse anesthetists who are known to develop conditions that may adversely affect their ability to practice nurse anesthesia (National Board of Certification and Recertification of Nurse Anesthetists, 2013). More specifically, the NBCRNA determines if a CRNA is properly licensed, has engaged in practice to maintain an adequate level of skill, has obtained a sufficient number of continuing education credits, and has avoided mental, physical or other problems which may interfere with the practice of anesthesia (National Board of Certification and Recertification of Nurse Anesthetists, 2013).

## **Error**

Human beings, in all lines of work, make errors, including nurse anesthetists. A medical error can be defined as the failure of a planned action to be completed as intended or the use of a faulty plan to achieve a goal (Kohn et al., 2000). According to Reason (1990), errors depend on two types of failures: either the correct action does not proceed as intended (an error of execution) or the original intended action is not correct (an error in planning). Reason (1990) defines error as “an occasion in which a planned sequence of mental or physical activities fails to achieve its intended outcome” (page 9). Reason, whose taxonomy draws upon aviation and nuclear industries as well as medicine, then further divides error into slips, lapses, and mistakes (Wheeler & Wheeler, 2005). A slip is the result of failure in the execution of an action and is said to be skill-based, occurring during an automated and highly integrated task that does not



require conscious control or problem solving (Reason, 1990). A lapse involves memory failure and may only be apparent to those who experience them. Whereas a slip and lapse occur when actions do not go according to plan, a mistake happens when a plan is inadequate (Reason, 1990). Reason (1990) suggests that when a person is aware of the problem but does not have the requisite knowledge and rules to solve the problem, a mistake will occur.

This is in contrast to Gorovitz and MacIntyre (1976), who assert that humans have two reasons for failure, either ignorance (humans err because they only partial understand a concept) or ineptitude (humans err in spite of existing knowledge because they incorrectly apply it). Gawande (2002) further asserts that when things go well in healthcare, competent providers who succeeded despite the organization and its complexity are exercising “good doctoring” and argues that failure in healthcare is the result of ineptitude.

However, Dekker (2011) argues that what appears on the surface as a competence problem often hides a much more complex systemic problem of system design, patient expectations and assumptions, and professional dispositions. Dekker (2011) points to the aviation industry as recognizing competence is not an individual virtue that people either possess or do not possess on release from training and entry into a profession and rather views competence as a systems issue. Dekker (2006) goes on to urge researchers to discard the “The Bad Apple Theory”, in which human errors cause accidents and humans are the dominant contributor to more than two thirds of error. He instead urges researchers to opt for “The New View” when considering human error. “The New View” asserts that human failure is not a cause of the failure, is not random, and is not the conclusion of an investigation, but instead the starting point (Dekker, 2006). Dekker (2006) asserts that in “The New View”, investigations are driven by one unifying principle: human errors are symptoms of deeper trouble.

Whatever the underlying cause of error may be, all of these experts illuminate that errors can occur in all stages in the process of the health care delivery system and can be attributed to a variety of different mechanisms. To prevent such medical errors from occurring, safer systems must be designed to ensure that patients are safe from such errors and thus accidental injury.

In June of 1998, the Institute of Medicine formed the Quality of Health Care in America Committee to develop a strategy that would result in an improvement in quality as it related to patient safety over the next 10 years (Kohn et al., 2000). The subsequent report was a call to action to make health care safer for patients by addressing issues related patient safety, a subset of overall quality-related concerns, and by laying out a national agenda for reducing errors in healthcare (Kohn et al., 2000). The committee cited several external and internal factors needed to incite this change, including an organizational culture that encourages recognition and learning from errors.

Although errors occur frequently in health care, errors do not necessarily mean that harm or injury will occur. Those errors that do result in patient injury are typically referred to as preventable adverse events (Kohn et al., 2000). An adverse event is defined as an injury resulting from medical management and is not attributed to the underlying disease process of the patient (Victoroff, 1997). However, while all adverse events are a result of medical management, not all are preventable, and thus can be attributed to errors. The Quality of Health Care in America Committee's report, *To Err is Human* (2000) found that more than two-thirds of the adverse events reported were preventable, with the most common types of errors being technical errors, diagnosis, failure to prevent injury, and errors in the use of a drug (Kohn et al., 2000). Furthermore, the report found that higher rates of adverse events occurred in highly technical surgical specialties, highlighting the contributions of technology and complexity as factors in

adverse events. In hospitals, errors with serious consequences were most likely to occur in intensive care units, operating rooms and emergency departments (Kohn et al., 2000).

Society as a whole must bear both direct and indirect costs as a result of medical errors, such as higher health care expenditures, lost productivity, disability costs and personal costs of care (Kohn et al., 2000). Preventable adverse events are a leading cause of death in the United States, with recent studies implying that “at least 44,000 and as many as 98,000 Americans die in hospitals every year as the result of medical errors” (Thomas et al., 1999). It is estimated that total national costs (lost income, lost household production, disability, health care costs) for adverse events exceed 37 billion dollars each year, while preventable adverse events costs exceed 17 billion dollars annually in the United States (Thomas et al., 1999).

According Seys et al. (2013) when an adverse event occurs there are three victims: (1) the involved patient and family, (2) the health care provider, and (3) the involved organization. Wu first introduced the term of second victim in 2000 (Wu, 2000). A second victim has been defined as a health care provider involved in an unanticipated adverse patient event, medical error and or patient related-injury, who then becomes traumatized by the event (Scott et al., 2009). Often second victims feel responsible for the unexpected patient outcomes and may feel as though they have failed their patient (Scott et al., 2009). It is estimated that as many as half of all health care providers have experienced the second victim phenomenon at some point during their professional careers (Edrees, Paine, Feroli, & Wu, 2011).

There is much that can be learned in an analysis of errors in healthcare from preventable adverse events. It allows for the health care system to assess and evaluate whether improvements to the delivery system would decrease the likelihood of similar events occurring in the future. Although literature related to errors in health care has witnessed steady growth over the past 10

years, there is still an incomplete picture of the epidemiology and incidence of errors. Much of this literature has focused on those patients that have experienced an injury and the impact of such an injury. Other studies have focused on the occurrence of errors and adverse events, but have primarily been conducted in hospital settings as opposed to other health care delivery settings. However, it is noted by the Committee on Quality of Health Care in America Committee those errors that do not result in patient harm also represent an important opportunity to identify system improvements and have the potential to prevent similar adverse events (Kohn et al., 2000). An additional barrier to completely understand errors in healthcare is the lack of standardized taxonomy for reporting adverse events and errors (Victoroff, 1997).

### **Medication Error**

Medication-related error has been studied extensively as it is one of the most common types of error, it affects a substantial number of patients, and it accounts for a large increase in health care costs (Johnson & Bootman, 1995). A medication error can be defined as an error involving the prescribing, ordering, selection or administration of a medication (Merry, Shipp, & Lowinger, 2011). Medication errors are often preventable and are can be classified as errors of omission (e.g., failure to administer a drug that was prescribed) or commission (e.g., administration of improper drug) (Kohn et al., 2000). The objectives of medication administration have often been described as the six ‘rights’: the right patient, right dose, right medication, right time, right route of administration, and the right record of the medications administered or wasted (Merry & Anderson, 2011).

Medication errors remain one of the leading threats to patient safety, contributing to more than 7,000 inpatient deaths per year in the United States (Flynn, Liang, Dickson, Xie & Suh, 2012). In anesthesia, the frequency of medication errors is difficult to determine as most

estimates rely on self-reporting (Merry et al., 2011). Furthermore, even if a medication error has occurred, it may go unnoticed, and thus could not be reported even if the intention to do so was present (Merry et al., 2011). Nurse anesthetists typically administer several hundred thousand doses of medications over the course of their career, thus they are more likely to commit an error as opposed to those healthcare providers who infrequently administer medications (Merry et al., 2011). Nurse anesthetists select, prepare, administer and record medications autonomously without the aid of safeguards and double checks of a pharmacist, physician, or any other healthcare provider.

It is well documented that medication names that look or sound alike (see Figure 1) increase the risk of medication errors (Aspden et al., 2007). The layout and presentation of medication information of the label can be visually confusing, especially if it is designed for marketing rather than for clinical purposes (Aspden et al., 2007). Currently, there are no consistent approaches to color-coding, container size, background or font size and type by manufacturers (Merry et al., 2011) (see Figure 2). A contributing factor to medication errors is confirmation bias, which causes a health care professional to read a label to select a drug product and see what they expect to see, rather than what is actually selected (Koczmara & Jelinic, 2007).

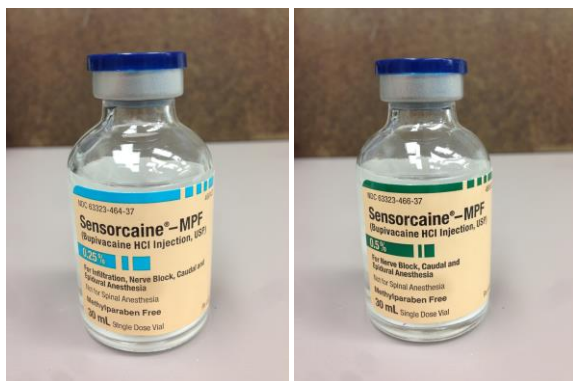


Figure 1. Look-alike Medications. Sensorcaine 0.25% and Sensorcaine 0.5% Vials

Examples of major naming, labeling, and packing problems include brand and generic names that look or sound alike, unclear dose concentration/strength designations, overemphasis on company logos and trade dress, lack of adequate background contrast, cluttered labeling with small font and serif typeface resulting in poor readability of printed information, and inadequate prominence of reminders and warnings (Aspden et al., 2007). To address these problems in labeling and packing designs, it has been suggested that the principles of human factors engineering and cognitive psychology should be undertaken to study error prevention strategies (Aspden et al., 2007).

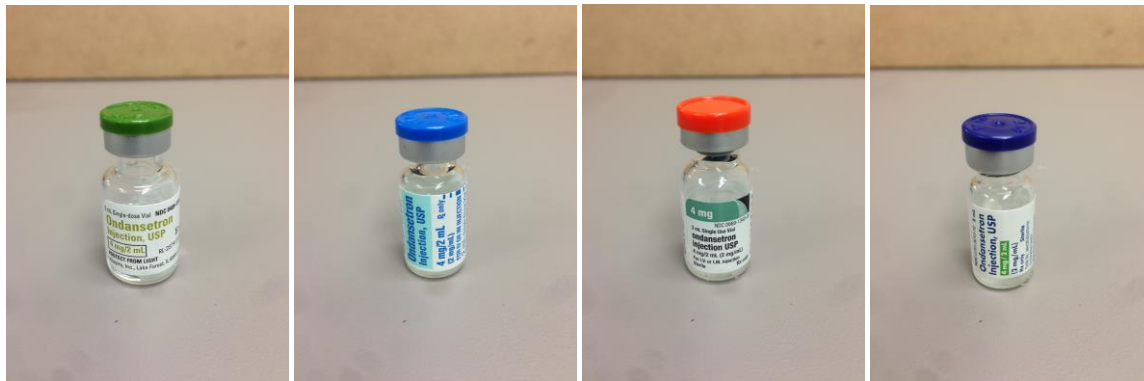


Figure 2. Variety in Medication Label and Coloring.

### **Anesthesia Error**

In 1978, a seminal study by Cooper, Newbower, Long and McPeck revealed the alarming number of anesthesia-related errors in healthcare. The study utilized a modified critical incident analysis technique in a retrospective analysis of human error and equipment failure in anesthesia (Cooper et al., 1978). Cooper et al. (1978) found that 82% of preventable incidents involved human error, with breathing circuit disconnections, inadvertent changes in gas flow, and medication syringe errors being frequent problems. Furthermore, they reported that 171 out of 583 human errors in anesthesia were due to the medication administration process, including medication syringe and ampule swaps, incorrect medication dosing, incorrect choice of

medications, intravenous catheter disconnection and incorrect intravenous catheter used for medication administration (Cooper et al., 1978).

This study, along with others, and Anesthesia Patient Safety Foundation initiatives, prompted technological advances and the application of patient safety principles to anesthesia and thus contributed to the delivery of safe anesthesia care (Cullen, Bates, & Leape, 2001). It has been suggested by some that anesthesia's efforts to reduce errors have been successful due to the effects of major anesthesia errors and because so many errors were readily identifiable (Cullen et al., 2001). It has been documented that the task of administering an intravenous drug to a patient during anesthesia is a highly complex procedure, often taking place under conditions of stress, haste, and fatigue (Abeysekera, Bergman, Kluger, & Short, 2005). Reason (2000) has identified that many errors can be attributed to slips or lapses that occur in a multitasked environment such as that in which nurse anesthetist work.

Wheeler and Wheeler (2005) contend that detecting anesthetists' medication errors in the operating room presents a particular problem as often anesthesia medications are recorded on separate anesthetic charts rather than patients' medication record, making the review of medication records an invalid technique to detect medication errors. Wheeler and Wheeler (2005) further assert that direct observation of medication errors is also impractical as anesthetists often prepare and administer medications unsupervised.

However, when medication-related error does occur in anesthesia it is often costly, with a recent review of closed claim studies citing 58 percent of all medication claims were associated with death or major morbidity (Mac Rae, 2007). A closed claim is defined as a demand for financial compensation for an injury resulting from medical care that has been dropped or settled by the parties or adjudicated by the courts (Mac Rae, 2007). The most common errors cited in

this review were incorrect dose, substitution of the incorrect medication, and administration of a medication not intended to be given (Mac Rae, 2007). The most common medications in these cases were succinylcholine, which result in prolonged neuromuscular blockade or awareness with paralysis, or epinephrine, which usually resulted in death or major morbidity (Mac Rae, 2007).

Anesthesia is an area in which very impressive improvements in safety have been made and is acknowledged as the leading medical specialty addressing issues in patient safety and human error (Kohn et al., 2000; Adams, 2005; Cullen et al., 2001). The improvements in the field of anesthesia are impressive and have resulted from improved monitoring techniques, the development and adoption of practice guidelines, and systematic approaches to reduce error (Kohn et al., 2000). However, although anesthetic techniques and equipment have undergone significant safety improvements over the past decade, filling syringes, mixing drugs, and administration techniques remain unchanged and are similar to those employed 100 years ago (Fraind, Slagle, Tubessing, Hughes & Weinger, 2002).

### **Prevention**

Since the 1940's the field of human factors research has focused on the circumstances in which error occurs and inquires about how a system might allow a person to commit an error and how the system could be changed or redesigned so that it would be difficult or impossible for humans to make a mistake (Dekker, 2011). Human factors research has evolved to take a radically different view of human error and human contribution to accidents. It has distanced itself from the view that solely attributes trouble to unreliable practitioners and has instead pointed to the system as the cause of error (Dekker, 2011).



At the forefront of human factors research as it relates to creating a safer system are aviation and occupational health (Kohn et al., 2000). Both of these industries have been leaders in increasing safety and have served as a role model for other industries seeking to improve safety. Retrospectively, their success has been attributed to setting standards, maintaining multiple databases to monitor trends, and supporting research to constantly improve systems (Kohn et al., 2000). Healthcare must draw on solutions from these fields to address the staggering problem of medication errors, and specifically anesthesia related medication errors.

There are certain factors in the operating room that increase risk to patients. Following the crew resource management model in aviation, these include but are not limited to communication, leadership, conflict, and vigilance (Marcucci, 2008). The crew resource management model includes the effects of fatigue, predictable perceptual errors, (i.e. misreading labels), and “the effects of various management and organizational styles in high-stress environments” (Marcucci, 2008, p. 769).

It has been suggested that systematic countermeasures should be employed to decrease the incidence of intravenous medication administration error in anesthesia (Jensen, Merry, Webster, Weller, & Larsson, 2004). Merry et al. (2011) assert that a formalized governance process of decision making and an effective operational process of implementing these decisions, educating staff members, promoting safe practices and monitoring all aspects of the system are necessary to improve medication safety. Furthermore, medication safety depends on a culture that places a high priority on patient safety and has little tolerance of poor practice in regards to safety (Merry et al., 2011). Whereas culture is defined as the sum of the attitudes of the individuals within a particular group, with attitudes best demonstrated and measured through behavior (Runciman, Merry, & Walton, 2007).

In summary, errors, whether medication and/or anesthesia related are complex, with considerable damage resulting from such errors. The literature review will now focus on attention and visual cognition as contributing factors to error in the operating room.

## **Attention**

At any moment in life, humans perceive, attend to, respond to, and make use of only a small fraction of the information from their surroundings that stimulate their sensory systems and from the internal information and skills stored in their memory and those acquired from their past experiences (Gopher & Iani, 2005). Attention is an active process where humans seek and attribute significance to external and internal events and can be conceptualized as a form of mental activity or energy that is distributed among information sources (Friedenberg, 2013). However, humans are limited in the amount and rate at which they can process information and perform corresponding tasks.

Donald Broadbent developed the first cognitive conceptualization of attention, the Early Selection Theory of Attention, which asserts that the attentional system is a single, limited capacity system (Broadbent, 1958). According to Broadbent, this system analyzes all incoming stimuli at the physical level, but only analyzes the most relevant information for symbolic and semantic properties. Broadbent suggested the presence of a filter that could block out ignored information, allowing only attended information to enter awareness. Kahanman and Treisman (1984) expanded on the work by Broadbent with the assertion that attention is limited in what it is able to process and functions as a bottleneck for incoming stimuli. They also assert that irrelevant stimuli are lost from awareness while relevant stimuli are held in sensory storage for further processing (Kahanman & Treisman, 1984).

