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EVALUATION OF AN EYE TRACKING DEVICE TO INCREASE ERROR RECOVERY BY NURSING STUDENTS USING HUMAN PATIENT SIMULATION

A Thesis Presented

by

Yan Shen

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of

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February 2010

Mechanical and Industrial Engineering

EVALUATION OF AN EYE TRACKING DEVICE TO INCREASE ERROR RECOVERY BY NURSING STUDENTS USING HUMAN PATIENT SIMULATION

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Mechanical and Industrial Engineering

ABSTRACT

EVALUATION OF AN EYE TRACKING DEVICE APPLICATION TO INCREASE ERROR RECOVERY BY NURSING STUDENTS USING HUMAN PATIENT SIMULATION

February 2010

YAN SHEN, M.S., UNIVERSITY OF MASSACHUSETTS AMHERST

Directed by: Professor Donald Fisher

This study evaluates the application of an eye tracking device in nursing education. An experiment is designed to test the effectiveness of the eye tracking device used as a tool for providing instructional feedback in error identification and recovery by nursing students undertaking tasks in a simulated clinical setting. This experiment is performed on three groups of nursing students. In the first phase, all groups are tested in a simulated clinical scenario and their eye movements are recorded using an eye tracking device. In the second phase, the *evaluation only* group (control group) gets instructors' feedback regarding their performance without referring back to the eye tracker record. The *eye tracker only* group (experimental group A) is provided with a video of their eye movements which was recorded during their first simulated exercise, but receives no feedback from the instructors. The *combined* group (experimental group B) is provided with both instructors' evaluations and their eye movement video. Finally, in the last phase, all the groups are tested once again in the simulated clinical settings. Their performance is observed and compared to determine their relative improvements. Based on these improvements, it will be possible to determine whether an eye tracking device

by itself or in combination with evaluation serves as a helpful instructional source during nursing education.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

1.1 Background

In today's America, with the increases in the aging population and patients' demand for new medical services, medical science and technology is developing much faster than ever before. However, in the health care delivery system it is normally difficult to ensure that applications which quickly follow from those developments are implemented with full attention given to their safety [1]. The Institute of Medicine's 1999 groundbreaking report "To Err Is Human" estimated that there are 44,000 to 98,000 people who died every year due to medical error [2]. This number is even higher than the deaths due to motor vehicle accidents (43,458), breast cancer (42,297), or AIDS (16,516) [3].

It should be noted that not all medical errors result in actual harm to patients, but all medical errors are potentially costly. And the total cost of medical errors is staggering. It is estimated that the cost of remediating adverse events affecting inpatients due to medical errors is around 2 billion per year [4]. And this cost, which happens during the time the patient stays in hospital, is only a small proportion of the total costs since medical error occurs not only in hospitals, but also in outpatient surgical centers, physician offices, clinics, retail pharmacies, and nursing homes, among others. In addition, medical errors are also costly because they are associated with opportunity costs and other costs due to the loss of trust toward medical systems.

Therefore, it is of considerable importance to reduce the occurrence of medical errors. The reduction of medical errors not only saves lives but also improves the efficiency of medical systems.

1.1.1 Nurses' Role in Emergency Department

Medical error occurs due to the failure to take the correct action or make the right decision to achieve a given purpose. Errors may happen in all stages of health care procedures: diagnosis, treatment, and prevention. High error rates and serious adverse consequences are more likely to occur in emergency departments (EDs) due to the fast-pace, constantly changing demands, and crowded environment. In an earlier study [5], Sucov, et. al., classified the medical errors in the ED based on the causes of the errors. There were 32% due to diagnosis and treatment mistakes, 25% due to communication errors, 24% due to system delays, and 11% due to medication errors. From the study of Fordycc et. al. [6], it is known that 40% of errors are reported by nurses. Also, Henneman, et. al. observed that among the 47% of reported Emergency Department errors that are recovered, the majority (60%) are recovered by nurses [7]. As a health care provider, nurses play important roles in insuring patient safety and preventing adverse effects due to medical errors.

1.1.2 Theoretical Model for Nursing Error Recovery

In order to explore the mechanism of medical error prevention by nurses, the Eindhoven model was introduced to investigate a "near miss" event [8]. This model was originally proposed for application in the chemical process industry. Then, it was applied to other settings and used to classify medical errors in health care systems. This model suggests a role for nurses in error recovery which includes identifying, interrupting, and

correcting medical errors. In this role, nurses could transform potentially negative outcomes into “near-miss” situations, in which the patient is not impacted by the error. This model suggests that medical errors may result from technical failures, human operator failures and organizational failures. Also, this model argues that the developed incident (triggered by the three failures) may or may not lead to an adverse outcome to the patient. Human recovery of errors is one of the safe mechanisms to transform a potentially negative outcome into a near miss situation. As key figures to recover errors, nurses play a crucial role here to stop or prevent the adverse effects [9].

1.1.3 Strategies Used by Nurses to Recover Medical Errors

In the literature, Elizabeth Henneman has reported a study of the efficient mechanisms and strategies that nurses can employ to recover from medical errors in the emergency department [10]. In her study, twenty nurses with at least 6 month’s experience were recruited to participate. Questions were asked regarding the role of nurses in an Emergency Department. The questions can be categorized into three phase of error recovery, namely error identification, error interruption and error correction. All response were recorded and studied. After that, each response was analyzed and summarized according to the three categories of strategies, defined above: identifying errors, interrupting errors and correcting errors.

From the perspective of error identification, it is stated that there are five most efficient methods that can be used to identify errors in an Emergency Department:

1) Surveillance: Nurses should expect that potential problems before they enter ED;

2) Anticipation: Nurses should be on alert to the potential errors when they go to patients;

3) Double checking: Nurses should check patient identifiers, ask questions, check medication dosages, etc.;

4) Awareness of the big picture: Nurses should always consider the ED as a place where potential errors prevail and be aware of any abnormal events in ED.

5) Experiential knowing: Nurses should use their previous experience to recognize something different from normal or expected scenarios.

From the perspectives of error interruptions, the article argues that it is easy for nurses to interrupt errors in the ED, especially for highly experienced and confident nurses. There are five most commonly used methods to interrupt errors:

1) Patient advocacy: Nurses interrupt errors to protect the patients, something with which they are all well aware;

2) Offer of assistance: Nurses provide patients with recommendations and questions (this is shown to improve the safety);

3) Clarification: Nurses clarify any written or oral communication if it is not clear; clarification is often used when nurses are unsure of the treatment plan;

4) Verbal interruption: Nurses use specific verbal warnings to interrupt an activity when there was a potential error; and

5) Creation of delay: Nurse may slow a process to interrupt an error. Nurses should delay an activity until getting necessary supplies, personnel or equipments.

In this study, it is shown that most of the errors are recovered by identification and interruption in the early stage. There are only a few examples where error correction

occurred while the actual error was in progress. The strategies to correct errors depend considerably for their success on a strong team and leadership during planning and delivery process.

From the study of Elizabeth Henneman, it can be observed that by employing correct methods nurses can prevent and stop medical errors. Also, error identification is a crucial stage where most of the medical errors can be prevented. Therefore, proper training of nursing students to identify potential medical errors is of significant importance in nursing education.

1.2 My Study

It is shown in the previous section that nurses play a crucial role in preventing the adverse effects due to medical errors. Therefore, training nursing students how to provide safe and effective care is an efficient method to decrease medical errors, especially when the focus is on error identification. In the nursing student's education, there is a significant amount of on-field training or number of simulated clinical exercises. This training is used to get the students familiar with the best practices during treatment. In this training, feedback is normally given to the students. This feedback is used to correct any mistakes that occurred during the students' practice. Therefore, the proper strategy of giving feedback during nursing education is of considerable importance.

In my thesis study, I am going to evaluate the most efficient way which can be used to give feedback in current nursing student training. During the nursing student training, it is hard to accurately determine the focus of human attention. Therefore, it is difficult to evaluate nursing students' performance and give them feedback according to

their individual performance. In my study, I am going to introduce a novel method to give feedback. This method involves the application of new technology in nursing research, an eye tracking device. In the study, eye tracking devices are used to record the eye movements of nursing students during their clinical practice. And the eye movement records are given to the students as a form of feedback. In my study, I have conducted experiments to compare the effectiveness of different feedback strategies.

1.3 Literature Review

There have been a number of earlier studies on proper methods to conduct nursing student education. Also, with the advance of technology, the educational methods themselves develop rapidly. Nursing educators have started to use computer programming, simulation in virtual environments, and other high technology devices to train nursing students. In the next subsections, errors frequently committed by nursing students are discussed. Also, some proposed educational methods from previous studies are discussed. Specifically, in the first subsection, a previous study regarding the common errors of nursing students during their education is introduced. In the next subsection, a study of how to design the specifications to improve medical safety is introduced. Then, in a final subsection, a simulation method is discussed, which is used in nursing education to recover medical errors.

1.3.1 Common Errors for Nursing Students

In [10], common errors committed by nursing students are studied. The types of medical errors include technical failure, human operator failure and organizational failure. In nursing education, the primary focus is to reduce human operator failures. There are three categories of human operator failures: knowledge-based, skill-based and rule-based.

These three different types of failures are thus classified based on the three different types of behaviors. Knowledge-based behavior occurs when people perform a novel task when previous knowledge or experience cannot be applied. Therefore, in these situations, completely conscious control is expected to be applied. Knowledge-based errors are due to the lack of knowledge during a decision making situation. During the nursing education, nursing students are generally provided with clear instructions and relevant knowledge before field practice or human performance simulation. Therefore, it will be assumed that nursing students have the requisite knowledge and knowledge-based errors are not likely to occur. Skill-based behaviors are routine activities conducted automatically and do not require allocation of attention. Rule-based behaviors are typically based on rules that can be verbalized or clearly defined. A person performs rule-based behavior when he or she undertakes certain tasks following a clear rule or procedure. For example, in nursing practice, nurses are expected to follow a systematic verification system when confirming a patient's identification before surgery. If errors occur in this stage due to not following the procedure, it is a rule-based error. On the other hand, skill-based behavior progresses without conscious attention. During nursing education, nursing students perform tasks after given clear instruction regarding the best-practice to follow. Therefore, skilled-based errors are less likely to occur. As a result, rule-based error is the type of error which mostly occurs during nursing education. And in most reports of research about nursing education, they focus on rule-based errors.

