2016

An Evaluation of Robotics in Nursing Homes to Reduce Adverse Drug Events

Ozell Ueal Jr.
Walden University

Walden University

College of Management and Technology

This is to certify that the doctoral dissertation by

Ozell Ueal

has been found to be complete and satisfactory in all respects,
and that any and all revisions required by
the review committee have been made.

Review Committee
Dr. Branford McAllister, Committee Chairperson,
Applied Management and Decision Sciences Faculty

Dr. Robert Kilmer, Committee Member,
Applied Management and Decision Sciences Faculty

Dr. Carol Wells, University Reviewer
Applied Management and Decision Sciences Faculty

Chief Academic Officer
Eric Riedel, Ph.D.

Walden University
2016

Abstract

An Evaluation of Robotics in Nursing Homes to Reduce Adverse Drug Events

by

Ozell Ueal Jr.

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

Applied Management and Decision Sciences

Walden University

November 2016

Abstract

Adverse drug events (ADE) cause many deaths annually in addition to affecting the quality of life of many others. The descriptive mixed methods approach, specifically exploratory case study and experimental design that guided this research utilized the survey and focus group methods to evaluate perceptions about robotic technology (RT) to reduce the rate of ADEs in U.S. nursing homes (NH). There is a lack of scholarly research into whether a conceptual approach rooted in RT can be implemented to assist with drug administrations in NHs. The purpose of this study was twofold. The first purpose was to evaluate the causes of ADEs specifically related to tablets, capsules, and pills. The second purpose was to evaluate the perceptions of nurses and administrators relative to the use of RT to assist in reducing ADEs. In the quantitative part, the sample means from 102 surveys from nurses and administrators were evaluated with the *t* test and the paired *t* test; while in the qualitative part, survey results, reported errors, and focus group data was assessed collectively. The research results did not indicate any new causes of ADEs and showed that the participants had a favorable perception of RT. Based on the results of this research, RT may be tailored in such a way that it can significantly reduce ADE occurrences for citizens in U.S. NHs.

An Evaluation of Robotics in Nursing Homes to Reduce Adverse Drug Events

by

Ozell Ueal Jr.

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

Applied Management and Decision Sciences

Walden University

November 2016

Acknowledgments

I am profoundly grateful for the superb guidance, insight, and patience from my mentor and committee chair Dr. Branford McAllister in making this dissertation a reality. I also want to express sincere gratitude to Dr. Robert Kilmer for his unwavering support, and to Dr. Carol Wells whose vast experience helped to shape the frame of this study. I am eternally grateful to my wife, Letrina Ueal, and my children (London, Michael, Kersten, and Joshua) who all graciously sacrificed during my time to complete this dissertation. I also give special thanks to my parents, Ozell and Florence Ueal Sr., my sister and brother, Kristy Callaway and Johnerson Ueal, and my friend and author Verkisserous T. Richey for their infinite encouragement to persist through the challenges. To my sister (Cynthia Ueal) who has gone on, thank you for your smiles from above.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction of the Study

According to Brandt and Zarowitz (2015), additional research is necessary to increase understanding of the complex problem of adverse drug events (ADEs) in nursing homes (NHs), especially since many health care systems overall are not optimally designed to prevent ADEs. In this regard, each NH participating in this research was evaluated regarding how solid drugs, specifically tablets, capsules, and pills, were administered in order to determine the causes of ADEs found in these NHs. Researchers in the current literature, examined in Chapter 2, identified the need for a new approach to substantially reduce ADEs due to the impact and longevity of this known problem throughout the medical community. In February 2012, Handler (2012) estimated that 93,000 NH residents in the U.S. will perish annually as a result of ADEs (p. 1). If 50% of these deaths can be prevented, 46,500 lives will be saved.

In this research, I investigated the utility of a noninvasive form of robotic technology (RT) for tackling the profound problem of ADEs in U.S. NHs. According to Van den Bemt, Jetske, Robertz, Kormelink, and Pels (2011), research related to the use of robotics-based innovations to reduce human-initiated ADEs in NHs does not exist.

It was appropriate then to evaluate the role that robotics-based innovations could serve in preventing thousands of deaths from the consequences of ADEs to determine if it could possibly become a viable option. Such a system may be able to overcome many of the reasons nurses fail to administer drugs consistently, adequately, and appropriately to

all NH residents. A robotic system tailored to assist with drug administrations may be able to curtail the overwhelming number of ADEs that occur annually in NHs.

A decrease in ADEs may lead to a decrease in death rates related to ADEs, thus extending human life and improving the quality of care given to thousands of NH residents. Also, the unfortunate hardships endured by many families of loved ones suffering from the difficulties of an ADE may be greatly diminished. A robotic system capable of assisting with drug administrations may be able to provide a medium that can offset errors in calculations, shortcomings in expert knowledge, and shortages of personnel qualified to administer drugs.

Chapter 1 includes a short review of current literature that describes what ADEs are and the negative impact they have on society. Despite advances in various technologies associated with reducing ADEs, scholarly literature on using RT to reduce ADEs in NHs is scarce. For that reason, I investigated how nurses and administrators felt about using RT for that possibility in addition to analyzing how ADEs occurred from several perspectives to answer three qualitative research questions and two quantitative research questions. Chapter 1 also contains a description of the parameters within which I conducted this research and why this research was important to society.

Background

Medication Errors in Nursing Homes

For several reasons, the number of Americans reaching the age of 65 or older is rising (Administration of Aging, 2014, p. 1). In 2013, this segment of the population represented 14.1% of the U.S. population and by 2040 the Administration of Aging

(2014) estimated that this number will grow to 21.7% (p. 1). As this segment of the population grows NHs will increase in their importance to society due to the need for specialized care (Harris-Kojetin, Sengupta, Park-Lee, & Valverde, 2013).

Many Americans will require the assistance of nurses with specialized skills that span all levels of care, including the administration of prescribed drugs, in order to sustain life. Although NHs are staffed with trained individuals, medication errors in these facilities are common and occur on a regular basis (Wittich, Burkle, & Lanier, 2014). In fact, Harris-Kojetin et al. (2013) claimed that NH residents are the most at-risk group that will suffer from medication errors.

Bates and Slight (2014) asserted that when these medication errors escalate to harm a patient or cause a patient to die, an ADE has occurred. Thus, Bates and Slight defined an ADE as an incident that causes unintended harm or death to a patient as a result of medications that were given. These events can occur at the preparation or administration stage of the medication-use process (Van den Bemt et al., 2011); the prescription or delivery stage of the medication-use process (Kiekkas, Karga, Lemonidou, Aretha, & Karanikolas, 2011); or the procuring, dispensing, or monitoring stage of the medication-use process (Bates & Slight, 2014). While the range is wide-spread across the medication-use process, Bates and Slight stated that many of these events are preventable mistakes regardless of the stage in which they occur.

Many researchers, whose work is summarized and analyzed in Chapter 2, have concluded that the causes of ADEs are numerous and occur during distribution, transcription, and administration, but more often during prescription and administration

according to Bates and Slight (2014). Researchers who aimed to improve upon distribution, transcription, and administrations have used information technology (IT) as a contributory tool to combat ADEs. Despite the widespread usage of IT in the medical industry (Sekhar, Tariq, Kim, Pridgeon, & Hannaford, 2013), the robotic sector of IT is not widely used in the NH industry (Borenstein, 2011).

In contrast to the lack of usage in NHs, Borenstein (2011) affirmed that robotic systems have been successful in dispensing medications in hospital pharmacies. Similar robotic systems have also been successful in delivering bulk medications to hospital wards, performing intricate surgical procedures, and providing precise telemedicine capabilities in intensive care units (Borenstein, 2011; Summerfield, Seagull, Vaidya, & Xiao, 2011).

Evaluation of ADEs in Nursing Homes

The medical industry has recognized that ADEs are common (Wittich et al., 2014) and cause a substantial financial burden in the U.S. (Harris-Kojetin et al., 2013). Nursing homes have also recognized the financial impact of ADEs (U.S. Department of Health and Human Services, 2014b) where, according to Harris-Kojetin et al. (2013), the financial burden placed on NHs is amplified by the fact that the elderly are at a greater risk of encountering an ADE. Barnett et al. (2011) claimed that this risk is magnified by the reality that many NH residents suffer from compound medical problems, which contributes to their limited physical capacity and inability to communicate symptoms. Collectively, these contributions could very easily increase their risk factor of ADEs,

especially since many NH residents are taking many drugs simultaneously (Campanelli, 2012).

In 2013, Aljadhey et al. (2013) found ADE incident rates at 8.5 per 100 admissions in an academic hospital in Riyadh, Saudi Arabia. Another study conducted by Weiss and Elixhauser (2013) reported ADE incident rates at approximately 75 per 10,000 for people aged 65 or older who had been discharged from U.S. hospitals across 32 states (p. 1). Also in the U.S., Sawarkar, Keohane, Maviglia, Gandhi, and Poon (2012) estimated that life-threatening ADEs occurred at a rate of 1.33 per 100 administrations in a single hospital (p. 5). Handler (2012) estimated that on average 2 million ADEs occur annually for all NHs in the U.S. and as a result of these errors an estimated 93,000 or 4.7% of NH residents die from related complications (p. 1). Aljadhey et al. reported in 2013 that death rates exceeded 105,000 people per year (p. 648).

With an increasing population people 65 years old or older (Administration of Aging, 2014, p. 1), these numbers will increase proportionately. Many more will perish, and an unknown number will suffer from the unfortunate incidents of ADEs. This is why there is world-wide concern over current percentages of ADE incident rates throughout the health care industry (Aljadhey et al., 2013).

These statistics indicate that previous and current methods, processes, and systems have not been able to overcome the significant problem of ADEs in NHs. While improvements have been made, the literature indicates that these improvements are based on extensions of existing methods, processes, and systems. Despite these improvements, the number of elderly persons affected is still overwhelming (Handler, 2012), indicating

the need for a new approach. Based on this indication, I examined the perceptions of NH professionals on the idea of using RT, one potential approach, to reduce ADEs at the administration stage.

Potential Use of Robotic Technology

In a few recent studies, several researchers examined the causes of ADEs in hospitals, pharmacies, and NHs. These researchers showed that a significant part of these errors can be directly linked to human error. Perhaps human error is one reason IT has become so instrumental in the medical industry (Kiekkas et al., 2011; Westbrook, Rob, Woods, & Parry, 2011). However, current drug administration systems may still lack the capacity to decrease ADEs to where occurrences can begin trending down. To improve upon this possibility, various disciplines of IT should be expanded in all stages of the medication-use process, particularly at the most vulnerable stages of prescribing and administrating (Bates & Slight, 2014). As one of many IT disciplines, RT should be considered in the quest to further reduce ADE numbers (Huston, 2013).

While many systems have been implemented to combat ADEs, the problem persists at an alarming rate (Handler, 2012). Perhaps RT should be considered to improve upon this alarming rate because of the astonishing successes of RT in other areas of the healthcare industry. Some of these successes may not have been possible otherwise (Herman, 2012). For example, Philip (2004) found that dispensing errors in hospitals within that study's sample population dropped by 67.1% when pharmacists used robotic dispensing systems (p. 282). Just 5 years later, Kirschling, Rough, and Ludwig (2009) found that the same kind of system was able to improve the delivery and dispensing of

medications from 67.7% to 95.6% in a different set of hospitals (p. 1754). In 2013, Francois et al. (2013) conducted a study in the University Hospitals in Geneva, Switzerland and found that pharmacists who used robotic dispensing systems were able to reduce manual error rates by 66% (p. 88).

With the rate of ADEs still unacceptably high (Aljadhey et al., 2013), it may be possible to emulate the fundamental use of stationary dispensing systems in hospitals in a different environment—mobile robotic systems in NHs—to assist nurses at the drug administration stage rather than at the dispensing stage. To this end, a different type of drug-assisting system may be necessary for long-term residents (in NHs) who typically have a consistent drug regimen for a long period of time as opposed to a typical short-term patient (in hospitals) whose drug regimen is brief, but could change frequently for various reasons (Bates & Slight, 2014). Despite many ground-breaking contributions resulting from RT, this technology has not been extensively explored as a potential alternative to reduce the numerous cases of ADEs in NHs (Wild, 2011). As a result, information related to robotic-based innovations to reduce human-initiated ADEs in NHs is scarce (Van den Bemt et al., 2011).

From a broader perspective, RT has transformed many aspects of the 21st century. In everything from assisting man in outer space to deep water exploration, from manufacturing automobiles to soldering the small components within cell phones, from surgical assisting medical equipment to unmanned vehicles, from hospital pharmacies to drug manufacturing, RT has played an integral role in advancing society from different perspectives (Dahl & Boulos, 2013). Dahl and Boulos (2013) asserted that the need to

innovate will ultimately drive more researchers to consider RT to solve many existing problems in addition to utilizing it to bring newer and better products and services to society. Perhaps this determination and necessity to innovate will result in a system capable of keeping ADE numbers low on a large and wide scale throughout the NH community.

Problem Statement

A substantial amount of current scholarly research indicates that ADEs occur regularly in NHs (Wittich et al., 2014; Sawarkar et al., 2012; Bates & Slight, 2014; Kruer, Jarrell, & Latif, 2014; Samaranayake et al., 2014). The literature associates this to several causes, but the human element may be the primary factor that contributes the most (Kiekkas et al., 2011; Westbrook et al., 2011). While NHs have implemented many initiatives to combat this problem, it persists, adversely affecting the quality of life for many residents. There is an abundance of scholarly research related to ADEs, but there is a lack of credible research into how effectively medications might be administered using innovative approaches that have been used very little or not at all. Specifically, there is a lack of scholarly research into the use of RT for administering drugs in nursing homes. As a result, there is an insufficient understanding about whether innovations in RT can improve upon human-initiated ADEs of solid medications in nursing homes (Van den Bemt et al., 2011; Wild, 2011).

Purpose of the Study

The purpose of this mixed methods research was twofold: (a) To evaluate the causes of ADEs, specifically related to tablets, capsules, and pills, in a NH environment.

(b) To evaluate RT in the same environment, assessing whether nurses and administrators think it could be useful in reducing ADEs. In this regard, perceptions regarding the potential for RT to reduce ADEs (a continuous numerical variable measuring the average response to research questions in a Likert-scale survey) was the dependent (response) variable. There were two independent variables in this study: The demonstration of a robotic model (a categorical variable reflecting whether the participant was or was not shown a demonstration of the model) is the first; and which survey (before and after a demonstration of the model) is the second.

Nature of the Study

In this mixed methods research, I examined the causes of ADEs related to solid medications, specifically tablets, capsules, and pills, administered to residents in NHs. I evaluated the results from the qualitative aspect of my research to provide a basis upon which to assess alternative methods of reducing the number of ADE occurrences that take place in these NHs. Despite the numerous approaches identified in current literature, sufficient scholarly research involving RT, one possible solution to solve this societal issue, is not available. Other alternatives may include education for doctors and nurses, procedure modification and enforcement, communication improvement, staff additions, and enhancement of existing techniques. Although all of these alternatives have been used in NHs, ADEs still occur on a regular basis.

An experimental design was the basis for the quantitative portion of my research where I investigated if showing a model of RT to nurses and administrators increased their acceptance of this technology to assist with solid drug administrations in NHs.

Lauer (2004) indicated that at a minimum experimental research must contain at least two randomly selected groups (control group and treatment group) so that the independent variable (reflecting the treatment) can be manipulated between the groups to determine if it influences the dependent variable. To carry out an experimental design, Lauer stated that the treatment is always applied to the treatment group whereas the treatment can be applied to a lesser degree or not at all to the control group.

In the quantitative portion of my research, I built a model of RT and used it for the purpose of demonstrating how this technology might be used in a NH environment to assist with solid drug administrations. To effectively assess how nurses and administrators felt about RT designed for this purpose, I selected two separate groups of participants (the control group did not see a demonstration of the model and the treatment group saw a demonstration of the model).

Prior to demonstrating the model to the treatment group, I asked both groups to take anonymously the RT survey found in Figure B1. Once completed, I demonstrated the model to the treatment group, via a group presentation, and asked those nurses and administrators to take anonymously the same survey again. Using the responses from the survey (before and after demonstrating the model), I was able to obtain data specific to the treatment group, the control group, and all participants in general. I then compared the perceptions of the two groups.

The qualitative portion of my research was guided by exploratory case study. According to Crowe et al. (2011), case study designs are appropriate when the researcher intends to investigate phenomena within their natural environment that they have little to

no control over. Crowe et al. added that it is also common for researchers to use case study designs when researchers seek to apply new ideas to existing phenomena when preliminary research is limited. As a result, how and why questions are formed because the borders between the phenomenon and the natural environment are not plainly apparent, such as the borders between RT and ADEs in NHs. Perhaps this is why Crowe et al. stated that case study research is a comprehensive research strategy that utilizes multiple methods to triangulate various sources of data, which can include both quantitative and qualitative data, to investigate real-life phenomena. Thus, case study designs can effectively led to new theory when new ideas are applied to existing phenomena. These characteristics of case study design are applicable to my research.

In the qualitative portion of my research, I integrated data from the Adverse Drug Event (ADE) survey (Appendix A), focus group discussions, and NH error reports in order to gain insight into the causes of ADEs. The focus groups was conducted after the treatment group has seen the model demonstration, and after both surveys have been completed. I gained some insight into the causes of ADEs in NHs from the personal perspective of nurses and administrators working in NHs. Thus, the ADE survey contains 26 questions related to experience, training, and guidelines & procedures, which are the three main areas associated with ADEs according to current literature.

I entered the data from the ADE surveys and from the focus group discussions into the NVivo analysis software, where I compared and contrasted the results with reported reasons that contribute to ADEs. By combining actual and perceived causes of

ADEs, my research led me to understanding the phenomenon more clearly, which will contribute to the success of any new measures to reduce the high rate of ADEs.

Research Questions and Hypotheses

To conduct this research, I evaluated nurse and administrator perceptions on why ADEs occurred in NHs. This evaluation extended further to assess the administration of solid drugs to residents to evaluate if there were procedural components that may also lead to ADEs. The causes of ADEs (related to solid drugs only) obtained from various data sources was identified to determine what and how errors occurred between residents and nurses.

Also, critical to this research was an evaluation related to nurse and administrator perceptions regarding the use of RT to assist in drug administrations. An evaluation from this perspective was necessary to determine if ADEs could possibly be reduced with some type of robotic system capable of dispensing medicines. Specifically, this research study was guided by the following five research questions (RQs); the first three pertain to the qualitative portion of the study and the last two pertain to the quantitative portion:

1. How are drugs administered in the participating nursing home?
2. How do ADE errors in the form of pills, tablets, or capsules occur in nursing homes?
3. What knowledge do managers have of existing practices to reduce ADEs?
4. Do nursing home professionals have a favorable perception about the potential for RT to reduce ADEs?

5. Do nursing home professionals have a more favorable perception about RT to reduce ADEs after viewing a demonstration of that technology?

RQs 1 through 3 were informed through the analysis of focus groups, document analysis, and the responses that I obtained from the ADE survey (Appendix A). RQs 4 and 5 were informed by a quantitative analysis (hypotheses and hypothesis tests) of the RT surveys (Figure B1). In Chapter 3, I will elaborate on the mathematical expression of the hypotheses and the data collection and analysis required to evaluate them.

Responses to the RT survey (Figure B1) were used to inform a response variable. In the survey, the response is based on a Likert scale ranking value of +1 to +5, with +3 indicating a neutral response (neither favorable or unfavorable). Thus, the higher the response, the more favorable the respondent's perception of RT became. Since it was unknown how NH professionals may be influenced by viewing or not viewing a robotic model, several hypotheses were used to address RQs 4 and 5.

Van den Bemt et al. (2011) noted that the use of robotic-based innovations to reduce ADEs in NHs is scarce. Regarding RQ4, it was possible that the participants overall may not view RT for reducing ADEs as a viable option in NHs. This means that nurses and administrators may have some difficulty in accepting or understanding an innovation that does not currently exist, regardless of whether they see a demonstration of the technology, via a model, or not.

Thus, the research hypothesis for RQ4 is that the mean response (nurse and administrator perceptions of RT) from all participants prior to the treatment group

viewing the model is greater than the neutral response. This would indicate whether or not the participants feel RT may change the rate of ADEs in NHs.

Regarding RQ5, it was possible that an actual demonstration of a model of RT would influence nurses and administrators to have a more favorable view of RT for the purpose of reducing ADEs in NHs. This determination could only be accomplished if the model is viewed by one group (treatment group) and not by another (control group). Hence, I assessed the data to understand nurse and administrator perception of RT from a broader perspective. Thus, for RQ5 I evaluated five hypotheses.

The first research hypothesis for RQ5 was that the mean response for the treatment group after the demonstration is greater than the mean response for the control group (on its second survey, administered after the demonstration). This would indicate a favorable impact on those who viewed the demonstration compared to those who did not.

The second research hypothesis for RQ5 was that the mean response from participants from the treatment group after viewing the demonstration is greater than a neutral response. This would indicate that the treatment group felt RT (as demonstrated by the model) may decrease the rate of ADEs in NHs.

The third research hypothesis for RQ5 was that the average paired difference in responses from the treatment group before and after viewing the demonstration is greater than zero. This would indicate that these participants felt more strongly about the benefits of RT after viewing the demonstration.

The fourth research hypothesis for RQ5 was that the average paired difference from the control group, from two surveys (one before and one after the treatment group

views the demonstration), is greater than zero. In the third research hypothesis, I attempted to determine if there was a difference in response for the treatment group after viewing the demonstration. This was, of course, the second time the treatment group took the survey. Thus, it was important to understand if that difference was solely the result of seeing the demonstration; or, if it was related to taking the same survey a second time. As a result, there was a need to evaluate the control group who took the survey a second time, but without seeing the demonstration. So, in this fourth hypothesis, I attempted to determine if there was a difference in the response for the control group between the first survey and the second.