In the late 1960's Keele, Norman, and Wickens developed late filter theories of attention (Wickens, 1984). These so called late filter theories propose that the bottleneck or filter is not at the point of sensory perception but later in the attentional process, at the point of decision-making. Thus, all stimuli are analyzed at the pre-attentive level of analysis and then passed on to higher-order processing areas, regardless of the content. The higher-order processing areas then filter stimuli by deciding what to attend to and what not to attend to (Wickens, 1984).

Due to the limitations of the filter theories, subsequent attentional theories, known as resource and capacity theories, were developed in the 1970's. These models state that stimuli are able to be processed in a parallel fashion and will continue to be processed in such a manner until the supply of stimuli overwhelms the capabilities of the resources and processing unit (Gopher & Iani, 2005). More recently, a "strategic solution view" has been presented that proposes there is no mandatory architecture to the flow of task performance or a scarcity of processing and response facilities. Rather, the best strategic solution to the task's performance is developed based on the nature of the task involved, the characteristics of the environment, the specific abilities and skills of the individual, and the individual's motivations and intentions (Gopher & Iani, 2005). The strategic solution view shifts the focus from the study of the sources of limitation to the study of the degrees of freedom of the human processing system and the ability of humans to control their attentional capabilities (Gopher & Iani, 2005).

## **Visual Cognition**

The perceptual process of analyzing an image is complex. Conflicting theories to explain this phenomenon have been presented, with some arguing that the observed image is "recorded" by the viewer's optic system while others contend the image meaning is constructed based on and individual's experience and preconception (Levie, 1987). Whereas Solso (2003) supports the

“constructivist” view and asserts that hypothesis testing motivates image perception. According to Solso (2003), images are interpreted via a top down model of information processing through the use of individually constructed schemas. Schemas are a part of the individual’s mental framework used to represent knowledge and are applied to image interpretation in a variety of fields, such as art, science, literature, music and history (Solso, 2003).

Levie (1987) describes the perceptual process as being composed of three primary components: (a) attention and scanning, (b) interpreting significant figures and cues, and (c) perceiving global meaning. Attention and scanning occur by combining the processes of foveal fixations and eye pattern movements. Foveal fixations can be defined as an attentional shift within an attentional window (a high acuity window area enveloping the fovea, to perform visual selection of interesting visual objects are targets (Sun, Fisher, Wang, & Gomes, 2008). Typically, foveal fixations occur for a period of approximately 300 ms per individual fixation (Levie, 1987). The specific location of each foveal fixation distinctly affects how individuals interpret an image and how it is encoded into memory. Saccade is the term that refers to the extremely rapid eye movements that separates individual foveal fixations (Levie, 1987) and can be defined as attention-drive gaze shift outside the window to assist attentional selectivity in the whole field of view (Sun et al., 2008).

Solso (2003) asserts that although human beings are capable of taking in information in a variety of different sensational formats, the brain will only focus its attention on particular selected items from such a vast amount of incoming sensational information. Zull (2002) expounds on this idea and contends that the expert is able to discern which features of the image are important and which are not, whereas the novice assigns equal significance to all features of the image.

## **Visual Search**

As described earlier, nurse anesthetists often rapidly and autonomously select and administer medications in the operating room. The anesthetist must first “prescribe” a medication, by deciding if a medication should be administered, and if so, which medication should be administered and the dosage of the medication. Next, the anesthetist must physically select the medication vial through a visual search of available medications, calculate the amount of medication to withdraw from the vial, withdraw the medication from the vial via a syringe and administer the medication to the patient via the correct route (e.g. intravenous). Prior to the administration of the medication, the nurse anesthetist often conducts a final check through visual confirmation (Kataoka et al., 2011).

Human beings conduct visual searches throughout the day on a daily basis; examples are looking for a cell phone, keys, a parking spot, an icon on a computer, and so forth (Wolfe, Alvarez, Rosenhooltz, Kuzmova, & Sherman, 2011). In the operating room, the nurse anesthetist performs several visual searches in order to locate the correct medication vial or ampule. The above examples illustrate that visual search is necessary, even for those targets that are in plain view. Wolfe (2010) explains that even though all targets may be visible at a specific time and a person has an impression of the scene, a person can only confirm the presence of a specific target once attention is shifted to the target.

The study of attention has traditionally focused on the “top-down” processing of information that has subjective constraints and is imposed by the human organism when organizing and selecting responses after interpreting information (Gopher & Iani, 2005). In some instances, it has been shown that attention can be captured automatically by sudden changes in the environment using “bottom-up” processes (Gopher & Iani, 2005). The exact interaction

between these two processes is still elusive, with at least three major theories on mechanisms of integration between bottom-up and top-down vision occurring in the visual cortex (Elazary & Itti, 2010).

The Feature Integration Theory (Treisman & Gelade, 1980; Treisman & Sato, 1990) asserts that several low-level visual features (a feature is a distinctive property such as color, size or orientation) are processed over the entire visual field in separate neuronal maps (called feature maps), and then combined to form a master map that guides attention (Elazary & Itti, 2010; Müller-Oehring, Schulte, Rohlfsing, Pfefferbaum, & Sullivan, 2013). If the target can be defined by a set of primitive feature maps, such as a distinct color or orientation, these features maps use top-down information to elicit the target location in parallel. However, if the target is defined only by some conjunctions of these feature maps, such as a unique combination of color and orientation, then a serial search is required to find the target (Elazary & Itti, 2010).

Guided Search is a model of human visual search, more specifically of search tasks in which a participant looks for a feature-defined target among distracting items (Wolfe, 2007). “Guided” search becomes more efficient as attention is guided to a subset of all the available stimuli in a scene based on the features of the target (Wolfe et al., 2011). Neider and Zalinsky (2008) have named the subset the “functional set size” and defined it as those set of items the visual system deems worth considering as targets because they share features with the target.

Traditionally, visual search models have described the mechanisms of search as serial or parallel (Egeth, 1966). In serial search, attention is directed towards one item, allowing each item to be classified as a target or a distractor (Sternberg, 1966). Parallel search models propose that many items or even several items are processed at the same time (Kyongje, 2008). Thus, the Guided Search method creates a master activation map where top-down knowledge is used to

weigh the relative contributions of bottom-up feature maps to emphasize both features and locations likely to characterize the target (Wolfe, 2007). The Guided Search model then uses the combination of these maps to shift attention towards the most promising locations (Elazary & Itti, 2010).

Lastly, the Biased Competition Model proposed by Desimone and Duncan (1995) involves competition between visual stimuli at each stage of processing, which is influenced by top-down processing. In this model, attention biases the response of a local feature detector when two stimuli are simultaneously exciting it. The response is biased in that the direction of the attended feature occurs in a different location (Elazary & Itti, 2010).

In conjunction search tasks (searching for multiple features of a target such as color and shape) there are many potential objects to which attention may be deployed that may or may not share a feature of the target (Williams, Henderson & Zacks, 2005). One way to examine the deployment of attention is to use eye-movement measures, because attention and fixation tend to be linked. There have been a multitude of studies that have examined eye movements and visual search (Williams, et al., 2005). Williams (1966) found a preference to fixate stimuli sharing target color as opposed to other features, such as size and shape. Additionally, recent studies found that participants were more likely to fixate distractor objects possessing a target feature (such as color) than distractors that did not possess a target feature (Hooge & Erkelens, 1999; Shen, Reingold, Pomplun, & Williams, 2003).

### **Color**

Vision is accomplished through the use of rods and cones located within the retina of the human eye (Solso, 2003). Rods (so named for their pole like appearance) are most useful in detecting black, gray and white stimuli and are most sensitive to light at a wavelength of 500 nm.

This is contrast to cones (so named because they are broader than rods and have a conical tip), which are most sensitive to light at a wavelength of 550 nm, which has a corresponding visible color of yellow-green. Humans have a trichromatic color vision system that utilizes three different types of cones (Solso, 2003). The three different types of cones differ based on the type of photosensitive pigment they possess.

The visible spectrum is the portion of the electromagnetic spectrum by which human beings are able to perceive color (Solso, 2003). Tufte (1990) states that a trained colorist can discern between approximately 1,000,000 different colors when asked to differentiate between paired colors in the laboratory setting, whereas the average viewer can only discern approximately 20,000 colors.

Tufte (1990) discusses the use of color in information design in his text, *Envisioning Information*. He states that color can serve in four major capacities in information design to: (a) label, (b) measure/quantitate, (c) represent/imitate reality, and (d) enliven/decorate/beautify. He explains that color in an image is translated by the viewer into quantitative data and will be perceived in different ways based on the viewer and their experiences (Tufte, 1990). However, care should be taken when using color in an image, as it will greatly add to the complexity of the image and it may overwhelm the viewer's processing ability. Peeck (1987) states that it is particularly important to exercise care when viewing time of the image will be limited. Tufte (1990) explains that the constraint in human visual memory is not the actual ability to discern between color variations. He asserts that rather if more than 20 to 30 colors are used to encode abstract information, the use of color may instead have an inhibitory effect on the learning process (Tufte, 1990). This is supported by studies that have shown that arbitrary use of color or



use of a poorly planned design for color application can easily detract from the learner's instructional gains (Goldsmith, 1987).

When discussing the use of color in images, it is essential to consider color's function. Early studies in the 1950's and 60's focused on the use of color in instructional material presented strictly for informational purposes (Dwyer, 1978). Color has many functions as related to instructional effectiveness and include: (a) directing attention, (b) increasing motivation, (c) eliciting emotional response, (d) cueing or coding, and (e) information design (Dwyer, 1978; Tufte, 1990). Studies have demonstrated that color is helpful in drawing attention to specific properties of an object. Color may also aid the viewer in detection in interrelationships or in making fine discriminations (Peeck, 1987).

### **Visual Comparison**

Image comparison can occur through two different mechanisms: simultaneous (parallel in space) or sequential (parallel in time) presentation modes. In his 1997 text, *Visual Explanations*, Tufte defines both of these mechanisms and offers the advantages and disadvantages of both forms of presentation. Tufte (1997) describes simultaneous image presentation as parallel in space, as the images are presented in close proximity to each other and appear within a single visual field. Furthermore, Tufte states that an advantage of spatial parallelism is the human capacity to compare and reason the meaning of multiple images that appear simultaneously. Furthermore he states that humans are able to “canvas, sort, identify, reconnoiter, select, contrast, review ways of seeing, all quickened and sharpened by the direct spatial adjacency of parallel elements” (p. 80). Tufte (1997) refers to sequential presentation modes as being parallel in time as the viewing of images occurs segmented by time. The viewing of images in two separate presentation fields, forces the viewer to remember the first image and then compare it to the

second image. Tufte believes this mode of presentation to be challenging and states that simultaneous comparisons are most effective. Tufte (1990, 1997, 2001) has developed a theory of graphical excellence, which can be used to guide the selection and design of graphics. The most basic principle of this theory is to use simple, but powerful graphic designs that efficiently and effectively illustrate complex concepts or relationships, such as the mode of presentation previously discussed.

When visual comparison is made via the use of parallel images, the viewer is able to note the like components of the images, including similarities in content, position, or image orientation. Zull (2002) explains that the physical arrangement of images simulates particular neural networks and when two images are presented side by side as opposed to in a series, the neuronal network for comparison is stimulated. Levie (1978) states that learning to associate or relate two or more objects/events is facilitated when they are encountered close together in time and space. He also states that these objects/events will tend to be perceived as somehow related allowing both similarities and differences to become more apparent.

### **Digital Imagery**

Images and pictures can be portrayed in a variety of forms, but in this study the stimuli source is digital photography. In today's society, many pictures are produced with digital cameras as opposed to film-based analog cameras (Gooskens, 2012). Mitchell (1992) argues such digital pictures are not photographs as they lack the realism typical of film-based photographs. Furthermore, Mitchell (1992) asserts pictures "created" by digital cameras may look like photographs but are completely different and are as different as a photograph is to painting. Bardis (2004) echoes his beliefs and states that new technologies have fundamentally transformed the way photographic images are both produced and perceived. Bardis (2004) goes

on to state that the transformation entails the translation of each part of the analogous image by the computer into a map of blocks of electronic data and that with the proper computer software portions of the photography may be modified, duplicated, or deleted with relative ease.

Wandersee (2000) describes four major photographic styles including realism, expressionism, formalism, and instrumentalism. Realism photographs allow for nature to be represented in its true to life form. Dwyer (1978) defines realist images as completely authentic, with its quality indistinguishable from the object itself. Dwyer's studies found a positive correlational relationship between the amount of realism in a picture and the amount of measured learning. He suggests that the best type of picture for use in a learning setting may be a hybrid photograph/drawing combination as too highly realistic an image may overwhelm a student and too basic a drawing may not provide enough needed stimuli. Gooskens (2012) asserts that photographs are epistemologically and ontologically realistic due to they are reliable informants about the visual properties of their depicta (object, events, or state-of-affairs represented by pictures) and they are causally connected to their depicta. Expressionism photographs are representative of the photographer's own personal experiences. Formalism photographs derive their substance from the form of the photographs as opposed to from the particular objects being photographed. Instrumentalism photographs are used to communicate moral, social, or economic messages. The digital photographs used in this study are a realist format.

## **Expertise**

Our civilization has always recognized exceptional individuals, whose performance in a field is superior to that of the rest of the population (Ericsson, Krampe, & Tesch-Roemer, 1993). These individuals have earned the title and are recognized as "experts". In the late 1800s, Sir Francis Galton became the first scientist to research the idea that excellence in a field or domain

was the result of a common set of causes (Ericsson et al., 1993). More recently, in 1946, De Groot conducted pioneering research on chess expertise, which led to an interest in the field of expertise (Ericsson & Smith, 1991). The field of expertise “seeks to understand and account for what distinguishes outstanding individuals in a domain from less outstanding individuals in that domain, as well as from people in general” (Ericsson, 2003, p. 1).

### **Definition of Expertise**

Since De Groot’s pioneering research, a body of literature has been amassed in the areas of competence, experience, expertise, expert performance and knowledge acquisition (Ericsson, 2006). Varying approaches have emerged to explain expert performance, as well as different viewpoints on the mechanisms and processes responsible for this performance (Whyte, Ward, & Eccles, 2009). Although noted researchers in nursing and chess expertise have suggested intuition or the intuitive access to stored knowledge is a primary moderator of performance at the highest levels, researchers from other domains have offered alternative views (Benner, 1984; Dreyfus & Dreyfus, 1986). Benner defines clinical expertise as a hybrid of practical and theoretical knowledge and asserts that clinically expert nurses are often distinguished from their colleagues by their intuitive ability to efficiently make critical clinical decisions while simultaneously looking at the complete picture (McHugh & Lake, 2010). This view is in contrast to researchers that have adopted the expert performance approach, who point to think aloud protocols that have been collected from expert performers during representative task performance that indicate intuitive knowledge access is not alone responsible for superior performance (Whyte et al., 2009).

Mintzes, Wandersee, and Novak (2000) report that “expert-novice” research has revealed that experts have the following characteristics: (a) experts tend to excel singularly in their

domain of knowledge and that transfer to other domains is quite limited in most instances, (b) experts tend to see large meaningful patterns in their knowledge domain and this enables them to solve problems more quickly, (c) experts generally possess a strongly hierarchical cohesive framework of related concepts, and (d) experts typically have strong ‘metacognitive’ or self-monitoring skills. Similarly, Bruer (1993) identifies three main factors upon which expertise in a given area depends: (a) highly organized domain-specific knowledge, (b) domain-specific metacognitive skills, and (c) general learning strategies or skills.

### **Acquisition/Development of Expertise**

Although it is generally agreed upon that an expert exhibits outstanding performance in their particular domain of knowledge, the exact mechanism by which experts acquire their unique characteristics is still a matter of debate. It is generally assumed that expert performance reflects a balance between training and experience (nurture) and differences in capabilities and talents (nature) (Ericsson & Lehmann, 1996). Galton’s research asserts that an individual possesses innate basic capacities that are unable to be modified despite training and practice (Ericsson & Lehmann, 1996). This is in opposition to the views of de Groot (1965) and Simon and Chase (1973) that experts’ knowledge and task-specific reactions must have been acquired and accumulated as the result of experience (Ericsson & Lehman, 1996). However, the idea that most talent is innate and that most anatomical and physiological characteristics are not modifiable does not apply to expert performance acquired through a decade of intense practice (Ericsson & Lehmann, 1996).

Benner (1984) states that both time in clinical practice and self-reflection allow preconceived notions and expectations to be confirmed, refined, or disconfirmed in real circumstances and settings. Benner asserts that encountering a patient, their condition and a

patient scenario is not experience; but rather experience is a nurse reflecting on their encountered circumstances to refine their decision making at an intuitive level. Finally, Benner concludes that experience is necessary but not sufficient for expertise and that not all experienced nurses are experts (McHugh & Lake, 2010).

According to Ericsson and Lehmann (1996) the age at which experts attain their highest level of performance is closely related to the domain of their expertise. In the arts and sciences there is a close relationship between the time of most unique achievements and the time of highest consistent productivity with the third and fourth decade of life (Ericsson & Lehman, 1996). Thus, age is related to the amount and type of experience in the field an individual has accumulated (Hoffman, Shadbolt, Burton, & Klein, 1995). Multiple studies in the area of expertise development, such as Chase and Simon's in chess expertise, Hayes and Bloom's in sports and the arts, and international performance expertise by Ericsson and Crutche, suggest that about 10 years of concentrated experience is necessary, if not required, for international recognition in a field, whereas international performance expertise is an expert who achieves international recognition in a field (Ericsson & Smith, 1991). In a well-established domain with a large number of active participants, only a small number of exceptions to the general rule that individuals require 10 or more years of preparation to attain international level performance (Ericsson et al., 1993). Necessary preparation can also be inferred for writers and scientists, although the starting points of their careers are more difficult to determine. It has been reported that scientists often make a career decision during their middle or late teenage years, yet it is not until a decade or two later that they publish an important contribution (Ericsson et al., 1993).