In the study reported in [10], a clinical experiment is performed. In the experiment, there are 50 senior nursing students participating in the simulation exercise. They all have previous experience assessing patients and administering medication in the

simulation lab. Also, they were given an understanding of the required procedures before the simulation exercises. There are two designed simulation scenarios. In the first one, an elderly patient with congestive heart failure (CHF) after a blood transfusion needs nursing help. In the second one, a patient with chest pain following a motor vehicle accident (MVA) needs medical attention. Each nursing student participated in one of the two simulation scenarios. In the study, they were evaluated for rule-based errors which include four categories: coordination, verification, monitoring and intervention. Errors in coordination include failures to communicate with the doctor, the patients or their families. Errors in verification include failures to confirm patients' identification or their allergy information. Errors in monitoring can be failure to correctly monitor patient assessment information or negligence of any abnormal findings. Errors in intervention include delay in treatment or failure to provide appropriate treatment.

In this study [10], video tapes are recorded during the experiment. Data were collected from video tapes to show the four categories of rule-based errors as well as errors recovered by the nursing student. The results show that the error frequencies between the CHF group and MVA group are not significantly different. Also, from the results, it is clear that errors occurred most frequently in the verification category. More than 80% of experimental subjects failed to verify a patient's identification and around 70% of the participants failed to verify the patient's allergies. Another frequently occurring error is coordination errors related to the interaction with physicians (CHF, 80%; MVA, 56%). For example, in CHF 80% subjects failed to communicate with the physician clearly regarding the complete assessment of a patient's respiratory status. And the least frequent errors are coordination errors related to the interaction with patients and families

(CHF, 28%; MVA, 8%). For example, in MVA only 8% of subjects failed to stop a conversation with family members when they initiated therapies to patients. The errors of monitoring and intervention are ranked intermediate between coordination errors and verification errors. Furthermore, the results show that students in both simulations have a low ability to recover errors embedded into the simulation (14%).

In the discussion section of this paper [10], the author argues that the results from this study show that patient safety is related to the verification of patient identification and allergy information. In this study, although students were taught to check the patients' identification and allergy before the simulation exercise, most of the students still neglect to do such during the simulation exercise. It suggests that this category of rule-based errors might be improved by the practice of human patient simulation (HPS) since performance is nowhere near ceiling. Regarding another common error (coordination), this study shows that student nurses frequently called physicians without knowing the important patient information (such as patient's full name and assessment). Also, this inefficiency in communication would lead to adverse outcomes. This paper recommends using a systematic communication template to improve the ability of the nursing student to efficiently communicate with physicians.

There are also some limitations in this study [10]. The experiment is performed with only a small group of people. And the scenario design may not be general enough. Therefore, the result should be generalized to a hospital setting with caution. Also, it is discussed in this paper that the accuracy of some evaluations (related to verification errors) is questionable because the attention of students can only be vaguely determined.

The study provides considerable background and information for my study. First, this paper provides me some suggestions regarding the simulation scenarios that might be used. It is discussed in this paper that failures in patient and allergy history identification are common among nursing students. Therefore, in my study, scenarios are deliberately designed to test whether these identifications have been performed. Second, the paper concludes that nursing education can be improved by using HPS. In my study, I will be determining whether a particular type of feedback strategy in HPS can decrease errors. Last but not least, the limitation of the previous work includes the inaccuracy in determining the gaze of nursing students to a particular location during the experiment. In my study, I have proposed to use eye tracking devices to help solve this problem. I want to show that a head mounted eye tracking device worn during the HPS can accurately determine the focus of human attention which can then be used after the HPS to provide efficient feedback to the nursing students. However, a caveat is in order. Specifically, note that I will be able to determine from this information whether a nursing student did not attend to some information (if they do not look, then they cannot attend). However, strictly speaking I will not be able to determine whether the individual who looks at a particular piece of information actually attended to (processed) the information.

1.3.2 Property Specifications Design for Medical Safety Improvement

Traditionally, in nursing education, informal process descriptions (such as the usage of checklists) are frequently used during medical education to improve the safety of healthcare processes. In [11], Elizabeth Henneman proposed a new method to improve the safety of current medical training. During her study of the educational practices in the blood transfusion process, she states that informal process descriptions only show

standard (or desired) conditions rather than some exceptions. In other words, traditionally the education procedures only identify the correct flow during the healthcare process. But the procedures fail to consider all the possible scenarios during the practice. Also, conventionally, the educational procedure is focused primarily on just enumerating the steps in the correct behavior (such as completing all the necessary steps on the checklist). Therefore, sometimes, the underlying purpose of each correct behavior during the practice is not clear or emphasized. In addition, during the traditional healthcare education, the different terminologies are likely to result in confusion. Therefore, it is important to introduce a systematic terminology in healthcare education.

In [11], Elizabeth Henneman introduces a formal process definition as one of the systematic methods to improve the quality of healthcare processes. In formal process definition, computer programming languages are used to describe the process which is best for patient safety. She uses a case study of blood transfusion as an example to show how computer programming languages can be applied in formal process definition. During blood transfusion to a patient, the delay and complexity of the process may affect patient safety. Therefore, the author introduces two computer techniques to improve the safety of patient care processes, namely the formal definition of a process and the formal definition of the properties of a process.

As discussed early, formal definitions of a process provide a systematic flow of the training practice. The flow diagram includes not only the correct behavior but also the likely happenings during a wrong practice.

A formal definition of the properties is used to describe the purpose of each best behavior during the process, which improves the safety of patient. Traditionally, in

healthcare, people usually get training based on the policies and the procedures which are often not stated in enough detail to make it clear to the individual what exactly is required. In that case, the healthcare provider may easily misinterpret the goal of the process. Therefore, the process might be executed incorrectly. In this scenario, any misunderstanding or confusion regarding the terminology or even some slight changes with respect to the training scenario is likely to result in unsafe practices during healthcare. Therefore, providing formal definitions of the properties, compared to the traditional method, not only identifies the correct behaviors which need to be followed, but also clearly states the underlying purpose of each correct behavior. In [11], it shows us an example of the difference between the formal definitions of properties and the procedure checklist method during blood transfusion. In the procedure checklist method, each must-follow behavior is explicitly listed, such as "verifies that informed consent has been obtained." And in the property specification, besides suggesting the must-follow behavior, the purpose of this behavior is also explained. For example, in the same above-mentioned scenario, during formal definitions of properties, instructions will be given as "before performing a blood transfusion for a patient, make sure that patients have agreed to a certain procedure in writing such as a consent form so as to clarify the treatment and avoid any legal issues." Through comparing these two statements, the word "verify" in the statement of checklist does not clearly indicate what must be verified. While, the statement of property specification clearly shows that the patient is required to agree to the procedure before blood transfusion. And a legal documentation is required.

In [11], it also recommends several steps to formally define a property. First, abstract goals need to be identified. It is argued that defining the underlying purpose

during the practices of healthcare using computer techniques is a challenge for healthcare experts and computer scientists. Either of them needs to be familiar with some background knowledge to which they don't have much exposure before starting work in healthcare. In this paper, a useful approach to fill this gap is introduced. It is explained that the definition of the underlying purpose during healthcare practice can be obtained through improving an existing healthcare training process and trying to discuss the reason for the improvements. During this process, the underlying purposes can be better understood. For the case of blood transfusion studied in this paper [11], through identifying some possible errors, which may happen during the process of blood transfusion, it can be found that the purpose of all the best practice behaviors is to make sure the right type of blood is being transfused to the right patient. Second, the property needs to be stated clearly. One problem which may affect the accuracy of the statement is that a terminology could be used to describe different concepts. For example, the term "transfusion" could be used to describe the single unit of blood product being infused. Also, it could be used to describe the entire transfusion process which includes multiple units of blood products. Another problem is that the same process could be described by different terms. For example, the term "unit" could be used to substitute either "blood product" or "bag of blood". Third, the property needs to be formalized, which means translating the property into mathematical formulas. Fourth, there may be several properties (underlying purposes) for one process step. In this study, some possible ways to organize these properties are discussed. For example, all the properties associated with the same terminology can be put together in a group. For example, all the properties describing a unit of blood product could be shown in one group.

As a conclusion, this paper [11] focuses on two important techniques to improve patient safety, the formal definition of a process and the formal definition of the properties of a process. The definition of process describes the ordering of tasks and possible exceptional conditions. And the definition of properties states the underlying purpose of each task.

In summary, this paper [11] provides a method of healthcare training using computer techniques. From a case study, it shows possible methods to define a systematic training process. The suggested training method (such as defining a systematic training procedure and stating the purpose of each best practice) is an alternative technique in nursing education. This paper provides me with more background regarding the state-of-art education theories regarding nursing education. In the next subsection, another training method for nursing education is introduced.

1.3.3 Application of Human Patient Simulation in Nursing Education

In [12], a novel training method, related to Human Patient Simulation (HPS), is introduced for nursing student education. Traditionally, in order to help nursing students become familiar with the complexity and reality in clinical settings, case studies and computer simulators are commonly used as teaching tools [13, 14]. However, these tools neglect the reaction among nurses, patients, patients' family and physicians. Therefore, HPS shows its advantages in mimicking the reality in clinical settings. With the popularity of HPS, recently, HPS was even recognized as a potential methodology to improve patient safety in nursing education. However, there are few practical cases regarding using HPS in nursing education to improve safety. Therefore, in [12], the

author shares her practical experience regarding a specific scenario in HPS to teach nursing students some critical safety skills.

The simulation scenario in [12] includes a patient complaining about chest pain after a motor vehicle accident (MVA). Nursing students are expected to participate in the assessment and brief treatment of this patient. Before the simulation, nursing students receive an orientation to the simulation settings. After that, they are provided with an introduction regarding the simulation exercise. In order to provide a useful learning experience for the students, nursing instructors who were assigned to the students are expected to give consistent instructions, which could help students to get a consistent learning experience. Also, this simulation exercise consists of some participant actors, such as patients, patients' relatives and physicians. Each actor was provided with specific guidelines, regarding his or her role and anticipated response during the conversation with students, to guarantee the consistency of the simulation.

The simulation center is equipped with both routine and emergency supplies. Instructors are provided with specific instructions on how to set up the simulation scenario. This setup includes some embedded errors in the scenario. By determining whether those errors are identified and corrected, the nursing students' performance during clinical treatment can be assessed. The mannequin (i.e., the human patient simulator) was programmed to represent the specific physiological parameters of the patient. Also, there is a monitor in the clinical setting which provides feedback to the nursing students regarding the results of their treatment.

In this study, the author states that there are two critical points which affect the learning experience of the nursing students. One is the debriefing process, which allows

instructors to review specific students' behaviors. Another is the consistency within the experiment (such as the consistency of instruction as discussed early). Also, since patient safety plays an important role in nursing education, the experimental scenario is designed to target patient safety. There are some embedded errors in the MVA scenario. For example, in the MVA scenario, the patient's allergy band is missing. Also, the intravenous pump is set at the wrong rate. Nursing students are required to identify these embedded errors during the exercise. Also, during the simulation exercise, nursing students need to avoid some other errors during their assessment of the patient.