Recall that for the treatment group and the third research hypothesis, if there was a difference, then one of two things happened. Either the treatment group watching the demonstration made a difference or taking the survey a second time made a difference. To eliminate the second reason, I performed the same hypothesis test for the control group during a second round of the survey after the treatment group viewed the demonstration. The control group showed no difference in response during the second survey, which provided evidence that taking the survey a second time did not influence the results.

The fifth research hypothesis for RQ5 was that the average paired difference from the treatment group is greater than the average paired difference from the control group. In this research hypothesis, I compared how much the treatment group response changed before and after viewing the model, to how much the control group response changed from taking the RT survey (Figure B1) the first time to the second time. This research

hypothesis would indicate that the treatment group had a more favorable view of RT as a result of seeing the demonstration than the control group which did not view the demonstration.

Conceptual Framework

A conceptual approach rooted in the successes of RT in other industries and in other aspects of the medical industry is presented in this research as one possible alternative to accomplish a reduction in ADEs. Many researchers have investigated the drug administration issue extensively, but according to Aljadhey et al. (2013) no one has published a comprehensive solution to reduce ADEs of all types throughout the medical industry. This calls for continued, more in-depth investigation into the causes, which potentially calls for new and innovative approaches to solving this long-standing problem. Over the last decade, RT has advanced a great deal and has brought benefits to society that otherwise may not have been possible (Sekhar et al., 2013). Perhaps this technology can be configured in such a way that it could also make a substantial positive impact for this particular social issue as well.

My research was guided by five RQs that were designed to investigate the acceptance of RT to reduce ADEs. With these questions, I gained insight into the causes of drug administration errors from three perspectives: actual causes of ADEs, why nurses and administrators believe ADEs occur, and the effect of internal policies and procedures on ADEs. The rationale for my research stemmed from the call for further research into ADEs and the lack of consideration of RT as a solution. Consider Bates and Slight's (2014) conclusion that stated many of the most serious cases of ADEs are preventable

while Van den Bemt et al. (2011) concluded that ADEs are due to many types of medication errors. Kiekkas et al. (2011) concluded the same as Van den Bemt et al., but added that these types of medication errors should undergo continued investigation.

Continued investigation suggests that the causes of ADEs are vast and that not enough is known to produce a system capable of reducing many of the preventable ADEs that Bates and Slight (2014) described. Perhaps the missing piece of this investigation is the personal perspective of the nurse, the administrator, and the medication-use policies and procedures in place in NH facilities. These perspectives collectively were not investigated in the literature that I reviewed in Chapter 2. It is possible then that these perspectives could play a vital role in discovering new information relative to the causes, which could contribute to significant progress on reducing ADE numbers, especially since these perspectives are present in all NHs where ADEs occur.

Definitions

ADE: an incident that causes any type of harm or death to a patient as a result of medications that were administered to the patient (Bates & Slight, 2014, p. 1027).

Early/late administration: administration of the transcribed medication 60 minutes or more before the prescribed time (early) or administration of the prescribed medication 60 minutes or more after the transcribed time (late) (Barker, Flynn, Pepper, Bates, & Mikeal, 2002, p. 1897).

Improper dosage: administration of a drug quantity, either in strength, weakness, or number, that was different from the prescribed order (Barker et al., 2002, p. 1897).

Improper technique: an incorrect administration of a prescribed medication as a result of exclusion, inclusion, or incorrect execution of any portion of the administration procedure indicated in the chart or as indicated by the manufacturer of the medication (Barker et al., 2002, p. 1897).

IT: acronym referring to information technology.

Medication errors: the error of execution, which is an event where there is failure to complete a planned medication action as it was originally intended; error of planning, which constitutes an error resulting from the use of a wrong plan to achieve an aim (Institute of Medicine, 2004, p. 30).

Model: executable specifications of a particular system that imitates a real-world system or hypothetical system (Murphy & Wakefield, 2013, p. 39).

No administration: an absolute failure to administer a prescribed medication according to the transcribed order in the chart (Barker et al., 2002, p. 1897).

NH (nursing home): acronym associated with a privately operated establishment where maintenance and personal or nursing care are provided for persons (as the aged or the chronically ill) who are unable to care for themselves properly (Webster's Ninth New Collegiate Dictionary, 1983, p. 812).

r (perception): the response (dependent) variable, individual nurse and administrator perception of the potential for RT to reduce ADEs (as measured using a survey).

R (sample mean): the mean response of a sample (nurse and administrator), measuring average perception of the potential for RT to reduce ADEs.

RT (robotic technology): a noninvasive subset of robots that are programmed to navigate independently based on human instruction with the ability to assist in drug administrations based on pre-assignment of specific drug cabinets for specific residents (Borenstein, 2011, p. 87).

RQ (research question): refers to one of five research questions that the research addresses.

Simulation: an act that uses a model to understand behaviors, characteristics, or outcomes of a proposed extension to an existing system, imitation of an existing system, or to a new concept (Sokolowski & Banks, 2009, p. 155).

Wrong medication: the negligent act of administering a medication that was not ordered or transcribed for a particular resident (Barker et al., 2002, p. 1897).

Assumptions

I assumed that the administration of drugs in the participating NHs was managed by a non-robotic system. In conjunction with the assumption of non-usage of a robotic system, I assumed that nurses would have no insight into how RT could work for the purpose of assisting with the drug administration task and would be willing evaluate the use of RT to potentially aid in the reduction of ADEs. In lieu of an actual robotic system, I built a model to demonstrate how the technology would work. I assumed that the model was an accurate and appropriate replica of a similar real-world system where medications are interconnected with some type of barcode technology. Thus, a simulation using this model would sufficiently gauge its intended purpose, which was to assess nurse and

administrator perceptions about RT for the purpose of assisting with drug administrations.

Scope and Delimitations

The research population was composed of three NHs within a 60-mile radius of the Memphis Metropolitan area that were categorized as NHs or skilled nursing facilities. According to the U.S. Census Bureau (2012), there are 15 other metropolitan areas across the U.S. of comparable size, approximately 1 million to 1.6 million citizens. The Memphis Metropolitan area was chosen because it is the closest and largest metropolitan area where I live that has a large number of NHs of various sizes and qualities to randomly choose from. This location also made collecting the data very convenient. Based on the literature I reviewed in Chapter 2, there have been no studies related to ADEs in NHs conducted in this geographical area.

The participating NHs were chosen based on a 5-point quality scale designed by the Centers for Medicare and Medicaid Services (CMMS) to rate overall care in NHs. NHs rated as 1, the lowest ranking, encountered many care issues while NHs rated as 5, the highest ranking, encountered very few care issues (CMMS, 2015). The research population was composed of three NHs where the associated quality ratings were 1, 1, and 2. The CMMS (2013) counted 2,848 out of 15,661 NHs in the U.S. that had a quality rating of 3 or below (p.1). Based on this statistic, the results from this research can be generalized to approximately 18% of all NHs in the U.S.

To more appropriately represent the population of NHs in the U.S. one small (less than 90 beds), one medium (between 90 and 180 beds), and one large (180 beds or more)

NH was recruited for this research. The classification of size was based solely on the number of beds to create the range of small, medium, and large. The small NH had 88 beds, the medium NH had 119 beds, and the large NH had 211 beds.

To conduct this research, I asked a specific group of nurses and administrators at each participating NH to participate in a survey. From this group of participants, I established two groups where I asked one group (treatment group) to view the robotic simulation (via a presentation) and the other group (control group) to refrain from viewing the simulation. To reduce the possibly of obtaining biased results from the two groups, I did not mention the model to the control group. NH residents were not a part of the study sample, because the simulation did not interface directly with residents. I asked only administrators and nurse supervisors from the same sample used for the survey to participate in a focus group discussion due to their availability and indirect care of residents.

Specific to delimitations, I used simulation to demonstrate limited functionality of a robotic system via a model. The model simulated assisting with the administration of solid drugs, specifically tablets, capsules, and pills, omitting all other categories of drugs. It was necessary to limit the categories of drugs because of the sheer number of drugs NH residents take and the delimitations in the simulation as opposed to a fully functional robotic system. An actual robotic application on a NH ward involving drug administration activities between nurse and resident did not take place.

This research was also delimited by three NHs. The inclusion of other NHs would have added a substantial amount of time and cost to collect the data. Therefore, the

sample size was relatively small, but represented NHs based on a quality care rating of 3 (average) or less on a 5-point scale as determined by the CMMS (2015). Similarly, this research was confined to 10 solid drugs only, a delimitation that was considered in order to adequately demonstrate the model to nurses and administrators in a short period of time. It was also confined to solid drugs only to simplify the complexity of the simulation to make it practical and realistic.

Limitations

My research was limited by two factors. First, the data acquired from the focus group and the survey may not represent accurate accounts of ADE experiences by each nurse and administrator taking part in this research. Second, it was necessary to use a simulated system in place of a real robotic system. As a consequence, it was not possible to fully explain the technology in a staged demonstration as compared to a real robotic system being used by nurses on the NH ward.

Significance of the Study

It is inevitable that human-initiated mistakes will occur at the drug administration stage in NHs. As indicated in the literature, the medical industry and the scholarly research community have realized that this problem is quite severe. This realization has spurred numerous research studies related to ADEs, which have produced measures that have reduced ADE numbers along with adding to the body of knowledge related to this phenomenon. Even with current successes, the problem of ADEs in NHs still persists at an alarming rate (Handler, 2012). Therefore, continued scholarly research to lessen the

effects that ADEs have on society, especially on the elderly who rely on others for their care in NHs, is necessary.

Existing strategies may not have the capacity to reduce ADEs on a bigger scale, which supports the need for more scholarly investigation of existing measures and new innovations, such as a noninvasive form of RT. RT has proven instrumental in various aspects of the medical industry, but Van den Bemt et al. (2011) reported that the use of robotics to reduce ADEs in NHs virtually does not exist.

It was possible that the simple model presented in this research would not convince nurses and administrators that robotics-based innovations would reduce ADEs at the administration stage by a great margin. Still, this concept may spur other researchers to expand upon it to where great margins may eventually be accomplished to garner positive social change on a bigger scale. As a result, more lives will be saved within a growing elderly population that will depend on NH care in the future.

An actual robotic drug administration assisting system would be successful if it were noninvasive and improved administration accuracy of prescribed medications well beyond current success rates expressed in the literature. If an additional 30%, 40%, or 50% of the 93,000 NH residents Handler (2012) estimated will die from ADEs could be isolated from them, the ending years of life for these seniors would at least be protected from this particular social issue.

Summary

The literature briefly mentioned in Chapter 1, and analyzed in greater detail in Chapter 2, clearly indicated that there is a significant problem with ADEs in U.S. nursing

homes. According to the Administration on Aging (2014), the number of Americans 65 years old or older is growing rapidly. As this trend continues, more and more Americans will be compelled to rely on NHs for extended care, but if ADEs are still prevalent, extended care for many will suffer due to ADEs. It is critical then for this social issue to undergo continued research to find plausible solutions that will consistently reduce the number of ADEs to where it is not a significant problem.

There are multiple ways the problem of ADEs could be addressed. Current literature indicated that researchers and businesses have found RT to be instrumental in many ways. The medical industry, in particular NHs, is finding new ways to incorporate RT in caring for a growing elderly population. Soler et al. (2015) noted that social robots are currently being used in NHs as an alternative therapeutic treatment for diseases such Dementia and Alzheimer's. Heylen, Van Dijk, and Nijholt (2012) conducted a study to evaluate the drawbacks of such robots to determine their validity for uses associated with the elderly. Borenstein (2011) noted that it is realistic to consider robotic systems in NHs because these systems can eliminate inconsistent behaviors that lead to ADEs.

Before any possible solutions can be explored with regards to significantly reducing ADEs in NHs, additional research must be done to determine the causes. Consequently, I carried out a comprehensive investigation into the causes of ADEs in my research. To support this investigation, I used a mixed methods approach to gain a holistic understanding of these causes so that both a quantitative and qualitative perspective can be considered. I collected the data from historical records (ADE errors

reported by the NH to the National Institute of Health), simulation, survey, and focus group.

In Chapter 2, I intend to document a thorough examination of existing studies related to ADEs in NHs. In this examination, I will explore existing methods, processes, and systems currently being used, as identified in the literature. In Chapter 3, I will justify the use of the mixed methods research method to describe how it was instrumental in exploring this phenomenon and include a thorough description of the data collection design previously mentioned. In Chapter 4, I will detail the results of the pilot study, and explain how the model was verified and validated for use in this research. I will also present a comprehensive description of the data and disclose thorough answers for each RQ. In Chapter 5, I will share my interpretation of the data, limitations that may have affected this research, recommendations for future research, and the implications for positive social change.

Chapter 2: Literature Review

In this chapter, I will examine existing literature on medication errors that may lead to unintended ADEs in NHs. Within this examination, I will also discuss some of the existing methods, processes, and systems that are currently in use for drug administration, with particular emphasis on mobile robotic drug-assisting systems. My examination will conclude with a summary on the possibility of utilizing RT in such a way as to reduce the rate of ADEs at the administration stage.

It was unclear from the literature just how many NH residents are affected by ADEs. It is clear, though, that the numbers are staggering, and with the elderly segment of the population poised to grow, so will the incident rate of ADEs. In fact, Parker-Pope (2011) reported that medication errors resulting in ADEs have risen more than 58% in the last few years, increasing from 1.2 million reported ADEs in 2004 to 1.9 million in 2008 (p. 1). Even more startling is that these figures relate only to hospitals. When hospitals and NHs are considered together, the number of people affected by ADEs yearly could be well over 2 million. Just in medium-sized NHs (50 to 105 beds) in the U.S., Handler (2012) claimed that at least 2 million ADEs will occur annually (p. 1).

Moore, Cohen, and Furberg (2007) highlighted the issue of ADEs from a compelling perspective. Based on information-related to voluntary reports of ADEs gathered by the US Food and Drug Administration, Moore et al. showed that between 1998 and 2005 adverse medication reactions grew from 34,996 to 89,842 while fatal ADEs grew from 5,519 to 15,107 (p. 1752). If non-reported cases were known and included in these figures, it is reasonable to suggest that the figures would be much

higher than what is currently documented. Even with the known cases, this upward trend clearly suggests that this issue is quite prevalent and will continue to increase, unless our knowledge related to ADEs is extended far enough to reverse this trend.

The literature indicated that researchers agree that a vast number of ADEs are preventable, yet they still occur (Bates, 2014; Tsao, Lo, Babich, Shah, & Bansback, 2014; Kruer et al., 2014). This could have indicated then that existing methods, processes, and systems are not adequate to further reduce the high numbers of preventable ADEs (Handler, 2012). According to Handler (2012), NHs should trend towards the use of an intelligent and reliable medication monitoring system to detect and manage ADEs from a broad perspective. Therefore, expansion of existing methods, processes, and systems alone may not be sufficient, unless expansion incorporates a high degree of intelligence and reliability. To this end, some form of a computerized system, such as RT, should be considered as a new approach to solve this problem.

Literature Search Strategy and Analysis

The literature that I reviewed throughout this chapter was gathered from a variety of electronic databases and sources. The electronic databases included ProQuest EBSCO, Academic Search Complete, ScienceDirect, PubMed, and GoogleScholar. The electronic sources included government websites such as the National Institute of Health, the Administration of Aging, and the U. S. Department of Health and Human Services. The peer-reviewed literature acquired directly from the electronic databases and sources were found using keywords such as medication errors in NHs, medication errors, adverse drug event in NHs, robotics in NHs, and reducing medication errors. These key search phrases

were identified by reading both peer-reviewed and non-peer-reviewed literature. The reference lists were successfully mined for additional sources.

Since this research was based on the claim that ADEs are a significant social issue that is common in today's society, an exhaustive and widespread view of current literature was necessary to describe that this is indeed a fact. For this reason, the selection of literature was broad to describe the definition, causes, effects, and prevention of ADEs in NHs. The literature also contained sources that described technologies that have been used and several that have not been used to highlight the possibility that RT might be instrumental in significant reduction of ADEs in NHs. The selection criteria resulted in over 85 sources, where approximately 60 qualitative and quantitative sources were chosen due to their relevance, thoroughness, and credibility to assess recent knowledge related to ADEs.

Definition of an ADE

Bates and Slight (2014) defined an ADE as an incident that causes unintended harm or death to a patient as a result of medications that were administered to the patient. An ADE can occur when a patient is given a wrong dosage that leads to an unwanted situation, like the loss of functions, confusion on the part of the patient, or rashes; or it can occur when medications cause allergic reactions (Brandt & Zarowitz, 2015; Wittich et al., 2013). An ADE can also occur as the result of administering the wrong medication to a patient or from administering the right medication in the wrong manner to a patient (Bates & Slight, 2014). Thus, ADEs are the result of medication errors that cause accidental harm, injury, or death.

According to the Institute of Medicine (2004), these medication errors can be of two types:

1. Error of execution, which is an event where there is failure to complete a planned medication action as it was originally intended.
2. Error of planning, which constitutes an error resulting from the use of a wrong plan to achieve an aim. (p. 30)

Causes of ADEs

A recent study conducted by the Agency for Healthcare Research and Quality (2001), also referred to as AHRQ, advocated that medical experts should embrace the fact that the causes of ADEs are divergent and varying. This means that no single cause can be identified as the root of such occurrences. In a typical health care facility setting, several factors can cause ADEs. However, AHRQ pointed to the fact that medication errors that result in injury or death are common across major hospitals. The reason why medication errors could comfortably be assigned by the research study as the major cause of ADEs is due to the fact that the medication-use process itself has several stages, which could have a number of different errors and mistakes.

Perhaps it is for this reason that AHRQ (2001) pointed out that various studies recognized that errors are likely to occur at all stages of the medication-use process, which includes ordering, transcription, dispensing, administering, and monitoring. If each stage is prone to a portion of errors and mistakes, then reasonably it can be expected that medication errors would account for the greater percentage of all forms of ADEs.

Subsequently, there are some researchers who actually hold the opinion that ADEs and medication errors are inseparable.

Regardless, medication errors resulting in patient injury or death are significant among hospitalized patients across all stages of the medication-use process (Bates & Slight, 2014). In NHs, medication errors are usually experienced at the prescription and administration stages (Kiekkas et al., 2011). The frequency of such errors usually depends on the specifics and intensity of the error-detection systems in use.

Kiekkas et al. (2011) found that the methods of detecting errors vary at different stages of the medication-use process. Conversely, Campbell, Karnon, Czoski-Murray, and Jones (2007) claimed that error-detection systems that are utilized for every stage, except direct observation of administration, suggest that the rate of prescription errors per patient on a daily basis is 1.3% for omissions and 0.53% for commissions (p. 26). In another study, Van den Bemt et al. (2011) employed the use of direct observation relative to drug administration and observed that there was a medication administration error rate of about 21.2% or 428 errors out of 2,025 observed (p. 489).

A medication error may result either from an act of omission or from an act of commission, which could lead to unfortunate harm to the patient and inaccurate administration of the medication (Aljadhey et al., 2013). For instance, there could be a prescription of the wrong dosage or the administration of the wrong dosage for medicines prescribed for a patient. Medication errors can also be due to the patient's failure to take his or her medication or the caregiver's failure to give the patient his or her medication.

Aljadhey et al. (2013) categorized these examples as diagnostic, treatment, and preventive types of medication errors.

The available data on the issue of incorrect drug administration in NHs indicates that care transition between home care provision and institutional care provision represents a high level of risk (Brandt & Zarowitz, 2015). This may be because the regimens for medication are frequently altered during this kind of care transition. Thus, further research about the ways in which interactions can be improved between these stages of the medication-use process is called for. As such, all the concerned parties must acknowledge this problem and strive to properly evaluate the various approaches that can be employed in tackling these issues.

Effects of ADEs

The effects associated with ADEs were described by AHRQ (2001) and Wittich et al. (2014) as being divergent and varying. This is because the effects of ADEs take on many different forms in various health care settings.

ADEs would bring about cost disincentives to the NHs due to the varying consequences that ADEs carry. For example, in many events of ADEs, there are injuries and loss of lives to patients. Once this happens, compensation should be paid to deserving patients and their families. It is these legal costs and compensation disincentives that often leave NHs and hospitals susceptible and liable to huge financial losses. According to the U.S. Department of Health and Human Services (2014a), also referred to as USDHHS, ADEs alone accounted for as much as $5 billion in expense annually in U.S. hospitals and NHs (p. 9). Indeed, this shows that there are heavy financial effects that

ADEs carry. Therefore, one of the best ways for healthcare facilities to trim unnecessary expenditures (and therefore increase their bottom line) is to ensure that there is a drastic reduction in the actual cases of ADEs.

In conjunction with susceptibility and liability, AHRQ (2001) brought to light that in a given year, ADEs could be responsible for as many as 770,000 injuries and deaths taking place across various hospitals (p. 1) while in NHs Handler (2012) estimated that approximately 93,000 deaths occur annually (p. 17). Injuries resulting from the inappropriate use of medications create a variety of adverse drug reactions, most of which are not fatal (Bates & Slight, 2014), but still detrimental for the patient. In such situations, patients will suffer unexpectedly from the reactions they go through.

Research indicates that adverse reactions are not always easily observed. Brandt and Zarowitz (2015) noted that nurses are in the best position to detect drug reactions, symptoms, and injuries that take place on the surface. Early detection is a critical factor to reduce ADEs as it gives medical experts much room to rapidly treat them. However, some reactions and injuries take place internally, where visibility virtually does not exist, unless the aide of medical equipment is used. It is these internal reactions and injuries that actually pose the greatest threat of the death (Samaras, Chevalley, Samaras, & Gold, 2010). What is even worse in some cases is that medical experts have not been able to identify injuries early enough, because many adverse drug reactions take place gradually and over a long period of time.

In fact, Samaras et al. (2010) claimed that some reactions resulting from medication errors are asymptomatic, until such a time that they become deadly. All in all,

the indication that seems present at this point is that medical experts have a very huge obligation in ensuring that they switch to the best means of reducing the effect, which is a preventive means. Otherwise, omission to manage these effects typically leads to dire consequences from multiple perspectives.