There is evidence that suggests practice at a young age as the body develops, may be necessary for certain adaptations to occur, such as for ballerinas and musicians (Ericsson & Lehmann, 1996).

The weak relation between experience and performance, especially in many of our common activities, can be attributed to few opportunities for effective learning and improvement of skill. Deliberate practice has been proposed by Ericsson (1991) to describe the individualized training activities designed by teachers to improve specific aspects of an individual's performance through repetition and successive refinement (Ericsson & Lehmann, 1996). Ericsson further asserts that in order for optimal learning and improvement of performance, a number of conditions should be met, including the participant's motivation to attend to the task and effort of performance, that the task takes into account the preexisting knowledge of the participant, and that the participants receive immediate informative feedback of their results (Ericsson et al., 1993). When these conditions are satisfied, practice improves accuracy and speed of performance on cognitive, perceptual, and motor tasks (Ericsson et al., 1993).

Simon and Chase (1973) conducted expert-novice research in the field of chess by studying the differences between expert and novices chess players. Their research revealed that the main difference between the expert and novice chess player is how they viewed the chessboard. Experts visually grouped individual pieces into familiar patterns so that when the board was viewed patterns were seen as opposed to individual chess pieces. This is in contrast to the novices, who did not see patterns, but rather only saw individual chess pieces. Zull (2002) explains that the expert is able to discern which features of the image are important and which are not, whereas the novice weights all features of the image as equal significance.

## **Levels of Expertise**

Dreyfus and Dreyfus (1980) developed a model of skill acquisition based on the study of chess players and aviation (Benner, 1984). The Dreyfus model asserts that during the acquisition and development of a skill, a student will pass through five levels of proficiency: (a) novice, (b) advanced beginner, (c) competent, (d) proficient, and (e) expert. Benner (1984) applied the Dreyfus model of skill acquisition to nursing and has documented that a nurse has the potential to reach each of these levels of proficiency.

Benner (1984) also describes seven domains of nursing practice. These domains are derived from 31 competencies that emerged as the result of an analysis of patient care episodes (Benner, 1984). The domains are: (a) the helping role, (b) the teaching-coaching function, (c) the diagnostic and patient monitoring function, (d) effective management of rapidly changing situations, (e) administering and monitoring therapeutic interventions and regimens, (f) monitoring and ensuring the quality of health-care practices, and (g) organizational and work role competencies (Benner, 1984). Each domain then consists of three to eight specific competencies.

Procedural descriptions of the competencies of administering and monitoring therapeutic interventions and regimens domain can be found in almost any procedural book, but that additional demands, resources, and constraints must be taken into account when considering this domain (Benner, 1984). Nurses often fail to give themselves credit for their skill in administering the complex and intricate therapeutic interventions and that many of these regimens have been delegated to nurses in an indiscreet manner, leaving nurses to develop new practices and skills (Benner, 1984).



In all domains, knowledge and technology are steadily accumulating and evolving, and the criteria for expert performances are undergoing continuous change. Once a practitioner has mastered the knowledge and techniques of their domain, they will have reached the status of expert. However, in order to make an eminent achievement, the expert must surpass those achievements already recognized experts in the field and then make innovative contributions to the domain (Ericsson et al., 1993). According to Benner (1984), most nurses take at least five years to reach the expert stage, if they are to reach it at all.

### **Expertise Superiority in Visual Domains**

There are several theories that seek to explain expert superiority in the comprehension of visualization, including long-term working memory (Ericsson & Kitsch, 1995), information-reduction hypothesis (Haider & Frensch, 1999) and the holistic model of image perception (Kundel, Nodine, Conant, & Weinstein, 2007).

The theory of long-term working memory assumes that “expertise extends the capacities for information processing owing to the acquisition of retrieval structures that allows advanced learners to rapidly encode information in long-term memory and efficiently access it for later task operations” (Gegenfurtner, Lehtinen, & Salgo, 2011, p. 524). The information-reduction hypothesis theory (Haider & Frensch, 1999) focuses on the learned selectivity of information processing and proposes that strategic considerations, such as neglecting task-irrelevant information and actively focusing on task-relevant information, selectivity allocate attentional resources (Haider & Frensch, 1999). Finally, the holistic model of image perception focuses on the extension of the visual span and proposes that expertise changes the temporal organization of the perceptual processes to allow advanced learners to extract information from widely distanced and parafoveal regions (the area surrounding the fovea that corresponds to two to ten degrees off

center of the retina (Kundel et al., 2007). The holistic model asserts that experts do not need to bring information into the fovea as they extend the visual span through parafoveal processing (reflected by longer saccade length and in shorter times to first fixate on target areas) (Kundel et al., 2007).

Gegenfurtner et al. (2011), assert the above theories provide complimentary accounts of the mechanisms underlying the reproducibility of expert task superiority during domain-specific visualizations. They believe each theory can be generalized across a range of visualizations and task characteristics and that it are these characteristics that moderate the size of expertise differences (Gegenfurtner et al., 2011).

### **Current Study**

The current study attempts to explore the differences in metacognition and comparative knowledge structures during medication selection between novices and experts while simultaneously examining how visual search differs between the two groups of participants.

The researcher hypothesizes that similar distractor medications will attract attention from the target medication during visual search. Research has shown that when one searches an environment different objects are more or less likely to attract attention based on their similarity to the search target (Williams et al., 2005; Kim & Cave, 2001). Additionally, studies have shown that participants are more likely to fixate on a distractor object possessing a target feature than objects that did not (Hooge & Erkelens, 1999; Williams, Reingold, Moscovitvh, & Behrmann, 1997). Williams (1966) found a preference to fixate on stimuli sharing the target color whereas other target characteristics, such as size and shape, were not as preferentially selected. Eye movements and visual search are used within this study to examine how attention is deployed as

studies have shown attention and fixation tend to be relatively tightly linked (Williams et al., 2005). Thus, the study will examine eye movements as a measure of attentional deployment.

Additionally, the researcher hypothesizes that because similar distractor medications attract attention during visual search, reaction time will increase when similar distractor medications are present, while accuracy will decrease. According to Becker (2010), when a search target is very dissimilar to all distractors and the distractors are all similar to one another the target “pops out” from the display and can be found immediately. Contrastingly, when a target is similar to the distractors, it takes much longer to find the target as search proceeds inefficiently. Distractors have been shown to capture attention and the eyes when they are similar to the target as compared to when they are dissimilar to the target (Ludwig & Gilchrist, 2002). Becker (2010) asserts that search times increase as the number of distractors in the display increases, suggesting the eight distractor medication vials will increase search times. Finally, Langer and Eikhoff (2012) states, “Vigilant attention- brain activity may be affected by whether the task requires stimulus detection or discrimination. In discrimination tasks, as compared to simple detection tasks, stimuli need to be processed more deeply, as identification is required, and the stimulus-response mapping is more complex, as each trial can either require the predefined response or require withholding this response” (p. 6). Thus, because the participant is asked to not only search for the target medication vial, but also to select the target medication vial via a mouse, a discrimination task will be completed, leading to an attentional shift.

Lastly, the researcher hypothesizes when similar distractors are present, expert participants will have an increased reaction time overall and as compared to novice participants. However, while expert participants will have an increased reaction time compared to novice participants, the researcher hypothesizes expert participants will be more accurate as compared

to novice participants. Several studies demonstrate that experts perform better on tasks within their area of expertise due to a more efficient allocation of visual attention and better memory performance (Christensen et al., 1981; Ferrari, Didierjean, & Marmèche, 2008; Jarodzka, Scheiter, Gerjets, & van Gog, 2010; Myles-Worsley, Johnston, & Simons, 1988). According to Ericsson et al. (1993), training and/or experience in a domain will lead to continued improvement on domain-relevant tasks. Expert image interpretation is characterized by a holistic approach and efficient visual search strategies (van der Gijp et al., 2014). Experienced observers fixate and recognize abnormalities faster (Kundel et al., 2007; Nodine, Kundel, Lauver & Toto, 1996) and terminate their search earlier (Christensen, et al., 1981). According to van der Gijp et al. (2014), experts fast holistic approach results in higher accuracy than the relatively slow search-to-find approach of less proficient observers” (p. 2). Beck, Trenchard, van Lamsweerde, Goldstein, & Lohrenz (2012) suggested, “expertise may lead to a more effortful and conservative approach to the target search task” as study participants performed better, but were slower to respond to stimuli during high clutter search (p.2). At the completion of the study, a variety of data will be collected and analyzed to answer each hypothesis as shown in Table 2.

Table 2  
Hypotheses and Dependent Variable Analyses

Hypotheses	Dependent Variable Analyses
1. Similar distractor medications will attract attention from the target medication and dissimilar distractor medications during visual search.	Dwell Time Proportion -Target -Distractor Post Experiment Questionnaire
2. Because similar distractor medications attract attention during visual search, reaction time will increase when similar distractor medications are present, while accuracy will decrease.	Accuracy Reaction Time
3. When similar distractors are present, expert participants will have an increased reaction time overall as compared to novice participants. However, expert participants will be more accurate as compared to novice participants.	Accuracy Reaction Time Verification Guidance

### **Chapter 3. Methodology**

This chapter addresses the study's research design, eye tracking instrument, digital camera and photograph use, population and sampling methods and procedures for data collection.

#### **Research Design**

A sequential, explanatory cross-sectional mixed methods design provides the framework for this study. This design is characterized by the collection and analysis of quantitative data in the first phase of research followed by the collection and analysis of qualitative data in the second phase that allows for results to be built upon the initial quantitative results (Creswell, 2009). Eye tracking data is collected via computer simulation of medication selection, followed by the administration of a demographic and post experiment questionnaire. Strengths of this design include the straightforwardness and ease of implementation due to the clear, separate stages and neutralizes the disadvantages of a single methodology (Creswell, 2009). The first phase of this study involves the visual search and selection of medications via a computer simulation with eye tracking utilized and was administered to both novices and experts. Upon completion of the simulation, participants then answered a brief demographic and post experiment questionnaire.

#### **Sampling Procedures**

The participants in this study consists of two different subpopulations: (a) 41 Nurse Anesthesia students from Our Lady of the Lake College (LOLC), both first and second year students, and (b) 16 Louisiana advance practice nurse licensed and nationally Certified Registered Nurse Anesthetists (CRNAs) who have practiced as a CRNA for a period five or more years.

OLOLC is a small, Catholic college with a total student population of approximately 2,000 students. The College's primary educational focus and preparation is in health care related careers. OLOLC is divided into two schools: (a) the school of Arts, Sciences and Health Professions, and (b) the School of Nursing. The Master of Science in Nurse Anesthesia (MSNA) program is included within the School of Nursing, as such a letter seeking permission to discuss the study with perspective student participants were sent the MSNA Program Director and Dean of Nursing (Appendix A).

The nurse anesthesia students who participated in this study are those enrolled in MSNA program at OLOLC in Baton Rouge, Louisiana. MSNA Students are college graduates with a Bachelor of Science in Nursing (BSN) from an accredited School of Nursing, have practiced a minimum of one year full time as a registered nurse in an adult intensive care unit and possess a current, unencumbered Louisiana registered nurse license.

The purpose of the MSNA program is to prepare the registered nurse for advanced clinical practice in the field of anesthesia as a certified registered nurse anesthetist. The MSNA program offers a comprehensive didactic and clinical curriculum in the field of nurse anesthesia. Since nurse anesthesia education requires a broad knowledge base in science combined with intense clinical training in order to provide patients with safe care during the perioperative process, classroom work provides a knowledge base for advanced pharmacology, anatomy, physiology, pathophysiology, and principles of nurse anesthesia, while clinical work is extensive and prepares the nurse to provide anesthesia services in various patient populations. Critical thinking, clinical judgment, clinical problem-solving skills, and communication skills are crucial for the nurse anesthetist. The OLOLC MSNA program is a 28-month continuous program of study that provides the appropriate number of anesthesia cases, classroom hours, and clinical

hours for each student. Table 3 outlines the current curriculum plan for the OLOLC MSNA program. Upon successful completion of the MSNA program, graduates are eligible to sit for the national certification examination offered by the NBCRNA.

Novice participants included both first year and second year students from the MSNA program. Twenty-eight first-year (21 males, 7 females) MSNA students participated in this study and were enrolled in the third semester of the program. While a total of 28 first year participants participated in the study, 12 first year participants were randomly excluded from the statistical analysis to balance the analysis with 16 participants from each level of expertise included in the statistical analysis for phase one and phase two of the experiment. The mean age of first year participants was 29 years, with all reported having normal or corrected vision. At the time of the study, the first-year participants had received a majority of didactic instruction and had just entered the clinical phase of the program. The mean number of total cases reported by the first year participants was 43.89 with an average of 6.69 medications administered per case. Each first year student participant was awarded two extra credit points per half hour of participation in the study towards Principles of Anesthesia III, ANES 5355. Sixteen second-year students (13 males, 3 females) participated in this study and at were enrolled in the sixth semester of the program. The mean age of second year participants was 31.25 years, with all reported having normal or corrected vision. The second year participants reported a mean number of total cases as 662.56 with an average of 7.75 medications administered per case. Each second year student participant was awarded two extra credit points per half hour of participation in the study to be used towards Advanced Research, ANES 5310. Prior to participation in the study, each student signed an informed consent (Appendix B) after reading an invitation letter to participate in the study based on his or her year of experience, first year or second year (Appendix C and Appendix D).

Table 3  
 OLOLC Master of Science in Nurse Anesthesia Curriculum Plan, 2013-2014  
 Curriculum Plan

Semester 1 (Fall)		
ANES 5310	Physical Science in Nurse Anesthesia	3
ANES 5420	Pharmacology I	4
ANES 5425	Advanced Anatomy, Physiology, & Pathophysiology I	4
ANES 5340	Professional Aspects of Nurse Anesthesia	3
ANES 5430	Principles of Anesthesia Practice I	4
	Total Semester Hours	18
Semester 2 (Spring)		
ANES 5320	Advanced Assessment	3
ANES 5421	Pharmacology II	4
ANES 5426	Advanced Anatomy, Physiology, & Pathophysiology II	4
ANES 5352	Principles of Anesthesia Practice II	3
ANES 5737	Anesthesia Skills and Simulation Lab	3
	Total Semester Hours	17
Semester 3 (Summer)		
ANES 5355	Principles in Anesthesia Practice III	3
ANES 5741	Clinical Practicum I	4
	Total Semester Hours	7
Semester 4 (Fall)		
NURS 5315	Advanced Statistics in Nursing	3
ANES 5360	Principles in Anesthesia Practice IV	3
ANES 5742	Clinical Practicum II	5
	Total Semester Hours	11
Semester 5 (Spring)		
ANES 5460	Principles in Anesthesia Practice V	4
ANES 5743	Clinical Practicum III	5
	Total Semester Hours	9
Semester 6 (Summer)		
NURS 5340	Advanced Nursing Research	3
ANES 5744	Clinical Practicum IV	5
ANES 5110	Senior Capstone	1
	Total Semester Hours	9
Semester 7 (Fall)		
ANES 5415	Anesthesia Seminar	4
ANES 5745	Clinical Practicum V	5
	Total Semester Hours	9
	Total Credit Hours	80



The second group of participants included sixteen (5 males, 11 females) experienced CRNAs currently practicing at Baton Rouge area hospitals and surgical centers. These hospital sites included: (a) Our Lady of the Lake Regional Medical Center, (b) Woman's Hospital, (c) Ochsner Medical Center, (d) Lane Regional Medical Center, (d) Orthopedic Surgery Center, (e) Surgical Specialty Center, and (f) Lake Surgery Center. The mean expert participant age was 48.06 years with all reported normal or corrected vision. The mean CRNA practice experience was 16.68 years, including a current average of 36.69 hours worked per week, with an average of 7.44 medications administered per case. Each CRNA participant was awarded 50 dollars for participation in the study. Prior to participation in the study, each CRNA signed an informed consent after reading an invitation letter to participate in the study (Appendix B and Appendix E respectively).

### **Apparatus and Stimuli**

The study was conducted at the Beck Visual Cognition Lab in B5 Audubon Hall on Louisiana State University's campus. The eye movement data was collected using the Eyelink II eye tracker at a sample rate of 500 Hz (SR Research Ltd.). Viewing was binocular, but only the dominant eye was tracked. Stimuli were presented on a Dell Computer with LCD Displays set with a 20" diagonal and a resolution of 1680 X 1050. A chin rest stabilized the eyes 57 cm away from the display. Manual responses were made via a game controller. Stimulus presentation and response recording was controlled by Experiment Builder (SR Research Ltd.).

One hundred sixty-one full-color photographs (800 X 600 pixels, 31.8° X 23.8°) of medication vials were used as stimuli. Prior to data collection, the researcher sent each manufacturer a letter requesting use of the photograph image for use in the researcher's dissertation (Appendix F). The researcher characterized each medication photograph based on

medication class, medication vial size, medication concentration, and medication label similarity. Each medication vial photograph was used a maximum of three times during the experiment with only one potential use as a target medication. The position of the medication vials within the search array was randomized by the Experiment Builder software, as was the target medication.

The researcher used a Nikon D5200 camera and photobox apparatus to create the photograph visual stimuli. The 9½ inch height by 13-inch wide by 8-inch depth photobox was lined with white felt paper and illuminated by three external light emitting diode light sources to produce a neutral and consistent background.