Finally, this paper [12] shows that HPS simulation can be used to evaluate the competency of nursing students. However, there are some challenges that are encountered while undertaking the evaluation in this study. For example, the evaluator may also be required to perform as an actor in the simulation exercise. Therefore, it's difficult to focus on all the behaviors of students. Also, the simulated scenario may vary depending on the different decisions made by students. Therefore, to minimize the variety of the exercises, it is important to define specific objectives for each step in the exercises. Also, there are expected behaviors from the nursing students in each stage of the exercises. And the students' performance is assessed based on the expected behavior. Therefore, the evaluation of students' performance is considerable subjective.

This work offers some good detailed knowledge regarding scenario design, experimental procedures, and performance evaluation in HPS. It is argued in this paper that the consistency of instruction is of significant importance in the experimental procedure. Therefore, during our proposed study, guidelines are defined for the conversations/interactions between nursing students and individuals playing other roles

(which include patients, medical physicians and etc.) in the simulation so as to provide a consistent experimental scenario. Also, as observed in this paper, it is important to minimize the variety of activities in which the participants engage during the exercises. Therefore, specific steps are defined in my proposed experiment to guide nursing students from one objective to another. More importantly, in this work, it is observed that it is challenging for the instructors to perform the duties of both actors and evaluators in the HPS exercises. Therefore, to reduce the possibility of error and inconsistency, in my proposed experiment, the role of actors and evaluators are separated and performed by different people.

1.3.4 Importance of Error Training and Feedback

To better understand the importance of feedback and error training during nursing education, some background regarding error training and feedback are discussed in this section.

Formal training usually involves learning new knowledge, skills, attitudes or other characteristics in one environment (the training situation) that can be applied or used in another environment (the performance situation) [15]. Feedback from the outcome of practice plays an important role in training. Feedback not only provides information regarding the learner's performance, but also informs the learner about the underlying structure of task.

"Transfer of training" refers to the application of knowledge and skills learned from practice to performance situations. There are two types of transfers: analogical transfer and adaptive transfer.

Analogical transfer involves using past experience from a familiar problem to solve a problem of the exactly same type [16]. It could be positive transfer or negative transfer. Positive transfer occurs when the rules or strategies underlying the training situation could be applied to an analogous problem since these two situations share a common underlying structures. On the other hand, negative transfer occurs when the rules and strategies can not be applied to another situation because both problems have similar superficial feature, but underlying structures are different. Positive transfer is enhanced and negative transfer is decreased if individuals are allowed to develop a more general understanding of a concept which omits superficial differences [17]. Errors encountered in training could help learners to understand the concepts underlying a problem and motivate the further learning of these concepts. The negative feedback provided by errors could stimulate learners to stop their actions, look for the root-cause of errors, and generate the solutions. Also, errors help define the contours of more abstract schemata [18]. For example, in driver training, when a learner hits the curb during reverse parking, it could provide the learner with further information regarding the limit of lateral distance moved during parking. Besides developing the abstract schemata, errors could also improve analogous transfer from one situation to another if in the transfer situation similar errors and their solutions were retrieved. It is stated in [19] that errors are stored in memory along with reasons for the failure so that their retrieval is facilitated.

Adaptive transfer is applied to solve the non-analogous problems. Adaptive transfer involves using the existing knowledge base to generate a solution to a completely new problem [20]. Unlike analogous transfer, adaptive transfer not only requires an

individual to understand of the underlying structures of tasks, but also requires the individual to develop meta-cognitive skills which include recognition of the changes in situations, modifications of the solution strategy and evaluation regarding the effectiveness of the revised solution. To improve the meta-cognitive skills, learners need to be trained in active problem-solving rather than only in memorization or direct instruction. Therefore, errors from the training are good opportunities to improve meta-cognitive skills. Errors could help learners to recognize why the errors occurred and how they can be solved. In addition, learners need to solve new problems on their own during adaptive transfers.

There are two ways to teach using errors, namely error training and guided error training. In error training, learners are allowed to make errors and feedback is given on the mistakes they made. It is an effective method to improve active involvement of learners and increase their meta-cognitive skills. The disadvantage of error training is that the errors committed by trainees are different. Sometimes, trainees may not make an error which otherwise would be instructive. Therefore, there is a limitation to what can be learned from error training. In guided error training, examples of errors made by others are presented together with the solutions to overcome these errors. It not only provides systematically informational feedback (which means all the trainees receive the same feedback), but also offers abstract rules and underlying principles through analogous transfer in training. However, it is not a good way to improve meta-cognitive skills during the guided error training.

In order to explore the effectiveness of learning form error, [21] conducted two experiments to investigate the effects of error training and guided error training in a

driving simulation. In the first experiment, the authors compare the performance of two groups, the error training group and the errorless learning group (there is no error designed in the training). The result shows that error training group made significantly more improvement in analogous test than errorless learning group. Also, the error training group effectively applied their knowledge and created solutions in a new and different driving situation. In the second experiment, the performance of guided error training group and errorless learning group (there is no error made in the video) are compared. The results show that the performance of guided error training group is only marginally better than that of the errorless learning group in an analogous test. Also, there is no difference in an adaptive test between the two groups. It is concluded in this study that error training is more effective than guided error training and errorless training.

In my proposed study, I am going to use the method of error training rather than guided error training. The purpose of my study is to evaluate the relative effectiveness of different feedback methods during nursing training on the performance of nursing students. Through the training, I hope the participants can solve the problems to which they are exposed rather than learn by memorization. Therefore, in my experimental design, I am going to train nursing students under the practice scenarios which are embedded with errors in HPS. Feedback is provided for all the trainees. And finally the students are to be tested regarding their performance using simulation scenarios other than the one used in the training. Therefore, error training is applied in my study.

1.4 Eye Tracking Devices and Their Applications

An eye tracking device is used to measure eye position and eye movement. Eye tracking is a technique to measure an individual's eye movements so researchers know

where the person looks at any given time and the sequence in which the eye shifts from one location to another [23]. Eye tracking technology was first used in reading research over 100 years ago [22]. Eye movements provide an insight into mental focus, search strategies, problem solving and many other aspects of cognition. Therefore, there are a lot of applications of eye tracking devices in human factors, human interface design, and cognitive ergonomics. In these applications, an eye tracking system can be put into one of two categories according to the purposes: diagnostic and interactive [23]. In its diagnostic role, the eye tracking device provides objective and quantitative evidence of the user's visual and overt attention process. For example, in the study of visual inspection [24], an expert inspector's eye movements may exhibit a systematic pattern which can be used to train novice inspectors. In marketing research, an eye tracking device can be used to explore what advertisement design will attract most attention [25]. From an interactive perspective, the eye tracking device serves as an input device. An interactive system interacts with users based on the observed eye movements without the need of mouse or keyboard inputs. This can be a great advantage for disabled individuals.

Eye tracking devices are also widely used in medical safety. Benjamin Law used an eye tracker in a simulated laparoscopic training system to compare the eye pattern of experienced and novice laparoscopic surgeons [26]. Through analysis of the eye movement data from the two groups, it is apparent that experienced surgeons require less feedback (i.e., make fewer eye movements) than novice surgeons. Also, F. Jacob Seagull used an eye tracking device in a surgery room to find the eye movement patterns of surgeons during the time they look at the monitor display. This provides insights into how to design the displays [27].

In addition to the above-mentioned application of eye-tracking devices, Philip L. Henneman used eye trackers to study the most common errors during healthcare [28]. He found that providers (physicians) in an Emergency Department tend to ignore verification of patients' identities during computer entry of lab tests from a written sheet. This common error might lead to adverse outcomes in the follow up healthcare services. In this paper, the author studied whether patients' identification is given enough attention in clinical settings. An eye-tracking device is used to measure the frequency and accuracy of ID verification by medical providers during the computerized provider order entry (CPOE) process. It is observed that ID errors are frequently ignored and patients' IDs are inadequately verified during CPOE.

In this study [28], the eye-tracking device is used to show providers' eye movements. And the study is conducted in the emergency department (ED) with around 100,000 patients annually. Computerized provider order entry (CPOE) is commonly used by providers in the ED. In the experiment, the participants know the eye-tracking device is used to record their eye movements. However, they are not told the device is used to evaluate their attention on patients' identification. It is thus done so as to assess the real performance of the participants. Participants read the study description first. Then the eye-tracking device is placed on the participants' heads and calibrated. After that, participants were asked to review 10 charts (scenarios). The charts could be either handwritten patients' names and DOBs or patients' information labels, which include names, DOBs and medical record numbers (MRNs). These patients are in the Emergency Department. Participants need to select the patient from a computer list and order tests for each patient. Two of ten charts have embedded ID errors (the patient ID information on

the charts does not match that on the computer, for example, exactly same name but different dates of birth or medical record numbers. One of them has a potential error (the patient ID information can be exactly matched to the patient listed in computer; however, the last names are identical whereas the first names are close, e.g., Jim Smith on the chart and James Smith in the computer). Besides the eye tracking device, there is a person who observes the behaviors of the participants in the experiment. The recorded eye-tracking videos were reviewed by two other people independently after the experiment. These two people determined whether participants have focused their eye movements on specific items. A third reviewer combined the results from first two reviewers to resolve any difference if there exists. Following Joint Commission standards, the participants are expected to look at name, DOB and MRN before selecting a patient from the computer list. Also, the participants are expected to look at names, DOBs or MRNs before ordering test for the patients.

In this study [28], there are totally 25 participants in the experiment. Fourteen percent of the eye-tracking data is considered to be invalid and hence not used in the analysis. For the two error scenarios (a total of 25 × 2 patient error scenarios), only three participants detected the ID errors and stopped during the experiment (3/50). One could ask whether this was because the participants failed to look, or because they looked, but did not see. Video records of eye movements were not available for all participants. However, of the eight participants who verified patient ID on the screen as indicated by the eye movement record, only two of them caught the error. The other six missed the error. Thus, it is clear that very few participants look for patient ID and of those who looked, very few actually caught the error.

For the eight scenarios without ID errors, all the subjects selected the correct patient even though in one scenario two patients have the same last name and similar first name. None of the participants verified patient ID by looking at name and MRN before selecting the patients on the screen. Only 23% of the participants verified patient ID by looking at the name and one or both of DOB and MRN before ordering test.