Further review of the literature revealed that morbidity and mortality resulting from ADEs is costly (Harris-Kojetin et al., 2013). Parker-Pope (2011) estimated that about 1.9 million preventable ADEs happened in the U.S. in 2008 (p. 1) in addition to an estimated 1.9 million hospitals stays that occurred annually as a result of ADEs (USDHHS, 2014a). Therefore, the cost of morbidity and mortality resulting from preventable ADEs is astronomically high, even though many studies have identified various causes of ADEs. Perhaps this high cost can be attributed to different processes applied to the medication-use process (Bates & Slight, 2014) and the various policies set by governing bodies at the state and local level (O'Shaughnessy, 2013). Combined, these policies and medication activities typically create a complex environment that contributes to the risk of morbidity and mortality resulting from ADEs.

Health care administrators and managers face severe financial consequences when ADEs occur (Wittich et al., 2014). For example, when news of injuries, deaths, and financial losses are repeatedly reported about in their facilities, they cannot expect the same level of patronage as before. Thanks to computers and the Internet, access to news and information is easier today than in years past. As a result, patients, residents, and other patrons of health care facilities have the ability to quickly spread news of ADEs that have taken place in a particular facility.

Furthermore, the spread of such negative reports may become worse when patients or victims are not given the best of customer relations in explaining the circumstances surrounding an ADE event. Subsequently, attendance to the facility may dwindle, and administrators and managers may suffer intense pressure. There could be constant monitoring by external health care supervisors (Kruer et al., 2014), and upon a number of warnings related to repeated cases, the health care facility could potentially face closure. When the problem reaches this stage, it could be said that the very worst has happened. Therefore, it is important to take every needed action to ensure that cases of ADEs do not become habitual or repeatable. To that end, the next section of the literature review looks at ways of preventing ADEs.

Prevention of ADEs

The reviewed literature overwhelmingly contended that most ADE events caused by errors in the medication-use process are preventable (Barnett et al., 2014; Bates & Slight, 2014). Medication errors as a result of human mistakes account for the greater portion of those causes (Westbrook et al., 2011). In much the same way, AHRQ (2001) revealed that minimizing medication errors would subsequently be a major step in preventing and eradicating ADEs. AHRQ is therefore of the opinion that instead of looking at the prevention of ADEs as a holistic intervention, more attention should be given to the prevention or eradication of various forms of medication errors in health care facilities overall. This approach would be especially effective in NHs, where Campanelli (2012) found that a majority of residents are taking several drugs daily.

In contrast, Aljadhey et al. (2013) asserted that limiting the prevention effort to minimizing medication errors would achieve only partial results. The fear is that ADEs may not be prevented in the long run if attention is paid only to medication errors. Similarly, according to the study conducted by AHRQ (2001) there are those who contend that medication errors and ADEs are inseparable while others reject the opinion that ADEs and medication errors are synonymous.

My research was based on the premise of AHRQ (2001), which held the view that prevention of medication errors should be the main focus in trying to achieve prevention of ADEs. AHRQ suggested that the best way to reduce cases of medication errors is to institute a systematized technology that incorporates the principles of modern computerized systems. Therefore, the major aim of my research was to investigate the use of RT to possibly reduce ADEs.

Many of the studies funded by AHRQ (2001) showed that computerized systems can be instrumental in efforts to reduce medication errors and ADEs. Computerized systems have the capacity to detect ADEs, which makes vital information available to administrators and managers from which they can create effective interventions and mitigation strategies to minimize these ADE events. These results are promising since previous studies have indicated that 28% to 95% of all ADEs are preventable. If computerized systems are used to prevent medication errors, the number of preventable ADEs may be greatly reduced.

Computerized interventions may potentially reduce the rate of medication errors in NHs. These computerized interventions include the use of automated dispensing

devices, pharmacy dispensing robotics, bar coding connected with computerized records for medication administration, automated point-of-use distribution systems, and computerized physician order entry systems (Van den Bemt et al., 2011). Externally, other tools, such as third party monitoring, used in tracking medications that patients have actually taken have also proven to be especially beneficial.

Sawarkar et al. (2012) believed that more emphasis should be given to prevention strategies to combat ADEs rather than focusing on incidence rates, especially since many administration errors go undetected. This approach requires comprehensive medication management where up-to-date records of medication regimens—including prescription and non-prescription drugs, patient-specific drug and food allergy information, and medications taken and not taken, along with dietary supplements—are readily available throughout the health care facility. This can be efficiently carried out through the use of RT coupled with other computerized systems.

The quality of patient care can improve when healthcare workers are coordinated with ready access to patient medication information (Brandt & Zarowitz, 2015), especially if the patient suffers from chronic conditions, sees numerous providers, or takes multiple medications. Perhaps the rate of medication errors can be reduced due to well-informed and engaged health care workers. These improvements can range from routine actions like double-checking patients' prescriptions to the more complex actions like forging an active partnership with providers in the management of health care.

In order to reduce ADEs in NHs and achieve a culture of safety, it is important for the management tier of health care organizations to devote an adequate amount of time

and attention to safety issues. Additionally, they should also ensure that resources are available for safety teams and improvement of quality in NHs (Cunningham et al., 2011). As such, management would have to authorize investment into technological resources that have a proven record of efficacy, which may not currently be implemented on a large scale in NHs. These technological resources include, but are not limited to, electronic health recording systems and computerized provider systems for entering orders.

Current Systems Used to Combat ADEs

Traditional Ambulatory Reporting Systems

For some time, a number of health care facilities have depended on the efficacy of traditional ambulatory error-reporting systems in combating ADEs. The traditional ambulatory error-reporting system, which is referred to in some quarters as a medication ambulatory error-reporting system, has its own strengths and advantages, such as being easily accessible and cost effective (Zafar, Hickner, Pace, & Tierney, 2008). Despite these few advantages, some researchers have claimed that a medication ambulatory error-reporting system is not viable in controlling or preventing most modern cases of ADEs. For example, Gandhi et al. (2003) noted that medication error-reporting, specific to outpatient practices, has declined in recent years due to hectic processes, limited access to comprehensive patient medication regimens, concerns of liability, and constant fear of potential bankruptcy proceedings.

What is more scaring is that the factors listed in Weiss and Elixhauser (2013) research are multidimensional, which means that the use of traditional ambulatory error-reporting systems renders itself ineffective in combating ADEs through several scopes

and means. By design, a traditional ambulatory error-reporting system seeks to identify errors and report them as soon as possible. However, because this is mostly done through a manual process, a large percentage of ADEs go unreported.

Mayer, Dowsett, Brahmavar, Hornbuckle, and Brookfield (2010) indicated that while in 2008 the FDA received reports of 527,000 possible ADEs from drug manufacturers and 33,000 directly from healthcare facilities (p. 15), the FDA still believed that this was only a small fraction of all ADEs that actually occurred in 2008. This implies then that for various reasons healthcare facilities are not reporting all cases of ADEs to the FDA. Even more disturbing is the number of actual and potential ADEs that go unreported by nurses to the facility itself. It is difficult to find ways of reducing the number of ADEs when so many are unreported and the causes are widespread.

Electronic Prescribing

At first glance, electronic prescriptions appear to be a noble alternative to eliminate the possibility of ADEs at the prescription stage. According to Wittich et al. (2014), any chance of misreading handwritten prescriptions from doctors is eliminated. Prescribed medications can be cross-referenced with the medical history of the patient to virtually eliminate any chance of a drug allergy or an adverse reaction caused by another drug. Because prescription information along with prescription history is stored electronically, multiple entities, such as hospitals, NHs, and pharmacies, can all have access to the same information, provided they have adequate computer systems.

When clinical decision support software is coupled with electronic prescriptions, the chance to reduce error rates of ADEs is heightened (Kruer, Jarrell, & Latif, 2014).

Kruer et al. (2014) claimed that this software can provide nurses with extensive information that can aid in the care of a patients drug regimen in addition to extensive advice on any drug a patient might be taking. If nurses need to understand the consequences of new drugs, a combination of drugs, or substitute drugs, they can inquire within the clinical decision support application to potentially avoid an ADE. Huston (2013) found that these systems can also be a plus for nurses to overcome issues such as poor competency in drug calculations, and to make them more efficient and effective at the drug administration stage.

Specialized Systems

Beyond traditional means of trying to prevent ADEs, namely non-computerized processes and procedures, several specialized systems were identified in the literature for this same purpose. The existence of these specialized systems indicates that the problem of ADEs is widespread and very difficult to solve (Wittich et al., 2014). However, it might be possible to expand upon these specialized systems in some capacity to produce a new system that may render a greater degree of success in reducing ADE error rates. Bates and Slight (2014) recognized the potential for this possibility by supporting the idea that information technology should be used in a greater capacity for prescribing, administering, and dispensing. Perhaps information technology should be considered for all stages of the medication-use process, especially since ADE error rates are still high (Handler, 2012).

According to Sawarkar et al. (2012), many ADEs manifest into injuries because these events are typically not detected or not reported. This implies then that nurses fail

from multiple perspectives to effectively manage these events before they become critical to the patient. In response to this failure, (Wittich et al., 2014) suggested that an alternative strategy was necessary to offset these misses, which appear quite prevalent with traditional means of managing drug administration in NHs. Referred to as a trigger tool, their alternative strategy sought to increase the efficiency of detecting ADEs by adding a manual systematic examination of charts, where the aim was to identify from recorded writing in charts anything that may indicate that an ADE has occurred or might occur.

In another study conducted by Van den Bemt et al. (2011), the use of an automated medication dispensing system was deployed to determine what effect it might have on reducing ADE error rates. As a type of robotic system, this system focused primarily on dispensing the right medication for the right patient. This indicates that the other stages of the medication-use process are still vulnerable to ADEs, especially since many studies have found a high number of errors to also occur during other stages of the process. However, this kind of system has the potential to greatly reduce ADE incident rates at the dispensing stage. Pedersen, Schneider, and Scheckelhoff (2012) described the usage of three distinct types of automated dispensing systems that were instrumental in reducing error rates at the dispensing stage: automated dispensing cabinets, stationary robotic systems using bar-code technology, and carousels.

The technique associated with these systems depict a stationary system confined within the hospital pharmacy where error reduction was emphasized at the dispensing stage. The pharmacists and pharmacy assistants using these systems were not

administering medications directly to patients. Rather, they worked in a limited area and were only concerned with filling orders that flowed into the pharmacy, via the computer system, that would eventually be delivered to a particular ward in the hospital. The robotic-based approach proposed in my research extends this technique where the dispensing system is transformed into a mobile, self-guided, patient-specific system that can assist nurses in administering medications as needed in various locations in a NH. Therefore, a system to enhance protection against ADEs at the administration stage rather than the dispensing stage is closer to the actual point of giving the medication to the patient, which may decrease ADE error rates in NHs.

Some attention has been given to the potential of RT to reduce ADE error rates at the administration stage in hospitals. In 2011, Summerfield et al. (2011) evaluated the effectiveness of a robotic medication courier system to deliver drugs from the hospital pharmacy to the intensive care unit. In 2013, Chen, Shen, Gurna, and Wu (2013) evaluated the usage of a robotic arm located in a hospital pharmacy to accurately fill patient prescriptions related to cancer treatments. In 2014, Samaranayake et al. (2014) implemented a bar-code assisted medication administration system in a teaching hospital in Hong Kong to reduce ADE error rates. Collectively, these self-guiding systems had a direct impact on ADE numbers in hospitals, but the fact that ADE numbers are still high in NHs (Handler, 2012) may inspire additional research to tailor these systems for the purpose of assisting with drug administrations in NHs.

While these systems have shown various degrees of reducing ADEs (mainly at the dispensing stage in the medication-use process), the implementation of these systems was

confined to hospitals. It is unknown what effect they may have in NHs. Perhaps some level of success with these systems can be achieved in NHs too, but arguably, they will have similar effects as were noted in the various hospitals. Aljadhey et al. (2013) recognized that the ideal technological system would be quite complex. Because no one system can definitively reduce ADE error rates from all perspectives, a collaborative combination of systems may be the answer to achieve ADE reduction from multiple perspectives rather than from an isolated single perspective (Wittich et al., 2014).

Robotic Technology

The available literature suggested that robotic systems cannot perform many of the tasks that require the cognitive and intellectual skills necessary to care for NH residents. However, RT may be instrumental in NHs for the performance of repetitive, non-cognitive, and non-intellectual tasks. In order to take advantage of its consistency, RT should be considered as an alternative approach to assist nurses in administering drugs. Herman (2012) acknowledged that significant opportunities exist for assistive robotic technologies designed to interface directly with NH residents to help them with various activities. These opportunities could also include a different category of assistive RT that could directly aid the health care worker who takes care of the NH resident. My research investigated the utility of a robotic system that would assist nurses in drug administrations to reduce ADEs, which is one avenue to improve upon the quality of life for NH residents.

Further, the available literature on medication errors indicated that there is a high level of risk inherent in the period of transition between primary home care for patients

and their placement in NHs. Bates and Slight (2014) found that medication regimes are prone to be altered during this transition. Thus, there is a need for further research into methods of improving communication systems between these two periods of time. In order to do this effectively, there must be proper acknowledgement of the issues involved and a thorough evaluation of alternative approaches that can be employed, including the use of RT.

A major strategy that can be used for reduction of errors during the transition period between primary/home care and NH care is the reconciliation of the medication orders between both points. This is especially relevant to outpatient situations, but also between different points within the NH. Kruer et al. (2014) mentioned that computerized prescribing is of great importance in outpatient settings, although this strategy might not yield visible safety benefits if additional decision support is not provided. This reconciliation may also involve carrying out a comparison of current medications being taken by the patient against medications being provided onsite so as to avoid any omission or transcription errors, drug-to-drug interactions, disease-to-drug interactions, and the possibility of duplicate therapy. The use computer technologies, including RT, can greatly enhance this process, and can help in determining the origin of such discrepancies (Bates & Slight, 2014).

There are some important gaps and methodological issues about medication errors in the existing literature that I reviewed. One such gap is the perceived emphasis on safe usage of medicines, which should be adjusted to focus not only on incidence rates, but also on strategies that can be employed for error prevention. The use of RT should

incorporate clinical decision support and reconciliation of prescribed medications, based on the fact that Wild (2011) found that these components have been instrumental in reducing ADEs.

Since medication administration is the last and most susceptible stage of the medication-use process, employing a combination of technologies at this stage would most likely be of great significance (Sawarkar et al., 2012). These technologies could include the use of electronic records for medication administration and machine-readable identification and matching. These technologies can be linked robotically and electronically in order to improve documentation of the medicines that have already been taken.

The importance of computerized administration management and decision support related to ADEs in NHs cannot be overstressed. However, this area has received inadequate attention, as there seems to be only a small amount of research about the efficacy of computerized administration and decision support in NHs (Van den Bemt et al., 2011). The implementation of computerized methods of administration within this setting can also be quite challenging because NHs typically have limited resources.

Gap in the Literature

Extensive research has been conducted to investigate the issue of ADEs from various perspectives. As a result of this research, many of the existing measures, systems, and approaches involve some form of information technology to reduce ADE occurrences. Despite the successful approaches mentioned earlier in this chapter, ADEs are still prevalent in U.S. nursing homes (Handler, 2012). This means that there is a need

to look into other possibilities, such as expanded applications of existing information technologies (Samaranayake et al., 2014), which may be able to trend ADE error rates down.

Borenstein (2011) noted that serious attention should be given to the practicality of robotic systems based on recent successes of these types of systems in hospital pharmacies. However, scholarly research related to the viability of robotic systems in NHs to assist with the drug administration task is scarce (Van den Bemt et al., 2011). This assertion appears true, because from the extensive literature search review I conducted, there were no studies that directly investigated the usage of RT in NHs to assist with drug administrations. Very little attention has been given to this particular possibility (Huston, 2013), which clearly indicates that it is a gap in the literature. Since ADEs negatively affect the quality of life of so many elderly citizens relying on NH care, it is worthy to explore this possibility to the fullest extent.

Justification for Research Approach

The premise of the mixed methods research lies in the utilization of both quantitative and qualitative methods in a single study. The characteristics of both methods are employed by the researcher to accomplish the intended goal of the research. Farquhar, Ewing, and Booth (2011) classified mixed methods research as a pragmatic approach to acquiring knowledge, where the knowledge claim is based on hypothesis outcomes and subjective conclusions related to actions, situations, and consequences. This approach guides the researcher to ask both closed and open ended questions to obtain data that may reveal more than one possibility. Thus, data collected from the

mixed methods approach is subjected to statistical and textual analysis to understand the phenomenon from different worldviews and assumptions.

O'Byrne (2007) acknowledged that mixed methods requires the researcher to use qualitative techniques for one aspect of a study and quantitative techniques for another aspect of the same study. Otherwise, significant results would not be possible if equal investigation from both perspectives is not conducted. Therefore, both inductive and deductive reasoning is performed. Grinnell and Unrau (2011) added that a mixed methods study can begin with either the qualitative portion or the quantitative portion (p. 352). Regardless of which portion the researcher begins with, the ultimate goal is to gain new knowledge about the phenomenon being studied by leveraging the respective benefits of each method.

In a general sense, quantitative data analysis tools are rooted in the physical sciences, because quantitative data analysis tools are designed to take objectivity and reliability into account since emphasis is placed on objects that do not involve people (Mangan, Lalwani, & Gardner, 2004). Quantitative research involves a standardized and structured method of data collection. In contrast, qualitative data analysis tools are based on analyzing content that comes in a non-numerical manner. By adopting a qualitative approach, the researcher gains the opportunity to develop multiple themes, some of which may be different from any anticipated expectations at the beginning of the study.

Quantitative research on the other hand, seeks to quantify the data by applying widely accepted statistical analysis (Craig et al., 2008). It also involves the quantification of the relationships between variables and can be used for proving a theory or

substantiating a hypothesis. Although results obtained through quantitative methods of research may provide less detail about human behavior than qualitative methods, human attitudes and motivation can be more effectively gauged through samples that represent potential trends in the population.

Both quantitative and qualitative research techniques are valuable and are used to complement one another. However, for my research, a mixed methods technique was more suitable than either approach alone, due to the severity of ADEs that occur during the drug administration stage. Therefore, much attention should be given to exploring this stage from a quantitative and qualitative perspective. Any decision to employ a single approach would reveal a great deal, but a single approach may leave important information undiscovered.

Data Collection Methods

When researchers embark on any research study, the question of which data collection method should be used or would be the most appropriate usually surfaces. According to Farquhar et al. (2011), researchers should choose methods that have the greatest chance of providing diverse information about the problem being studied. However, this approach may be difficult for new researchers due to their limited knowledge of either qualitative or quantitative approaches. Among social researchers, Farquhar et al. contended that mixed methods research is growing in popularity, meaning social researchers would have to be familiar with both approaches. It is critical then for the data collection method to coincide with the nature of the study and that the researcher is up to par on the chosen approach.

A combination of positivism and interpretivism obtained from a mixed methods approach is gaining interest among health and social researchers who study complex problems (Farquhar et al., 2011). These researchers are free to choose methods that complement each other to enhance the depth of understanding related to the problem being studied. It is important, though, that researchers choose an appropriate set of methods based on predetermined notions of what techniques will acquire the greatest results. Determining the cause of ADEs in NHs is an emerging event, because the causes randomly occur based on various situations (Wittich et al., 2014). Therefore, to gain a greater understanding of ADEs in NHs beyond what is present in current literature, it may be necessary to use a combination of methods to view the issue from a positivism and interpretivism perspective simultaneously.

To gain insight into whether NH personnel will embrace robotic systems to assist with drug administrations, the researcher must assess their perspective as to whether this approach would meet their needs. Since robotic systems are not currently being used in NHs for this purpose, a survey will provide a medium to acquire some feedback to evaluate this approach.

Given that the process of administering drugs is a social interaction that takes place in various locales within the NH facility, the mixed methods design is ideal to begin discovery of the acceptance of robotic systems in this environment. A major advantage of the mixed methods design is that it calls for a combination of data collection methods. These in turn give the researcher an opportunity to gain a greater comprehension of the phenomenon, simply by exploring related data broadly. A deeper interpretation of ADEs

can be achieved if reported causes are combined with a specific list of related questions synthesized with verbal assessments of the when, why, and how.

Furthermore, data collected from secondary methods can enhance the validity of data collected from primary methods, if the datum from any secondary method correlates. For example, the data collected from a focus group can either support or refute data collected from a survey within the same study. Thus, correlation can be determined in regards to validity of the data collected from the two methods. An advantage of using a focus group is that enhanced conversation can occur in a single setting with individuals who are close to the issue. A standard set of questions can be elaborated upon directly with the participants or expanded upon based on responses from the participants. With these advantages, the researcher has a great opportunity to collect a rich set of data by asking appropriate questions relative to the conversation that can support the data from another method.

If only a single method is used as the primary data collection tool to evaluate ADEs, the data may be insufficient to determine the full realm of ADE causes. Survey participants can very easily fabricate their answers, which would not reveal the true nature and causes of ADEs. Participants of focus groups can very easily exaggerate ADE instances they witnessed, actually caused, or simply heard about. Verbal feedback in this setting can be untrue, partially true, or influenced by peer pressure, which also weakens the context of the data. Flawed discovery of the nature and cause of any phenomenon is not the aim of scholarly research. These possible scenarios highlight the need for

researchers to be aware of their choices and the consequences that they may bring to their research.

Verification and Validation of Models

In general, Sargent (2013) noted that models are commonly used to design new systems, extend existing systems, and research new approaches to existing problems. Sokolowski and Banks (2009) added that a model can be used to substitute a real system to gain new understanding of some particular aspect of it. Sargent further noted that every model should be predicated on a specific purpose. Consequently, each implementation of a specific purpose is to study a real-world or proposed system (Law & Kelton, 2000), which is the fundamental utility of a model.