### **Pilot Study**

Three expert professionals with five or more years of experience as a CRNA participated in the pilot study. The pilot study served three purposes including: (a) determination of time estimates for expert identification of medications, (b) accuracy of medication selection, and (c) clarity of medication photographs. Upon completion of the simulation, each participant completed a post pilot test questionnaire to rate the difficulty of the experiment, the clarity of photographs, the ease of pretest directions, and the ease of the use of the game controller/computer to select medications (Appendix G). Based on the experts' performance and the responses to the post experiment questionnaire, the experiment was not modified.

### **Data Collection Procedures**

Prior to beginning the research study, a request for exemption status was submitted to the LSU Institutional Review Board (IRB) and the OLOLC IRB. (Appendix H and Appendix I). The study was conducted during the summer 2014 semester.

The experiment utilized a 3 (expertise: first-year student, second-year student, expert) X 2 (target presence: present, absent) X 2 (similar distractor presence: present, absent) mixed

factorial design. Expertise serves as the between subjects variable with target presence and similar distractor presence serving as the within subjects variables.

Prior to the experiment each participant underwent a randomized nine-point calibration procedure that was validated to ensure the average error was less than  $0.5^{\circ}$  and the maximum error in one calibration point was less than  $1^{\circ}$ . Recalibrations were performed during the experiment as needed. Before each trial sequence, a drift correct was applied as the participant fixated on a dot in the center of the screen. When the drift error was deemed successful (drift error less than  $1^{\circ}$ ), the experiment initiated the trial. Prior to the start of the actual trial, each participant attempted a practice trial and was given the opportunity to again read the instructions (see Figure 3).

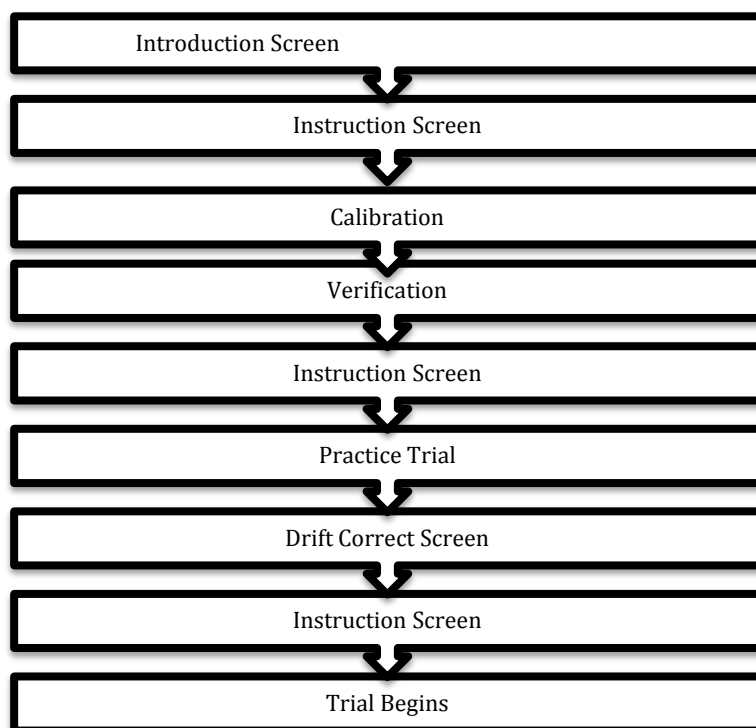


Figure 3. Procedure for Experiment. Participants underwent eye tracker calibration, validation and completed a practice trial prior to the initiation of the trial sequence.

Following successful drift correct and initiation of the trial, the target medication name was presented in the center of a white screen. After reading the target medication name, the

participant began the trial by a button press on the game controller. The medication search screen then appeared with an array of eight medication vials. The participants then searched for the target medication, responding with a right button press if the target was located. If the participant was unable to locate the target medication, the participant responded with a left button press and the trial ended. Following the button press to signify that the target medication had been located; a white screen appeared with instructions for the participant to select the target medication. Following a button press by the participant, the medication selection screen appeared with the same medication array as presented on the medication search screen. The participant then clicked on the target medication via a mouse clicker (see Figure 4).

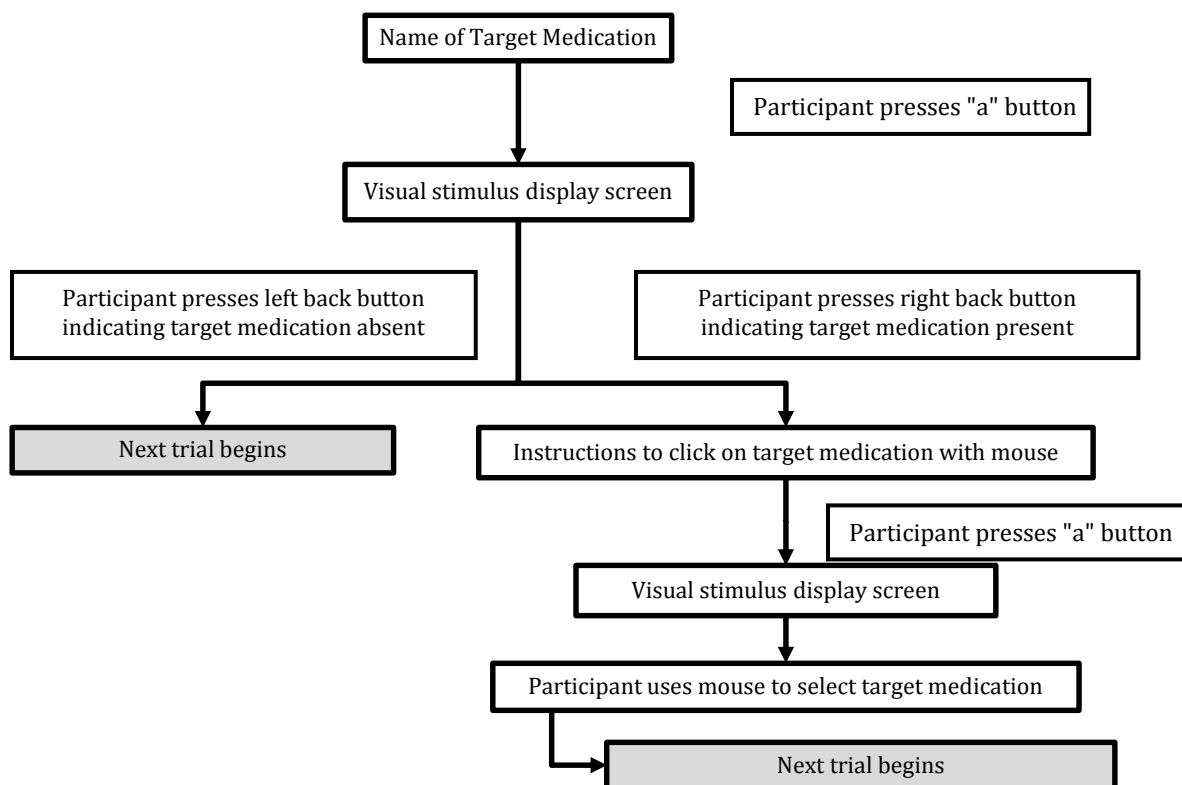


Figure 4. Trial Sequence. Includes overview of participant actions during trial.

Each participant completed a total of 80 visual search trials that included two levels in each of two variables: (a) target presence and (b) similar distractor presence. Twenty trials

captured variations of each variable: (a) target present/similar distractor present, (b) target present/similar distractor not present (c) target absent/similar distractor present and (d) target absent/similar distractor not present (see Figure 5). The similar distractors possessed a feature that defines the target object (vial color, size, label design and color) that was similar to the features of the target, while the non-similar distractors possessed features different from the target (vial color, size, label design and color). The trial types were intermixed and presented in a random order for each participant as were the position of the medication vial photographs. Each medication vial was positioned in a random location of a 3 X 3 grid with the center square left empty (see Figure 6). The eye movements for all trials were recorded. The experiment lasted approximately 30 to 45 minutes.

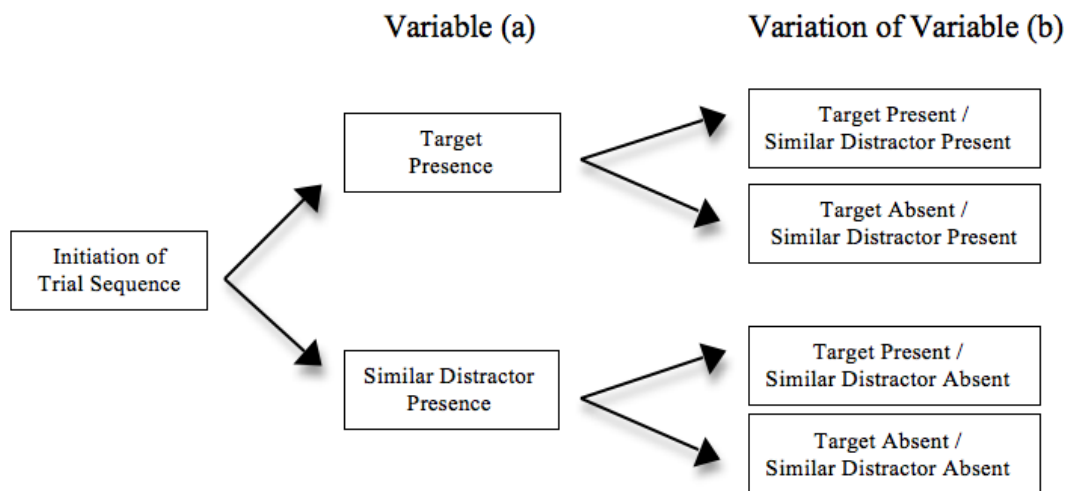


Figure 5. Visual Representation of Experiment Variables. Representation of each variable type (a) and the corresponding variation of the variable (b). Each participant completed a total of 80 trials to include 20 trials of each variable variation (b).

The researcher collected all participants' data via the eye tracker and utilized a script so as to repeat the same instructions to each participant (Appendix J). Immediately after completion of the eye-tracking portion of the experiment, the participants completed a demographic

questionnaire (Appendix K for first and second year students; Appendix L for experts) and post experiment questionnaire (Appendix M) in the same location via SuperLab software on an Apple Macintosh computer.



Figure 6. Visual Stimulus Display. Stimulus medication vials in 3 X 3 grid.

### Interest Area Definition and Analysis

The interest areas for scoring eye movements were defined as the smallest fitting rectangle that encompassed either the top of the medication vial or the bottom of the medication vial label within the photograph. Two interest areas (“top” and “bottom”) in each photograph were defined with this criterion (see Figure 7). Raw data were parsed into saccades and fixations using the SR Research algorithm. Responses were considered correct if the participant pressed the “target present” button during the medication search screen and correctly clicked the “top” or

“bottom” interest area of the target medication photograph during the medication selection screen for the target present trials. During target absent trials, responses were considered correct if the participant pressed the “target absent” button. Timeouts were defined as no response given within one minute of trial initiation.



Figure 7. Visual Stimulus Display with Interest Areas. Each interest area was coded as “top” or “bottom” and uniquely identified to include the location of the medication vial.

## Post Experiment Questionnaire

A post-experiment questionnaire was administered to all participants immediately after the conclusion of the eye-tracking portion of the experiment (Appendix M). The post experiment questionnaire allowed the participants to self-report their attitudes, beliefs, and feelings held towards visual search when selecting medications in the operating room (Teddle & Tashakorri, 2003). The questionnaire is a combination of close-ended and open-ended questions, making it a

mixed methods instrument. The mixed method approach allows for an overlapping format, the generation of complex mixed data and more efficient data analysis and collection (Teddlie & Tashakorri, 2003). The closed-ended questions addressed whether the participant reports they have received instruction related to visual search during nurse anesthesia school, if the participant reports they have committed a medication error, and if the participant reported having experienced a “near-miss” incident. The open-ended questions addressed general visual search process during medication selection, modification of visual search process during medication selection, medication features that are most difficult to distinguish during medication selection, type of instruction during nurse anesthesia school, factors that led to medication error and factors that led to “near-miss” event. The questionnaire was administered via a Macintosh computer with a 21” diagonal monitor, utilizing the SuperLab software. Upon completion of the post experiment questionnaire, the participant was given a debriefing paper further explaining the purpose of the current study (Appendix N).



## Chapter 4. Results and Discussion

### Accuracy

A 3 X 2 X 2 mixed factorial ANOVA was conducted on accuracy with expertise (first year students, second year students, experts) as the between-subjects factor and target presence (present, absent) and similar distractor presence (present, absent) as the within-subjects factors. Accuracy was calculated by dividing the number of accurate trials by the number of trials for which a response was given within the one-minute time limit (100%). Overall performance was very good: for all trials and across all levels of expertise the mean accuracy was 96.09 percent ( $SD = 0.04$ ). There was no main effect for expertise,  $F(2, 45) = 2.04$ ,  $MS = .004$ ,  $p = 0.14$ , and no main effect for similar distractor presence,  $F(1, 45) = .000$ ,  $MS = .000$ ,  $p = .56$  (see Figure 8). However, there was a main effect for target presence,  $F(1, 45) = 10.2$ ,  $MS = .02$ ,  $p = 0.003$ , with a higher accuracy on target present trials (see Figure 8). There was also a significant interaction between target presence and distractor similarity,  $F(1, 45) = 5.45$ ,  $MS = 0.01$ ,  $p = 0.024$ . Paired sample t-tests show the presence of a similar distractor on target absent trials, increased accuracy (decreased false alarms),  $t(47) = 5.78$ ,  $p < .001$ . Across all participant groups, participants were more accurate when the target was present as compared to when the target was absent. During target absent trials with a similar distractor present, accuracy was increased, which indicates a decrease in false alarms.

### Reaction Time

Reaction time analysis was conducted for only accurate trials. A 3 X 2 X 2 mixed factorial ANOVA was conducted with expertise (first year students, second year students, experts) as the between-subjects factor and target presence (present, absent) and similar distractor presence (present, absent) as the within-subjects factors. While there was no main

effect of expertise,  $F(2, 45) = 1.15$ ,  $MS = 37216666.05$ ,  $p = .327$ , there were main effects of target presence,  $F(1, 45) = 283.65$ ,  $MS = 335382023$ ,  $p < .001$ , and distractor similarity presence,  $F(1, 45) = 9.81$ ,  $MS = 1047361.55$ ,  $p = 0.003$  (see Figure 9). Reaction times were faster in target present trials, and overall there was a slower reaction time across all participant groups when a similar distractor was present (independent of target presence). There was a significant interaction between expertise and distractor similarity presence,  $F(2, 45) = 4.19$ ,  $MS = 447661.72$ ,  $p = 0.021$  (see Figure 9). Planned comparisons show an effect of similar distractor presence only for experts ( $t(15) = 2.39$ ,  $p = 0.030$ ), meaning that the presence of a similar distractor reaction time for expert participants.

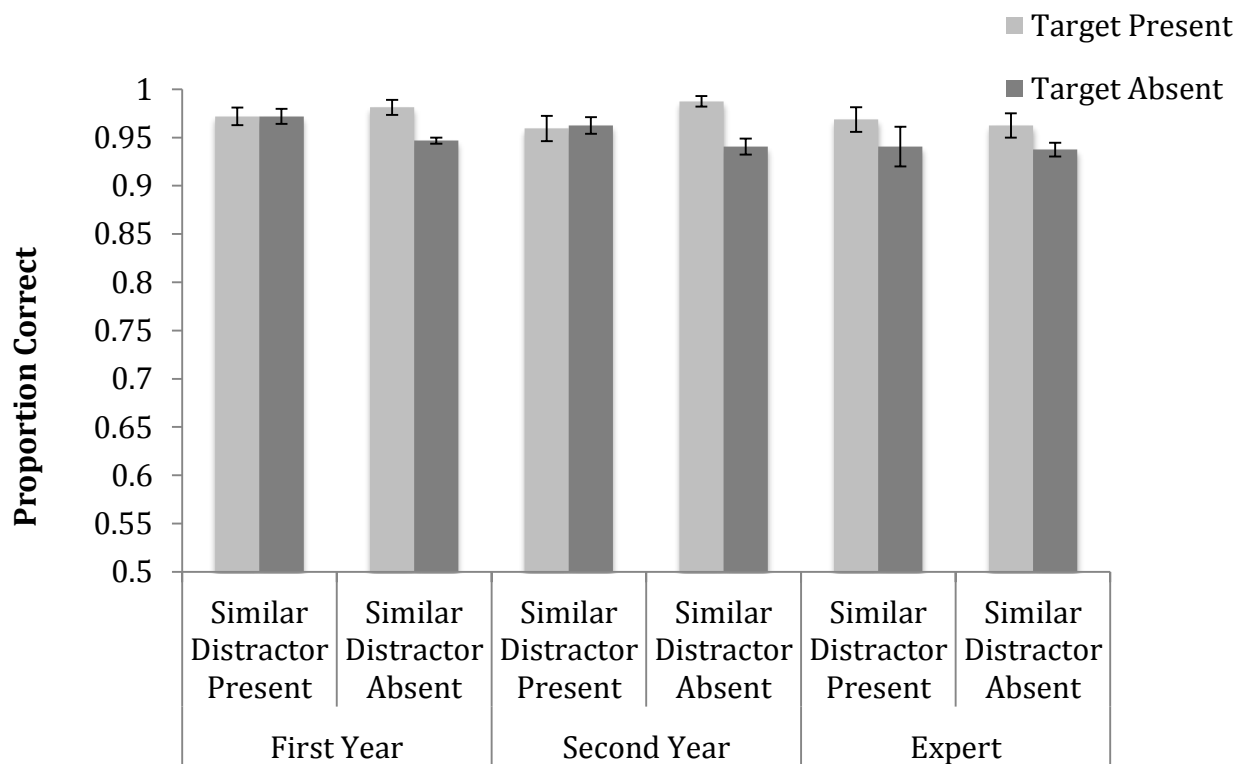


Figure 8. Accuracy Results. Reported as a proportion of all trials. Standard errors of the mean are represented in the figure by the error bars attached to each column.