As discussed in this paper, medical providers often make patient ID errors during CPOE. Also, from the eye tracker data, the author found, even though the participant has looked at the patient identifiers, they often fail to attend to the information, thereby making the same errors that they did even when they did not look at all at the relevant information. Computerized provider order entry (CPOE) is recommended by the Institute of Medicine to improve medical safety. However, in the meantime, CPOE also introduces opportunities for errors (such as failure of correct identification). Therefore, it is argued in the paper that there not only needs to be an improvement in the providers' training, but also there needs to be an improvement in the system and process so as to minimize the errors. The eye tracking device used in this study helps researchers understand the eye movements of providers when selecting a patient. More importantly, using eye-tracking devices, it is observed that even though providers may look at the patient identifying information, they still failed to identify the errors. This is a clear case where the provider looks but does not attend. Assuming that the same general problems arise for nurses as arise for doctors in a similar setting, the above study raises the importance of paying extra attention to patients' ID verification during nursing education.

These previous studies give us a good background regarding how to use eye-tracking devices in medical care study. Eye-tracking devices could help researcher to

further understand the eye-movements of participants, and, in particular, to see whether they performed ID identification [28]. This provides another way to infer the attention of the participant, a way which does not have the disadvantage of the subjectivity of traditional methods (observing the behaviors of participant through human eyes). However, in [28], it also shows that even though healthcare providers looked at the patients' IDs, they might still fail to identify the errors. Therefore, in my proposed studies, I need to design embedded errors in the experiment scenarios to help us find whether experiment participants really identify errors (rather than only look at the right position during experiment). Also, in [28], it is argued that failure of correct patient identification is a common error during clinical settings. Improving the accuracy of patient identification is one of the safety goals which reduce medical errors. Appropriate patient identifiers include the identification of full name, date of birth, and medical record number. It is important to confirm the identification of patient. Therefore, nursing training should be tuned so as to reduce this potential error. As a result, in my experiment, I have deliberately designed the scenarios in a way that emphasizes the role of patient identification. I have focused the criteria on the good practice during patient identification.

1.5 My Contribution in the Study

In the study of nursing student education, educators start to use human patient simulation (HPS) as an effective technique to teach nursing students and evaluate their performance. However, it is difficult to determine to what nursing students attend during the conduct of an experiment. Therefore, eye tracking provides objective data regarding subjects' visual interaction with the system. In my proposed study, I plan to use eye

tracking devices as a means to provide feedback to nursing students after their HPS. By comparing their own gaze focus and the expected practice, nursing students who receive feedback are expected to have a more effective education. Therefore, the contributions of my proposed study include:

- The application of eye tracking devices during a clinical exercise with a HPS to provide feedback in nursing education; and
- The experimental study of the effectiveness of feedback based on eye tracking results in nursing education.

In the following section of this paper, I am going to introduce my study in detail. The experimental design, data collection, data analysis and results are discussed in the following section.

CHAPTER 2

EXPERIMENT

2.1 Introduction

In this project, I will study the effectiveness of using an eye tracking device in nursing education to provide feedback to students about the errors that they made. Conventionally, in nursing education, oral instructions and personal feedback from the instructor are provided during practice to educate students about the correct best-practices for nurses. This kind of method depends considerably on instructors' personal experience and observations. Therefore, it is significantly subjective.

In my proposed study, eye tracking devices are used to monitor the eye movements of nursing students during their practice of various procedures. It is believed that eye movements can be related to the focus of mental attention. At the very least, I will know that if someone does not fixate a given piece of information or equipment, they did not attend to it. Therefore, I propose the application of eye tracking devices as an effective source of feedback in nursing education. Through eye tracking devices, the eye movements during practice can be recorded. This record can provide students with personalized feedback. Through this feedback, students can potentially learn where they should improve and what the best-practices are.

To evaluate the effectiveness of the application of eye tracking devices in nursing education, my study is performed on three groups of nursing students. In the first phase, all groups are tested in a simulated clinical scenario. This scenario evaluates nurses' performance during patient identification and patient monitoring. In the simulation, bad

practices or errors from nursing students will be observed and recorded by an instructor. Also, the eye movements are recorded using the eye tracking device. After the simulation, in the second phase, the first group gets instructors' feedback regarding their performance (the *evaluation only* group). It should be noted that this feedback is not given at the time the nurses are performing the simulation. But rather, the feedback is given in one setting after the simulation. The feedback is based on instructor's observations during the experiment. It can be based on the actions nursing students performed, (for example, head movements or attention focus), or messages nursing students deliver. It is not based on a review of the eye tracker record by the instructor. The second group is provided with a video of their eye movements during their first simulation (*eye tracker only* group). However, no instructors' feedback is given to the second group. The third group will be provided with both instructors' evaluations and their eye movement video (*combined* group). The information that the instructor provided is same as the feedback given in the evaluation only group. Finally, in the last phase, all the groups are tested once again in the simulated clinical settings. Their performance is observed and compared to determine their relative improvements. Based on these improvements, the best educational methods can be determined.

2.2 Study Hypothesis

Before the experiments, it was believed the following hypothesis would be observed. Specifically, it was hypothesized that the following would hold:

Hypothesis 1: The combined group would perform better than the other two groups.

The associated null hypothesis is that the combined groups' performance is no different from either the evaluation only or eye tracker only groups.

During the second phase of the experiment, both instructors' feedback and eye movement records are provided to the combined group. Therefore, it is believed that the students in this group can take the most advantage of the feedback. They can compare the best-practices (from the instructors' feedback) with their own behavior. Hence, they would be able to identify the right improvements on their own.

It was also hypothesized that the eye movement only feedback group would perform better than the instructor only feedback group. Specifically, it was hypothesized that the eye movement only group which gets feedback from the eye movement video would perform better than the instructor only feedback group that gets instructors' evaluation only. This hypothesis might be controversial. However, it is assumed that the students have some prior knowledge of the best-practices in clinical scenarios. The instructors' feedback only re-enforces their knowledge. However, the eye movement video can provide them with another perspective. From this perspective, the students have a more clear understanding of their own behavior during practice. And therefore, they should be able to identify their own wrong behavior in clinical settings. Again, this argument is controversial and needs to be further validated in our experiments.

2.3 Method

2.3.1 Participants

There are 47 subjects registered for the experiment. All of them are senior nursing students at the University of Massachusetts at Amherst. Therefore, it is believed that they have some previous knowledge regarding the best-practices in the emergency department.

These 47 students are randomly assigned to three groups. During the experiment, there were only 38 students that showed up. Besides that, seven students' eye movements were not successfully recorded by eye-tracker. Therefore, in the end there were 13 subjects in eye-tracker only group, 9 subjects in evaluation only group and 9 subjects in combined group.

It is worthwhile to mention again that the first group gets only instructors' feedback regarding their performance in the second phase of the experiment. To simplify our explanation, from here on, this group is called evaluation-only group. The second group is provided with the video of their eye movements. From here on, this group is called eye-tracker-only group. The third group will be provided with both instructors' evaluations and their eye movement video. Again from here on, this group is mentioned as combined group.

2.3.2 Experimental Environment:

Clinical simulation is used in this experiment. The clinical setting, which is called the simulation center, is equipped with both routine and emergency medicine supplies. In this simulation, a human patient model is included as part of the clinical setting. The patient model lies on the emergency bed as shown in Figure 1. A human actor sits behind a one way transparent window. In this setting, the human actor can clearly see the behavior of the test subjects, i.e., the nursing students. However, the test subjects can not see the human actor. The human actor made conversation with the test subjects in different roles, which include the patient, the doctor and even the secretary. In this experimental setting, the test subjects (nursing students) try to interact with the patient model lying on the bed. For example, the nursing students need to introduce themselves,

check the patient's name, birth date, and allergy history as well as confirm the medication order. The human actor, behind the window, answered all questions and carried on the conversation according to some specific guidelines and recommended response. In the experimental setting, medical errors were deliberately introduced. For example, the patient's name was misspelled on physician's order, but not on the patient's ID band.

2.3.3 Scenario Design:

In this study, four scenarios were designed. All these scenarios are based on real cases in the emergency department. In each scenario, potential errors and pitfalls are included so as to test the participants' responses. The embedded errors in each scenario are similar. They are mostly from the same medical error category, which is related to the patient identification. In the section below, I will describe each scenario in detail.

2.3.3.1 Scenario 1:

In this scenario, patient Michelle Green has an altered level of consciousness after falling off from her bicycle. She is waiting for a CT scan in the emergency department. In this case, the experimental participant (nursing student) comes into the emergency room. He/she is provided with the scenario information sheet as shown in Table 1.

The performance of the nursing students was evaluated according to the following criteria):

- Do the emergency room self-preparation (which includes washing hands);
- Introduce him/herself to the patient (which includes healthcare work's name and identification);
- Inquire about the patient's identification and medical history (which includes patient's name, date of birth, allergy history, etc.); and

- Double check the patient's identification and medical order (which includes checking patient's ID band, allergy band, patient's symptoms, doctor's prescription, etc.). For the instructor's feedback, given in the evaluation only group and the combined group, this procedure is evaluated by the instructor in real time based on nursing student's head movements.

In this experimental scenario, two potential pitfalls are introduced:

1. When patient was asked about his or her name, the patient answers "Mich" instead of Michelle Green. The experimental participant (nursing student) is supposed to identify this and double check the full name with the patient once again to obtain both the last name and first name as they appeared in the ID band.
2. When the CT department calls, the prepared treatment is different from the doctor's order (contrast CT versus non-contrast CT). The experimental participant (nursing student) is expected to notice this discrepancy and check with the doctor regarding the correct prescription.

2.3.3.2 Scenario 2:

Patient Janet Hernandez is in the emergency department with shortness of breath. Also, she has a bad headache and asks for some medicine. In Janet's medical history, it is shown that she has a history of asthma and migraines. Similar to scenario 1, the nursing student is provided with the scenario information sheet as shown in Table 2. Also, similar to scenario 1, the experimental participant is expected to perform self-preparation, self-introduction, patient inquiry and cross-checking of patient's medical history/prescription.

In this scenario, the following two pitfalls are deliberately embedded:

1. The date of birth on the ID band is different from the patient's answer. In this scenario, on the ID band it shows that the date of birth is 3/13/1957. However, when being asked, the patient answered 3/15/1957. The participant (nursing student) is expected to notice this discrepancy and double check the birthday with the patient.
2. The doctor's prescription is actually contraindicated by the patient's allergy history. The patient is known to be allergic to Ibuprofen. But the doctor has ordered it as a prescription. The experimental participant is expected to realize this discrepancy and notify the doctor.