According to Feinstein and Cannon (2001), a main problem with a model is that the degree of effectiveness depends on the model's intended purpose. Stated another way, the validity or acceptable range of accuracy, as predetermined by the model designer, is based on its intended purpose (Sargent, 2013). In some cases it is critical for the model to function exactly as intended without errors, issues, or concerns. In other cases it is acceptable if the model is not exact, meaning it is acceptable if the model functions close to the real system. Perhaps this is why researchers must take into consideration the constructs of fidelity, verification, and validity to justify the acceptable range of accuracy in either case.

Model Fidelity

The fidelity of a model is concerned with the perception of the learner on how real the simulation seems when it is compared to the real-world system (Feinstein &

Cannon, 2001). Ignoring this consideration may lead to creating a model that is insufficient to carry out the intended purpose. Therefore, the designer should place emphasis on the equipment associated with the model to create a high degree of similarity to the real-world system relative to the environment. Sargent (2013) cautioned though that it is costly to obtain absolute fidelity of a model, meaning some of the equipment used to develop the model may be different from the real thing. Sokolowski and Banks (2009) described this difference as an approximation of the real thing.

Because approximation is a possibility in the construct of models, it is critical for the designer to test the model until the acceptable range of accuracy Feinstein and Cannon (2001) described is accomplished. Otherwise, the model is invalid and not sufficient for the intended purpose. However, Sargent (2013) noted that even for models that are deemed valid, the designer should be cognizant that the model still may not handle all situations in the environment in which it will be demonstrated.

Model Verification

Feinstein and Cannon (2001) asserted that verification and validation go hand in hand. Verification is ensuring that the implementation of the model is correct (Sargent, 2013); it is a process by which the designer applies various approaches to determine if the model produces the desired results (Feinstein & Cannon). Validation, on the other hand, is the process of determining that the model satisfies its intended goal within the established domain of accuracy (Feinstein & Cannon; Sargent).

According to the definitions of verification, designers cannot render a model correct if it contains serious errors. Depending on the type of model, mathematical or

symbolic, different approaches to verification may take place. For instance, a mathematical model may be verified through debugging software while a symbolic model may be verified by accomplishing all the conditions of a well-crafted plan that incorporates all possible outcomes of the intended purpose (Sokolowski & Banks, 2009).

Both mathematical and symbolic models can also be validated through comparison testing, where the results from multiple variations of the same model are compared for consistency (Sokolowski & Banks, 2009). Regardless of the type of model, whenever possible the verification process should involve subject matter experts who can objectively evaluate the fitness of the model by comparing it to a real system (Feinstein & Cannon, 2001). The general outcome from this approach reduces risk, builds confidence, and reinforces justification that the model will be able to meet the intended purpose.

Model Validation

In tandem with verification is the process of validation. Sokolowski and Banks (2009) defined validation as a cyclical process of testing to ensure that the model meets its intended purpose as determined by the model designer. As part of the cyclical process of testing, the designer is tasked to assess the degree of accuracy of the model's representation of the real system by the results that it produces as compared to expectations set during the design stage of the model. This means that a model may produce results that may be close to being accurate or vary slightly among multiple tests and still be deemed valid by the designer.

However, Sargent (2012) cautioned that if a model fails to meet any of its predefined experimental conditions, it cannot adequately represent the pertinent aspects of the real-world system. Thus, the results from testing the model will be invalid. Even with this possibility, Sokolowski and Banks (2009) noted that the degree of accuracy depends on the intended purpose of the model and how it is tested. Ultimately, the degree of accuracy is the level of confidence that the designer has in the model based on the results it produces as compared to the expected results (Sargent, 2013).

Advantages and Disadvantages of Modeling and Simulations

Sokolowski and Banks (2009) presented a general list of advantages and disadvantages that are common in modeling and simulation. Perhaps the biggest advantage of simulation is the ability for the designer to confirm feasibility ahead of investing time, money, and resources into building a real system (Murphy & Wakefield, 2013). It is far easier to adjust and test a model for various conditions repeatedly than it is to design, redesign, and retest the real thing repeatedly. By using simulation to confirm feasibility, model designers have the ability to introduce various behaviors, if desired, to see how the model will react.

Since models typically imitate real systems, investigating the effect of various behaviors and addressing any problems that result from them are important in ascertaining that the model is valid (Sokolowski & Banks, 2009). This investigation could also reveal unforeseen constraints, which could expose a weakness in the model, causing the developer to revise the model's functionality to enhance its validity. In this regard, Sargent (2013) acknowledged that modeling and simulation provide a means to

develop in-depth understanding and research of a hypothetical or proposed application. Therefore, the model must be fit to accomplish the goal of understanding and research.

Sokolowski and Banks (2009) noted that the results of a simulation do not have to be conclusive to render the simulation successful. In general, what-if questions may arise with respect to the outcome of the simulation, but for simulations where inferences are avoided, what-if questions are expected. In either case, adjustments to the model may become necessary, which extends the time of when the model could become real. Sokolowski and Banks declared that this is acceptable because stakeholders should be confident in the simulation results before investing money and resources to develop the model into a real system. On the other hand, sometimes a real system is not the goal. Instead, the real system already exists, but the goal of the simulation is training, which is typically better and more cost effective versus training on the real system.

Simulations Using Models

Sokolowski and Banks (2009) explained that a model, which imitates a particular real-world system, is the instrument used by simulation. Thus, simulation is an act that uses a model to understand behaviors, characteristics, or outcomes of a proposed extension to an existing system, imitation of an existing system, or to a new concept. Murphy and Wakefield (2013) stated that models used within simulations are executable specifications of a particular design. Therefore, as the specifications change, so does the model which gives the designer the opportunity to refine the model so that it eventually functions as desired to accomplish its intended purpose.

Sokolowski and Banks (2009) noted that simulation is no longer primarily used only by military branches for training activities. Simulation is also used in many other areas, such as business, politics, transportation services, social sciences, and health sciences (Sargent, 2013; Sokolowski & Banks, 2009). Stakeholders in these industries are concerned about the viability of the targeted approach, but before investing time, money, and resources into the approach, they are looking for some assurance that the approach has a high probability of success as determined through simulation. For example, Old Dominion University and the Virginia Model, Analysis, and Simulation Center combined their efforts to establish a research program for the purpose of developing models to represent innovative solutions for a variety of problems that persist in the medical industry (Sokolowski & Banks, 2009). The outcomes of their simulations ultimately determine go-forward decisions to invest time, money, and resources to transform models into real-world systems.

In simulation, the model is typically put through repeated trials to determine its fitness with respect to its intended goal. Stated another way, it is necessary to execute the model many times to verify and validate that it produces a consistent result over time relative to the environment that it is designed for. However, in some cases a model is merely a one-time show or demonstration of its intended purpose. Sokolowski and Banks (2009) called this facet of simulation experience, where the model is designed for the purpose of new development or for the enhancement of motor skills, decision-making skills, or operational skills. Therefore, the usage of a model to demonstrate experience can be investigated through simulation.

Simulation, which executes a model, can be used when the real system is unavailable. In other words, this could be because the real system does not exist or because engaging the real system could be hazardous to human life (Sokolowski & Banks, 2009). This latitude provides model designers with the opportunity to investigate, by way of simulation, the feasibility of ground-breaking innovations beyond what currently exists. Murphy and Wakefield (2013) asserted that simulation used in this manner is a significant contributor to ground-breaking innovations that eventually become real-world systems.

Summary and Conclusion

The literature that I reviewed in Chapter 2 presented overwhelming evidence that ADEs are a significant problem in NHs and hospitals. While there is no single definition for an ADE, Bates and Slight (2014) presented a simple explanation of what constitutes an ADE; an ADE is any type of injury or death to a patient as a result of medication they were given. However, the types of injuries that result are quite vast, which may be a contributing factor into why this problem is persistent and difficult to solve. AHRQ (2001) and Wittich et al. (2014) described it as divergent and varying.

ADE errors can occur in all stages of the medication-use process (Bates & Slight, 2014), where human involvement is required to order, transcribe, dispense, and administer medications. These mistakes degrade the quality of life for unfortunate recipients. Some patients even die from them. Health care facilities are negatively affected by the huge financial costs associated with the effects of ADEs. In this regard, professionals from the medical industry and the scholarly research community realize the

severity of this problem and are actively carrying out research to decrease the high number of ADEs reported in the literature.

Even with recent advancements, such as traditional ambulatory reporting systems, computerized error-reporting systems, electronic prescribing, and various types of specialized systems, AHRQ (2001) suggested that researchers should investigate the extended use of technology as a viable alternative to reduce ADE numbers further. This implies that current forms of technology should be evaluated in new ways to produce innovation that might have a positive impact on this problem. For instance, RT has brought many benefits to society, particularly in the medical industry, but with regards to ADEs, the utilization of RT has been very limited in the NH setting (Van den Bemt et al., 2011).

Even with an investigation into RT as a possible solution, a broader view of the causes of ADEs must be understood, especially since ADE numbers are extraordinary (Handler, 2012). None of the literature that I reviewed in Chapter 2 approached exploration of the problem from multiple perspectives simultaneously. Perhaps this limitation limited progress. Regardless, it is crucial to understand the natural causes of the issue firsthand along with the personal perspective of management and the employee in the same arena at the same time.

Farquhar et al. (2011) supported the idea of using multiple methods, because the researcher typically acquires a more comprehensive view of the problem, which increases the depth of understanding. Relative to my research, it was necessary because ADEs are a long standing problem that can have devastating effects on patients, their family, and

often times the NH. In this case, a mixed methods approach is called for. With this type of approach, naturally occurring cases, along with the personal perspective of those directly involved with the drug administration task in NHs, can be analyzed both qualitatively and quantitatively. In Chapter 3, I describe my research design in detail and how the gap in the literature (the scarce usage of RT to reduce ADEs in NHs) was addressed.

Chapter 3: Methodology

The first purpose of this mixed methods research was to assess the causes of human-initiated ADEs of solid drugs, namely tablets, capsules, and pills in the NH environment. The second purpose was to assess the perceptions of nurses and administrators in regards to the usefulness of RT to aid in reducing the frequency of ADEs within NHs.

To carry out the second purpose, I built and utilized a physical model to demonstrate RT to a limited group of nurses and administrators within Memphis-area NHs. Primary data collected via the focus group method, the survey method, and historical records (past ADE errors reported to the National Institute of Health) was used to address the RQs. This chapter contains a detailed description of the research design and methodology that I chose to explore ADEs and the robotic simulation that was demonstrated to nurses and administrators. Further details in regards to how the chosen research design and methodology was instrumental to explore this issue are forthcoming in this discussion. In this narrative, I also provided a rationale for the chosen data collection design, selection logic of the participants, justification for the sample size, instrumentation, and how the design helped me answer the RQs and test six hypotheses. In addition, the data analysis plan was expressed along with possible threats to validity and issues of trustworthiness.

The plans expressed for this research were reviewed and conditional approval was granted by the Institutional Review Board (IRB) on November 9, 2015. Approval to proceed in conducting this research was contingent upon providing the IRB with a signed

letter of cooperation from each of three community research partners. The Walden IRB approval number associated with this research is 11-09-15-0123805.

This research was conducted in two randomly selected NHs in the Memphis Metropolitan area and one randomly selected NH slightly outside of the Memphis Metropolitan area. Among the three NHs, collectively more than 368 residents were being cared for during this research. In comparison to the Memphis Metropolitan area, there were 15 other metropolitan areas across the U.S. of comparable population size of approximately 1 million to 1.6 million citizens. The Memphis Metropolitan area was chosen because it is where the researcher lived, which made collecting the data easy and convenient to acquire.

The three NHs selected for this research had three distinct characteristics: size and quality. First, one NH was small (less than 90 beds), one NH was medium (90 to 180 beds), and one NH was large (more than 180 beds). Second, selection was based on availability to participate in this research. Third, selection was based on a medium quality rating of 3 (out of 5) or less to eliminate any bias in the results due to the quality rating of the NH. According to this scale established by the CMMS (2015), a rating of 1 was the lowest ranking, meaning these NHs were plagued with a high number of care issues. A rating of 5 was the highest ranking, meaning these NHs did not have a high number of care issues.

Research Design

This research was guided by the mixed methods approach, where both quantitative and qualitative methodologies were used in the analysis of the data. The

basis for the qualitative portion was exploratory case study and the basis for the quantitative portion was an experimental design. This approach allowed me to utilize a variety of instruments, including surveys and focus groups, analyzed both qualitatively and quantitatively.

The mixed methods approach permitted me to examine ADEs from two viewpoints. First, according to Sawarkar et al. (2012), nurses are primarily responsible for administering drugs in the NH setting. Therefore, there is a direct relationship between ADEs and the administration activities nurses perform. For this reason, it was necessary to understand what circumstances caused nurses to make mistakes during administration activities that led to ADEs.

Second, the issue of ADEs is so critical (Parker-Pope, 2011) that for ethical, employment, and legal reasons nurses may refrain from reporting or admitting to drug errors that they may have caused. While this is a serious consideration to ponder, additional consideration was taken to understand how and why errors at this stage of the medication-use process occurred. From this research, I gained insight from varying angles how to possibly minimize drug administration mistakes so that any new approach, such as RT, can be designed in a manner that would help reduce ADEs. Based on previous studies in this area of research (as noted in Chapter 2), RT has not been used to assist with drug administration in NHs (Borenstein, 2011). This deficiency makes the mixed methods methodology ideal to begin discovering the possibilities of this approach.

Design Composition

The study design entailed five parts. In the first part, I planned to investigate historical ADE data collected and reported by each participating NH over a consecutive 3-month period of time within the last six months prior to my research. A current timeframe provided me with the opportunity to evaluate recent occurrences of ADEs. Within this investigation, I focused specifically on solid drugs, because the model was designed and constructed only for drugs that come in solid form. Regardless, this limitation still allowed effective triangulation with the data that I collected from the survey and the focus group. To protect the privacy of the historical data, I asked the NH only for the name of the drug, the time of day associated with the ADE, and the reason for the ADE.

In the second part, I used two separate 5-point Likert scale surveys. I used the ADE survey (Appendix A) for a qualitative assessment of how nurses and administrators believe ADEs may occur related to the areas of experience, training, and guidelines & procedures. The results from the ADE survey helped to answer RQs 1, 2, and 3. I used the RT survey (Figure B1) for a quantitative evaluation of how nurses and administrators feel about RT for the purpose of assisting with solid drug administrations to reduce ADEs. The results from the second survey helped to answer RQs 4 and 5.

Prior to administering either survey, I explained the nature and purpose of both surveys to all participants. I did not explain that I would assign them to a control group or to a treatment group. I also did not make the participants of the control group aware that the treatment group would see a demonstration of RT. As far as the control group knew,

they would simply be taking a survey, twice, regarding RT's feasibility in a NH environment. The treatment group was told, separately, that they would see a demonstration of RT.

For the control group, I explained the reason for taking the survey a second time as follows. It was necessary for me to obtain a second round of responses to determine if distractions or interruptions may have caused a variance in their initial responses, especially since everyone (participants) would not be available at the same time. I explained that I was seeking their honest and objective perceptions of the use of RT to assist in drug administrations in NHs. To make this determination, I only needed to re-survey some of the participants instead of all participants.

After answering a few questions that arose, I asked all participants to immediately and anonymously take both surveys. By administering both surveys at the same time, I limited disruption to their work schedule in addition to saving time to collect and organize this segment of the data. After one week, I asked the control group participants to take the RT survey (Figure B1) for a second time. The time delay between the first time the control group took the survey and the second time was intentional. By waiting a week, the participants may be less likely to remember all of the answers they provided on the first occasion, and this was the case. Thus, taking the survey again and after a period of time allowed me to determine if their responses changed simply because they took the survey a second time.

The 1 week delay took place in advance of but just prior to demonstrating the model to the treatment group and in advance of the treatment group taking the RT survey

(Figure B1) a second time (after they view the model). I anticipated that this timing would minimize any influences and biases that the treatment group may impose on the control group relative to them viewing the model and taking the survey on the second occasion.

In the third part, I introduced the model to the treatment group to gain their individual perspectives on using RT, after they saw a demonstration of how the technology would work, to assist in drug administrations. By demonstrating the model to the treatment group and not to the control group, I had the opportunity to determine if a physical demonstration of the model would influence their answers to the RT survey as compared to the control group.

Both groups were comprised only of administrators, registered nurses, licensed practical nurses, certified nurse assistants, and one nurse practitioner. Direct interaction between the model and the participants did not occur, because I built the model for demonstration purposes only. For this reason, I did not use the model on the NH floor to interact with actual residents. I merely demonstrated the model in a conference room that was designated by the lead administrator at each participating NH.

In the fourth part, which began immediately after demonstrating the model, I asked the treatment group to take anonymously the RT survey (Figure B1) a second time. This timing allowed me to acquire data that expressed how the treatment group thought about RT before seeing the model and how the treatment group thought about RT after viewing the model. To prevent interfering with their work activities, I granted each

participant from the treatment group five days from the day of the demonstration to complete the RT survey for the second time.

After the survey period concluded, I began the fifth part where I gathered the thoughts and opinions of administrators (including nurse supervisors) via a focus group discussion guided by the focus group questions listed in Appendix D. Since administrators do not typically administer medications, the focus group approach was ideal to capture their perspective on ADEs. In addition, the focus group provided me with a means to obtain some insight into current processes and procedures deployed within each NH.

By assessing the issue of ADEs with three data collection methods, I was able to integrate the data from each method to thoroughly answer the RQs and gain a greater understanding of ADEs at the administration stage. I executed all five parts in each participating NH separately and in succession.

Research Rationale

The design framework for my research was comprised of a group presentation (a demonstration of a model of robotics technology), two surveys, and a focus group discussion. The scholarly literature covering these methods was described in Chapter 2. This design served two purposes. First, combining the data collected from these methods provided the means to associate quantitative and qualitative data to assess the issue of ADEs comprehensively. By acquiring multiple perspectives on the same issue, a profound level of understanding would most likely emerge during the research (Farquhar et al., 2011). Since the issue of ADEs in NHs is a serious problem that is costly from

multiple viewpoints (USDHHS, 2014a), it was necessary to understand as much about the issue as possible in this research, so that any potential solution can achieve minimizing ADEs on all points.

Second, understanding from multiple viewpoints was critical to my research. Currently, many individuals suffer from ADEs and others die, despite valiant efforts by past researchers to find better solutions. With the population of the elderly gradually increasing (Administration of Aging, 2014), so will the number of seniors who rely on NHs for their care. Similarly, the number of individuals suffering or dying from ADEs will increase too, unless a universal solution can be found to keep ADE numbers low. Because a universal solution has not been found, a broader view of different segments of data at the same time may be the key to finding a universal solution. Only a small number of studies examined in the literature that I reviewed took this approach, where different segments of data was collected and analyzed with a mixed methods design.

According to Grinnell and Unrau (2011), it is common to use a combination of methods in research studies (p. 335). Several researchers in the reviewed literature used this approach and found that it substantially improved the outcome of their studies. In the case of my research, a combination of methods is warranted, because insight from both nurses and administrators is necessary to understand the root causes of ADEs to a greater extent than what is currently known.

Multiple researchers from the reviewed literature showed how various technological applications reduced the occurrences of ADEs (Van den Bemt et al., 2011). As the literature review in Chapter 2 indicated, incremental progress has been made, but

to deal with the human element, which is the main cause of most ADEs (Westbrook et al., 2011), a new system must be developed, one that incorporates the main benefits of existing systems while adding new measures to reduce error rates even more (Samaranayake et al., 2014). A system of this nature cannot be developed unless the issue is thoroughly evaluated with various assessments simultaneously. Evaluating the issue of ADEs with various techniques was the purpose of the mixed methods approach employed in my research.

Research Questions and Hypothesis

Qualitative Portion of the Research

Research question 1. How are drugs administered in the participating facility? The notion that adverse drug events are prevalent in nursing homes (Horowitz, 2014) may indicate that NHs vary greatly in how they administer drugs. Such drug administration processes and procedures vary for many reasons, but since ADEs are affecting the quality of life for so many seniors dependent on NH care, it was necessary to evaluate these processes and procedures to determine if they contributed to ADE occurrences, either directly or indirectly. Familiarity with the processes and procedures at the participating NHs was acquired through the focus group discussions. Consideration of how NH processes dictate how nurses administer medications was also necessary to determine if a robotic system could potentially be instrumental to overcoming situations where a human-initiated ADE may otherwise have occurred.

To answer this RQ, administrator personnel (including nurse supervisors) in each NH were asked to participate in a focus group discussion. Since administrators are the

governing body within these NHs, their perspective on how drug administration errors occurred was important to assess whether processes and procedures are contributing factors in addition to the mistakes nurses make. The focus group discussion took place within each NH after the survey period for both groups had concluded. As anticipated, this timing generated heightened excitement among administrators and stimulated enhanced conversation. As an expression of gratitude, a catered lunch accompanied this discussion, which was structured using the six focus group questions listed in Appendix D.

The questions posed during the focus group were intended to gain insight into whether drug administration policies were designed as a result of funding, management's opinion as to the cause of ADEs, management's knowledge of existing prevention measures, and whether internal training is available to refresh and extend the skills nurses have related to drug administration. As the discussion unfolded, additional questions emerged from the responses received from participants. In addition to focus group data, the scores obtained from the ADE survey (Appendix A) were also used to answer this RQ.

Research question 2. How do ADE errors in the form of pills, tablets, or capsules occur in nursing homes? According to the reviewed literature, the causes of ADEs are vast (Wittich et al., 2014). Some of the reasons for ADE occurrences more than 10 years ago may still be prevalent today. However, processes, procedures, and technologies used within NHs are most likely not the same as they were 10 years ago, due to a variety of factors aimed to improve care. For these reasons, any attempt to address ADEs must

continue with discovery of the current causes. As Horowitz (2014) indicated ADEs are still high, which justifies the need to re-evaluate the causes since they may or may not be the same as they were during previous research.