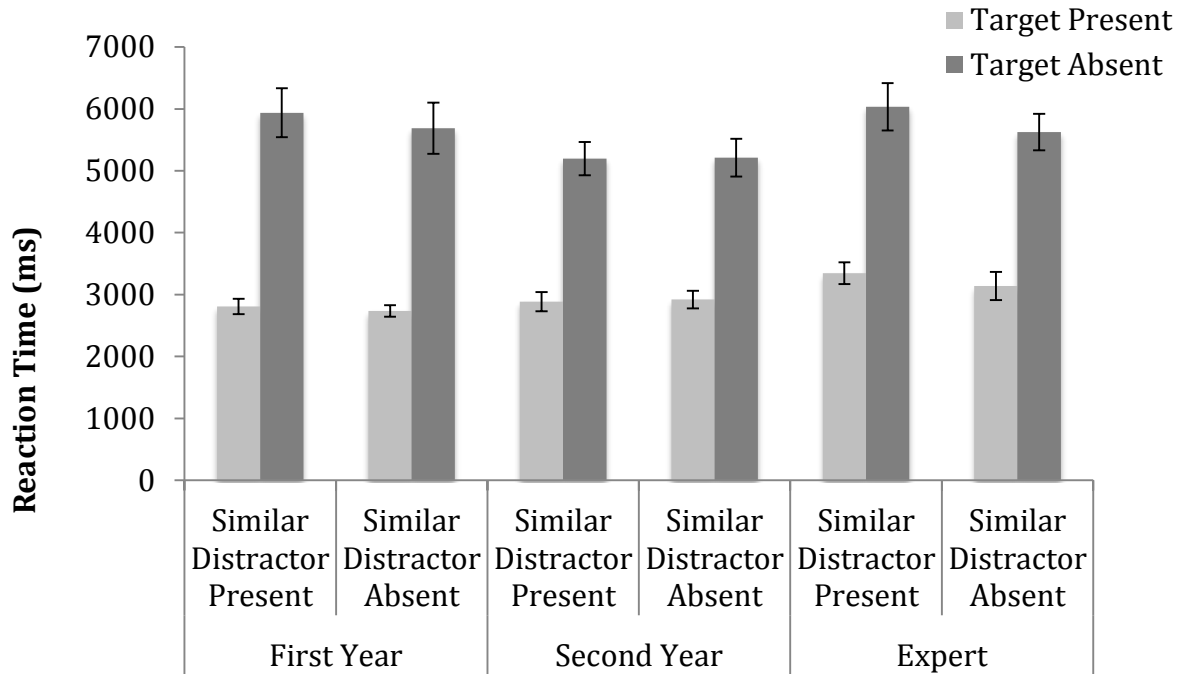


Figure 9. Reaction Time Results. Reported in milliseconds. Standard errors of the mean are represented in the figure by the error bars attached to each column.

## Dwell Time Proportion

### Target Dwell Time Proportion

Target dwell time proportion (i.e., the proportion of all fixation time in a trial that was spent on the target) was calculated for target present accurate trials. A 3 X 2 X 2 mixed factorial ANOVA was conducted with expertise (first year students, second year students, experts) as the between-subjects factor and interest area location (top, bottom) and similar distractor presence (present, absent) as the within-subjects factors. There was a marginal effect for expertise,  $F(2, 45) = 1.29$ ,  $MS = 0.003$ ,  $p = 0.054$ , with small differences noted in the mean target dwell time proportion (first year students:  $M = .19$ , second year students:  $M = .20$ , experts:

$M = .21$ ). There were main effects for location,  $F(1, 45) = 2295.38$ ,  $MS = 7.11$ ,  $p < 0.001$ , and for distractor similarity presence,  $F(1, 45) = 547.05$ ,  $MS = .62$ ,  $p < 0.001$  (see Figure 10).

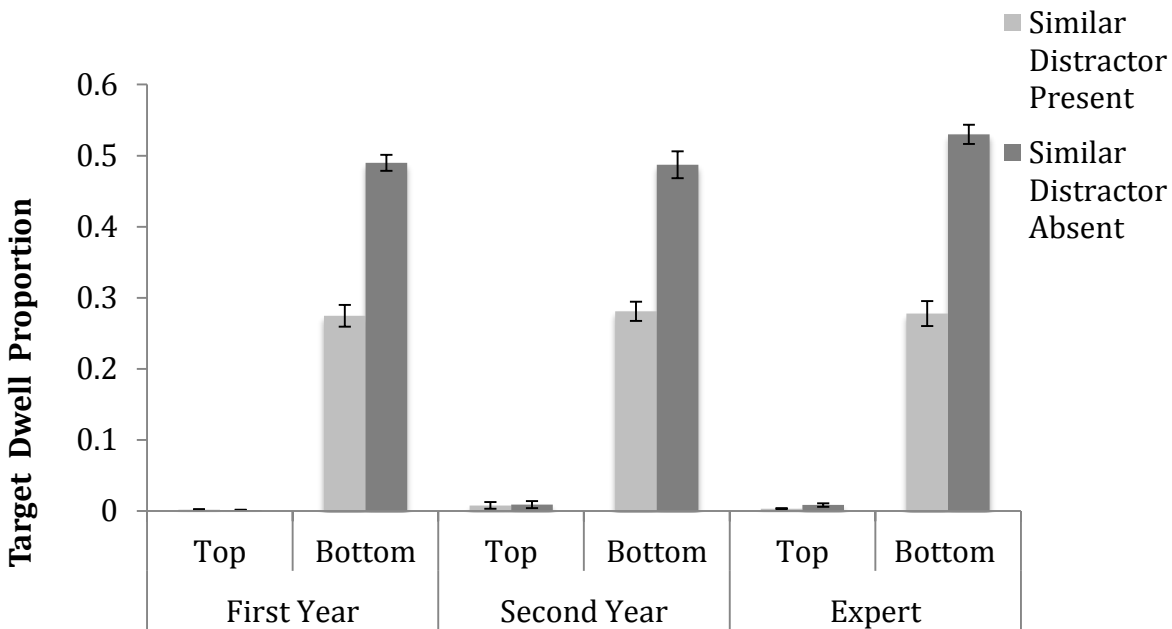


Figure 10. Target Dwell Time Proportion Results. Standard errors of the mean are represented in the figure by the error bars attached to each column.

Participants looked at the target more when the similar distractor was not present, and spent more time looking at the target bottom as compared to the target top. There was also a significant interaction between location and distractor similarity presence,  $F(1,45) = 458.86$ ,  $MS = .59$ ,  $p < 0.001$  (see Figure 10). This was driven by a significant effect of distractor similarity presence, for the bottom ( $t(47) = -22.03$ ,  $p < 0.001$ ), but not for the top ( $t(47) = -1.83$ ,  $p = 0.066$ ). To summarize, the effect of expertise on the amount of time spent on the target was small, and all participants looked at the bottom of the target more than the top of the target and did so more when similar distractors were not present.

### **Distractor Dwell Time Proportion**

Distractor dwell time proportion (i.e., the proportion of all fixation time in a trial that was spent on the distractor) was calculated across all accurate trials. For similar distractor present trials, the similar distractor was used for data analysis and for the similar distractor absent trials, a randomly chosen non-similar distractor was used for data analysis. A 3 X 2 X 2 mixed factorial ANOVA was conducted on distractor dwell time proportion with expertise (first year students, second year students, experts) as the between-subjects and target presence (present, absent) and similar distractor presence (present, absent) as the within-subjects factors. Fixations on the top of distractors were very rare ( $M=.002$ ), thus data analysis focuses on the fixations on the distractor bottom interest area. The main effect of expertise was not significant,  $F(2, 45) = 0.50$ ,  $MS = 0.001$ ,  $p = 0.61$ , and expertise did not interact with target presence or similar distractor presence. There were main effects for target presence,  $F(1,45) = 75.6$ ,  $MS = 0.07$ ,  $p < 0.001$ , and for similar distractor presence,  $F(1,45) = 477.3$ ,  $MS = 0.71$ ,  $p < .001$  (see Figure 11). There was also a significant interaction between target presence and similar distractor presence,  $F(1,45) = 330.17$ ,  $MS = 0.33$ ,  $p < 0.001$  (see Figure 11). Across all levels of expertise, more time was spent fixating on the similar distractor as compared to the randomly chosen non-similar distractors for both target absent trials ( $t(15) = 14.6$ ,  $p < .001$ ), and for target present trials ( $t(15) = 21.9$ ,  $p < .001$ ). This effect of similar distractor presence was stronger for the target present ( $d = 0.95$ ) trials as compared to the target absent trials. These findings suggest the participants were comparing the similar distractor to the target medication.

### **Guidance**

As previously discussed visual search is often divided into three distinct phases: initiation, guidance and verification (Castelhano et al., 2008; Malcolm & Henderson, 2009; Spotorno et al.,

2014). The current study combines the traditional initiation and guidance phases into one phase known as guidance. Guidance time was defined as the time from the appearance of the stimuli until the first fixation on the target and is representative of the actual search process (Castelhano et al., 2008; Malcolm & Henderson, 2009).

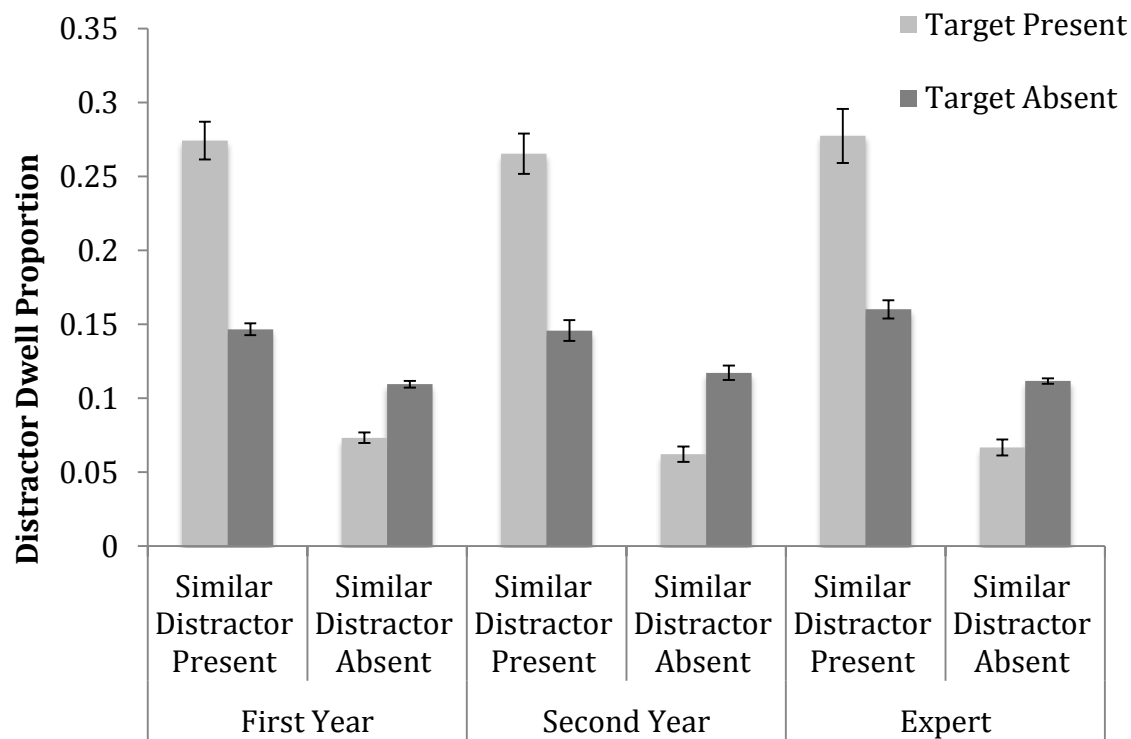


Figure 11. Distractor Dwell Time Proportion Results. Standard errors of the mean are represented in the figure by the error bars attached to each column.

Again, due to the low number of total fixations on the target top interest area only the target bottom interest area was included in data analysis. A 2 X 3 mixed factorial ANOVA was conducted with similar distractor presence (present, absent) as the within-subjects factor and expertise (first year students, second year students, experts) as the between-subjects factor. While there was no main effect for expertise,  $F(2,45) = .128$ ,  $MS = 23774$ ,  $p = 0.88$ , nor similar distractor presence,  $F(1,45) = 105.8$ ,  $MS = 146359$ ,  $p = 0.076$ , there was a significant interaction

between similar distractor presence and expertise,  $F(2,45) = 4.03$ ,  $MS = 178474$ ,  $p = .024$  (see Figure 12). Paired-sample t-tests revealed a significant effect of similar distractor presence only for the second year students, ( $t(15) = -2.77$ ,  $p = 0.014$ ), and not for the first year students ( $t(15) = -1.406$ ,  $p = 0.312$ ) or the experts ( $t(15) = 1.36$ ,  $p = 0.194$ ). Therefore, the second year students had a significantly shorter guidance time when a similar distractor was present. This is consistent with the lack of a similar distractor presence effect on reaction time for second year students and supports the conclusion that the similar distractors were not as distracting for second years as compared to first year students and experts.

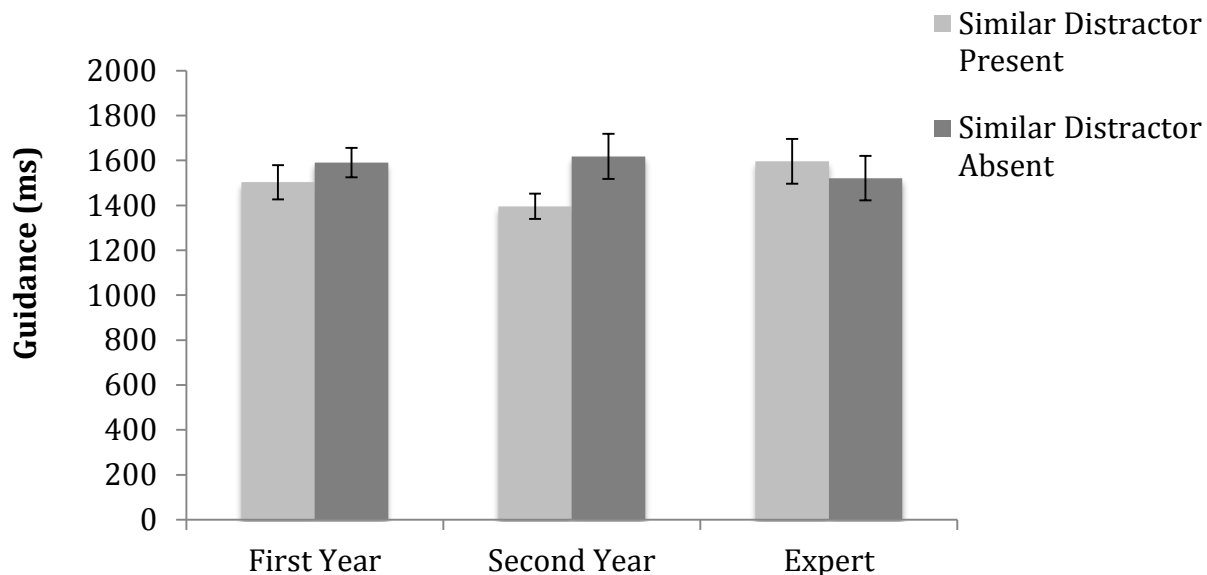


Figure 12. Guidance Results. Reported in milliseconds. Standard errors of the mean are represented in the figure by the error bars attached to each column.

## Verification

Verification time was defined as time from the first fixation on the target until a correct response is elicited (Malcolm & Henderson, 2009). While guidance and verification contain fixation points that reflect some similar processes (deciding if the target is present), there are enough functional difference to separate these processes to distinct measures (Malcolm & Henderson, 2009). Whereas guidance is a part of the visual search process, it is the search that

occurs prior to the target being located (Castelhano et al., 2008). Verification is the search process after the target is located and includes subsequent time looking at other distractors to ensure the distractor is not the target (Castelhano et al., 2008).

A 2 X 3 mixed factorial ANOVA was conducted with similar distractor presence (present, absent) as the within-subjects factor and expertise (first year students, second year students, experts) as the between-subjects factor. There were main effects for expertise,  $F(2,45) = 5.39$ ,  $MS = 1713744.8$ ,  $p = 0.008$ , and similar distractor presence,  $F(1,45) = 8.27$ ,  $MS = 611655.73$ ,  $p = 0.006$  (see Figure 13). However, there was not a significant interaction between similar distractor presence and expertise,  $F(2,45) = .088$ ,  $MS = 6511$ ,  $p = 0.916$  (see Figure 13). Planned comparisons show significant differences between first year students and experts ( $LSD = 0.002$ ) and between second year students and experts ( $LSD = 0.047$ ). Experts had a significantly longer verification time as compared to both first year and second year students. Thus, experts took longer to initiate a correct response, demonstrating again that similar distractors were more distracting to experts as compared to novice participants.

### **Post Experiment Questionnaire Results**

At the conclusion of the experiment, all participants (N=60) completed the post experiment questionnaire to include 28 first year students, 16 second year students and 16 experts. All participants' responses were exported from the SuperLab software to Microsoft Excel spreadsheets. However, not all first year student responses were analyzed. Just as in phase one of the experiment, the same randomized 16 first year participants' responses were analyzed so as to balance the participant groups.