2.3.3.3 Scenario 3:

In this scenario, patient Jennes Greene in the emergency department has a flank pain due to a motor vehicle accident. The participant (nursing student) is provided with the scenario information sheet which is shown in Table 3 before he/she comes into the emergency department. Similar to scenario 1, the participant is expected to check the identification of the patient and then take care of the patient. In this scenario, the embedded pitfalls are:

1. The patient name is spelled incorrectly on the MD order sheet, but spelled correctly on the patient ID band. The correct last name should be "Greene" rather than "Green" shown on the order sheet. The participant is expected to identify this misspelling and double check it with the patient.
2. The doctor's prescription is actually contraindicated by the patient's allergy history. Percodan is ordered to cure the moderate pain for the patient on the medication order sheet. Percodan contains aspirin. However, the patient's

medical history shows that she is allergic to aspirin. The experimental participant is expected to realize this discrepancy and notify the doctor.

2.3.3.4 Scenario 4:

In this scenario, patient Elizabeth Smith is a 101 year old lady. She is admitted from the local nursing home with acute onset confusion and fever. The participant (nursing student) is provided with the scenario information sheet which is shown in Table 4 before he/she comes into the emergency department. Similar to scenario 1, the participant is expected to provide necessary service to the patient. The embedded medical pitfalls are:

1. When asked about her name, the patient responds "Liz" instead of "Elizabeth". The experimental participant (nursing student) is supposed to identify this and double check the full name with the patient once again to obtain both the last name and first name as appeared in the ID band.
2. The doctor's prescription is actually contraindicated by the patient's allergy history. Amoxicillin is ordered on the medication order sheet. Amoxicillin contains Penicillin. However, the patient's medical history shows that she is allergic to Penicillin. The experimental participant is expected to realize this discrepancy and notify the doctor.

In all these four scenarios, the responses from the patient, the doctor and the CT department to the experimental participant's (nursing student's) questions are pre-designed. The recommended response guidelines for each scenario are summarized in Table 5 to Table 8 respectively.

2.4 Experimental Design and Procedure:

As described earlier, this entire experiment is divided into three phases, namely pre-training (with pretest), feedback and post-training (with posttest) phases. In the following subsection, I am going to introduce the experimental procedure in each individual phase.

First Phase (pre-training phase):

The purpose of the pre-training phase is to evaluate the relative performance of all the experimental participants (nursing students). Since all the participants are randomly selected and assigned to the three groups (evaluation only, eye tracker only, combined), we expect all the groups are going to perform relatively the same on the pre-training phase evaluation.

In this phase, first, a videotaped instruction regarding this experiment is given to the experimental subjects to watch. In this video, the whole experimental procedure is introduced to the nursing students. Then, the experimental subject is given a report regarding the patient information. The patient information for the four scenarios is shown in Table 1 to Table 4. Before the experiment, the eye tracking device is calibrated for the experimental subject. The eye tracking device is used to identify where the experimental subject's eyes are looking during the simulation. After all these setups, one experimental simulation is randomly selected from the four scenarios described in section 5.5.3. The experimental subject is required to perform all the duties necessary to complete the emergency room procedures in the designed scenario. The performance of the experimental subjects is evaluated based on how many errors (which are deliberately

introduced) he/she has identified and how many best-practices he/she has followed. This serves as the pretest.

Second Phase (feedback phase):

This phase is designed so as to provide feedback and education to the participating nursing students. Though all the participating students have some previous knowledge regarding the medical procedures in an emergency department, it should be noted that a lot of the best practices are easily ignored. Therefore, the feedback phase provides an educational opportunity to re-enforce the knowledge and experience regarding the correct procedures in an emergency department.

To compare the effectiveness of different feedback methods, each group is given different feedback:

1. Eye tracker only Group. After the first phase, the experimental subjects are provided with the eye-tracker video after four days. We can not provide the eye tracker video immediately after simulation because it takes some time to calibrate the video afterwards. Also, experiment participants are not on campus every day. Therefore, four days after the experiment is the earliest time that the eye-tracker videos can be distributed. The video shows the location and movement of their eyes during the first phase experiment. This is shown in Figure 2. The individuals in this group are required to watch the video before coming back for the third phase. They are given no indication of whether they looked in the correct places or not.

2. Evaluation only group. In this group, a check sheet was pre-developed for the experiment. (We will explain the check sheet in more detail in the following

section regarding dependent variables.) The experimental subjects are given a verbal evaluation regarding their behaviors based on the check sheet during the experiment. In the written evaluation, all the mistakes they have made are identified and summarized according to the check sheet. Also, the expected behavior is explained.

3. Combined group. In this group, all the subjects are provided with both the verbal evaluation immediately and the eye tracker video after four days. And participants can learn the assessments regarding their performance and watch the video by themselves. Therefore, they can relate their eye-movements in the video with the verbal evaluation from the instructors.

Third phase: (post-training phase)

The purpose of the third phase is to compare the effectiveness of the three different feedback methods. After the feedback phase (a week after first phase), all the subjects participate in another evaluation. The experimental settings are exactly the same as in the first phase. However, the experimental scenarios are chosen to be different from the ones in the first phase. In the combined group, six participants were given Scenario 1 in the pre-test and Scenario 4 in the post-test, four participants were given Scenario 2 in the pre-test and Scenario 3 in the post-test. In the eye-tracker only group, nine participants were given scenario 1 in the pre-test and Scenario 4 in the post-test, four participants were given scenario 2 in the pre-test and Scenario 3 in the post-test. In the evaluation only group, seven participants were given scenario 1 in the pre-test and scenario 4 in the post-test, two participants were given scenario 2 in the pre-test and scenario 3 in the post-test. It should be noted that same skills are tested in all these

scenarios. Therefore, all the scenario are designed to be equivalent. And through the experiment, the effectiveness of analogous transfer by using error training is tested. It is thus designed so as to test how much the subjects have learned and how much they can derive from their learning through the feedback in the second phase. In this experiment, the number of best-practices, which the experimental subjects have observed, will be recorded. This data will be compared with the result from the first phase experiment (pre-training) so as to evaluate the relative improvements.

Normally in experimental design, counter-balancing is frequently used so as to minimize systematic error due to the difference in experiment design. For example, it is preferred that in pre-tests, half of the subjects take experiment A and the other half take experiment B. Then after training, in the post-test, the two groups switch the test they take. Through this counter-balancing technique, the impact on results due to the difference (such as content and difficulty level) in experiment A and B can be minimized. However, in my study, it is not feasible to apply counter-balancing technique. In my experiment, the subjects are nursing student from same class. Most of them know each other. If the counterbalance technique is applied, after the pre-test, students might share their feedback and evaluations. Then, in the post-test, if two groups exchange their test scenario, it is very likely they are well familiar with the exact test scenario and even the exact embedded errors being tested. Therefore, counter-balancing techniques are not implemented in my experiment. Instead, the test scenarios are designed to be equivalent to each other (meaning they test the same skills). This can help to balance the test and eliminate the impact due to difference in the test scenario.

2.5 Dependent Variables

The evaluation criteria for each experimental group include six major best-practices in the emergency department. They are:

1. Wash hands immediately after entering the emergency department;
2. Introduce one's self to the patient in detail [Experimental participants (nursing students) are required to introduce their first names, last names and roles to the patient];
3. Check patient's name and ID band (Experimental participants are required to check the ID band and ask the patient to state his/her name so as to compare the stated name with the name on the ID band);
4. Check date of birth (Experimental participants are required to ask the patient to state his/her date of birth and compare it with the date recorded on the ID band);
5. Check the patient allergy history (Experimental participants are required to check the allergy band and ask the patient if he/she has any allergy history so as to compare it with the record);
6. Check the medication order. And determine whether there is any potential error in the prescription. If no, then the experimental participant will administer the medication. Otherwise, the experimental participant is required to double check the prescription with the doctor.

Based on these evaluation criteria, a detailed evaluation sheet was designed. It is shown in Table 9: Evaluation Sheet. The content of Table 9 includes all the criteria stated above. More importantly, in the safety category of Table 9, the focus has been given to

whether the potential pitfalls (which are deliberately introduced in the scenario as stated in the scenario design session) have been identified and correctly treated. Therefore, the measurements based on Table 1 consider both the best-practices in emergency departments as well as the success in avoiding medical errors.

There are a total of 18 criteria in Table 9. Based on these 18 criteria, the number of mistakes each student made in the experiment is recorded. After the evaluation, the mistakes according to all the 18 criteria are added up to obtain an overall performance measure. It is shown in Table 10: # of mistakes in eye tracker only group (Pre-test)-Table 18: # of mistakes summary by group. This number is used as a measurement for the participants (nursing students). In our experiment, the number of mistakes during the pre-training evaluations is compared with this number during the post-training evaluations so as to determine the effectiveness of three different training/feedback methods. The detail of this analysis is discussed in the next section.

2.6 Analysis and Results

In the scenario part, it is assumed there is no difference in Scenario1 and Scenario2. Also, there is no difference in Scenario 3 and Scenario 4. In order to test whether the assumption is valid, students' performance on Scenario 1 and Scenario 2 is cross–compared in the pre-test. And students' performance on Scenario 3 and Scenario 4 is cross-compared in the post-test. In the pre-test, the average mistake made is 4 in Scenario1 and 3.4 in Scenario 2. ANOVA analysis is used here (Table 16 ANOVA: Scenario1 v.s. Scenario 3). And P-value of 0.49 is obtained, which shows that the difference between Scenario 1 and Scenario 2 is not statistically significant. In the post-

test, the average mistake made is 2.0 in Scenario 3 and 2.4 in Scenario 4. And a P-value of 0.65 (Table 17 ANOVA: Scenario2 v.s. Scenario 4) is obtained which shows that the difference between Scenario 3 and Scenario 4 is not significant.

Also, within the 18 criteria, there are 16 criteria, which are rule based behavior (ie. check ID band, check allergy band and etc.). The other 2 criteria which are related to embedded errors can be considered as knowledge based error. For the rule based criteria, the average number of mistakes, made in the experiment, decreased 1.9 in the eye tracker only group, 1.2 in the evaluation only group and 2 in the combined group. For the knowledge based criteria, there is no improvement after training among three groups. Therefore, it is observed that this training is helpful to improve the performance due to rule based errors, but not due to knowledge based errors.