To answer this question, I identified the causes of ADEs through an evaluation of historical evidence (errors reported by the NH to the National Institute of Health) to determine which errors occurred and how they occurred between residents and nurses, and results from the ADE survey (Appendix A). This segment of data collection did not involve direct observation of any drug administration activities. Instead, I used the historical ADE data collected from each participating NH to help answer my first purpose, which was to evaluate the causes of ADEs.

Research question 3. What knowledge do managers have of existing practices to reduce ADEs? The focus group discussion at each NH and data from the ADE survey (Appendix A) provided a forum to answer this question. Since the issue of ADEs is quite prevalent (Handler, 2012) any new attempts to reduce incident rates should evaluate recent improvements, especially in the area of technology. Improvements in the domain of ADEs have had a positive effect, but not to the degree to reduce the thousands of deaths and countless medical complications of unfortunate patients Handler mentioned. Evidence lies in the literature where it was reported that ADE occurrences are steadily increasing (Horowitz, 2014).

Diaz Pavon and de la Portilla (2011) observed that technology, specifically RT, has brought some magnificent benefits to the medical industry. Perhaps the usage of RT can assist in the administration of medications and produce similar ground-breaking

benefits, such as a significant reduction in ADE error rates in NHs where Van den Bemt et al. (2011) stated that RT does not exist.

To answer this question, I used the same administrative population selected for RQ1 at each NH. I assessed their knowledge and perceptions of existing measures to reduce ADEs via a focus group discussion. It was important to discover if their lack of knowledge or their perceptions are contributing factors to ADEs. This potential deficiency aligns with the contention of Westbrook et al. (2011) and Kiekkas et al. (2011) that human error is the primary reason for ADEs. Although, the idea expressed here was that management's lack of, or limited knowledge of, existing measures that could be deployed to reduce ADEs in their NHs is also a kind of human error. If management is not up to par on current knowledge of existing measures, then errors can result as a consequence of simply not knowing. Also, critical for this question was an assessment of management's enthusiasm and support for new measures that may contribute to reducing ADE error rates.

Quantitative Portion of the Research

The quantitative portion of my research involved one dependent variable, individual participant survey response (*r)*; two independent variables: whether or not the participant witnessed the robotic simulation and which survey (the first or second RT survey) (Figure B1). The population property that I measured was the individual's (nurses and administrators) response to each question on the RT survey (*r*). Since there were two independent variables with two categorical values each, there were four populations (2 x 2 = 4) associated with my research from an experimental design

perspective. To answer the RQs, and test the research hypotheses, I made the following statistical comparisons between those populations:

- Control group at the time of the first survey (before the treatment group sees the robotic demo).
- Control group at the time of the second survey (after the treatment group sees the robotic demo).
- Treatment group prior to seeing the demo (first survey).
- Treatment group after seeing the demo (second survey).

Using the numerical index of the individual responses (r) from all participants, I calculated several mean responses (R) calculated from samples of the four populations. I used the sample means to perform three categories of hypothesis tests: (a) comparing a sample mean (the mean response regarding robotics) relative to a fixed number (a neutral response = 3); (b) comparing the sample means of two separate, independent populations (a control group and a treatment group); or (c) comparing sample means between two related populations (e.g., the treatment group before and after the robotic demonstration or the control group between the first and second survey). Details related to the actual hypothesis tests that I performed are described in the next section. Specifically, I executed six hypothesis tests to analyze the participants' views regarding robotics and their comparative reactions to the robotic demonstration.

Variables and comparisons. To answer the hypotheses described in RQs 4 and 5, I calculated several sample means (R) based on the individual responses (r) from the RT survey (Figure B1) to perform several comparisons (hypothesis tests). Figure 1

depicts the various sample means and comparisons (hypotheses). Table 1 depicts the comparisons in this research.

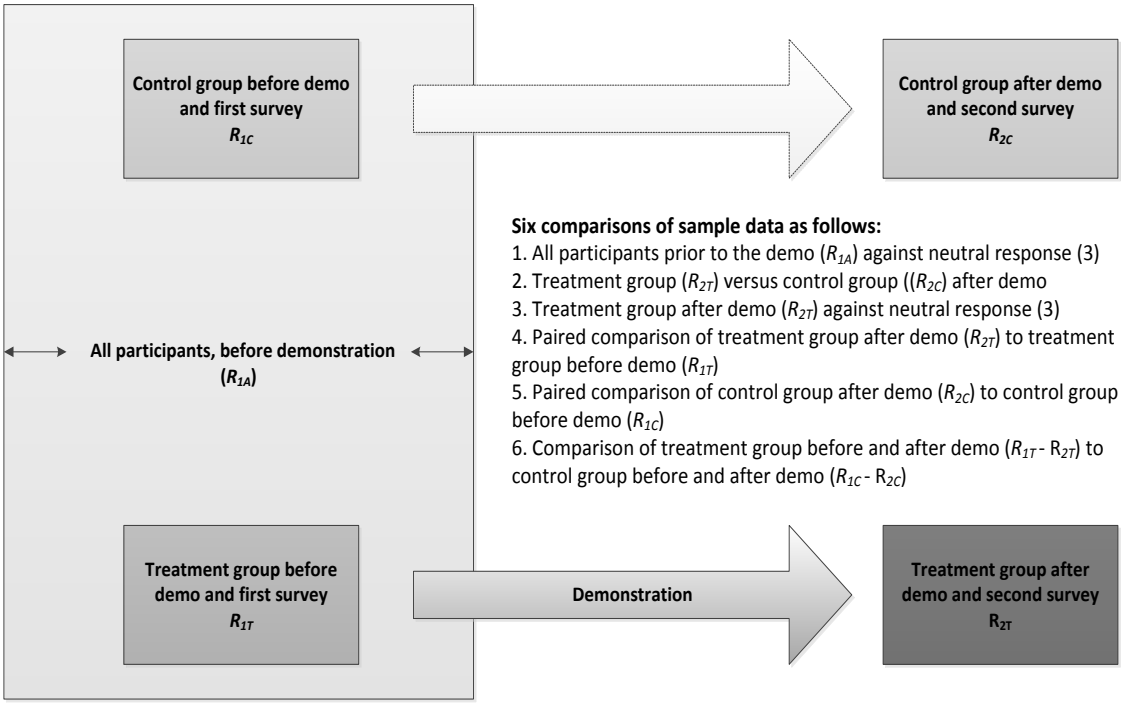


Figure 1. Relational diagram of RT survey posttest and pretest comparisons.

Table 1

Relationship of the Population Parameters and Sample Means

	Population parameter	Response sample means
All participants of the sample population (first survey)	μ_{1A}	R_{1A}
Control group before demo (first survey) to treatment group	μ_{1C}	R_{1C}
Control group after demo (second survey) to treatment group	μ_{2C}	R_{2C}
Treatment group (first survey) before demo	μ_{1T}	R_{1T}
Treatment group (second survey) after demon	μ_{2T}	R_{2T}
Paired difference of control group (first and second survey)	$\mu_{DC} = \mu_{1C} - \mu_{2C}$	$R_{DC} = R_{1C} - R_{2C}$
Paired difference of treatment group (first and second survey)	$\mu_{DT} = \mu_{1T} - \mu_{2T}$	$R_{DT} = R_{1T} - R_{2T}$

In the quantitative portion of this research (addressing RQs 4 and 5), there were six comparisons (and hypothesis tests) involving survey sample means (R):

- Response of all participants before the demonstration (R_{1A}) compared to a neutral response (3).
- Response of the treatment group (R_{2T}) compared to the control group (R_{2C}), after the demonstration.
- Response from the treatment group (R_{2T}) after the demonstration compared to a neutral response (3).
- Response from treatment group after the demonstration compared to the response from the same group before the demonstration (R_{DT}).
- Response from the control group during a second survey (after the treatment group sees the demonstration) compared to the same group the first time they took the survey (R_{DC}).
- Change in response for the treatment group (before and after viewing the demonstration) compared to the change in response for the control group (before and after the treatment group views the demonstration) (R_{DT} versus R_{DC}).

The fifth of these comparisons addressed the issue of determining whether or not any differences in the treatment group response after viewing the demonstration was due to taking the survey a second time. To eliminate this potential influence, I performed the same hypothesis test for the control group during a second round of the survey, which

was after the treatment group viewed the demonstration. With this direction, if the control group showed no difference in their response during the second survey, then there would be significant evidence to support the claim that taking the survey a second time would not influence the results. If there was a difference, I would not be able to determine with certainty that for the treatment group, the demo made a difference or that taking the survey a second time made a difference.

Research question 4. How do nursing home professionals feel about the potential for RT to reduce ADEs? According to the reviewed literature, it is unknown if RT can be effective in reducing the rate of ADEs due to its sparse use in assisting with the administration of medications in NHs. Van den Bemt et al. (2011) acknowledged this sparse use. On the contrary, the success of robotic systems in hospital pharmacies to dispense medications opens the door to question if it can be successful in the NH setting as well.

I answered RQ4 based on the responses to the 5-point Likert scale RT survey (Figure B1) from both groups collectively and prior to the treatment group viewing the model, meaning none of the participants had seen the model. In this quantitative portion of my research, I understood how NH professionals felt in general about RT to assist with solid drug administrations in NHs without the influence of a model of the RT. Their perception may have indicated that an advanced technology that was currently not being used in NHs was necessary to reduce ADEs or their perception may indicate that a technology that has no history of being used to assist with solid drug administrations in NHs was impractical. It was also possible that their overall perception would be neutral

(a Likert scale ranking of 3), which could have meant that nurses and administrators felt RT may or may not change the rate of ADEs in NHs.

Hypothesis 1 (H1): Pertained to the favorability of all participants (prior to the demonstration) from all three NHs collectively. For *H1*, I used the mean response to all 10 questions for all participants to determine if their perception of RT was greater than the neutral response. The null hypothesis was that the mean response from all participants is less than or equal to a neutral response. This would indicate that the participants overall felt RT would increase the rate of ADEs or keep the rate of ADEs the same in NHs. The alternative hypothesis was that the mean response from all participants is greater than the neutral response. This would indicate that overall the participants felt RT may reduce ADEs, despite not having seen how the technology might work. The higher the mean response (for all of the survey questions collectively), the more favorably the participants perceived the technology. The computed mean provided data to test the hypothesis with the *t* test of the mean of a single population. The hypothesis was expressed mathematically as follows:

$$H_{10}: \mu_{1A} \leq 3$$

$$H_{1a:} \mu_{1A} > 3$$

Research question 5. Do nursing home professionals have a more favorable perception about RT to reduce ADEs after viewing a demonstration of that technology? Some nurses and administrators may find it difficult to visualize RT working in a NH environment to assist with solid drug administrations to reduce ADEs. Van den Bemt (2011) stated that RT does not exist in NHs for this purpose. Therefore, an historical

basis for nurses and administrators to base their opinion on did not exist, which could possibly lead them to believe that RT for the purpose of reducing ADEs in NHs is not possible.

During the course of my research, I built a physical model similar in nature to existing robotic systems that are used to dispense medications in some U.S. hospitals. Using the model, I demonstrated the technology only to nurses and administrators assigned to the treatment group to acquire data that represented how they viewed RT after seeing how it would work. I did not demonstrate the model to the control group, which gave me the opportunity to compare how the treatment group thought about the technology as opposed to the control group.

Hypothesis 2 (H2): Pertains to comparing the treatment group with the control group from all three NHs collectively, after the treatment group viewed the model. For hypothesis 2, I compared the mean response from the treatment group (after viewing the model) to the control group (their second survey, administered after the treatment group has viewed the model). The mean response was the average score from all 10 survey questions for all participants of each group (the treatment group and the control group). The null hypothesis was that the mean response from the treatment group is less than or equal to the mean response from the control group. This would indicate that the treatment group felt RT (based on a demonstration of the model) may increase or not change the rate of ADEs in NHs compared to the control group. The alternative hypothesis was that the mean response from the treatment group is greater than the mean response from the control group. This would indicate that the treatment group felt RT could reduce ADEs in

NHs as compared to the control group. The computed mean provided data to test the hypothesis with the *t* test of the means of independent populations. The hypothesis was expressed mathematically as follows:

H_{20}: $\mu_{2T} \leq \mu_{2C}$

$H_{2a:}$ $\mu_{2T} > \mu_{2C}$

Hypothesis 3 (H3): Pertains to all treatment group participants (after viewing the model) from all three NHs collectively. For hypothesis 3, I compared the mean response from the treatment group (after viewing the model) to a neutral response. The null hypothesis was that the mean response of the treatment group is less than or equal to a neutral response. This would indicate that the treatment group felt RT may increase or not change the rate of ADEs in NHs. The alternative hypothesis was that the mean response from the treatment group is greater than a neutral response. This would indicate that the treatment group had a favorable view of RT to reduce the rate of ADEs in NHs. The computed mean provided data to test the hypothesis with the *t* test of a single population. The hypothesis was expressed mathematically as follows:

H_{30}: $\mu_{2T} \leq 3$

$H_{3a:}$ $\mu_{2T} > 3$

Hypothesis 4 (H4): Pertains to the perception of the treatment group (after and before viewing the model) from all three NHs collectively. For hypothesis 4, I assessed the paired differences for the treatment group, before and after viewing the model. I first calculated the mean response of each participant to all 10 questions before viewing the model, and then calculated the mean response for each participant to all 10 questions

after viewing the model. Then for each participant, I subtracted their mean response *before* from their mean response *after* to come up with their difference scores. Then I calculated the mean difference scores for the treatment group participants.

The null hypothesis was that the mean difference for the treatment group is less than or equal to zero. This would indicate that the demonstration did not influence positively the perception of participants within the treatment group (or negatively influenced them). The alternative hypothesis was that the change in mean response for the treatment group is greater than zero. This would indicate that the demonstration did influence positively the perception of the treatment group. I tested the hypothesis with the paired *t* test of the means of two related populations. The hypothesis was expressed mathematically as follows:

$$H_{40}: \mu_{DT} \leq 0$$

$$H_{4a}: \mu_{DT} > 0$$

Hypothesis 5 (H5): Pertains to the perception of the control group (after and before the treatment group view the model) from all three NHs collectively. For hypothesis 5, I assessed the paired differences for the control group, before and after the treatment group sees the demonstration of the model. I first calculated the mean response of each participant to all 10 questions on the first survey, and then calculated the mean response for each participant to all 10 questions on the second survey. Then for each participant, I subtracted their mean response *before* from their mean response *after* to come up with their difference scores. Then I calculated the mean difference scores for the control group participants.

The null hypothesis was that the mean difference for the control group is less than or equal to zero. This would indicate that the control group provided a similar response, after taking the RT survey a second time. The alternative hypothesis was that the difference in mean response from the control group is not equal to zero. This would indicate that the control group provided a different response the second time, possibly as a result of taking a second survey. I tested the hypothesis with the paired *t* test of the means of two related populations. The hypothesis was expressed mathematically as follows:

$$H_{50}: \mu_{DC} = 0$$

$$H_{5a}: \mu_{DC} \neq 0$$

Hypothesis 6 (H6): Pertains to the perception of the treatment group (before and after viewing the model) as compared to the control group (before and after the treatment group views the model) from all three NHs collectively. For hypothesis 6, I compared the average paired difference from the treatment group (obtained from Hypothesis 4) to the average paired difference from the control group (from Hypothesis 5). The null hypothesis was that average paired difference from the treatment group is less than or equal to the average paired difference from the control group. This would indicate that the treatment group had a less favorable view of RT (after seeing a demonstration of the model) than the control group which took a second survey but never saw the demonstration. The alternative hypothesis was that the average paired difference from the treatment group is greater than the average paired difference from the control group. This would indicate that the treatment group had a more favorable view of RT (after seeing the

model) than the control group which did not see the model. I tested the hypothesis with the *t* test of the means of two independent populations. The hypothesis was expressed mathematically as follows:

$$H_{60}: \mu_{DT} \leq \mu_{DC}$$

$$H_{6a}: \mu_{DT} > \mu_{DC}$$

Role of the Researcher

As the researcher, I handled all activities related to the ADE survey (Appendix A) and the RT survey (Figure B1) as these activities did not require specialized skills to oversee. I handled the focus group discussion by beginning each of three discussions (one per NH) with the focus group questions listed in Appendix D. During the course of the discussion, I intentionally evolved the conversation with additional questions based on responses from the participants while limiting the discussion to an hour or less. I also handled all activities related to demonstrating the model, which included setting it up, describing it, and acquiring the minimum calculated sample size for each of the two groups within each participating NH.

Prior to the demonstration of the model, I explained to all nurses and administrators within the treatment group the context of my research, the overall intent of the model, and what was expected of them. I provided the same explanation to the control group, but without mentioning the model. I hoped that this brief conversation would generate enthusiasm among all participants and inspire them to respond with genuine feedback during the demonstration and/or on the survey. I also explained to nurses and administrators that their contribution to provide any feedback was not mandatory. Rather,

it was requested to support my research and the potential future benefits that RT may bring. Naturally, I acquired informed consent from the NH and from each nurse and administrator prior to their inclusion in my research.

Sampling and Survey Plan

To ensure that each of the two samples (participants who viewed the model and participants who did not view the model) contained an equal number of participants, I assigned every other participant, based on the order in which they consented to participate, to one of the two groups based on simple random sampling. The participants were mainly from the day shift since the majority of medications are administered during day shift hours when residents are typically awake. This timeframe lowered the number of available participants; however, the number of available participants was still slightly greater than the number of willing participants.

I asked any participant with a heavy or busy workload to refrain from participating along with informing the administrator that enough participants had already consented to take part in the research. This strategy resulted in the sample size being slightly above the minimum sample size needed, which saved a considerable amout of time and effort during the data collection period.

Along with randomly assigning the participants to the control group or treatment group, I assigned the participants of each group to a numerical code beginning with 1. For example, I assigned one person in both groups to number 1, one person in both groups to number 2, and so on. As I made these numerical assignments, I kept a manual record (first name, last initial, last 4 of phone number, group, and numerical assignment)

for each participant to ensure that I would administer the appropriately marked RT survey (Figure B1) to the correct particpant at the right interval of this research. The RT survey instrument was subtly different (only indicated by an identification code) to ensure that I would able to match the before and after results from each participant, but coded in a way that would make it difficult to trace the results to a specific participant. The ADE survey (Appendix A) was not marked with an identification code, because all participants took this survey once, and the results were aggregated for all NHs taking part in my research.

I coded the before and after RT survey (Figure B1) with a three part numerical identification code separated by a single dash. The first number (first part) identified the group the participant was assigned to where a 1 indicated the control group and a 2 indicated the treatment group. The second number (second part) identified which occasion of the survey the results were from. For the control group, a 1 indicated their first occasion of taking the survey and a 2 indicated their second occasion. For the treatment group, a 1 indicated their survey results before viewing the demonstration and a 2 indicated their survey results after viewing the demonstration. The last number (third part) anonymously identified an individual participant. For example, participant 5 of the control could be John and participant 5 of the treatment group could be Bill. Only I, as the researcher, knew the numerical assignment (last part) associated with each participant.

As an example of the identification code, the RT survey (Figure B1) for participant 5 of the control group was coded with 1-1-5 in the upper left hand corner, meaning the results were from the control group (1), the first survey (1), and participant 5

of the control group. For participant 5's second survey, the survey had identification code 1-2-5 in the upper left hand corner, meaning the results were from the control group (1), the second survey (2), and participant 5 of the control group.

The before and after RT survey (Figure B1) for the treatment group was coded in a similar pattern. For example, the *before survey* was coded with identification code 2-1-5, meaning the results were from treatment group (2), before the demonstration (1), and participant 5 of the treatment group. For the same participant, the *after survey* was coded with identification code 2-2-5, meaning the results were from the treatment group (2), after the demonstration (2), and from participant 5 of the treatment group.

Each individual NH was not represented in the schema of the identification code, because I did not intend to assess each NH independently. My assessment was collective. So, there was not a need to identify a participant in either group to a specific NH.

Survey Sample Size

The ultimate goal in computing an adequate sample size is to reduce the probability of making a false positive (Type I error) outcome or a false negative (Type II error) outcome. Using the values Cohen recommended, the chances that a researcher might make a false negative claim (failure to find an actual difference in means) is greater than the chances of a making a false positive claim (detecting a difference in means that does not exist). While neither a false positive or false negative claim is the goal of scientific research, the claim of a false negative is more tolerable, because inaccurate results are not distributed throughout scholarly literature.

Using the G*Power software designed by Faul, Erdfelder, Lang, and Buchner (2009), I calculated a minimum sample size for each hypothesis. For a conventional a priori power analysis, I used Cohen's (1992) recommendation of a medium effect size of 50% with a statistical power of 80% (where $\beta = 0.20$) and a confidence level of 95% (where $\alpha = 0.05$) to compute a minimum sample size for a normally distributed population.

For *H1* and *H3*, I intended to determine if there was a difference between a mean index and a constant value of three (neutral response). For *H2* and *H6*, I intended to determine if there was a difference between the means of two independent populations. For *H4* and *H5*, I intended to determine the difference in means between two related populations (paired).

I evaluated *H1* and *H3* with a single-group, one-tailed *t* test; *H2* with a two-group, one-tailed *t* test; *H4* with a paired, one-tailed *t* test; *H5* with a paired, two-tailed *t* test; and, *H6* with a two-group, one-tailed *t* test. The *t* test was appropriate in each case because the population standard deviation of the survey responses was unknown. For *H1*, *H3*, and *H4* (single-group, one-tailed test), I computed a minimum sample size of 45. For *H5* (two-tailed test), the minimum sample size was 54. For *H2* and *H6* (two groups), the minimum sample size was 51 per group or 102 total.

Mowery (2011) stated that collecting data beyond the calculated sample size increases the accuracy and validity (power and confidence) of any statistical test. Therefore, I used the larger sample size of 102 or 51 per group (where critical t =1.660)

as the minimum required sample size for each hypothesis test, which exceeded the minimum computed sample size of *H1*, *H3*, *H4*, and *H5*.