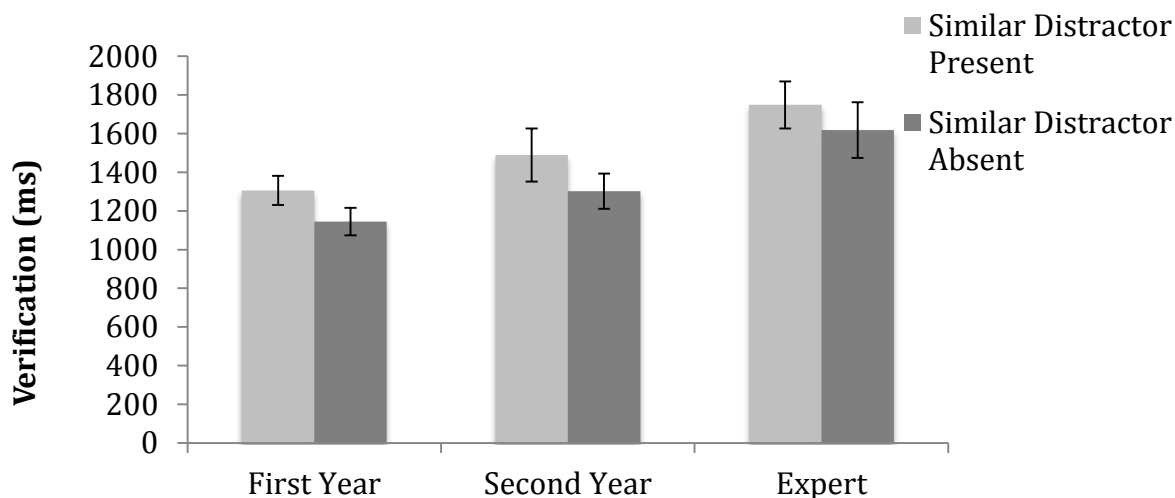


Figure 13. Verification Results. Reported in milliseconds. Standard errors of the mean are represented in the figure by the error bars attached to each column.

As suggested in Creswell (2009), prior to data analysis and coding, the researcher read through all responses to get a general sense of the information and to reflect on the overall meaning of the responses. Next, the researcher began the analysis by developing a coding process. Coding is defined as the process of organizing the material into chunks or segments of text before bringing meaning to the information (Rossman & Rallis, 1998). Coding involves taking data gathered during data collection, segmenting responses into categories, labeling those categories with a term, often a term based on the actual language of the participant (Creswell, 2009). During coding, the researcher developed codes only based on the participants' response as opposed to placing the participant's responses into a predetermined category(s) or a combination of predetermined and emerging codes. The traditional approach in the social sciences is to allow the codes to emerge during data analysis (Creswell, 2009).

### Question One

Question one asked the participant to, "Please describe in as much detail as possible, the general visual search process you utilize when selecting medications for administration"

(Appendix M). Data analysis revealed eight common codes of search measures deployed during medication selection as shown in Table 4.

During data analysis and coding, it was noted that participants' responses often described several different visual search processes during medication selection with 75 percent of first years' responses, 50 percent of second years' responses, and 62.5 percent of experts' responses being coded to include more than one visual search processed deployed (n=91). As a high percentage of participants selected more than one process or feature used to guide search, it can be suggested that preattentive attributes (color, motion, size) are processed across a visual field in parallel (Wolfe, 2010). Of the eight identified codes, medication label ("reading, scanning, and viewing") was described as the most common visual search method deployed during medication selection within each participant group, followed by "color" in first year participants, "search pattern" ("counterclockwise, systematic and methodical") in second year participants, and shape ("medication vial, medication") was the second most common theme in the expert group was identified as shown in Table 4.

Table 4  
Post Experiment Questionnaire Question 1. Description of general visual search process used during medication selection.

	First Year (n = 31)		Second Year (n = 28)		Expert (n = 32)		All Groups (n=91)	
Response	n	%	n	%	n	%	n	%
Scan drawer	2	6.5	1	3.6	2	6.25	5	4.7
Search pattern	4	12.9	8	28.6	1	3.125	13	12.4
Color	7	22.6	5	17.9	4	12.5	16	15.2
Shape	2	6.5	2	7.1	6	18.75	10	9.5
Label	8	25.8	8	28.6	12	37.5	28	26.6
Top	1	3.22	1	3.6	0	0	2	1.9
Size	3	9.7	1	3.6	3	9.375	7	6.6
Location	4	12.9	2	7.1	4	12.5	10	9.5

## **Question Two**

Question two asked the participant “What types of activities have you found to be the most critical in assuring accuracy during the visual search for a medication in the operating room? Specifically, why have you found these activities to be so critical?” (Appendix M).

Data analysis revealed six codes of visual search activities as described by participants to be most critical in assuring accuracy during medication selection as listed in Table 5. Similar to question one responses, participants’ responses described more than one code (activity) as critical during the visual search for medication in the operating room. However, the percentage of participants who chose more than one code was lower overall, with 50 percent of first year participants and 31.25 percent of expert participants indicating more than one code in their response. Second year participants increased their multiple code responses from the first question with 56.3 percent of second year participants describing more than one theme as opposed to 50% during question one. Visual search activities described as most critical to accuracy and efficiency during medication selection included “double checking” of the medication and “reading” the medication label as shown in Table 5. According to Wolfe et al. (2011), humans search because they cannot fully process all items in the visual field at one time. Search becomes inefficient when attentional resources are deployed at random, which may be indicated with the multiple coded responses per participant.

As noted in Merry et al. (2011), medication manufacturers do not have consistent labeling approaches regarding color-coding, container size, and background or font size. As most participants’ responses indicated “reading the label” and “double checking the label” as the visual search activities most critical to ensuring accurate and efficient medication selection, it can be assumed that the need to double check the medication label may be due to poor labeling

practices. In the United States, the Food and Drug Administration (FDA) has mandated barcodes at the unit level to assist with the double check process and ensure the correct medication has been selected (Merry et al., 2000). However, there is no mandate for the medication system in anesthetizing locations to include the operating room area (Merry et al., 2000).

Table 5

Post Experiment Questionnaire Question 2. Description of activities deployed to ensure accuracy during visual search for medication.

	First Year (n = 24)		Second Year (n = 25)		Expert (n = 23)		All Groups (n=72)	
Response	n	%	n	%	n	%	n	%
Double Check	6	25	11	44	7	30.4	24	33.3
Color	4	16.6	0	0	1	4.3	5	6.9
Location	8	33.3	4	16	5	21.7	17	23.6
Read label	3	12.5	8	32	8	34.8	19	26.3
Scan	1	4.16	0	0	0	0	1	1.4
Same process	2	8.3	2	8	2	8.7	6	8.3

### Question Three

Question three asked the participant “In your opinion, which types of medication features are the most difficult to distinguish when visually searching for a medication?” (Appendix M). Data analysis and coding revealed eight codes of medication features that participants indicated are most difficult to distinguish during the visual search for a medication as shown in Table 6.

As in previous question analyses, participants’ responses were often coded to include more than one code or theme. The most common feature listed as difficult to distinguish during medication search was “color”, with responses such as, “drugs with the same color label and tops”; ‘same color label for multiple medications”; “similar vial size, similar label color and similar vial color”; “ white with limited color”; and “the name being underneath a color line and not bolded”. While these responses are not inclusive of only the theme “color”, they do reveal several difference facets of the role of color during the visual search for a medication. The

responses to the question suggest that color is a feature that is often used to distinguish the target medication from other medications during visual search and includes the color of the vial, label and top of the medication. This confirms Wolfe's (2007) assertion that guiding attention on the basis of a salient color works very well. The deployment of attention in any search is guided by one or more sources of information, via preattentive attributes, such as color and size that can be processed across the visual field in parallel (Wolfe, 2010). Becker (2010) states that attention during visual search is guided by feature contrast and feature value of the search target. Feature contrast (saliency of target and distractors) is responsible for the pop-out effect: When the search target is very dissimilar to the distractors and the distractors are all similar to one another, the target pops out from the display and can be found more quickly (Wolfe, 1994). The eye tracking portion of the experiment incorporated color as the similar feature of distractor medications as compared to target medications. Color similarity was most commonly represented via the medication label but was incorporated into the medication top (similar color medication top) and the vial itself (similar color of medication vial).

Table 6

Post Experiment Questionnaire Question 3. Description of medication features most difficult to distinguish during visual search for a medication.

	First Year (n = 31)		Second Year (n = 32)		Expert (n = 25)		All Groups (n=88)	
Response	n	%	n	%	n	%	n	%
Color	7	22.6	10	31.3	8	32	25	28.4
Label	8	25.8	1	3.1	4	16	13	14.7
Top	0	0	1	3.1	0	0	1	1.1
Size	1	3.2	3	9.4	3	12	7	7.9
Shape	1	3.2	4	12.5	1	4	6	6.8
Concentration	1	3.2	2	6.25	3	12	6	6.8
Lettering/font	8	25.8	6	18.8	4	16	18	20.5
Similar look	5	16.1	5	15.6	2	8	12	13.6

## Question Four

Question four asked the participant “Through your experience, how have you evolved or modified your visual search process to increase accuracy? Efficiency?” (Appendix M). The question focused on accuracy and efficiency related to modification of visual search processes as opposed to general modification of visual search. Data analysis and coding revealed nine common themes of modification of visual search process during medication selection as listed in Table 7. Although nine themes were identified, one of those themes was coded as “none” for those participants who indicated they have not modified their visual search process.

Table 7

Post Experiment Questionnaire Question 4. Description of modification of visual search process

	First Year (n = 31)		Second Year (n = 28)		Expert (n = 22)		All Groups (n=97)	
Response	n	%	n	%	n	%	n	%
None	0	0	3	10.7	0	0	3	3.7
Double check	3	9.7	2	7.1	2	9.1	7	8.6
Familiarity	4	12.9	1	3.6	2	9.1	7	8.6
Read label	8	25.8	9	32.1	12	54.5	29	35.8
Look at vial	1	3.2	3	10.7	2	9.1	6	7.4
Shape	2	6.5	2	7.1	3	13.6	7	8.6
Color	3	9.7	4	14.3	1	4.5	8	9.8
Location	9	29.0	4	14.3	0	0	13	16.0
Environment	1	3.2	0	0	0	0	1	1.2

Data analysis revealed “location” as the most common response for first year participants, while both second year and expert participants responding “read label” as the most common modification of the visual search process to increase accuracy and efficiency. Previous research on expertise eye tracking effect size has demonstrated that extraneous material, information that is not needed to comprehend visualizations (such as medication labels vials with text), is difficult to process and may be detrimental for novices (Mayer, 2010; Sweller, 1994). This may explain

the first year participants' response as "location" as compared to "read label", which was the most common response in second year and expert participants.

### **Question Five**

Question five asked the participant, "In nurse anesthesia school, what, if any, instruction did you receive regarding visual search in medication selection? Was this instruction helpful?" (Appendix M).

While 81 percent of first year participants and 88 percent of second year participants indicated they had received visual search technique instruction during nurse anesthesia school, only 31 percent of expert participants indicated they had received instruction during nurse anesthesia school. However, the overall percentage of all participants who receive instruction during nurse anesthesia school was 67 percent. Data analysis revealed seven common types of instruction received during nurse anesthesia school with reading of the label and double check as the most common instructions for each group and for all groups as seen in Table 8.

During data analysis, the most common theme that emerged for first year participants was "double check", while "read label" was the most common response in second year and expert participants. Interestingly, in question five, the most response to modifications made to visual search processes to increase accuracy and efficiency was "double check" the medication label (33.3 percent for all participants) followed by "read label" (26.3 percent for all participants). This brings the question as to what has led the participant to modify their visual search processes: instruction during nurse anesthesia school or from practice?

The second most common theme identified across all groups was to "double check" the medication, indicating that upon location of the target medication, the participant will again verify it is the correct target medication. Although not all participants clarified or described

which feature of the medication was being “double checked”, participants often described the label and vial as the features that were instructed to be double-checked during the visual search process. The participants’ responses reinforce that traditionally; anesthesia providers have been encouraged to read medication labels carefully, up to three or four times for confirmation (Mangar, Miguel, & Villarreal, 1992). As previously discussed, medication manufacturers do not have consistent labeling approaches regarding color-coding, container size, and background or font size (Merry et al., 2011). This lack of consistency may be a reason participants often read labels multiple times as the background, color, and or font size of current labels do not provide for a clear indication that the medication is correct to include the dose and concentration.

Table 8

Post Experiment Questionnaire Question 5. Description of visual search technique instruction received during nurse anesthesia school.

	First Year (n = 22)		Second Year (n = 23)		Expert (n = 12)		All Groups (n=57)	
Response	n	%	n	%	n	%	n	%
General	1	4.5	0	0	0	0	1	1.8
Location	4	18.1	1	4.3	2	16.7	7	12.3
Read label	3	13.6	13	56.5	5	41.7	21	36.8
Warnings	3	13.6	3	13	2	16.7	8	14.0
Characteristic	3	13.6	0	0	0	0	3	5.3
Double check	5	22.7	6	26	3	25	14	24.6
Routine	3	13.6	0	0	0	0	3	5.3

### Question Six

Question six asked the participant, “Have you ever committed a medication error? If so, what factors led to this error?” (Appendix M).

Overall, 42 percent of all participants indicated they had made a medication error, with the highest percentage attributed to expert participants (68.75 percent). While second year participants yielded a slightly higher percentage of participants who had made a medication error with 31 percent as compared to 25 percent of first years. Prior to a description of the responses



the participants report as having led to the medication error, it is essential to discuss error reporting. The nature of reporting medication errors in the health care setting is complex and is often a voluntary basis, which has considerable limitations to include first recognizing that an error has occurred and then reporting that said error (Cooper & Nossaman, 2013). If a participant in this study was unaware of a previously made medication error, the participant would be unable to correctly answer the question as they are not aware of their error. Even if the participant is aware he/she has previously made a medication error, the participant may not have reported the error due to fear of litigation or other consequence (Cooper & Nossaman, 2013). It can be assumed that based on these limitations and challenges, the number of participants who reported having previously made a medication error may be lower than the actual number of participants who have actually made a medication error.

Additionally, question six did not specify as to when the participant made the medication error, thus it did not limit the response to only those errors that occurred in the anesthesia setting. Several participants indicated in their responses that the medication error occurred in a critical care area prior to entry into the nurse anesthesia program. Similarly, as the question did not specify medication error in the anesthesia setting versus the non-anesthesia setting, participants may have assumed that the question only sought to discuss errors related to the anesthesia setting leading to underreporting in novice participants. This may explain the higher percentage of medication errors reported by expert participants as opposed to novice participants. Alternatively, the average years of experience of the expert participant was 16.68 with an average of 36.69 hours worked per week.

Data analysis and coding of participant responses revealed five themes of factors that led to medication error as shown in Table 9. The most common theme reported by all participants

was a similar medication label (60.8 percent). The responses often did not include which features of the medication label led the participant to commit the medication error, but based on question two responses (medication features that are most difficult to distinguish during visual search for medications) it can be assumed that color, lettering and font are key features that make a medication label appear “similar” to a target medication. This reinforces what has already been documented in existing literature, that the similarity of medication names, drug vials and label colors all are significant contributors to the occurrence of medication errors in anesthesia (Hanna & Levine, 2011).

Table 9

Post experiment questionnaire Question 6: Description of factors that led to medication error

	First Year (n = 7)		Second Year (n = 5)		Expert (n = 11)		All Groups (n=23)	
Response	n	%	n	%	n	%	n	%
Carelessness	1	25	0	0	0	0	1	5
Similar label	2	50	2	40	9	81.8	13	65
Order changed	1	25	0	0	0	0	1	5
Location	0	0	0	0	2	18.1	2	10
Critical situation	0	0	3	60	0	0	3	15

### Question Seven

Question seven asked the participant, “Have you ever had a “near-miss” medication incident? If so, which factors led to this incident?” (Appendix M).

The percentage of participants’ responses that indicated they had experienced a “near-miss” medication incident was considerably higher than for medication errors, with 75 percent of all participants indicating they have experienced a near-miss event. Additionally, 100 percent of the second year participants indicated they had experienced a near-miss medication incident as compared to 68.7 percent of first year participants and 56.3 percent of expert participants. Data analysis and coding revealed eight themes of factors that led to a “near-miss” medication

incident as listed in Table 10. The most common factor within each group of participants and between each group was “similarity”. The responses did not always specify what was “similar” between the two medications that led to the “near-miss” incident but did include “labeling, vial size, vial shape, and color”. These themes are consistent with those identified in previous questions based on participants’ response; similarity and salient features attract attention during visual search and may lead to medication errors and/or near-miss events. Based on the responses to question seven, the theme “transfer”, emerged which previously had not been identified or discussed. Interestingly, over 30 percent of expert practitioners responded that “transfer” of a medication led to a near miss event to include “hand off meds”; “gave meds to someone else”; “medication was given to me by another provider”; and “another CRNA labeled the medication”. These responses reinforce that practitioners often develop routines, habits and or safe guard regarding medication administration and when this said routine is altered it may lead to near-miss event or medication error.

Table 10  
Post Experiment Questionnaire Question 7. Description of factors that led to a “near-miss” medication incident.

Response	First Year (n = 15)		Second Year (n = 16)		Expert (n = 11)		All Groups (n=42)	
	n	%	n	%	n	%	n	%
Carelessness	1	6.7	0	0	0	0	1	2.4
Transfer	1	6.7	1	6.3	4	36.4	6	14.3
Familiarity	1	6.7	0	0	0	0	1	4.8
Location	3	20	1	6.3	1	9.1	5	11.9
Rushed	2	13.3	2	12.5	0	0	4	9.5
Similarity	5	33.3	10	62.5	6	54.5	21	50
Ordering	1	6.67	0	0	0	0	1	2.4
Critical situation	1	6.67	2	12.5	0	0	3	7.1

## **Chapter 5. Conclusions**

The current study sought to examine the differences in visual search during medication selection between novices and expert nurse anesthetists, and at the same time identify those features that guide attention during medication selection. The researcher hypothesized that similar distractor medications would attract attention from the target medication and dissimilar distractor medications during visual search. This was confirmed in during analysis of the dwell time proportion of distractor medications as participants spent a greater amount of time looking at the similar distractor as compared to randomly chosen non-similar distractors when a similar distractor was present.