In the next analysis, the relative improvements of each group are evaluated. For each group, the number of mistakes made during the first phase (pre-training) is compared with the number of mistakes made during the third phase (post-training). Table 18: # of mistakes summary by group shows the number of mistakes each subject made during pre-test and post-test together with the difference between them. From Table 18: # of mistakes summary by group, it can be observed that, in the evaluation only group, the average number of mistakes is 3 (17% of the total number of evaluated criteria) in the pre-test, and 1.78 (10%) in post-test. It shows that the average number of mistakes made by one experiment subject decreased by 1.22 (7%) when he/she is provided with verbal evaluations as feedback. In the eye tracker only group, the average number of mistakes is 4 (22%) in pre-test, and 2.38 (13%) in post-test. It shows that the number of mistakes decreased by 1.62 (9%) per subject after watching the eye tracker video as feedback. And

in the combined group, the average number of mistakes is 4.33 (24%) in pre-test, and 2. (13%) in post-test. It shows that the number of mistakes is reduced by 2 (11%) per subject after experimental subjects are given both verbal evaluations and eye tracker video as feedback. In addition, here, a paired T-test is used for each group to determine whether the change differs significantly from zero. Table 19: T-test (Eye tracker only), Table 20: T-test (Evaluation only) and Table 21: T-test (Combined) summarize the T-test comparisons between the pre-training and post-training results for evaluation only group, eye-tracker group and combined group, correspondingly. In all the three T-tests, the null-hypotheses is that the student performs the same in the pre-training test as in the post-training test. And our experimental data shows that, in eye tracker only group, P-value is 0.01; in combined only group, p-value is 0.045; and in evaluation only group, P-value is 0.068. Therefore, our experiment data supports the observation that eye tracker only group and combined group improve significantly in the post- training evaluation. However, the difference in evaluation only group is not significant.

Then, cross group comparisons of improvement after training (the difference between post-test and pre-test) are conducted here. One-way ANOVA is used to compare the average number of delta (difference in number of mistakes made) in the three groups (evaluation only; eye-tracker and combined). The null hypothesis is constructed as H_0: $\mu 1=\mu 2=\mu 3$ (the improvement are equal), which essentially implies that the three feedback strategies are identically effective. Table 22 ANOVA Analysis (include outlier) among three groupsshows the result of ANOVA analysis. The P-Value is 0.8 which indicates there is no statistically significant difference among three groups.

It should be noted that, here, due to the limitation of the number of experimental subjects, it may happen that the overall results are significantly affected by the unusual performance of only a few subjects. It is not expected that all the subjects have treated the training and experiment seriously. Therefore, it is found that, after training, although the overall performance in the test improves significantly, there are some individual cases in which the experimental subjects made considerably more mistakes in the post-training test than in the pre-training test. For example, one subject followed the procedure very well in her pre-training test. However, in her post-training test, she forgot to introduce herself (she followed this procedure requirement in the pre-training test.). This may be due to her nervousness or some random behavior we cannot control in the experiment.

Hence, in my analysis, in order to better analyze the cross-group performance comparison, I have further applied data filtering techniques and excluded the outliers from both the top and bottom tails of the dataset (i.e., those participants whose performance change the most between posttest and pretest. Either their performance improvement is too significant or the degradation is too significant), assuming in these cases, experimental subjects did not undertake the experiment with due seriousness, which unnecessarily skewed the performance difference between pre-training and post-training tests. It should be noted that given a large dataset, this treatment would be unnecessary. However, in our experiment study, we can only afford to recruit 40 subjects. Therefore, the application of proper data filtering technique becomes important.

Excluding the outliers from the result data, the ANOVA test is applied once again. The result of one-way ANOVA test is summarized in table 23. The P value is calculated as 0.072, which indicates the null hypothesis may not be true. This observation implies

that there is difference among the feedback methods we applied during training. It should be noted that, in ANOVA test, the p value indicates the probability that the hypothesis might be true. For example, p=0.1 means that if the null hypothesis is true, the result would be expected to occur, probabilistically 1 times out of 10 samples. Normally, the null hypothesis is rejected when p value is less than 0.05. In this case, it shows strong evidence against the null hypothesis. There are also some case that null hypothesis can be rejected when p value is less than 0.1. However the evidence is not as convincing as p value set at 0.05. In my ANOVA test, the P-value is 0.072 (Alpha=0.1), which is bigger than 0.05 but smaller than 0.1.

Figure 3: Mean Plots by group shows the mean plots regarding the occurrence difference of mistakes between pre-training test and post-training test (outliers are not included in this figure). From Figure 3: Mean Plots by group, it is visually intuitive to conclude that the combined group performs significantly better than either evaluation only group or eye tracker only group. To support this hypothesis, now post hoc comparisons are performed for any two groups. Table 24 summarizes the results. It can be concluded that, statistically, the combined group has received a more effective feedback during training than evaluation only group or eye tracker only group. However, the relative difference between the evaluation only and eye tracker group does not show a significant difference.

Therefore, it can be concluded that the application of eye-tracker devices is an effective supplement to the current nursing education. It is observed in our experiment that combining the eye-tracking videos with the instructor evaluations provides more effective feedbacks to nursing students and hence improves their performances. Also, by

using eye-tracker device as the only instructional feedbacks, considerable performance improvement is observed for nursing students.

2.7 Discussion

The purpose of this research is to explore whether an eye tracker would be a potential training device which could help nursing students avoid medical errors. Compared to the conventional methods which were widely applied in the nursing education, such as HPS (human patient simulation and evaluation), the application of eye trackers should be evaluated from two perspectives. One is its relatively convenient operation compared with the existing methods. Another is its effectiveness compared to other methods. In my above experiment, I tried to answer both of these two questions.

2.7.1 Application of Eye tracking device

Eye tracking devices are widely used in driving safety, human interface design, and cognitive ergonomics. The application reported above is the first time that an eye tracker was used in the training of nurses. Here, nursing education provides unique challenges to eye tracker applications.

For example, the way that nurses take care of patients is inherently a dynamic process in which the nurse is moving physically himself or herself from one location to the next. This is not true of driving, reading or many of the other tasks undertaken by individuals who remain more or less stable with respect to a given environment. Nurses will not stay at a specific position in the emergency room. They are always walking around the room, observing the monitor, checking a patient's ID and allergy band,

looking at MD's prescription, and taking care of patients. That causes a little bit of a challenge for eye trackers that are used in nursing education.

Also, eye trackers have some other limitations. For example, an eye tracker is not easy to calibrate for the subjects who have light colored eyes or wear eye glasses (which, in turn, requires that goggles be worn over the eye glasses).

In this next section, I have tried to summarize both the procedures I applied when using the eye tracker in nursing education and my findings from the experiment.

Prior to the eye tracker being used on a subject, it is calibrated. The purpose of this initial setup calibration is to adjust the position of the image and align the eyes so as to focus on the pupil and spots. (This is a very important step which will determine whether the calibration is successful or not.) This process may fail in the following scenario:

1) Subjects have lightly colored irises;

2) Subjects move the goggles during the simulation exercise and their eyes are not exactly focused on the screen after moving; and

3) The object that subjects look at is not within the scene of the camera (because the camera moves with subject's head rather than his or her eyes);

After the video is recorded, there is another calibration process on the computer. The purpose of this process is to make visible the crosshairs indicating the eye fixation point on the screen. After this calibration, we know what the subject is looking at exactly. The success of this process depends on the initial set up calibration. Most of the time we don't know whether it's successful or not in the initial setup calibration. Therefore, we need to check it in the computer when the calibration is properly done.

In our experiments, I find that 20% of the subjects failed the calibration. The major reason for failures in this specific experiment is due to the movement of the subjects. When we use an eye-tracker for nursing students it's impossible for them to keep the same posture all the time. Also, it's challenging to predict how subjects would move their heads and eyes during the experiments. As a result, pre-compensation techniques cannot be applied during the calibrations. Therefore, sometimes we lost the eye tracking crosshairs in the screen due to the scope limitation of the camera.

As a result, for an eye tracker to be applied in nursing education, students should be carefully trained to use eye tracker devices. This training should include the following items:

1. Encouraging particiapnts to avoid abrupt head movements so as to minimize the chance eye tracker lost its calibration;
2. Encouraging participants to move their head rather than move their eyes only when deploying attention to some items;
3. Encouraging participants to avoid touching or moving the eye tracker goggles even if it might feel uncomfortable; and
4. Encouraging participants, if possible, to wear contact lens instead of glasses.

2.7.2 Effectiveness of eye tracking device in nursing students training

From the above experiment and analysis, it is found that eye tracker only group and combined group are performing better after training. Also among the three groups, it is observed that the performance of combined group improves more than eye tracker only

group after training. From this observation, it can be concluded that eye tracker helps nursing students to follow the best practice and prevent medical errors in the emergency room effectively.

In addition, in my experiment, the performance of the eye tracker only group is not improved as significantly as the combined group. This observation may be due to the process which was used to provide the eye tracking video to students. In this experiment, the eye tracking video is provided to subjects without any instruction and pre-editing. Therefore, it's hard to know whether all the subjects watching the eye tracking video took it seriously before conducting post-training (or even knew that for which they should be looking). Also, without instruction or video pre-editing, subjects may not catch all the details on which they need to focus. But rather, they might get lost during watching the long and not exciting video. This reduces the effectiveness of eye tracking videos which could help them to understand their eye movements and where they can improve.

Therefore, it can be concluded that the application of eye tracking devices is a good supplement in current nursing education. It is shown from my experiment and analysis that combining eye tracking devices into the current human instruction based education can significantly improve the quality of nursing education.

CHAPTER 3

CONCLUSION

This study evaluates the application of an eye tracking device in nursing education. An experiment is designed to test the effectiveness of the eye tracking device used as tool for providing instructional feedback in error identification and recovery by nursing students undertaking tasks in simulated clinical setting. This experiment is performed on three groups of nursing students. In the first phase, all groups are tested in a simulated clinical scenario and their eye movements are recorded using an eye tracking device. In the second phase, the evaluation only group (control group) gets instructors' feedback regarding their performance without referring back to the eye tracker record. The eye tracker only group (experimental group A) is provided with a video of their eye movements during their first simulated exercise, but receives no feedback from the instructors. The combined group (experimental group B) is provided with both instructors' evaluations and their eye movement video. Finally, in the last phase, all the groups are tested once again in the simulated clinical settings. Their performance is observed and compared to determine their relative improvements.

From the experiment, it is concluded that the application of eye tracking devices is a good supplement in current nursing education. It is shown from the experiment and analysis that combining eye tracking devices into the current human instruction based education can significantly improve the quality of nursing education. Also, methods, regarding improving the efficiency of eye tracking devices in nursing education, are discussed.

TABLES

Table 1: Information Report for Scenario 1:

Patient Name: Michelle Green

Diagnosis: Altered LOC s/p bicycle accident

Medical Record Number#: 5556782

D.O.B.: 12.14.82

Gender: Female

Primary MD Name: Martinez, Maxine R.

Past Medical History: Appendectomy 4/04/04

Report Information: Ms. Green is a 24 year old female admitted with an altered level of consciousness after falling off her bicycle. She has no known allergies and a past medical history of appendectomy 3 years ago. She is waiting to go to CT scan and is very anxious. She rates her pain (headache) as a 2/10. She is also nauseated. All ordered labs have been sent. She is awake and oriented times three.