I estimated that among the small, medium, and large NHs that I would select for my research, each NH would have, respectively, a minimum of 45, 55, and 65 nurses and administrators on staff to cover all shifts over the course of a week. Thus, the available population would be more than sufficient to acquire the calculated sample size to effectively test each hypothesis.

Regarding the calculated sample size of 102 and three NHs, each of the six groups (three control groups and three treatment groups) would require a minimum of 17 surveys (102/6 = 17) to obtain adequate sampling. This yielded a minimum required sample size of 34 in each NH, 51 responses from the control group and 51 responses from the treatment group.

There was no guarantee that all participants in each group would take part in my research. Since both groups (control and treatment groups) took the RT survey (Figure B1) initially and at the same time, the number of participants in the treatment group prior to viewing the model (17 at a minimum) dictated the final number of participants for the treatment group after viewing the model and for the control group. For example, if 17 of 30 available participants from the treatment group (prior to viewing the model) took the survey, the participants in both the control group and the treatment group would be limited to 17 to preserve equal sampling between the two groups. Ensuring equal sample sizes between the two groups may have required a random discard of surveys (participants) from each group.

If the required sample size for the treatment group (at the stage when they view the model) was not acquired in one day, the group session to show the model would extend to a second or third day with the purpose of demonstrating it to other available participants. If the required sample size was still not acquired, I planned to reduce the number of surveys acquired from the control group to equal those acquired from the treatment group to no less than the minimum required sample size of 17. As a last option, I planned to choose a different NH with adequate available staffing to obtain the minimum required sample size of 17.

Focus Group Sample Size

The focus group provided a means of gathering candid feedback in a single setting from individuals who have extensive knowledge on issues related to ADEs. The three individual sessions (one session in each of three participating NHs) provided an environment where administrators (including nurse supervisors) felt comfortable sharing openly their experiences, opinions, and perspectives. The promise of confidentiality added to their comfort level and allow healthy, open conversations.

A mathematical formula was not used to calculate the minimum sample size for each focus group. According to the literature, an adequate sample size for a focus group can range from 4 to 12 people. For example, Krueger and Casey (2008) recommended 4 to 12 and Doody, Slevin, and Taggart (2013) recommended 6 to 10 as an adequate number of participants for a focus group. Gibbs (1997) pointed out that small sample sizes for focus groups are acceptable if the participants have similar backgrounds and are comfortable discussing the topic of interest in a group setting. More importantly, the

researcher should be able to obtain relevant, diverse, and similar information to assess the topic of interest from multiple perspectives with the small sample size (Gibbs, 1997).

Carlsen and Glenton (2011) pointed out that for a focus group a suitable sample size should be based on the number of groups rather than the number of participants within each group. This implies that the researcher must be careful to establish enough groups so that similar and diverse themes can be heard among them (DePaulo, 2000). To this end, the researcher must be careful to set an appropriate sample size in each group, comprised of individuals with specific characteristics (for example, gender, experience, and race), to obtain comprehensive data from the perspective of the participants (Gibbs, 1997). Gibbs (1997) further contended that the researcher must also establish enough groups based on similar research, availability of research participants, or the discretion of the researcher as to how many groups are applicable.

Based on the recommendations from Krueger and Casey (2008) and the general guidelines from Gibbs (1997), my sample size was set to a minimum of four administrators (and nurse supervisors) for each focus group session (one in each of three participating NHs). I chose this sample size because I anticipated that at least four administrators (including nurse supervisors) would be present in the NH on the day that I would conduct the focus group session.

In the event that additional administrators were available to participate, I purposely set the maximum sample size to six so that their responses could be included. Overall, the minimum size for each of three focus group sessions was four and the maximum was six, for an overall maximum of 18 participants.

Instrumentation

ADE Scorecard

All ADEs analyzed from the historical ADE data acquired from each participating NH was recorded on the ADE Scorecard (Appendix C) that I designed for this purpose. The data recorded on the ADE Scorecard was categorized from several perspectives. For example, type of medication, category of medication, frequency, and reason for the ADE. This data was qualitatively analyzed and triangulated with the survey results to provide critical information to answer the RQs.

Prior to my analysis of the historical ADE data, I printed hardcopies of the ADE Scorecard so that I could manually write on it during the inquiry. I chose that route to clearly delineate what information from the raw historical data I included in my research and how it was assessed. Each manually written upon sheet was scanned into a computer and stored in a password-protected directory onto an external hard drive. At the conclusion of my research, I stored the hard drive in a safety deposit box for a minimum of 5 years.

Survey Design

For my research, I designed two separate 5-point Likert scale surveys. The first survey, entitled Adverse Drug Event Survey (Appendix A), was based on the literature that I reviewed in Chapter 2 in which many authors concluded that most ADEs fall into one of three categories: training, experience, and guidelines & procedures. I used that survey in the qualitative portion of the research.

The second survey, the Robotic Technology Survey (Figure B1), addressed an additional topic, robotic technology, because the use of RT to assist with administering solid medications in NHs was not evident in the literature. Regarding this last topic, I sought the opinions of nurses and administrators about their outlook on RT to reduce ADEs. I used that survey in the quantitative portion of the research.

Each statement in both surveys could have been answered with one of five possible responses: *strongly disagree, disagree, neutral, agree,* and *strongly agree*, where the number assignment ranged from +1 to +5 respectively. The 5-point Likert scale enabled me to quantify the responses based on a middle point of three (neutral). A response to the left of the middle point on the scale represents a pessimistic (negative) response. A response to the right of the middle point on the scale represents an optimistic (positive) response. Thus, pessimistic responses are ($R \leq 2$); neutral responses are ($R = 3$); optimistic responses are ($R \geq 4$).

Each survey was designed to include both negatively and positively worded statements. Negatively phrased statements elicit a low level of agreement for the attribute being measured and positively phrased statements elicit a high level of agreement for the attribute being measured (Van Sonderen, Sanderman, & Coyne, 2013). According to Van Sonderen, Sanderman, and Coyne (2013), the inclusion of both types of statements on the same survey reduces the possibility of response bias, which occurs when participants respond with answers that do not reflect their true belief, answer all items in an auto-pilot fashion (acquiescent bias) with either high or low scores, or answer the items without paying much attention to the context of each individual item.

The ADE survey (Appendix A) was designed to collect a variety of qualitative data related to three dimensions: training, experience, and guidelines & procedures. Since I did not compare the means of each dimension and did not use the results for quantitative analysis, it was not necessary for me to ensure that the directionality of the items were consistent. Therefore, I did not reverse score any of the negatively phrased items associated with this survey.

The RT survey (Figure B1) was designed to collect quantitative data to assess the participants' perceptions of using RT at the administration stage. Currently, RT designed to assist with drug administrations at the administration stage in NHs does not exist (Van den Bemt et al., 2011). As a consequence, nurses and administrators do not have any real-world experience with an RT system of this nature. Therefore, it is reasonable to assume that the general consensus among nurses and administrators would be that even with an RT system human involvement would still be the determining factor. This means that any negatively phrased item would most likely receive a low score. To ensure that a low score would represent agreement, reverse scoring must be considered for any type of statistical analysis so that all of the items would have the same meaning in terms of high agreement or low agreement—that is, the same directionality in response.

In an effort to prevent any manner of response bias as described by Van Sonderen, Sanderman, and Coyne (2013), I phrased 3 out of 10 items on the RT survey (Figure B1) negatively. I used the survey responses to conduct six different hypothesis tests; therefore, it was necessary for me to reverse score the negatively phrased items

prior to calculating the mean responses of the four samples. By reverse scoring these three items, all items were consistent in terms of the directionality of the responses.

Specifically, survey items 3 ("A comprehensive interactive computer system will cause nurses to be less aware when administering medications."), 5 ("A robotic system would not be useful to assist in administering solid medications."), and 8 ("A robotic system would decrease the success rate of administering medications on time.") from the RT survey (Figure B1) elicited a response for which a higher score would indicate that the respondents perceived RT as *not* being a good option to reduce ADEs at the administration stage in NHs (in contrast to the other questions). The expressions of "will cause nurses to be less aware" in item 3, "would not be useful to assist" in item 5, and "would decrease the success rate" in item 8 define these items as negative.

To compute the mean responses to test the hypotheses, I first averaged the response for each participant to all 10 questions of the RT survey (Figure B1) to calculate an individual mean response. Using the individual mean responses, I calculated a mean response for all participants from the participating NHs collectively. I then separated the individual means for the control group (before and after) and the treatment group (before and after) based on the first two parts of the identification code. Based on this separation, I calculated the following means:

- Mean response for all participants before the treatment group views the model in all participating NHs collectively (R_{1A}).
- Mean response for all control group participants before the treatment group views the model in all participating NHs collectively (R_{1C}).

- Mean response for all control group participants after the treatment group has viewed the model in all participating NHs collectively (R_{2C}).
- Mean response for all treatment group participants before viewing the model in all participating NHs collectively (R_{1T}).
- Mean response for all treatment group participants after viewing the model in all participating NHs collectively (R_{2T}).

The identification code was not be used to identify a particular NH. Since the survey results were aggregated to represent all three NHs, knowing exactly which NH the results came from was not important in my research. Therefore, the ADE survey (Appendix A) was not marked an identification code, because I only administered it once to all participants. Pertaining to the RT survey (Figure B1), the identification code was used to match the before and after results from each participant from each group. The identification code also provided a means of eliminating results from the same participant from the control group or the treatment group to maintain equal sampling within each participating NH. The identification code was not used to individually assess the results obtained from each NH or from an individual participant. Rather, assessment of the data was collective.

Pilot Study

To assess reliability and validity of the surveys, I conducted a pilot study with a small group of nurses and administrators who were not associated with the three NHs that participated in this research. By conducting this pilot study, I acquired the perspective of nurses and administrators working in the healthcare industry to gain a better

understanding of what questions would work best to determine how they felt about the potential use of RT to reduce ADEs. The pilot study also helped me acquire their perspective of ADEs in the general areas of experience, training, and guidelines & procedures. I carried out this pilot study after IRB approval to conduct this research. The details related to the pilot study are disclosed in Chapter 4.

Survey Administration

Participants completed both the ADE survey (Appendix A) and the RT survey (Figure B1) anonymously. Upon completion, they placed their surveys in a box, which remained sealed and secured throughout the duration of the survey period at each participating NH. The same box was used by all participants in each participating NH. As the survey period concluded in one NH, I physically transported the box to the next NH. By using a single box, I was able to protect the integrity of the data as well as the privacy rights of the individuals involved.

I received participation from the majority of those who received a copy of the surveys. There were a few cases where a participant did not take the surveys, because he or she was on temporary assignment or was no longer servicing the NH, the participant was no longer employed with the NH, or the participant was too busy attending to his or her assigned duties.

Focus Group

To protect the confidentiality of the participants, I assigned each participant to a unique number. At the beginning of each session, I asked each participant to introduce themselves with their numeric assignment. Correlation of the numeric assignment and the

actual administrator (or nurse supervisor) was only known to the researcher, but not revealed in any manner to anyone else.

I recorded the conversations from the focus group discussions using a digital voice recorder. At the conclusion of those conversations, I transcribed each recording on paper, using Microsoft Word, to create an electronic and backup source. To further organize the data acquired from the focus group sessions, I uploaded the Microsoft Word version of the transcribed conversations into the NVivo software application for a detailed and thorough analysis. After completion, I correlated the results with my qualitative assessments from the ADE survey (Appendix A), the historical errors recorded on the ADE Scorecard, and the outcomes of the quantitative assessment of nurse and administrator perceptions on using RT to reduce ADEs.

Robotic Model

Since an application of RT to assist in patient-specific drug administrations does not exist in NHs (Van den Bemt et al., 2011), the use of a model was ideal to evaluate personal perspectives on the prospect of using RT to reduce ADEs in a NH environment. My model was sufficient for this evaluation and eliminated the complexity, time, and cost it would have taken to build an actual robotic system.

Physical Mechanization of the Model

The model that I built was similar in concept to the stationary robotic dispensing cabinets used in centralized and decentralized distribution systems within various hospitals. Tsao, Lo, Babich, Shah, and Bansback (2014) mentioned that a majority of these stationary cabinets interface directly with pharmacy information systems to deliver

medications, but the effectiveness of this technology to reduce ADEs varies depending on how it is implemented in each hospital. This may explain why Wakefield, Ward, Loes, and O'Brien (2010) found that these kinds of systems have had varying degrees of success in a limited number of critical care hospitals that have implemented this technology.

Interestingly, these dispensing cabinets were not patient-specific. Rather, these cabinets held a specific assortment of drugs that could be delivered based on the prescribed orders of many patients or commonly used drugs within specific locations of the hospital. To receive a medication contained within the system, the nurse had to scan a barcode, but it was the exclusive responsibility of the nurse to extract the correct medicine and quantity for a particular patient.

Pedersen, Schneider, and Scheckelhoff (2012) noted that robotic dispensing systems are present in 63% of hospitals in the U.S. (p. 780). However, many of these hospitals have implemented dispensing systems that contain automated dispensing cabinets that stock drugs in bulk based on patient-specific profiles (p. 771). Although, these systems still required the nurse to the extract the right quantity or dosage once they have acquired access to the drugs in the system. The model that I designed for my research mimicked these patient-specific cabinets in their ability to connect a patient to a specific drug regimen via a scanned barcode. In contrast to existing non-mobile patient-specific cabinets, my design contained the added features of self-guided mobility, and automation directly linked to prescribed orders. Specifically, the components of my model are listed in Table 2.

Table 2

Components of the Robotic Model

	Component Name
A	Multidrawer cabinet
B	Prelabeled numbered drawer
C	Cardboard poster
D	Microsoft access application
E	Laptop
F	Index cards representing fictitious resident
G	Wired scanner
H	Mobile cart
I	Printout of drug regimen preassignments

Deployment of the Robotic System Replicated by the Model

The model that I built was based on the idea of a mobile, patient-specific, semi-intelligent robotic system that would assist nurses in administering medications. A real-world application of my model would work from these two high level perspectives: load component and delivery component.

The load component would require someone at the NH to place solid drugs received from an external pharmacy into a stationary multidrawer cabinet that was not permanently connected to the mobile robotic unit. Each of these drawers in the cabinet would contain a specific type of solid drug of which these assignments would be known, through software, by the robotic system. At various intervals throughout the day, the mobile robotic unit would automatically navigate to the stationary multidrawer cabinet and connect to it in order to fill or refill drugs prescribed for administration into its inventory or to remove drugs from its inventory that were not administered during a

particular shift. This connection between the mobile robotic unit and the stationary multidrawer cabinet would also serve to recharge the batteries that power the unit.

As each resident's electronic record of their prescribed medications was read from the host system by the robotic system, the two systems would work in tandem to transfer drugs from the stationary multidrawer cabinets to the mobile, patient-specific robotic unit. Only drugs, based on prescribed drug orders, which were not loaded on a previous load would be loaded during the process. The robotic unit would then remain dormant at the docking cabinet until it was summoned by a nurse who is ready to administer a medication.

The delivery component would involve the independent movement of the robotic unit to a specific location, via GPS positioning boundaries, within the NH when dispatched by the nurse. Each nurse assigned to administer drugs would wear a watch-like device that pairs that nurse, via wireless technology, to the mobile robotic unit. This means that no other nurse or individual would have the ability to dispatch the mobile unit or be able to extract drugs from it.

To dispatch the mobile robotic unit to a specific location, the nurse would press a button on the watch-like device, which would send the GPS coordinates of the nurse's location at the time of the initial dispatch summon. With the GPS coordinates and other parameters that manage the mobility of the system, the robotic unit would automatically navigate its way to that location.

Upon arrival of the robotic unit to the dispatched location, the nurse would use a scanner that is physically attached to the robotic unit to scan a unique barcode that is

assigned to one specific resident. Via a computer screen affixed to the robotic unit, the software system will respond to the scanned barcode by displaying the prescribed drug order associated with the resident assigned to the scanned barcode or, if necessary, by notifying the nurse that the barcode is invalid.

Simultaneously, the system software will compare which drugs were loaded and recorded to the drawer against what was actually prescribed to the resident according to the host system at the time of the administration. If differences are noted, the system software will alert the nurse with a low intermittent beeping tone, emitted from the watch-like device. The nurse must then make an exception entry on the computer screen and confirm before the system will continue with any further actions. If no differences are noted or after an exception entry is made, the correct drawer corresponding to the scanned barcode will open to give the nurse access to the medications.

Once the administration is complete, the nurse will be required to confirm the completion on the computer screen. Otherwise, the robotic unit will not allow him or her to go forward with another administration. If another administration does not take place within a configurable amount of time, the robotic system will automatically return to the docking cabinet or the nurse can dispatch the unit to return to the docking cabinet immediately via a return home option on the computer screen.

Another aspect of this system is the software application. In addition to controlling mobility of the system, the software will maintain detailed records of all activities for auditing purposes. It will keep an accurate account of which medications went into the system, who extracted the medication from the system, which resident it

was extracted for, the medication quantities administered, and the time at which the medication was removed from the drawer. In addition to these basic features, the software system will be semi-intelligent and sophisticated enough to handle all the intended functions under various conditions.

The basic idea that I have described here will start with a small number of drugs and a small number of mobile units. Once a working system is up and running, refinements to the system, including hardware and software, can take place to perfect how it operates from all perspectives.

Verification and Validation of the Model

To determine if the model that I built would be fit to carry out this research, I adopted the approaches described in Chapter 2 to assess verification and validation. Specific to verification, I subjected the model to several scenarios to ensure that it functioned as expected. Specific to validation, I subjected the model to a series of predefined tests in additional to exposing it to a group of IT professionals for additional scrutiny. The details of how I tested, verified, and validated the model are forthcoming in Chapter 4.

Simulation Demonstration

For my research, I employed the model in a demonstration, which simulated how a robotics system might be employed in a NH setting. Here are the specifics of that demonstration.

A unique barcode that corresponded to a specific fictitious resident and a prelabeled numbered drawer in the cabinet was assigned in advance of the simulation.

Each of 10 physical barcode labels was affixed to a cardboard poster (see item C in Figure 2) where each label represented one fictitious resident as identified on individual index cards (see item F in Figure 2). The simulated representations did not mimic actual drug regimens for seniors living in NHs, which rendered the limitation of 10 solid drugs tolerable for the demonstration. This consideration made the simulation appear more practical and realistic, because the number of possibilities evaluated was relatively small and tailored to solid drugs.

Figure 2. Model configuration.

For each real drug, I assigned a specific colored jellybean to represent that drug in the simulation. For example, an orange jellybean represented Warfarin, a blood thinning

medication and a purple jellybean represented Oxycodone, an opioid pain medication. See Table 3 for the full list of selected drugs for the simulation and the correlating jellybean color.

Table 3

Correlation Table of Actual Drug to Jellybean

	Drug name	Jellybean color
1	Aspirin	White
2	Warfarin	Orange
3	Oxycodone	Purple
4	Lorazepam	Pink
5	Fentanyl	Black
6	Furosemide	Yellow
7	Alprazolam	Blue
8	Metoprolol	Lime
9	Omeprazole	Red
10	Clonazepam	Green

Prior to the simulation, I loaded each prelabeled numbered drawer (see item B in Figure 2) with the specific color and quantity of jellybean, which represented the simulated drug(s) that a fictitious resident was currently taking. For example, fictitious resident number one was taking two units of Warfarin and one unit of Fentanyl. In this case, I preloaded drawer number one with two orange jellybeans and one black jellybean. See Appendix E for a storyboard arrangement of the model.

To begin the group session to demonstrate the simulation, I gave a brief description of the setup and design of the model to those in attendance. To engage the participants, I asked for a volunteer for the purpose of randomly choosing one of 10 index cards representing a fictitious resident and their fictitious drug regimen (see item F in

Figure 2). Each participant also received a printout of the preassignments (see item I in Figure 2) so that they could easily follow and validate the outcome of each simulated administration that corresponded directly with the index cards.

As the barcode corresponding to the number on the chosen index card was scanned, the Microsoft Access application showed the drugs and corresponding jellybeans on the laptop screen. Immediately following, I instructed the volunteer to open the associated drug cabinet drawer, which contained the appropriate colors and quantities of jellybeans prescribed for the chosen fictitious resident, thus demonstrating that the model had the capacity to assist nurses in accurately administering the correct solid drugs to residents. By involving the participants in conversation and engagement in the demonstration, I expected the survey results to be rich and reflective on this approach to reduce ADEs.

Data Analysis Plan

Quantitative Analysis of Survey Data

I acquired the data necessary to test each hypothesis only from the RT survey (Figure B1). To carry out these tests, I averaged the responses (reverse scored where appropriate, as explained earlier) from each survey from all three participating NHs collectively to compute several means based on a Likert scale ranking value of +1 to +5: (a) a single mean for all participants prior to the treatment group viewing the model, (b) a single mean for the control group prior to the treatment group viewing the model, (c) a single mean for the control group after the treatment group view the model, (d) a single

mean for the treatment group before viewing the model, and (e) a single mean for the treatment group after viewing the model.

For a one-tailed test, when the null hypothesis includes a *less than or equal* expression, the null hypothesis is rejected when the *t* statistic is greater than the critical value of *t*. However, the statistical power, confidence, and effect size chosen by the researcher factor into the probability of correctly rejecting the null hypothesis. If the researcher intends to prove that the treatment group surpasses the control group or from a specified constant (rejection of the null hypothesis), high statistical power is imperative for the significance test (Liu, 2012).

According to Mowery (2011), it is common among health care researchers to use the paired *t* test to determine if there is a significant difference between two normally distributed and related groups. The paired *t* test was applicable to my research because of the natural pairing of the before and after survey results associated with *H4* and *H5*. As a result, I acquired another view of how NH professionals felt about RT, since the participants assigned to the treatment group took the RT survey (Figure B1) before and after viewing the model. The participants in the control group also took the survey twice, but without viewing the model on either occasion.

Disposition of Survey Data

To protect and save the survey results from both surveys, I scanned each physical survey into a computer and stored the electronic copies in a password-protected directory on an external hard drive. Upon completion of my research, I stored the external hard drive in a safety deposit box for a minimum of 5 years.