Additionally, participants' responses during the post experiment questionnaire revealed that similar medication labels are difficult to distinguish during visual search for medications in the operating room, with both "similarity" and "similar medication labels" indicated as the most common contributors to "near-miss" events and medication errors respectively. The researcher also hypothesized that because similar distractor medications attract attention during visual search, reaction time will increase when similar distractor medications are present, while accuracy will decrease. This was also partially confirmed, as across all participant groups, reaction times were slower when a similar distractor was present, with the greatest effect seen in expert participants but accuracy did not increase as hypothesized. During target present trials with a similar distractor present, accuracy actually increased for all participants, which indicated a decrease in false alarms.

Finally, the researcher hypothesized that when similar distractors are present, expert participants will have an increased reaction time overall as compared to novice participants but that expert participants will be more accurate as compared to novice participants. This was again

partially confirmed by expert participants' increase in reaction times as compared to other participants and as expert participants were significantly slower than both first year and second year participants. Furthermore, the use of verification and guidance as eye movement measures to divide the search process, allowed for additional data analysis related to target similarity as a feature that guides attention during visual search. Data analysis of guidance time again confirmed that second year participants were much less distracted by similar distractors as compared to first year and expert participants. However, the hypothesized increase in expert participant group accuracy as compared to novice accuracy did not occur as anticipated.

### **Implications for Practice**

The results of the current study have shown that similar medication vials and labels attract attention during visual search and may be a potential source of medication error in the operating room. Likewise, the current study demonstrates that despite encountering similar medication vials and labels during the study, expert participants are able to still perform accurately, although their reaction times and verification times may be longer. The current study also revealed that many participants' responses indicated that they had not received specific instruction related to visual search during nurse anesthesia school attendance.

Based on these findings the researcher proposes several implications for nurse anesthesia education and practice to include: incorporation of medication safety and role of visual search into nurse anesthesia program curriculums; an international labeling system for medication labels; separation of look-alike medications in medication bins; and the institution of a "Double Check System" in the operating room.

As previously discussed, as nurse anesthesia education requires a broad knowledge base in science combined with intense clinical training in order to provide patients with safe care

during the perioperative process, classroom work provides a knowledge base for advanced pharmacology, anatomy, physiology, pathophysiology, and principles of nurse anesthesia, while clinical work is extensive and prepares the nurse to provide anesthesia services in various patient populations. Visual search during medication selection can easily be introduced and integrated into nurse anesthesia programs' curriculums, as it reinforces safety during patient care during the perioperative process. In addition to the incorporation of generalized visual search during medication selection into nurse anesthesia programs' curriculums, the researcher suggests visual search expertise in nurse anesthetists as a guiding principle in the education of visual search related to medication selection. It has been documented that experienced observers fixate and recognize abnormalities faster (Kundel et al., 2007; Nodine et al., 1996) and terminate their search earlier than novice participants (Christensen, et al., 1981). According to van der Gijp et al. (2014), experts fast holistic approach results in higher accuracy than the relatively slow search-to-find approach of less proficient observers" (p. 2). Beck et al. (2012) suggested, "expertise may lead to a more effortful and conservative approach to the target search task" as study participants performed better, but were slower to respond to stimuli during high clutter search (p.2). Based on these studies, the researcher asserts that visual search in expert nurse anesthetists is superior to novice nurse anesthetists. As such, it would be logical to introduce and explain expertise visual search patterns to novice participants.

The researcher also suggests an international labeling standard and system for medication labeling. It is well documented that medication names that look or sound alike increase the risk of medication errors (Aspden et al., 2007). The layout and presentation of medication information of the label can be visually confusing, especially if it is designed for marketing rather than for clinical purposes (Aspden et al., 2007). Currently, there are no consistent

approaches to color-coding, container size, background or font size and type by manufacturers (Merry et al., 2011) To address these problems in labeling and packing designs, the researcher suggests that visual cognition be utilized in the development of an international labeling standard and system so as to increase patient safety in the field of nurse anesthesia.

Just as medication labels are problematic in medication selection during the perioperative period, so too are the similarity of medication vials and the close location of similar medications (label, shape, color).

Williams (1966) found a preference to fixate stimuli that share target color as opposed to other features, such as size and shape. Additionally, recent studies found that participants were more likely to fixate distractor objects possessing a target feature (such as color) than distractors that did not possess a target feature (Hooge & Erkelens, 1999; Shen, Reingold, Pomplun, & Williams, 2003). According to Becker (2010), when a search target is very dissimilar to all distractors and the distractors are all similar to one another the target “pops out” from the display and can be found immediately. Contrastingly, when a target is similar to the distractors, it takes much longer to find the target as search proceeds inefficiently. Distractors have been shown to capture attention and the eyes when they are similar to the target as compared to when they are dissimilar to the target (Ludwig & Gilchrist, 2002). The current study demonstrated the relationship between attention and visual search while describing the impact of medication similarity on both processes. Since similar medication vials divert attention from target medication vials, it is recommended that similar medication labels be omitted when possible from all patient care settings. This recommendation is an extension of the proposed labeling standard and system as previously suggested by the researcher.

The close proximity and ways in which medications are typically stored in the operating room compounds the complexity of visual search during medication selection. Medication storage machines or bins often have dividers, pockets, and sections for medications within a drawer, with several drawers stacked horizontally. As noted earlier, Tufte (1997) describes simultaneous image presentation as parallel in space, as the images are presented in close proximity to each other and appear within a single visual field. Furthermore, Tufte (1997) states that an advantage of spatial parallelism is the human capacity to compare and reason the meaning of multiple images that appear simultaneously. The viewing of images in two separate presentation fields, forces the viewer to remember the first image and then compare it to the second image. Tufte (1997) believes this mode of presentation to be challenging and states that simultaneous comparisons are most effective. Similarly, Levie (1978) states that learning to associate or relate two or more objects/events is facilitated when they are encountered close together in time and space. He also states that these objects/events will tend to be perceived as somehow related allowing both similarities and differences to become more apparent. Current medication storage machines and bins essentially do not allow anesthetists to make comparisons between medications due to the fractioned storage system. Additionally, these medication storage machines typically store medications in the same dedicated location within the machine (e.g., a specific drawer and pocket number). However, during analysis of the post experiment questionnaire responses, it was noted that location was identified as a contributing factor to both medication errors and near-miss events. Location was also noted as a feature used to described the general visual search process during medication selection. The researcher proposes a call for reconfiguration of the current medication storage machines and systems based on previously mentioned visual cognition principles to include easily comparison of medication features, the



avoidance of look- alike medications in same vicinity and a notification system for medication location changes.

Finally, as nurse anesthetists select, prepare, administer and record medications autonomously, they are without the aid of safeguards and double checks of a pharmacist, physician, or any other healthcare provider. A final implication for practice is the use of a verification or double check system in the operating room. Many respondents in the post experiment questionnaire indicated that they utilized “double-checking” of medications during visual search and selection. It has been suggested that systematic countermeasures should be employed to decrease the incidence of intravenous medication administration error in anesthesia (Jensen et al., 2004). However, such countermeasures have yet to be employed as evidenced by the FDA mandated barcodes at the unit level to assist with the double check process and ensure the correct medication has been selected that has been omitted in anesthetizing locations, such as the operating room area (Merry et al., 2000).

### **Limitations of the Study**

The study had several limitations. The first is that it used a small convenient sample. Due to the small number of nurse anesthesia students in the Baton Rouge area, it was difficult to obtain a large sample. As the eye tracking portion of the study was completed within the Beck Visual Cognition Lab at Louisiana State University, it was difficult for the researcher to recruit students from outside the Baton Rouge area. Additionally, there are only two nurse anesthesia programs in the state of Louisiana, thus presenting a limited student population for both the current and future studies. The small sample likely affected the power of the data analyses, possibly impacting potentially significant results.

The eye tracking portion of the experiment reused photographs up to three times during the experiment. Jiang and Chun (1998) noted that search was faster when the target appeared with the same distractor set as on previous trials even though all items were in new positions. While the same target and same distractor set was not used, there were some trials that included a previous target as a distractor with other distractors. This introduces the possibility participants may have familiarized themselves with medication photographs in the beginning of the trial which may have influenced their reaction times later in the trial.

### **Recommendations for Future Research**

The researcher recommends several modifications to the current study for future research to include a larger sample size with true “novices” as opposed to experienced nurses who are currently enrolled in nurse anesthesia school. As previously discussed, it may be difficult to repeat the study in its current location due to the limited student nurse anesthesia population in the state of Louisiana. The study may be deployed on campus in its current form with any non-medically trained participant qualifying as a novice participant to increase sample size.

It is also suggested that the current study, if it were to be reproduced obtain additional medication vial photographs so as to not reuse the stimuli during the experiment so as to not potentially influence visual search times and/or accuracy during the experiment. Additionally, the current study can be modified to include medications that are not commonly used in the operating room suite by anesthesia providers. By using non-familiar medication vials or less familiar medication vials, the experiment may be revised to explore visual search in nurse anesthesia providers to exclude long term memory as confounding variable during the experiment.

Several modifications can be made to the programming of the existing study so as to allow for calculation of the traditionally defined initiation time, defined as the time from the appearance of the stimuli (photograph search array) until the first saccade away from the initial fixation point (Malcolm & Henderson, 2009). This would alter the current definition of guidance time as the time away from the appearance of the stimuli until the first fixation on the target to be defined as the elapsed time between the first saccade (the end of initiation) to the first fixation on the target (Castelhano et al., 2008; Malcolm & Henderson, 2009). In addition to modifications of the current study, additional data analyses may be performed on the existing data to answer additional research questions that emerged during the study, such as: how long does it take after the medication text cue for the participant to push the start button to allow for start of the trial and what target medications and distractor medication combinations most increase reaction time?

The information elicited from the post experiment questionnaire while descriptive may become more descriptive with modification of the existing questions. The researcher would suggest revisions of the current questions to include more rationales for participants' self-described visual search patterns. A differing approach would be to include more quantitative responses within the questionnaire based on the themes identified during the current study. As opposed to coding themes based on the participants' responses, the researcher would use the current themes as multiple (or singular) choice responses and score each question mean score individually. Alternatively, as opposed to the use of a questionnaire, interviews may be used to ask potentially "difficult or uncomfortable" questions (such as medication error or near miss events) or any follow up questions as needed. Finally, the current questionnaire may be modified so as to clarify the questions are related to nursing practice in general (or are not) as opposed to nurse anesthesia practice.

Finally, the current study demonstrated that medication similarity effects many facets of visual search during medication selection. What is not known are the effects of similarity on medication administration as this study was limited to medication selection. Future studies may modify the current study to include visual search during medication selection and subsequent medication administration in a simulation environment.

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## **Appendix A. Letter to Dean and Director**

Dear Dean Beck and Dr. Pedersen,

I am a doctoral student at Louisiana State University conducting research on visual search during medication selection in student nurse anesthetists. The focus of my dissertation is to determine the differences between the student nurse anesthetists' and expert nurse anesthetists' visual search patterns during simulated medication selection and to identify which features guide attention during visual search. The Louisiana State University and Our Lady of the Lake College Institutional Review Boards have both approved this study.

I am soliciting Our Lady of the Lake College's participation in this research. If you agree, I would like to utilize both first year and second year nurse anesthesia students in your Master of Science Degree in Nurse Anesthesia Program. In order to participate in the study, students will travel to Louisiana State University, where they will complete computer simulated medication selection and two questionnaires. If you have any questions regarding this study, please do not hesitate to contact me at [abadea4@lsu.edu](mailto:abadea4@lsu.edu) or by phone at 225-490-1624.

Thank you in advance for your participation,

Aimee L. Badeaux, PhD(c), CRNA

Educational Theory, Policy and Practice Graduate Student

## Appendix B. Participant Informed Consent Form

### PARTICIPANT CONSENT FORM

1. Study Title: Medication errors and eye tracking in novice versus expert nurse anesthesia providers.
2. Performance Site: Louisiana State University and Agricultural and Mechanical College
3. Investigator: The investigator, Aimee Badeaux, is available Monday-Friday from 9:00 am- 5:00 pm at (225) 490-1624.
4. Purpose of the Study: The purpose of this study is to explore/evaluate the use of eye tracking and visual search in medication selection in student and expert nurse anesthetists.
5. Subject Inclusion: Students enrolled in the nurse anesthesia program at Our Lady of the Lake College. Nationally certified, licensed nurse anesthetists with at least 5 years of experience post graduation from a nurse anesthesia program.
6. Number of Subjects: 75-90
7. Study Procedures: Student and expert nurse anesthetists will complete basic visual search tasks of medication vials via a computer while eye tracking is employed by the researcher. The search tasks, demographics questionnaire, and post-test questionnaire are estimated to take 30-45 minutes per participant.
8. Benefits: This study may yield interesting and valuable information about medication errors and visual search in the student nurse anesthetist and the expert nurse anesthetist. Both students and experts will be given full access to all study results, which will include both expert and student medication error statistics, as well as eye tracking information. Medication errors and the associated eye movements may serve as a learning tool in improving visual search in student nurse anesthetists. Student nurse anesthetists will be awarded extra credit in their research course to participate in the study. Certified Registered Nurse Anesthetists will be awarded 25 dollars for participation in the study.
9. Risks: There are no known risks to participants in this research project.
10. Right to Refuse: Participation in this research is voluntary. Subjects may choose not to participate or withdraw from the research study at any time without penalty or loss of any benefit to which they might otherwise be entitled.



11. Privacy: Results of the study may be published, but no names or identifying information will be included in the publication. The subjects' identity will remain confidential unless disclosure is required by law.

12. Signatures:

The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators. If I have questions about subjects' rights or other concerns, I can contact Robert C. Mathews, Chairman, LSU Institutional Review Board, (225)578-8692, [irb@lsu.edu](mailto:irb@lsu.edu), [www.lsu.edu/irb](http://www.lsu.edu/irb). I agree to participate in the study described above and acknowledge the researchers' obligation to provide me with a copy of this consent form if signed by me.

Subject Signature: \_\_\_\_\_ Date: \_\_\_\_\_

Study Exempted By:  
Dr. Robert C. Mathews, Chairman  
Institutional Review Board  
Louisiana State University  
203 B-1 David Boyd Hall  
225-578-8692 | [www.lsu.edu/irb](http://www.lsu.edu/irb)  
Exemption Expires: 4/30/2016

### **Appendix C. Consent Letter to First Year Students**

Dear Student Nurse Anesthetist,

I am a graduate student conducting a study on the visual search patterns used in medication selection in nurse anesthesia students under the direction of Dr. Earl Cheek at Louisiana State University in Baton Rouge, LA. This letter is written to request your participation in my research study, which will include the completion of computer simulated visual search tasks utilizing eye-tracking, a demographic and post experiment questionnaire, and will take approximately 45 to 60 minutes to complete. Your participation in this study is voluntary and if you choose not to participate, there are no consequences. If you choose to participate in this study you will be awarded 2 extra credit points for each hour of participation to be applied to ANES 5320, Advanced Assessment. Though the results of the study may be published, your responses will be anonymous.

If you have any questions concerning this study, please contact me at 225-490-1624 or email me at [abadea4@lsu.edu](mailto:abadea4@lsu.edu). You may contact my committee chairperson, Dr. Earl Cheek at 225-578-6017 or email at [echeek@lsu.edu](mailto:echeek@lsu.edu).

Sincerely,

Aimee L. Badeaux, PhD(c), CRNA

Educational Theory, Policy and Practice Graduate Student

## **Appendix D. Consent Letter to Second Year Students**

Dear Student Nurse Anesthetist,

I am a graduate student conducting a study on the visual search patterns used in medication selection in nurse anesthesia students under the direction of Dr. Earl Cheek at Louisiana State University in Baton Rouge, LA. This letter is written to request your participation in my research study, which will include the completion of computer simulated visual search tasks utilizing eye-tracking, a demographic and post-experiment questionnaire, and will take approximately 45 to 60 minutes to complete. Your participation in this study is voluntary and if you choose not to participate, there are no consequences. If you choose to participate in this study you will be awarded 2 extra credit points for each hour of participation to be applied to ANES 5460, Principles of Anesthesia Practice V: Advanced Concepts. Though the results of the study may be published, your responses will be anonymous.

If you have any questions concerning this study, please contact me at 225-490-1624 or email me at [abadea4@lsu.edu](mailto:abadea4@lsu.edu). You may contact my committee chairperson, Dr. Earl Cheek at 225-578-6017 or email at [echek@lsu.edu](mailto:echek@lsu.edu).

Sincerely,

Aimee L. Badeaux, PhD(c), CRNA

Educational Theory, Policy and Practice Graduate Student

## **Appendix E. Consent Letter to CRNAs**

Dear Certified Registered Nurse Anesthetist,

I am a graduate student conducting a study on the visual search patterns used in medication selection in nurse anesthesia students under the direction of Dr. Earl Cheek at Louisiana State University in Baton Rouge, LA. This letter is written to request your participation in my research study, which will include the completion of computer simulated visual search tasks utilizing eye-tracking, a demographic and post experiment questionnaire, and will take approximately 45 minutes to complete. Your participation in this study is voluntary and if you choose not to participate, there are no consequences. Though the results of the study may be published, your responses will be anonymous.