Her vital signs on admission are: Temp 98.6 degrees F **P** 100 **RR** 24 **BP** 110/78

Table 2: Information Report for Scenario 2

Patient Name: Janet Hernandez

Diagnosis: SOB

Medical Record Number#: 2020004

D.O.B.: 3.13.57

Gender: Female

Primary MD Name: Kelly, Patrick M.

Past Medical History: Asthma, Migraines

Report Information: Mrs. Hernandez is a 50 year old female admitted with shortness of breath. Her past medical history is significant for asthma and migraines. Mrs. Hernandez is reporting shortness of breath of 5 on a 1-10 scale after receiving her first albuterol treatment. She is also very anxious and has a bad headache. The ED physician has said he wants her to receive prednisone ASAP. All ordered labs have been sent.

Vital signs on admission: Temp: 98.6 OF **P** 110 **RR** 24 **BP** 110/60 She has expiratory wheezes bilaterally

Table 3: Information Report for scenario 3

Patient Name: Jennes Greene

Diagnosis: s/p MVA with flank pain

Medical Record Number#: 7765676

D.O.B.: 01.04.78

Gender: Female

Primary MD Name: Asselin, Maureen W.

Past Medical History: Tonsillectomy 1986

Report Information: Ms. Greene is a 28 year old female admitted with flank pain following a motor vehicle accident. Her past medical history includes a tonsillectomy in 1986. She is allergic to aspirin. Ms. Green is reporting pain at a scale of 6 on a 1 to 10 scale. All ordered labs have been sent.

Vital signs on admission: **Temp**: 98. 2 F **P** 96 **RR** 20 **BP** 90/50

Table 4: Information Report for Scenario 4

Patient Name: Elizabeth Smith

Diagnosis: Acute onset of confusion and fever

Medical Record Number#: 2636636

D.O.B.: 03.07.1906

Gender: Female

Primary MD Name: Spark, Frank D.

Past Medical History: CHF, Afib, s/p MI, Type 2 DM

Report Information: Mrs. Smith is a one 101 year old female admitted from the local nursing home with acute onset confusion and fever. Her past medical history is significant for CHF, atrial fibrillation, and Type 2 diabetes. She is status post an AMI 2 months ago and is allergic to penicillin. Her medications in the nursing home include: digoxin, lasix, potassium and coumadin. The ED physician would like her to receive her first dose of antibiotic STAT. She also has Tylenol ordered for fever. All ordered labs have been sent.

Vital signs on admission are: **Temp** 101.5 F **P** 84 **RR** 24 **BP** 85/50 She has decreased breath sounds bilaterally.

Table 5: Anticipated Response in Scenario 1

role	***Patient***	***MD***	***CT secretary***
Response	Patient's Name: Michelle Green DOB: 12.14.82 Allergies: NKA 1. "My name is Mich Green" 2. "I hate emergency rooms" 3. "I feel so sick to my stomach" 4. "I think I'm going to be sick to my stomach"	"CT with no contrast"	"Please give CT contrast now- we will be taking the patient in one hour."
Supplement:	Demeanor of Voice: Anxious	If nurse calls to question CT order	call

Table 6: Anticipated Response in Scenario 2

role	***Patient***	***MD***
Response	Name: Jennifer Hernandez DOB: 3.15.57 Allergies: Bees, Plums and Ibuprofen 1. "My breathing is feeling better" 2." I'm just so nervous" 3. "I have a bad headache- it's my usual migraine (6/10)" 4. "Can I get something for my headache?" 5. If asked about allergies says "I'm allergic to motrin" 6. If asked response to motrin say "I just don't feel good"	"She can have ibuprofen 600 mg PO every 6 hours as needed for headache"
Supplement	Demeanor of Voice: Anxious has headache	if Nurse calls MD during the scenario

Table 7: Anticipated Response in Scenario 3

role	***Patient***	***MD***
Response	Patient's Name: Jennes Greene DOB: 01.04.78 Allergies: Aspirin 1. "My leg hurts (6/10)" 2. "Can I get something for pain?"	MD if called about wrong name spelling and or/Percodan: 1. "Oh- I'll redo orders. I misspelled the name. It is Jennes Greene I meant the orders for." **2.** "Thanks for picking that up-I'll change the order"
Supplement	Demeanor of Voice: Patient in pain	if Nurse calls MD during the scenario

Table 8: Anticipated Response in Scenario 4

role	*Patient*	*MD*
	Patient's Name: Elizabeth Smith DOB: 03.07.1906 Allergies: Penicillin 1. "Where am I?" 2. "My name is "Liz Smith" 3. "I'm a hundred years old 4. "Not so good " (How are you?) 5. "Are they going to give me something for (the) fever? " (If the nurse mentions the high temp.) 6."I came from the nursing home" (if asked where they were before this)	"Thanks for picking that up- I'll change the order in the computer."
Supplement	Demeanor of Voice: Confused	if calls about allergy and to change order on Amoxicillin

Table 9: Evaluation Sheet

	Nursing Simulation Observation
1	Washes hands on entering room
	Introduction
2	Introduces self with first name
3	Introduces self with last name
4	Introduces self as student nurse or nurse caring for the patient
	Patient Name and ID
5	Checks for presence of ID band
6	Asks patient to state name
7	Compares patient stated name with name on ID band
	Date of Birth and ID
8	Ask patient to state date of birth
9	Compares patient date of birth with date on ID band
	Allergy
10	Checks for presence of allergy band
11	Asks patient if he/she has any allergies
12	Compares stated allergies to allergy bracelet
	Safety
13	Stops process when discrepancy between stated Name and ID band data is recognized
14	Stops process when discrepancy between stated date of birth and ID band data is recognized
15	Stops process when discrepancy between stated allergy and allergy band data is recognized
	Medication
16	Check medication order
17	Questions order and holds medication due to allergies
18	Administer medication

Table 10: # of mistakes in eye tracker only group (Pre-test)

Eye tracker only	***Pretest***												
Subjects #	2	3	5	7	11	17	23	24	28	35	38	47	10
Nursing Simulation Observation													
1. Washes hands on entering room					1		1	1		1		1	
Introduction													
2. Introduces self with first name									1	1			
3. Introduces self with last name	1	1	1		1	1	1	1	1	1		1	
4. Introduces self as student nurse or nurse caring for the patient	1							1	1	1			
Pt Name and ID													
5. Checks for presence of ID band													
6. Asks patient to state name												1	
7. Compares patient stated name with name on ID band	1			1								1	
Date of Birth and ID													
8. Ask patient to state date of birth												1	1
9. Compares patient date of birth with date on ID band												1	1
Allergy													
10. Checks for presence of allergy band	1	1	1	1			1	1					1
11. Asks patient if he/she has any allergies				1	1	1		1					
12. Compares stated allergies to allergy bracelet							1	1			1	1	
Safety													
13. Stops process when discrepency between stated Name and ID band data is recognized		1	1			1						1	
14. Stops process when discrepency between stated date of birth and ID band data is recognized													
15. Stops process when discrepency between stated allergy and allergy band data is recognized													
Medication													
16. check medication orders													
17. Questions order and holds medication due to allergies(CT Contrast)				1	1	1					1		
18. administer													
SUM	***4***	***3***	***3***	***4***	***4***	***4***	***4***	***6***	***3***	***4***	***2***	***8***	***3***

Table 11: # of mistakes in eye tracker only group (Post-test)

Eye tracker only	***Posttest***												
Subjects #	2	3	5	7	11	17	23	24	28	35	38	47	10
Nursing Simulation Observation													
1. Washes hands on entering room				1									
Introduction													
2. Introduces self with first name									1				
3. Introduces self with last name	1	1	1		1	1	1	1	1	1			
4. Introduces self as student nurse or nurse caring for the patient					1				1				
Pt Name and ID													
5. Checks for presence of ID band													
6. Asks patient to state name													
7. Compares patient stated name with name on ID band													
Date of Birth and ID													
8. Ask patient to state date of birth													1
9. Compares patient date of birth with date on ID band													1
Allergy													
10. Checks for presence of allergy band											1		
11. Asks patient if he/she has any allergies											1		
12. Compares stated allergies to allergy bracelet		1									1		
Safety													
13. Stops process when discrepency between stated Name and ID band data is recognized				1	1		1	1	1		1	1	
14. Stops process when discrepency between stated date of birth and ID band data is recognized													
15. Stops process when discrepency between stated allergy and allergy band data is recognized													
Medication													
16. check medication orders													
17. Questions order and holds medication due to allergies(CT Contrast)				1				1	1		1	1	
18. administer													

Table 12: # of mistakes in evaluation only group (Pre-test)

Evaluation only	***pretest***								
Subjects #	4	15	16	18	20	30	45	48	40
Nursing Simulation Observation									
1. Washes hands on entering room				1					
Introduction									
2. Introduces self with first name								1	
3. Introduces self with last name	1			1				1	
4. Introduces self as student nurse or nurse caring for the patient								1	
Pt Name and ID									
5. Checks for presence of ID band				1					
6. Asks patient to state name				1					
7. Compares patient stated name with name on ID band	1			1					
Date of Birth and ID									
8. Ask patient to state date of birth				1					
9. Compares patient date of birth with date on ID band				1					
Allergy									
10. Checks for presence of allergy band	1					1			
11. Asks patient if he/she has any allergies	1		1						
12. Compares stated allergies to allergy bracelet						1			
Safety									
13. Stops process when discrepancy between stated Name and ID band data is recognized	1	1	1	1			1		
14. Stops process when discrepency between stated date of birth and ID band data is recognized						1			
15. Stops process when discrepency between stated allergy and allergy band data is recognized									
Medication									
16. check medication orders									
17. Questions order and holds medication due to allergies(CT Contrast)	1			1			1		1
18. administer									
SUM	***6***	***1***	***2***	***9***	***0***	***3***	***2***	***3***	***1***

Table 13: # of mistakes in evaluation only group (Post-test)

Evaluation only	***posttest***								
Subjects #	4	15	16	18	20	30	45	48	40
Nursing Simulation Observation									
1. Washes hands on entering room									
Introduction									
2. Introduces self with first name								1	
3. Introduces self with last name				1				1	
4. Introduces self as student nurse or nurse caring for the patient								1	
Pt Name and ID									
5. Checks for presence of ID band									
6. Asks patient to state name									
7. Compares patient stated name with name on ID band				1					
Date of Birth and ID									
8. Ask patient to state date of birth									
9. Compares patient date of birth with date on ID band									
Allergy									
10. Checks for presence of allergy band									
11. Asks patient if he/she has any allergies									
12. Compares stated allergies to allergy bracelet									
Safety									
13. Stops process when discrepency between stated Name and ID band data is recognized	1			1	1	1			
14. Stops process when discrepency between stated date of birth and ID band data is recognized									
15. Stops process when discrepency between stated allergy and allergy band data is recognized									
Medication									
16. check medication orders									
17. Questions order and holds medication due to allergies(CT Contrast)	1	1	1	1	1	1		1	
18. administer									
SUM	***2***	***1***	***1***	***4***	***2***	***2***	***0***	***4***	***0***