Qualitative Data Analysis

In addition to the hypothesis tests for the quantitative assessment, I conducted a qualitative assessment with the historical ADE data in conjunction with the focus group data and the ADE survey (Appendix A) data from all participating NHs collectively. In particular, I entered the unstructured survey data, which pertained to training, experience, and guidelines & procedures and the focus group data into the NVivo software application so that I could utilize the software's query, summarization, and visualization tools to analyze the data from different angles.

I analyzed the data to determine if any additional themes or patterns exist that have not otherwise been stated in the scholarly literature. I extended my analysis further by looking for any other subtle trends or connections within the data. Overall, I analyzed the data from these various perspectives to better understand the reasons for ADEs and the potential impact for RT to reduce their numbers. The continued persistence of ADEs (Handler, 2012) warrants exploration into every possible avenue for decreasing their prevalence.

I used triangulation to synthesize and correlate the data acquired from the ADE survey (Appendix A) with the reasons associated with the reported ADEs received from each NH and with the data acquired from the three planned focus group sessions. The results from the survey from all three NHs, collectively, were categorically tabulated to view the data in terms of frequency (high, medium, low, average). The results were further reduced to numerically summarize each scale of the response categories. From

these tabulated results, I applied inductive reasoning to draw broad generalizations for each category, which I analyzed in conjunction with the other sources of data.

I expected that the data collection design employed in this mixed methods approach would offset the limitations inherit within each individual data collection method being used. Together these data collection methods provided a view of ADE causes from three perspectives: actual ADEs reported by the facility, the personal perspective of the nurse, and the personal perspective of the administrator. As a result, the data was fertile with common information which supported the outcome of the simulation to combat ADE occurrences. With this design, I delivered a high degree of reliability and validity relative to the outcome of my research.

Threats to Validity

The design framework presented in this chapter called for the utilization of two survey instruments to acquire a qualitative and quantitative perspective from nurses and administrators involved with the drug administration task. Using these instruments, I gained their personal accounts, perspectives, and beliefs as to why ADEs occur at this stage of the medication-use process. Since all the participants that took the surveys work in similar environments (NHs) with similar care seekers (residents), the answers I acquired from both surveys was consistent among the three participating NHs.

The ADE survey instrument (Appendix A) was a custom-designed survey that provided a means for me to gain some insight into three areas: training, experience, and guidelines & procedures. These areas of focus was based on the literature that I reviewed in Chapter 2.

Van den Bemt et al. (2011) emphasized training as an opportunity to prevent errors when transferring medications while Wittich et al. (2014) expressed training as continued education to stay abreast of new medications introduced within the NH. Aljadhey et al. (2013) saw experience as a significant factor in improving care related to administering medications while Wittich et al. mentioned experience in reference to the excessive workloads and stressful situations nurses, doctors, and pharmacists must endure when executing any stage of the medication-use process. USDHHS (2014b) noted that some problems related to ADEs can be minimized if existing guidelines are followed while Sawarkar et al. (2012) recognized that busy workflows could sometimes lead to ADEs.

Thus, I intended to gain insight into the causes of ADEs directly from nurses and administrators relative to these areas of focus. The RT survey (Figure B1) was also a custom-designed survey. It provided a means for me to gauge how nurses and administrators view RT to assist in drug administrations from several viewpoints. However, to avoid overlooking potential issues of internal validity, I administered the survey to both the control group and the treatment group on two occasions: once before the treatment group viewed the model and again after the treatment group viewed the model.

Nachmias and Nachmias (1992) noted that it is necessary for the researcher to ensure that any change affecting the dependent variable is influenced only by the independent variable. To account for the possibility of different responses to the RT survey (Figure B1), I calculated the associated means (before and after) of the control

group in case these participants provided different answers on each occasion of taking the survey. The questions on the RT survey were derived directly from the researcher, because scholarly literature related to the use of RT for the purposes of reducing ADEs in NHs is scarce (Van den Bemt et al., 2011).

The importance of both Likert scale surveys was the design of the questions where the choice and assembly of words for each question conveyed the same meaning and intent to each participant. As a result, each question was interpreted consistently among the participants. Each question was short and direct, which allowed the survey participant to provide direct responses to all questions, except for the last one question. With these questions, I intended to place nurses in the same frame of thinking by isolating groups of questions within the same area of the survey. The surveys also took into account the possibility of self-incrimination that nurses or administrators may have felt. To minimize this emotion, all questions referred to current or past colleagues, which may have encouraged participants to answer all questions associated with both surveys. The results were consistent and abundant with information pertaining to the ADE issue from the personal perspective of the nurse and the administrator.

Issues of Trustworthiness

My study design incorporated two data collection methods. In addition, I used the technique of triangulation to strengthen the evidence rendered by the data collected. As expected, some of the data from the ADE survey (Appendix A) and the focus group correlated, which enhanced the validity of the overall findings. Through triangulation, I

also found that the errors associated with the reported causes from each NH and the outcome of the hypotheses further supported the validity of the overall findings.

To minimize issues related to external validity, I purposely pursued NHs of various dimensions in order to generalize the results to all NHs in the Memphis Metropolitan area. Beyond choosing NHs with a quality rating of 3 (medium as determined by the CMMS) or less my design included several additional aspects to minimize external validity. For example, small, medium, and large NHs based on the number of beds were randomly selected, and bias towards well performing NHs or extremely poor NHs was avoided.

Beyond the selection criteria, the data collection design solicited a high rate of participation and acquired similar data from several sources where clear triangulation was possible to support the results. It was well established in the literature that all U.S. NHs suffer from occurences of ADEs. Given this assertion, the results obtained in my research can be generalized beyond just NHs in the Memphis Metropolitan area.

I captured all of the data collected in the natural environment of the NH, where the course of how nurses and residents interact was not manipulated or altered in any manner. Preconceptions or biases of the researcher was not be an issue because the data collected was reflective of the participants and their thoughts. By maintaining objectivity in this manner, the data represented the complex interactions that take place within these NHs.

Ethical Procedures

Preceding the collection of any data, I acquired a signed consent document from the administrator of each of the three participating NHs, in which I summarized the interaction with nurses and the abstention of any interaction with residents. I obtained permission from the Institutional Review Board (IRB; Approval No. 11-09-15-0123805) to conduct the presentation to demonstrate the robotic simulation, administer the surveys, and conduct a focus group discussion at these NHs. At no time during the course of data collection, none of the NHs that I recruited expressed the desire to withdraw from the study. Therefore, recruitment of replacement NHs was not necessary.

Comparably, I did not require nurses or administrators to take either of the two surveys or participate in this research. Likewise, I did not require administrators to participate in the focus group discussion, but I did strongly encouraged both groups to participate for the benefit of this research. At the conclusion of my research, I presented each NH with a full copy of my research for their reference.

Measures Taken for Protection of Participants

Nursing homes that participated in my research remain anonymous. Similarly, nurses and administrators within these NHs also remain anonymous. However, for the purpose of matching the before and after RT survey (Figure B1) results, I assigned each participant to a unique number within their assigned group. This numeric assignment did not apply to the ADE survey (Appendix A), because it was not necessary for me to know from which participant those results came from.

Since residents are not direct participants in my research, I did not make any identifiable references to individuals in this population. Rather, I created fictitious residents that had no reference to any actual residents to use within the simulation, where a barcode that corresponds to a fictitious resident was necessary. These barcodes were not affixed to any actual residents, property of the NH, or personal property of the resident. Instead, I affixed each barcode, uniquely assigned to a particular fictitious resident, to a single cardboard poster board (see item C on Figure 2).

Summary

In this research, I investigated the reasons for ADEs caused at the drug administration stage in conjunction with a personal assessment on the effect RT might have on reducing the high incident rate of ADEs. My research was based on a mixed methods approach, where I collected and analyzed both quantitative and qualitative data to view the issue from a broader perspective. This broader perspective included an evaluation of historical ADEs recorded by each NH along with the perceptions and beliefs of both nurses and administrators related to why drug administration errors occur.

To acquire the qualitative data, I used the survey method and the focus group method to collect two distinct classes of data from three different NHs. I began data collection in each NH by acquiring historical data directly from each NH and progressed into administering the ADE survey (Appendix A) to all participants taking part in my research. In addition, I asked administrators and nurse supervisors in each participating NH to give feedback during the focus group discussions, which provided me with data to take into account a view from management to establish a comprehensive result.

To acquire a portion of the quantitative data, I used a model to demonstrate how RT might work to assist with solid drug administrations in NHs, and used the RT survey (Figure B1) to assess overall how nurses and administrators feel about the technology. I administered this survey on two occasions to determine if the perception of the control group remained the same or changed between the first and second survey, and if the perception of the treatment group changed after viewing the model as compared to before viewing the model. Using the results obtained from both occasions of the survey, I computed five separate means to answer RQ4 and RQ5.

It was unknown how NH caregivers might view a robotic system capable of assisting with the drug administration task, namely due to the fact that scholarly research into whether or not RT can reduce ADE error rates is lacking (Van den Bemt et al., 2011). Therefore, this investigation into whether this kind of technology could be instrumental at all was necessary, before time and money is spent building an impractical and unacceptable system. To assess the perception of how nurses and administrators perceived the use of RT to reduce ADEs, specifically at the administration stage, I relied on the *t* test to analyze four hypotheses and the paired *t* test to analyze the other two hypotheses.

Collectively, the mixed methods data that I collected allowed me to fully answer the RQs. These questions addressed five pertinent inquiries related to the premise of my research: how are drugs administered, how do ADEs occur, what options are available to prevent errors, how do NH professionals feel about RT in general, and how do nursing professionals feel about RT after seeing how it would work. Together, these questions

formed a strong basis to begin discovery related to the possibilities of RT to assist with the administration of solid medications in NHs. Details related to the data collected for this research are forthcoming in Chapter 4.

Chapter 4: Discussion

The purpose of this mixed methods research was twofold. The first purpose was to evaluate the causes of ADEs specific to solid drugs (tablets, pills, and capsules only) using several sources of data. The second purpose was to acquire the perspective of nurses and administrators in the NH environment on the use of RT to assist in the drug administration task to decrease ADEs.

To address the first purpose, I triangulated the causes of ADEs specific to solid drugs in NHs from three perspectives. These perspectives included actual errors that occurred at the participating NHs (reported ADEs), the nurse perspective on the causes of ADEs via the ADE survey (Appendix A), and the administrator (including nurse supervisors) perspective on the causes of ADEs via the focus group session. This data was used to answer the three qualitative questions, which addressed how drugs are administered, how ADEs of solid form occur, and how familiar NH managers are on current technologies.

To address the second purpose, I addressed two quantitative questions which comprehensively assessed the participant's perception of RT to assist with the drug administration task. I answered these questions with the RT survey (Figure B1) data where I performed six hypothesis tests relative to two experimental groups (control and treatment).

Chapter 4 includes the results of the pilot study, which was conducted to validate the survey instruments, and the validation and verification process that was used to assess the robotic model. This chapter includes a detailed presentation of the data and the

themes/patterns that I found. I describe how the data were used to address the qualitative and quantitative RQs. A discussion of data analysis and results, evidence of trustworthiness, and data collection and recording are also included in this chapter.

Pilot Study Results

To assess reliability and validity of the ADE Survey (Appendix A) and the RT survey (Figure B1), I recruited eight nurses (including two administrators) who worked in the NH environment, and lived in Chesapeake, VA to evaluate the intended purpose of each survey. I designed the ADE Survey to acquire firsthand data on how nurses and administrators believe ADEs occur in the general areas of experience, training, and guidelines and procedures. I designed the RT survey to acquire nurse and administrator perceptions on the use of RT to reduce ADEs at the administration stage in the NH environment.

Reliability of the Survey Instruments

I began the pilot study by explaining to the pilot study participants that the objective of their participation was to assess each survey for reliability and validity. I explained to them that these survey instruments were researcher-created and had never been used in prior research. Thus, the surveys required a rigorous assessment by an appropriate sample to determine if they would be reliable and valid for this research project. According to Sullivan (2011), reliability means acquiring consistent responses among the same participants. I designed the surveys to acquire information related to ADEs in the general areas of experience, training, and guidelines & procedures; and the

perception of nurses and administrators (including nurse supervisors) on the use of RT to assist with the administration of solid medications.

After explaining the purpose of the pilot study, I encouraged the participants to provide honest feedback at any juncture of the pilot study that they believed would improve the quality of the survey instruments. The participants were separated into two groups of four in hopes that the separation would discourage them from influencing each other on their answers to the survey questions. Both groups took both surveys twice on different days.

To properly manage the results from the surveys, I modified the definition of the identification code to be slightly different for the pilot study as opposed to the actual research. Instead of the first number of the three digit code representing the group (control or experimental), it simply represented whether the participant was in the first group or the second group. For example, survey results marked 1-2-3 indicated first group (1), second occasion of taking the survey (2), and participant number three (3). I did this so that I could easily match the before and after results from each participant.

I compared the results of the first and second ADE survey to determine the extent of correlation. Using the mean score of each question and Pearson's correlation coefficient equation, I calculated a correlation coefficient of 1, which indicated strong positive correlation. I also compared the results of the first and second RT survey in the same manner using the mean score for each question. This calculation also resulted in a correlation coefficient of 1, which again indicated strong positive correlation. As a result, I did not add any new questions or remove any existing questions from either survey.

Validity of the Survey Instruments

To assess validity, I used the same pilot study participants (nurses and administrators) that I had recruited to assess reliability. I asked these nurses and administrators to share their opinions and thoughts to the questions on both surveys to assess whether they thought the questions were applicable to acquiring diverse information on the causes of ADEs and the use of RT to assist with the drug administration task. The majority (6 out of 8) of the participants believed that the questions were adequate for the purpose of the research, but suggested rewording several questions to avoid misinterpretation. Based on their expertise in the healthcare industry, I modified the wording of several questions for better clarity. One nurse questioned the small number of questions, but after explaining to her that the research participants would be taking the surveys in their natural environment (NH) keeping the survey short was critical for completion.

As a result of this pilot study, I improved face validity of the survey instruments by modifying the structure of the questions into a consistently phrased statement to encourage better responses. I also rearranged the categories (experience, training, and guidelines & procedures) so that an entire section of questions would be present on a single page to avoid disruption of thought. After I made these changes, the participants raised no additional questions or concerns.

Robotic Model

According to Van den Bemt (2011), a mobile, self-directing robotic system does not exist in NHs for the purpose of assisting nurses with the drug administration task. To

acquire some understanding of how NH professionals feel about RT for this purpose, it was necessary to build a visual model that would give them a practical representation of how the technology would work. An actual robotic system was not practical because of the complex operations it would take to make RT function safely in a NH environment. To determine if the model that I built was adequate to acquire data on how NH professionals felt about RT, I subjected the model to the constructs of fidelity, verification, and validity to justify its reasonableness and acceptable range of accuracy.

Fidelity of the Model

It was important to establish fidelity of the model in terms of how it related to existing systems to diminish concerns about its ability to produce similar behavior. Real-world systems, comparable to the concept of my model currently exist and mainly deal with delivery, distribution, and dispensing of medications primarily in hospitals. For example, Summerfield et al. (2011) evaluated an RT application associated with delivery. Chen et al. (2013) evaluated an RT application associated with distribution and Samaranayake et al. (2014) examined an RT application that focused on dispensing. The common factor among these systems was their usage of computer technology coupled with some form of barcode technology, which was the underlying foundation of my model.

To conduct this research, I built a simple model consisting of a movable cart, a numbered (ranging from 1 to 10) multidrawer cabinet, a scanner, code 39 type barcodes, a laptop computer, and a simple Microsoft Access application (software) where together these components mimicked the most basic features of similar real-world systems. These

basic features included assigning a barcode to a specific entity (person or specific medication) where access to the entity was only granted through the act of scanning a barcode. While my model lacked the detailed functionality of a real-world system, an approximation of the real thing was acceptable as long as the model accomplished its intended purpose (Sokolowski & Banks, 2009).

I custom-built the software components that worked in conjunction with the physical components of the model explicitly for this research. Since the software was specific for the model, extensive error checking or extreme functionality was not coded into the software. The basic error-handling that was included was sufficient to adequately demonstrate the successful operation of the software. The software was composed of two user interfaces and a database consisting of three tables. Each table was manually loaded to contain 10 fictitious residents that were assigned to a unique barcode (ranging from 1 to 10) and 10 solid medications represented with uniquely colored jellybeans. The assignment of a fictitious resident with a fictitious medication regimen containing multiple medications (jellybeans) was defined prior to inserting into the database.

Since the model was an approximation of the real thing, it was necessary to conduct a series of test on it to assure that it functioned within an acceptable range of accuracy. Feinstein and Cannon (2001) declared that the researcher cannot omit detail testing if the intent is to abolish concerns about the effectiveness of a model. After extensive testing, the model performed as I expected where the software displayed the scanned barcode and the correlating medications (jellybeans) on the laptop screen. Upon

opening the drawer matching the scanned barcode, the drawer contained the same colors and quantities of jellybeans as displayed on the screen.

Verification of the Model

The most common approach for verifying a model makes provisions for the researcher to subjectively determine if it encapsulates all possibilities related to its intended purpose (Sokolowski & Banks, 2009). A secondary approach seeks to determine if the model can produce the desired results given all possibilities related to its intended purpose (Feinstein & Cannon, 2001). Stated another way, these approaches direct the model designer to confirm that the model was implemented correctly according to its conceptual design.

In consideration of these approaches, the intended purpose of my model was to direct the user to a specific medication drawer (fictitious) that was associated with a specific resident (fictitious) based on a scanned barcode. As a first of two steps to address verification of my model, I rigorously tested it multiple times and verified that it accurately and consistently produced the correct result. Sargent (2013) cautioned though that while researcher-testing is appropriate when verifying a model, it is also imperative for the researcher to determine if the model satisfies its predefined experimental conditions before rendering it acceptable to partially impersonate a real-world system. My test results showed that the model successfully met the predefined test cases that I created while building the model.

As a second of two steps to address verification of the model, I summoned the assistance of four IT experts to assess the model in terms of face validity. Feinstein and

Cannon (2001) noted that this is a critical part of effectively verifying a model. When a model can be evaluated and assessed from a different perspective, it is likely that genuine reasonableness can be determined and any deficiencies missed by the model builder can be found. Accomplishing both will increase confidence in the model's credibility.

After explaining to the experts the purpose of the model, I separated them into two equal groups. I gave each group five unique test cases (and the expected outcome) that I defined during the build stage of the model and asked them to execute each test case in succession. They concluded that the model did not contain any errors and was reasonable for its intended purpose.

As a final assessment of face validity, I compared the barcode aspect of my model to Pyxis, a real-world drug dispensing cabinet. The Pyxis system essentially directs the user, based on a scanned barcode, to a specific stationary cabinet containing one specific medication for patients in general (Weekes, 2014). Thus, the similarity of scanning a barcode to direct the user to a specific medication cabinet was basically the same as in my model. My model differed slightly, because it was built on the premise of assembling different medications for the same patient in one location versus the Pyxis system assembling medications of the same kind in one location.

Validation of the Model

Validation is concerned with the degree to which a model will meet the functionality expectations set by the model builder (Feinstein & Cannon, 2001; Sargent, 2013). To this end, I expected the test results from the IT experts to be consistent with the results I achieved during my own testing. The first four out of five test cases required the

experts to scan the barcode for five different fictitious residents, and then compare the fictitious medications (jellybeans) shown on the laptop screen to those present in the corresponding numbered cabinet. For example, if the user scanned barcode number two, the user interface would show the fictitious medication regimen for resident two on the screen. Upon the user opening drawer number two, it contained the exact fictitious medications and quantities as shown on the laptop screen.

The fifth test case required the experts to scan an unassigned barcode or any random barcode of their choice to confirm that the software did not direct them to an incorrect drawer. It was important to establish, through testing, that the system would not direct the user to an incorrect drawer, which would result in an inaccurate assisted administration. Beyond these five test cases, I encouraged each group to test other scenarios of their choice to validate the functionality of the model. Based on their objective testing, one additional test case emerged and was added to the standard test set. The experts requested confirmation that a barcode could be manually entered if the scanner failed. This test case was tested several times by each group (and myself) and passed without having to make modifications to the software. Overall, the model generated an outcome that was consistent with my initial expectations.

Research Setting

To conduct this research, I initially set out to recruit three NHs that had a Medicare/Medicaid quality rating of 3 (medium). According to the CMMS (2015), a quality rating of 3, on a scale of 1 to 5, is medium. NHs rated as a 1 were found to have a significant number of care issues and NHs rated as a 5 had the least number of care

issues. By choosing NHs with a medium quality rating, I intended to eliminate choosing all poorly or highly scored NHs to dismiss any potential influence on the data. Ultimately, I settled on three NHs who had quality ratings of 1, 1, and 2 due to their willingness to take part in this research (Table 4) within the permitted timeframe. Each NH assured me that since their last inspection, respectively June 19, 2015, October 24, 2014, and January 15, 2015 (NH 1, Director of Nursing, personal communication, 2015; NH 2, Director of Nursing, personal communication, 2016; NH 3, Director of Nursing, personal communication, 2016), they had taken the necessary steps to improve upon the violations (mostly unrelated to drug administrations) that dictated their rating.

Table 4

Nursing Home Characteristics in the Research Sample

	NH1 (small)	NH2 (medium)	NH3 (large)
Number of available beds	88	130	211
Number of occupied beds	69	120	180
Medicare/Medicaid quality rating	1	1	2

Two of the three nursing homes were located within the Memphis metropolitan area and one was located 10 miles outside of the Memphis metropolitan area in Mississippi. Extension outside of the Memphis area became necessary after other NHs with the desired quality rating declined to take part in this research. The participating NHs collectively had 429 beds and an 86% (369/429 * 100 = 86%) occupancy rate at the time of this research (Table 4). To care for 369 current residents, these NHs collectively

employed 215 nurses and administrators to handle the daily activities of its residents as required by regulating agencies and their residential care plans.