If you have any questions concerning this study, please contact me at 225-490-1624 or email me at [abadea4@lsu.edu](mailto:abadea4@lsu.edu). You may contact my committee chairperson, Dr. Earl Cheek at 225-578-6017 or email at [echeek@lsu.edu](mailto:echeek@lsu.edu).

Sincerely,

Aimee L. Badeaux, PhD(c), CRNA

Educational Theory, Policy and Practice Graduate Student

## **Appendix F. Letter to Manufacturers**

Date

Name of company

Address

Dear Sir or Madam:

I am a graduate student at Louisiana State University. I am in the process of preparing a dissertation and am seeking permission to include the following material in my publication: self-taken photographs of medication vials and ampules produced by your company. A copy of the work is enclosed. I would like to include the images of (LIST EACH MEDICATION HERE) in my dissertation and as a part of my research study.

The work will be used in the following manner: I will include photographed images of the above mentioned medication labels in my dissertation, which will be published. I will also include photographed images of these same medications during my research and ask study participants to select medications from an array of medications. The publication information is as follows: A science education study using visual cognition and eye tracking to explore the medication selection in the novice versus expert nurse anesthetist, Dissertation, Louisiana State University Electronic Thesis/Dissertation Database, to be published in Summer of 2014.

Please indicate your approval of this request by signing the letter where indicated below and returning it to me as soon as possible. Your signing of this letter will also confirm that you own the copyright to the above-described material. If you have any questions concerning this study, please contact me at 225-490-1624 or email at [abadea4@lsu.edu](mailto:abadea4@lsu.edu).

Sincerely,

Aimee L. Badeaux, PhD(c), CRNA

For copyright owner use:

### **PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:**

By:

Title:

Date:

### **Appendix G. Post Pilot Test Questionnaire**

1. Were the directions easy to understand?
  - a. Yes
  - b. No
2. Were the medication labels easy to read?
  - a. Yes
  - b. No
3. Did the medication labels fit onto the screen properly?
  - a. Yes
  - b. No
4. Did you have enough time to complete the task?
  - a. Yes
  - b. No
5. Was the administration software and equipment user-friendly?
  - a. Yes
  - b. No
6. Was the testing environment quiet and comfortable?
  - a. Yes
  - b. No
7. Please list any modifications you would make to the administration of this simulation.

## Appendix H. Institutional Review Board Approval LSU

### Application for Exemption from Institutional Oversight

Unless qualified as meeting the specific criteria for exemption from Institutional Review Board (IRB) oversight, ALL LSU research/ projects using living humans as subjects, or samples, or data obtained from humans, directly or indirectly, with or without their consent, must be approved or exempted in advance by the LSU IRB. This Form helps the PI determine if a project may be exempted, and is used to request an exemption.



Institutional Review Board  
Dr. Robert Mathews, Chair  
131 David Boyd Hall  
Baton Rouge, LA 70803  
P: 225.578.8692  
F: 225.578.5983  
irb@lsu.edu  
lsu.edu/irb

-- Applicant, Please fill out the application in its entirety and include the completed application as well as parts A-F, listed below, when submitting to the IRB. Once the application is completed, please submit two copies of the completed application to the IRB Office or to a member of the Human Subjects Screening Committee. Members of this committee can be found at <http://research.lsu.edu/CompliancePoliciesProcedures/InstitutionalReviewBoard%28IRB%29/item24737.html>

-- A Complete Application Includes All of the Following:

- (A) Two copies of this completed form and two copies of parts B thru F.
- (B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1&2)
- (C) Copies of all instruments to be used.  
\*If this proposal is part of a grant proposal, include a copy of the proposal and all recruitment material.
- (D) The consent form that you will use in the study (see part 3 for more information.)
- (E) Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing or handling data, unless already on file with the IRB. Training link: (<http://phrp.nihtraining.com/users/login.php>)
- (F) IRB Security of Data Agreement: (<http://research.lsu.edu/files/item26774.pdf>)

1) Principal Investigator: Aimee L. Badeaux Rank: Student  
Dept: ETPP Ph: (225)490-1624 E-mail: abadea4@lsu.edu

2) Co Investigator(s): please include department, rank, phone and e-mail for each  
\*If student, please identify and name supervising professor in this space

Dr. Earl Cheek, Executive Director; Patrick and Edwidge Olinde Endowed Professorship in Education  
Phone: (225) 578-6017  
Lab Phone: (225) 578-9135  
E-mail: [echeel@lsu.edu](mailto:echeel@lsu.edu)

IRB# <u>8299</u>	LSU Proposal #
<input checked="" type="checkbox"/> Complete Application	
<input checked="" type="checkbox"/> Human Subjects Training	

3) Project Title: A Science Education Study Using Visual Cognition and Eye Tracking to Explore Medication Selection in the Novice versus Expert Nurse Anesthetist

Study Exempted By:  
Dr. Robert C. Mathews, Chairman  
Institutional Review Board  
Louisiana State University  
203 B-1 David Boyd Hall  
225-578-8692 | [www.lsu.edu/irb](http://www.lsu.edu/irb)  
Exemption Expires: 4/30/2016

4) Proposal? (yes or no) No If Yes, LSU Proposal Number                     

Also, if YES, either  
☐ This application completely matches the scope of work in the grant  
OR  
☐ More IRB Applications will be filed later

5) Subject pool (e.g. Psychology students) Graduate Nurse Anesthesia Students

\*Circle any "vulnerable populations" to be used: (children <18; the mentally impaired, pregnant women, the ages, other). Projects with incarcerated persons cannot be exempted.

6) PI Signature Aimee L. Badeaux Date 5/11/2013 (no per signatures)

\*\* I certify my responses are accurate and complete. If the project scope or design is later changes, I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at LSU for three years after completion of the study. If I leave LSU before that time the consent forms should be preserved in the Departmental Office.

Screening Committee Action: Exempted <input checked="" type="checkbox"/> Not Exempted	Category/Paragraph <u>2</u>
Signed Consent Waived?: Yes <input type="checkbox"/> No <input checked="" type="checkbox"/>	
Reviewer <u>Mathews</u> Signature <u>Robert C. Mathews</u> Date <u>5/11/13</u>	

## Appendix I. Institutional Review Board Approval OLOLC



OUR LADY  
OF THE LAKE  
COLLEGE

*Franciscan Missionaries of  
Our Lady Health System*

Date: May 6, 2013

Study Number: 1311

Study Title: *A Science Education Study Using Visual Cognition and Eye Tracking to Explore Medication Selection in the Novice Versus Expert Nurse Anesthetist.*

Primary Investigator: Aimee Badeaux, PhD, CRNA Assistant Director, CRNA Program

Secondary Investigators: Earl Cheek, PhD

Approval Designation: Expedited Review

Primary Reviewer (Date): Rhoda Reddix (May 6, 2013)

Secondary Reviewer (Date): Tammie Kubelka (May 6, 2013)

Dear Ms. Badeaux,

I am pleased to inform you that Rhoda Reddix and Tammie Kubelka of the Our Lady of the Lake College Institutional Review Board have reviewed and approved your proposed study entitled *A Science Education Study Using Visual Cognition and Eye Tracking to Explore Medication Selection in the Novice Versus Expert Nurse Anesthetist* conducted by Aimee Badeaux and Earl Cheek.

Thank you for your submission and I would like to wish you success with your study.

Best regards,

Dr. Michael T. Dreznick,

Associate Professor and OLOL College IRB Chair



## Appendix J. Experiment Script

### Medication Selection Summer 2014 Eye Tracker Instructions

Before the participant arrives, have their name accessible, with their experiment start and end time. Retrieve the necessary forms from the experiment folder (consent form, sign in sheet, debriefing form (if asked for) and extra credit form (novice participants only).

To set up the experiment computer:

Open the folder titled “Medication Selection” in the “Deployed to Collect Data” file.

Double click on the eye icon

Enter the Subject number from the sign in sheet.

When participant arrives, check their name and ask them about removing their eye make-up if present. Next direct the participant to the consent form. Have the participant sign and date the consent form. During this time the experimenter will fill out the participant’s name, time of experiment, and experimenter’s initials on the sign-in sheet.

The experiment can now press OKAY on the display computer and clean the chinrest with rubbing alcohol.

Retrieve the consent from the participant and bring him/ her into the eye tracking room. Tell the participant to have a seat in front of the display computer.

### SCREEN 1: EYE TRACKER INSTRUCTION SCREEN

**Experimenter:** In this experiment, we will use an eye tracker to detect your eye movements. This eye tracker will rest on your head, and contains two eye cameras that are used to capture eye movements. This eye tracker will work best if you move your head and body as little as possible. Therefore, you will keep your chin in this chinrest throughout the entire experiment while you are wearing the eye tracker. Once the eye tracker is on your head, please look at the computer screen even when I speak to you. Do you have any questions about this? After we finish the eye-tracking portion of the experiment, you will complete both a demographic and a post-experiment questionnaire.

In this experiment, your task is to find the target medication vial. I am interested in how quickly and accurately you find the target. You will go through a practice trial after initial eye tracker set-up.

### SCREEN 2: BLANK WHITE SCREEN

*Ask the participant to push their chair as close to the desk as possible and ask them to place their chin in the chinrest. Adjust the chin rest so they are comfortable.*

Experimenter: We are now going to set up the eye tracker. Please place your chin in the chinrest. Are you comfortable?

Arrow over to the head position screen. Make sure the host computer is set to track both eyes. With the participant's head in the chinrest place the eye tracker on their head. Adjust the cameras.

Before advancing, check that the left hand side of the host monitor both Pupil in the left hand column and 500 hz in the right hand column are selected.

Press "c" on the host computer to begin calibration and hand the game controller to the participant.

### SCREEN 3: CALIBRATION DOT

Experimenter: Before we begin the experiment, we need to calibrate the eye tracker. You will be presented with a black dot with a white center. This dot will move to nine different positions on the computer monitor. You are to make an eye movement to the dot when it appears and fixate on it. It is important that you do not make an anticipatory eye movement to where you believe the dot will appear. People have a natural tendency to anticipate the movement of the dot, and move their eyes before the dot actually reappears in the new position on the monitor. However, the calibration will work better if you keep your eyes still until the dot reappears in a new position and then move your eyes. Once the calibration is completed the process will be repeated for validation. The dots will not appear in exactly the same order, but the task is the same. Once again, make an eye movement to the dot, fixate on it and do not make an eye movement to where you anticipate the dot to appear. In addition, it is important that your entire body stays as still as possible from this point forward. Do you have any questions about this task?

In order to start, please look at the center of the dot and press the big round button on the left hand side of the controller.

The dot will move around the screen, when the calibration is complete, a tone will sound, followed by a blank screen. Check the box made on the host computer. If the box is off, check the cameras or do the calibration again.

### SCREEN 4: BLANK SCREEN

Press "v" on the host computer to begin validation.

### SCREEN 5: VALIDATION DOT

Experimenter: You are now going to complete the task for a second time for validation. Remember to remain as still as possible. When you are ready to begin, look at the center of the dot and press the big round button.

If calibration and validation are successful, press "enter" then "o" on the host computer to begin the trial. Otherwise, click the cameras and complete calibration and validation again. Also note the eye picked to track. For each following calibration, validation, and experiment trials track this eye.

## SCREEN 6: SECOND INSTRUCTIONS

**Experimenter:** Next you will begin the practice trial. Your task is to accurately identify the target medication by pressing the back right button of the game controller. If you indicate the target medication is present, you will then be presented with a reminder screen to click on the target medication vial with the yellow mouse triangle. If the target medication is not present or you are unable to locate the target medication, you will press the back left button of the game controller. After each trial this drift correct dot will reappear for the start of the next trial. Do you have any questions?

You will now be given the controller. Please do not press any buttons until instructed to do so.

*Hand the participant the game controller.*

**Experimenter:** You may press the “a” button to advance.

## SCREEN 7: DRIFT CORRECTION DOT

Experimenter: Before every trial you will see this black dot with a white center in the middle of the screen. This allows the eye tracker to make small adjustments throughout the experiment. Whenever you see this dot, look into the center of the dot and press the big round button. The looking into the dot and pressing the big round button is the start of the trial. It is important that you try to focus on the very center of the dot. Rarely the big round button will not advance the screen. Simply look in the center of the dot and at the same time press the big round button again.

## SCREEN 8: FINAL INSTRUCTIONS

**Experimenter:** Your task is to accurately identify the target medication by pressing the back right button of the game controller. If you indicate the target medication is present, you will then be presented with a reminder screen to click on the target medication vial with the yellow mouse triangle. If the target medication is not present or you are unable to locate the target medication, you will press the back left button of the game controller.

## SCREEN 9: COMPLETED EYE TRACKER PORTION

**Experimenter:** You have now completed the computerized eye tracker portion of the experiment.

## AFTER EYE TRACKER COMPUTER EXPERIMENT ENDS

Following the end of the experiment you will have the participant move to the questionnaire computer where they will complete the demographic and post-experiment questionnaire via Superlab software. To deploy the program, click on the medication selection questionnaire folder

on the desktop and select the level of participant (novice, expert, pilot). The experimenter will enter the participant's ID number prior to start of the questionnaire.

Experimenter: Please complete the demographic and post-experiment questionnaire. Please let me know when you finish. Do you have any questions?

After the participant answers the questions, hand them any requested forms (debriefing, copy of informed consent) and an extra credit form if the participant is a novice.

### **Appendix K. Novice Demographic Questionnaire**

1. Please indicate your grade level in your nurse anesthesia program.
  - a. First year student.
  - b. Second year student.
2. Second year students- How many anesthetics have you administered since you enter the clinical portion of the nurse anesthesia as signified by your case total?
3. Second year students- What is the average number of medications that you administer to a patient during an anesthetic?
4. Please indicate your level of experience, post-graduation from a nursing program in whole years, rounding to the nearest tenth. (Examples: 2.3 years = 2 years; 5.8 years = 6 years).
5. Please indicate your gender.
  - a. Female.
  - b. Male.
6. In what year where you born?
7. What is your ethnicity?
  - a. Black, African American
  - b. Asian
  - c. Caucasian (White)
  - d. Native American
  - e. Pacific Islander
  - f. Spanish/Hispanic/Latino/Mexican
  - g. Other:\_\_\_\_\_
8. Do you have normal, corrected to normal, or uncorrected vision?
9. Are you colorblind?

## **Appendix L. Expert Demographic Questionnaire**

1. Please indicate your level of experience, post-graduation from a nurse anesthesia program in whole years, rounding to the nearest tenth. (Examples: 2.3 years = 2 years; 5.8 years = 6 years).
2. How many hours do you typically work per week in the anesthesia setting where medication administration is required? Enter amount in whole number, rounding to the nearest tenth. (Example?)
3. Do you specialize in a particular type of anesthesia?
4. What is the average number of medications that you administer to a patient during an anesthetic case?
5. Please indicate your gender.
  - a. Female.
  - b. Male.
6. In what year were you born?
7. What is your ethnicity?
  - a. Black, African American
  - b. Asian
  - c. Caucasian (White)
  - d. Native American
  - e. Pacific Islander
  - f. Spanish/Hispanic/Latino/Mexican
  - g. Other: \_\_\_\_\_
8. Do you have normal, corrected to normal, or uncorrected vision?
9. Are you colorblind?

### **Appendix M. Post Experiment Questionnaire**

1. Please describe in as much detail as possible, the general visual search process you utilize when selecting medications for administration.
2. What types of activities have you found to be the most critical in assuring accuracy during the visual search for a medication in the operating room? Specifically, why have you found these activities to be so critical?
3. In your opinion, which types of medication features are the most difficult to distinguish when visually searching for a medication?
4. Through your experience, how have you evolved or modified your visual search process to increase accuracy? Efficiency?
5. In nurse anesthesia school, what, if any, instruction did you receive regarding visual search in medication selection? Was this instruction helpful?
6. Have you ever committed a medication error?
  - a. If so, what factors led to this error?
7. Have you ever had a “near-miss” medication incident?
  - a. If so, which factors led to this incident?

## **Appendix N. Debriefing Script**

Thank you for your participation in the Medication Selection and Visual Search Study.

The current experiment examines novice and expert nurse anesthetists' visual search strategies during medication selection. The ability to find an item you are searching for depends largely on other items present as you search for a target item. If there are several other items and/or similar items to the target, these items may prevent you from accurately and quickly finding the target item. This experiment also examines the features that guide attention during medication selection in the novice and expert.

If you have specific questions or concerns regarding this research, please contact Aimee Badeaux via email at [abadea4@lsu.edu](mailto:abadea4@lsu.edu) or via phone at (225) 490-1624.



## **Vita**

Aimee Ladreyt Badeaux currently is the Program Director of the Nurse Anesthesia Program at Our Lady of the Lake College. She completed her Bachelor of Science in Nursing in 2002 at Louisiana State University Health Sciences Center. Badeaux completed her Masters of Science in Anesthesiology at Our Lady of the Lake College in 2007. Upon graduation and certification as a nurse anesthetist, Badeaux joined the heart team at a hospital in Baton Rouge Louisiana where she cared for cardiovascular patients and patients undergoing major cardiovascular surgery. She remained an anesthetist on the heart team until she left her full time practice in order to teach nurse anesthesia students full time. Badeaux currently practices part time as a nurse anesthetist in Baton Rouge Louisiana.

Badeaux is an active member of the American Association of Nurse Anesthetists, Louisiana Association of Nurse Anesthetists, Sigma Theta Tau National Honor Society, Gold Key International Honor Society, and Phi Kappa Phi National Honor Society. She is married to Brian; has a son, Benjamin Michael; and a daughter, Elizabeth Mary.