Table 14: # of mistakes in combined group (Pre-test)

Combined Group	***pretest***								
Subjects #	*1*	*6*	*12*	*19*	*21*	*25*	*29*	*41*	*43*
Nursing Simulation Observation									
1. Washes hands on entering room		1	1		1	1		1	
Introduction									
2. Introduces self with first name			1						
3. Introduces self with last name			1			1		1	1
4. Introduces self as student nurse or nurse caring for the patient			1						
Pt Name and ID									
5. Checks for presence of ID band				1					
6. Asks patient to state name	1								
7. Compares patient stated name with name on ID band	1			1					
Date of Birth and ID									
8. Ask patient to state date of birth								1	
9. Compares patient date of birth with date on ID band								1	
Allergy									
10. Checks for presence of allergy band		1	1	1			1	1	1
11. Asks patient if he/she has any allergies				1				1	1
12. Compares stated allergies to allergy bracelet				1			1	1	1
Safety									
13. Stops process when discrepency between stated Name and ID band data is recognized	1		1					1	1
14. Stops process when discrepency between stated date of birth and ID band data is recognized				1			1		
15. Stops process when discrepency between stated allergy and allergy band data is recognized									
Medication									
16. check medication orders									
17. Questions order and holds medication due to allergies(CT Contrast)				1		1			1
18. administer									
SUM	***3***	***2***	***6***	***7***	***1***	***3***	***3***	***8***	***6***

Table 15: # of mistakes in combined group (Post-test)

Combined Group					***posttest***				
Subjects #	*1*	*6*	*12*	*19*	*21*	*25*	*29*	*41*	*43*
Nursing Simulation Observation									
1. Washes hands on entering room					1				
Introduction									
2. Introduces self with first name		1							
3. Introduces self with last name		1	1		1			1	
4. Introduces self as student nurse or nurse caring for the patient		1							
Pt Name and ID									
5. Checks for presence of ID band									
6. Asks patient to state name									
7. Compares patient stated name with name on ID band									
Date of Birth and ID									
8. Ask patient to state date of birth								1	
9. Compares patient date of birth with date on ID band								1	
Allergy									
10. Checks for presence of allergy band								1	
11. Asks patient if he/she has any allergies								1	
12. Compares stated allergies to allergy bracelet								1	
Safety									
13. Stops process when discrepency between stated Name and ID band data is recognized				1	1		1		
14. Stops process when discrepency between stated date of birth and ID band data is recognized									
15. Stops process when discrepency between stated allergy and allergy band data is recognized									
Medication									
16. check medication orders									
17. Questions order and holds medication due to allergies(CT Contrast)		1		1	1	1	1	1	
18. administer									
SUM	***0***	***4***	***1***	***2***	***4***	***1***	***2***	***7***	***0***

Table 16 ANOVA: Scenario1 v.s. Scenario 3

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	21	84	4	5.4
Column 2	10	34	3.4	4.266667

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.43871	1	2.43871	0.483078	0.492563	4.182964
Within Groups	146.4	29	5.048276			
Total	148.8387	30				

Table 17 ANOVA: Scenario2 v.s. Scenario 4

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	21	44	2.095238	3.490476
Column 2	10	24	2.4	1.6

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.629186	1	0.629186	0.216678	0.645059	4.182964
Within Groups	84.20952	29	2.903777			
Total	84.83871	30				

Table 18: # of mistakes summary by group

Group	Subjects #	pretest(# of mistakes)	posttest (# of mistakes)	pretest-posttest
Eye Tracker only	2	4	1	3
	3	3	2	1
	5	3	1	2
	7	4	3	1
	11	4	3	1
	17	4	1	3
	23	4	2	2
	24	6	3	3
	28	3	5	-2
	35	4	1	3
	38	2	5	-3
	47	8	2	6
	10	3	2	1
	Average	***4.00***	***2.38***	***1.62***
Evaluation Only	4	6	2	4
	15	1	1	0
	16	2	1	1
	18	9	4	5
	20	0	2	-2
	30	3	2	1
	45	2	0	2
	48	3	4	-1
	40	1	0	1
	Average	***3.00***	***1.78***	***1.22***
Combined	21	1	4	-3
	6	2	4	-2
	29	3	2	1
	41	8	7	1
	25	3	1	2
	1	3	0	3
	12	6	1	5
	19	7	2	5
	43	6	0	6
	Average	***4.33***	***2.33***	***2.00***

Table 19: T-test (Eye tracker only)

	pre-test	***post-test***
Mean	4	2.384615
Variance	2.333333333	1.923077
Observations	13	13
	-	
Pearson Correlation	0.236038738	
Hypothesized Mean Difference	0	
df	12	
t Stat	2.540405191	
P(T<=t) one-tail	0.012959488	
t Critical one-tail	1.356217334	
P(T<=t) two-tail	0.025918976	
t Critical two-tail	1.782287548	

Table 20: T-test (Evaluation only)

	Pre-test	*Post-test*
Mean	3	1.777778
Variance	8	2.194444
Observations	9	9
Pearson Correlation	0.626501361	
Hypothesized Mean Difference	0	
df	8	
t Stat	1.648969716	
P(T<=t) one-tail	0.068882265	
t Critical one-tail	1.39681531	
P(T<=t) two-tail	0.13776453	
t Critical two-tail	1.859548033	

Table 21: T-test (Combined)

	pre-test	***post-test***
Mean	4.333333333	2.333333
Variance	6	5.25
Observations	9	9
Pearson Correlation	0.133630621	
Hypothesized Mean Difference	0	
df	8	
t Stat	1.921537846	
P(T<=t) one-tail	0.045449842	
t Critical one-tail	1.39681531	
P(T<=t) two-tail	0.090899684	
t Critical two-tail	1.859548033	

Table 22 ANOVA Analysis (include outlier) among three groups

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
eye tracker only	13	21	1.615385	5.25641
evaluation group	9	11	1.222222	4.944444
combined group	9	18	2	9.75

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.72236	2	1.36118	0.210998	0.811052	3.340386
Within Groups	180.6325	28	6.45116			
Total	183.3548	30				

Table 23 ANOVA Analysis (exclude outlier) among three groups

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
eye tracker only	8	18	2.25	0.785714
evaluation	5	5	1	0.5
combined	6	17	2.833333	3.366667

ANOVA
(Alpha=0.1)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9.45614	2	4.72807	3.108868	0.072337	2.668171
Within Groups	24.33333	16	1.520833			
Total	33.78947	18				

Table 24: Post Hoc Analysis

Tukey's Studentized Range (HSD) Test for #of mistake

Note: This test controls the Type I experimentwise error rate.

Alpha	0.1
Error Degrees of Freedom	17
Error Mean Square	1.513072
Critical Value of Studentized Range	3.11017

Comparisons significant at the 0.1 level are indicated by ***.				
group Comparison	Difference Between Means	Simultaneous 90% Confidence Limits		
combine VS eye tracker	0.9444	-0.4813	2.3702	
combine VS evaluation	1.8333	0.1953	3.4714	***
eye tracker VS combine	-0.9444	-2.3702	0.4813	
eye tracker VS evaluation	0.8889	-0.6200	2.3978	
evaluation VS combine	-1.8333	-3.4714	-0.1953	***
evaluation VS eye tracker	-0.8889	-2.3978	0.6200	

FIGURES

Figure 1: A patient model lying in the Emergency Department during HPS

Figure 2: Eye tracking video showing ID band being looked at.

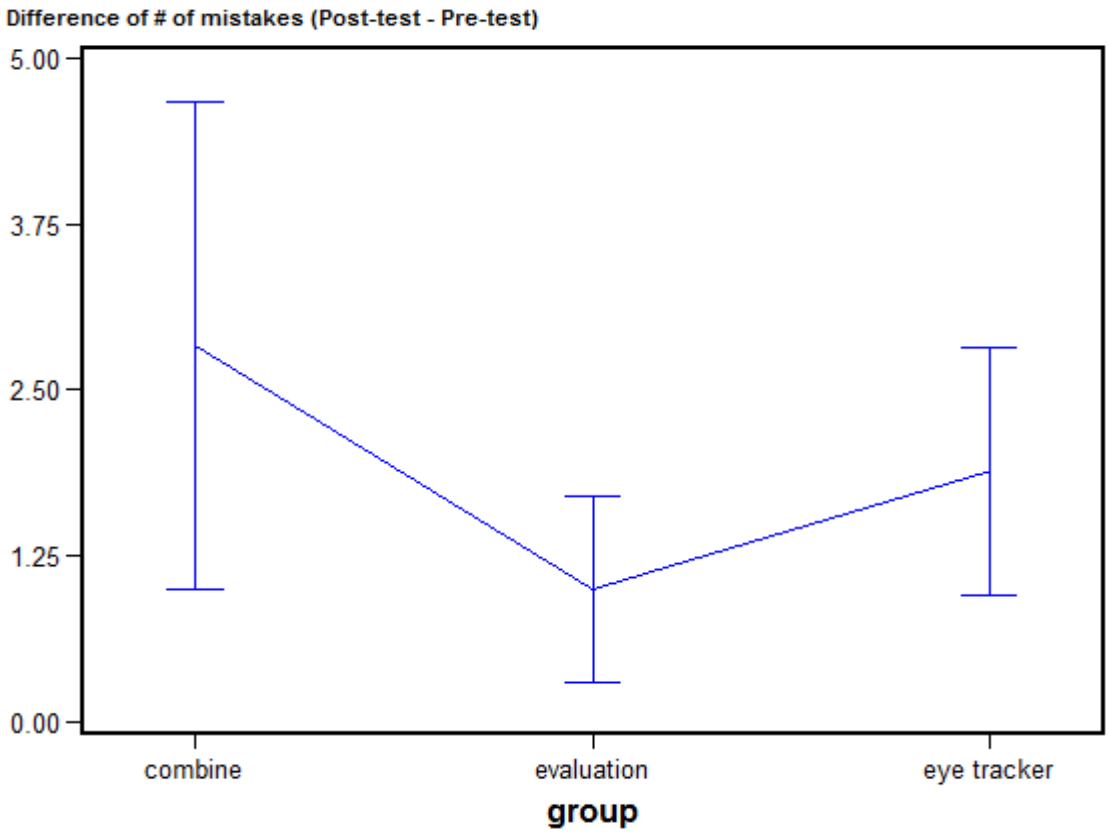

Figure 3: Mean Plots by group

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