At the time of this research, none of the NHs was using an automated medication system to assist nurses at the drug administration stage. Even though an automated system was not used at the administration stage, these NHs employed technology, like the Medication Administration Record (MAR) system, the Electronic Medication Administration Record (EMAR), and the Automated Dispensing Unit (ADU), along with other checks and balances to assist with other stages of the medication-use process mainly to keep an electronic record of medication movement and administration within the NH. The non-usage of technology at the administration stage required the nurse to heavily rely on their personal skills, knowledge, and experience to extract and administer the correct quantities of medications for the correct residents under their care.

I collected the data in the natural environment of each NH. Therefore, data collection was intermittent because all participating nurses were not able to assemble at one time due to their responsibilities of resident care. Nonetheless, nurses were comfortable taking the surveys and expressed interest in this research with questions and comments.

Demographics

The total number of participants to the ADE and RT surveys was $N = 105$; however, three were excluded because (a) the majority of their responses were neutral (3) or (b) they did not have nursing qualifications (2). Table 5 outlines the characteristics of

N = 102 valid participants to the ADE and RT surveys that were included in the statistical analysis.

Table 5

*Characteristics of Participants in ADE Survey (*N *= 102)*

Characteristic	Group	*n*	%
Nursing Home	1	34	33.3
	2	34	33.3
	3	34	33.3
Number of Beds	1	88	20.5
	2	130	30.3
	3	211	49.2
Title	LPN	41	40.2
	CNA	39	38.2
	RN	14	13.7
	RN (Supervisor)	2	2.0
	Director of Social Services	1	1.0
	RN -Director of Clinical Education	1	1.0
	RN/Assistant Director of Nursing	1	1.0
	RN/Director of Nursing	1	1.0
	Nurse Practitioner	1	1.0
Certified to Administer	No	34	33.3
	Yes	68	66.7
Years of Experience	1-5	21	20.6
	6-10	35	34.3
	11-15	26	25.5
	16-20	9	8.8
	21-25	8	7.8
	>25	3	2.9

The participants were distributed equally among the three NHs. The most frequent job titles were LPN (*n* = 43, 43/102 = 42.2%) and CNA (*n* = 39, 39/102 = 38.2%) with the remainder including RNs, a Director of Social Services, and a Nurse Practitioner. Over two thirds (*n* = 68, 68/102 = 66.7%) of the participants were certified to administer

drugs. The experience of the participants ranged widely from 1 to 34 years (M = 11.05, SD = 7.01). The most frequent group classified by years of experience (n = 35, 35/102 = 34.3%) was 6-10 years, while participants with greater than 25 years of experience were the most infrequent (n = 3, 3/102 = 2.9%). Other characteristics, like sex, race, or age was not captured as it was not important for my research.

The number of beds at each participating NH exceeded my original classification of small (less than 50 beds), medium (50 to 105 beds), and large (greater than 105 beds). My original classification was based on the number of beds at NHs in the Memphis metropolitan area that had a quality rating of 3. These NHs varied in their number of beds at approximately 50, which dictated the preset bed range at an increment of 50. However, the number of beds in the participating NHs did not fit this definition, which rendered a change in my definition of size. The participating NHs had 88, 130, and 211 beds respectively. Thus, based on the actual participating NHs, I reset the bed range at an increment of 90. As a result, small NHs were redefined as less than 90 beds, medium as 90 to 180 beds, and large as more than 180 beds (see Table 5).

Data Collection

I asked each of the three participating NHs to provide a list of ADEs (qualitative data) that occurred within a 3-month period of time at the onset of my research. Collectively, these NHs only had two reported ADEs that occurred over that period of time. While there was no expectation of a small or large number of ADE's over a 3-month period, the actual number of two ADEs was too small to make a realistic assessment related to the causes of ADEs in general. As a result, I expanded the range to

6 months, June 2015 through December 2015, which revealed seven solid ADEs among the NHs. ADEs in other forms (a total of four), like liquids and ointments, were eliminated from consideration, since my research focused specifically on solid medications that came in the form of pills, tablets, and capsules.

Prior to conducting this study, I did not have an expectation of the type, classification, or quantity of ADEs in any of the participating NHs. Thus, the ADE scorecard was designed from a general perspective to categorize ADEs in seven general areas that were prevalent in the literature that I reviewed in Chapter 2. Stated, these general areas were (a) wrong medication (b) improper quantity (c) late administration (d) early administration (e) no administration (f) improper technique, and (g) other errors beyond those that were mentioned. See Figure 3 for a graphical view of the reported medications errors, which developed into an ADE that I gathered from the NHs collectively.

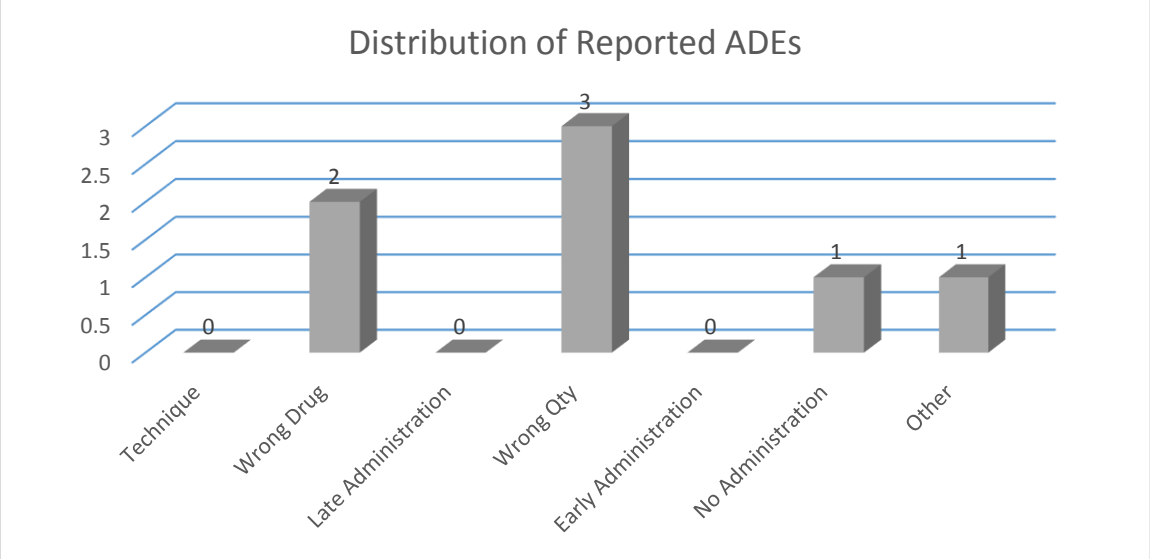


Figure 3. Distribution of reported ADEs.

In addition to the accumulation of reported ADEs, I acquired another portion of qualitative data through the ADE survey (Appendix A) and from the focus group sessions. I recorded and later transcribed to paper the data gathered from the three separate focus group sessions (one in each NH). The length of each focus group session was less than an hour and was conducted using the predefined focus group questions listed in Appendix D. As the conversations unfolded within each session, I asked secondary questions either to gain clarity of their answers or to encourage further discussion to acquire additional information. Each session collectively contained four participants, composed of nurse supervisors and administrators that were already a part of the overall participant pool.

Data Analysis

Qualitative Analysis

This section presents a collective content analysis of the transcripts of the discussions between the researcher and the participants of the focus groups. A total of 73 significant statements were extracted from the transcripts (see Appendix F). Each statement was a sentence or phrase which was considered relevant to answer the RQs. In the first stage of the content analysis, I coded each significant statement with a number and a name which served to identify the statement as constituent of a primary theme. I identified six primary themes, as listed in Table 6. The largest theme was *Reasons for ADEs* based on 24 statements. The smallest theme was *Cost Savings* based on five statements.

Table 6

Primary Themes Extracted from Transcripts of Focus Groups

Number	Primary Theme	Statements
1	Reasons for ADEs	24
2	Process of drug administration	6
3	Use of technology	15
4	Training	14
5	Financial incentives	9
6	Cost savings	5

In the second stage of the content analysis, I recoded each significant statement within the six primary themes with a number and a name, which served to identify the statement as constituent of a secondary theme. I identified a total of 29 subthemes, as listed in Table 7.

Table 7

Subthemes Extracted from Transcripts of Focus Groups

Number	Primary Theme	Number	Sub-theme	Statements
1	Reasons for ADEs	1.01	Not paying attention	5
		1.02	Too busy	6
		1.03	Limited time	2
		1.04	Stress and fatigue	2
		1.05	Transcription errors	3
		1.06	Medicine not up from the pharmacy	1
		1.07	Unknown medical history of patients	1
		1.08	Wrong patient, wrong drug	1
		1.09	Drug received at wrong time	1
		1.10	Updating MAR	1
		1.11	Lack of community of care	1
2	Process of drug administration	2.01	Time and effort	6
3	Use of technology	3.01	MAR and EMR	5
		3.02	ADU	1
		3.03	Best practice alerts	3
		3.04	PCAS	1
		3.04	Robotic Technology	5
4	Training	4.01	No training	2
		4.02	Training is inadequate	1
		4.03	Training is adequate	2
		4.04	Connect Care class	1
		4.05	Health Stream	1
		4.06	Medication tests	1
		4.07	Orientation	1
		4.08	Training for EMR	1
		4.09	More training is needed	4
5	Financial incentives	5.01	Agree	6
		5.02	Other incentives	3
6	Cost savings	6.01	Reducing ADEs results in cost savings	5

Note. ADU = automatic dispensing unit; EMAR = electronic medical administration records; MAR = medical administration records; PCAS = patient controlled analgesia system.

Theme 1: Reason for ADEs. The focus group participants suggested many reasons for ADEs of which the most frequent were "not paying attention" as exemplified by Participant 9, who stated the following:

> I [a nurse] worked with a nurse who had medicine ready to go in one patient's room and was then called into another patient's room, but she could not leave that medicine there. But in her haste, she went into the wrong room with this medicine and administered this medicine to this patient, because she was not paying attention at the time at what she was doing.

"Too busy" was also frequently mentioned, as suggested by Participant 9: "because of patient load they [the nurses] want you to go here, here, here and here. Now you have everybody [the residents] calling at one time wanting their medicine and everyone [the nurses] talking about everybody [the residents] ready to go to sleep."

"Limited time" was illustrated by the following comment from Participant 5: "The problem is that you [the nurses] have one hour before and one hour after and that's what your JCHAO [Joint Commission on Accreditation of Healthcare Organizations] standards are, but it's absolutely impossible to pass those meds during that time." Not paying attention, too busy, and limited time were linked to comments from Participant 5 that included "A lot of times of stress and fatigue" and Participant 6 that included "You may have someone [a nurse] that may take an additional shift, because someone didn't come to work. That would cause the fatigue that she's speaking of."

Three statements were concerned with "Transcription errors". Participant 3 stated, "Sometimes a doctor's handwriting can come to you [the nurse] and you can't quite read

what he has written out or either you read it and it is typed in wrong." Single statements indicated further reasons for ADEs where Participant 2 stated, "The medicine not being up from the pharmacy usually is an issue;" Participant 3 stated, "I think the biggest reason we see adverse drug events with patients are their unknown medical history that contradict the use of certain medications;" Participant 8 stated, "Wrong patient, wrong drug" and "Some of your adverse med errors are strictly based on the fact that the patient didn't receive the medication at the right time;" Participant 5 stated, "The problem with the MAR is that if a physician comes in and updates a medication it may not be changed over into the MAR;" and Participant 7 stated,

> I believe one of the largest indicators is the lack of continuity of care from caregivers in the nursing home. We have a high turnover rate and that . . . the orientation rate for the new nurses can be really stressful on them and I believe a lot of our errors are from that.

Theme 2: Process of drug administration. The participants highlighted the considerable amount of "time and effort" involved in the process of drug administration. For example, Participant 4 stated, "We have to come all the way down from B wing hall to all the way to A wing hall, because A wing is the only one with the unit [medication cart];" Participant 1 stated, "So, I [nurse supervisor] get my report on my patients. I make a list of all the medications that are to be administered throughout my shift and then I prioritize, you know the patients I need to see first." Participant 8 stated,

> Well normally you [the nurse] have patients in your undesignated space, which is normally one or two halls and those medications are on your med trays. On those

> med trays though each patient is different and individualized . . . and this is where a lot of nurses loose time and where some errors may come in.

Theme 3: Use of technology. Most of the statements about the use of technology referred to the use of MAR, EMAR, and ADU, e.g., Participant 2 stated, "We have a scanning system. It's all computerized. So, it comes up on the MAR what the patient is supposed to take and we scan each medication;" Participant 3 stated, "Our EMAR is fully equipped with a scanning system." Participant 3 also stated, "As far as what we [the nurses] have, we have our MAR. That will tell us when we're giving a medication, if we're giving a medication too soon or if it's not scheduled or the wrong patient, wrong medication;" and "They [the administrators] moved everything to the electronic MAR or EMAR, and the ADU [automated dispensing unit]." Participant 9 stated,

> It [ADU] will stream out 24 hours' worth of medications and the 11 to 7 shift puts those medications in each individual patient's slot. So for that 24-hour period, every medication that the patient will take is put into that slot.

The use of "Best practice alerts" was referred to, indicated by the following statement from Participant 9:

> It [ADU] alerts you that it's not time. It would have a time on there when the medication was given. It would have the date and the time it was last given. So you know, you can see in red the date and the time that it was given so you don't give it too early, because it would have on their give every six hours or, you know, so you don't give it too early.

Participant 3 stated, “However, the good thing is that the scanning system does stop us from overriding the best practice alerts where there is something wrong with the administration.” Participant 3 suggested that “I do kind of have a feeling that this might be taking away the nurses responsibility of doing their checks, the patient identified and the five rights of drug administration.” Participant 3 also mentioned PCAS, stating “Our PCAS [Patient Controlled Analgesia System] will tell us if we were not administering a specific narcotic correctly with heparin, for example.”

The other statements concerned the use of RT for which the nurses all provided positive views, highlighted where Participant 2 stated, “If your robotic can effectively handle patient and med safety it would be an awesome addition to what we already have;” and Participant 4 stated, “Yes, it would be an improvement. If your robot can follow and go patient to patient I mean that works.”

Theme 4: Training. The statements about training were contradictory. Participants 7 and 9 said they had “no” training, but four considered that training was inadequate, exemplified where Participant 2 stated, “I think there’s other education that is need to be incorporated in our surrounding, not just surrounding the drug administration itself, but the rights of the patient when administering the medication;” Participant 3 stated, “I don’t think we actually have training for events for that;” and Participant 2 stated, “I also think there’s a lot of pharmacology re-education that needs to be done when people get out of school that we don’t focus as much on because we rely too heavily on micro medics.”

Other participants provided details of their training, including (a) Connect Care: Participant 1 stated, “When you get accepted to being a new nurse you learn how to, you know, how to administer meds, you go to a Connect Care class on the computer to learn how to scan the medication;” (b) Health Stream: Participant 1 also stated, “We have our annual medication requirements that we do on Health Stream;” (c) Medication tests: Participant 3 stated, “Every nurse in here takes a medication test;” (d) Orientation: Participant 5 stated, “Well, all staff have to go through an orientation and they have to go for training.;” and (e) Training for EMAR: Participant 1 stated, “There have been some trials though with new employees coming on to our electronic medical records system and having to correlate the training with the EMAR and the drug administration.”

Theme 5: Financial incentives. All the participants agreed with the idea that financial incentives should be offered to reduce ADEs, highlighted by six statements, including. Participant 1 stated, “I [nurse supervisor] would love to give financial incentives to my nurses;” “Yes, money is a huge incentive to us I think;” Participant 2 stated, “If we had a financial incentive I think we would do better;” Participant 10 stated, “I think it would motivate a person to do what they are supposed to do or actually focus more, let me say that” and Participant 5 stated

> That would raise the stakes. Well, I [administrator] think it would actually lead to a lot of good things. If you had less adverse reactions, one you would retain your nurses because they would be working in an environment in which they will be happy. And that’s your goal. And once you can achieve that environment you’re going to retain that staff.

Three statements referred to incentives that were other than financial, such as acknowledgement, recognition, and appreciation, indicated where Participant 1 stated, "I am the type of manager that will acknowledge not only the mistakes at work but over acknowledge the accomplishments and the recognition that need to be had on the floor;" and Participant 7 stated, "Or even give them at the end of every quarter some kind of recognition, like a banquet or you know like a special dinner for them" and Participant 8 stated,

> I don't know if that . . . will it necessarily have to monetary. It can be like a day off or maybe an extra hour for lunch. I think any type of incentive would encourage or may make that employee feel more valued and more appreciated.

Theme 6: Cost savings. All of the focus group participants agreed that reducing ADEs would result in cost savings, exemplified where Participant 1 stated,

> I do believe that any decrease in any adverse event is going to save the facility money. I think that because with medication. I think seeing the cost saving on the treatment that are provided to reverse effects, would be less costly if we prevented ADEs.

Participant 3 stated, "When people make med errors people die and get sicker and we have to fix that" and "Yes, it would save everybody a lot of money."

Triangulation of qualitative data. The responses to the ADE survey indicated that the perceptions of the participants toward training were the most positive. In contrast, the focus group responses provided contradictory evidence concerning training. Some nurses complained of no or inadequate training, while others reported adequate training.

The significant statements extracted from the focus groups provided rich details concerning the many reasons why the participants thought ADEs occurred, and also explained the difficulties that the nurses experienced in the use of technology, including MAR, EMR, and ADU. These statements reflected the relatively negative perceptions of the participants to the questions in the ADE survey, based on their experiences, training, and guidelines & procedures.

All of the participants in the focus groups welcomed the potential usage of RT, which they believed could reduce ADEs. This positive viewpoint was also reflected by the responses to the RT survey (Figure B1), which showed that, after viewing the demonstration, the treatment group perceived that RT could reduce ADEs.

Descriptive Statistics

I evaluated the survey response data using descriptive statistics to (a) analyze the responses to the ADE survey (Appendix A), and (b) compare the responses from the RT Survey (Figure B1) of the treatment group (who viewed the demonstration) and the control group (who did not view the demonstration) using inferential statistics before and after viewing the demonstration. The results of the hypothesis tests are described for RQs 4 and 5 (later in this chapter) while the scores related to the ADE survey are further discussed in this chapter specific to qualitative RQs 1, 2, and 3.

Descriptive statistics of the ADE survey. Tables 8, 9, and 10 summarize the responses to the 26 items in the ADE Survey, classified by three dimensions (a) experience; (b) training, and (c) guidelines & procedures. I computed the mean (*M*) and standard deviation (*SD*) of the responses to each item using the designated 5-point scale,

where 1 = *strongly disagree*, 2 = *disagree*, 3 =*neutral*; 4 = *agree*, 5 = *strongly agree*. I listed the items based on the numerical sequence on the survey so that the results could be easily matched to the item.

For the experience dimension of the ADE survey (Table 8), there were no mean scores greater than 4.0. The highest level of agreement, was for "Administration mistakes are commonly caused by a lack of attention" (M = 3.82). The lowest scores (< 3) corresponding to the lowest level of agreement, were for "A nurse with more than 3 years of experience is likely to make a drug administration mistake" (M = 2.75); "Administration errors are common because of the number of drugs prescribed to nursing home residents" *(*M = 2.90); "Nurses administer prescription medications to residents that were not prescribed by a doctor" *(*M = 2.90); and "Nursing home residents cause incorrect drug administrations" *(*M = 2.15).

Table 8

*Summary of Responses to Experience Dimension of ADE Survey (*N = *102)*

Item Nbr	Item	M	SD
1	A nurse with less than 1 year of experience is likely to make a drug administration mistake	3.45	1.12
2	A nurse with more than 3 years of experience is likely to make a drug administration mistake	2.75	1.08
3	Administrative errors are common because of the number of drugs prescribed to nursing home residents	2.90	1.23
4	Administration mistakes are commonly caused by a lack of attention	3.82	0.89
5	When administration errors occur they are reported	3.48	1.05
6	Solid medications, like pills, tablets, and capsules, are more prone to administration errors	3.04	1.13
7	When a drug appears inappropriate, nurses question transcription orders made by doctors	3.41	0.98
8	Nurses administer prescription medications to residents that were not prescribed by a doctor	2.21	1.10
9	Nursing home residents cause incorrect drug administrations	2.15	0.94
10	Nurses vary administration techniques based on the resident	3.35	1.17

For the training dimension of the ADE survey (Table 9), the highest scores (> 4.0) corresponding to the highest level of agreement (reflecting a favorable perception) were for “Nurses are encouraged to ask questions about prescribed orders that appear inappropriate” (*M* = 4.02) and “Nurses are encouraged to report adverse drug events that they are aware of” (*M* = 4.20). The lowest scores (< 3.6) corresponding to the lowest level of agreement, were for “Nurses with less than 1 year of experience are adequately trained to administer drugs” (*M* = 3.58); “Educational seminar's related to new drugs are available in nursing homes” (*M* = 3.59); “Nurses are required to attend educational

seminars on new drugs" (*M* = 3.58); and "Adequate information about drugs readily exist on NH wards" (*M* = 3.56).

Table 9

*Summary of Responses to Training Dimension of ADE Survey (*N *= 102)*

Item Nbr	Item	M	SD
11	Agency nurses are adequately trained to administer medications common in nursing homes	3.67	0.88
12	Nurses with less than 1 year of experience are adequately trained to administer drugs	3.58	0.83
13	Nurses with more than 3 years of experience are adequately trained to administer drugs	3.90	0.64
14	Educational seminar's related to new drugs are available in nursing homes	3.59	0.75
15	Nurses are required to attend educational seminars on new drugs	3.58	0.90
16	Adequate information about drugs readily exist on nursing home wards	3.56	0.82
17	Nurses are encouraged to ask questions about prescribed orders that appear inappropriate	4.02	0.61
18	Nurses are encouraged to report adverse drug events that they are aware of	4.20	0.60

For the guidelines & procedures dimension of the ADE survey (Table 10), there were no mean scores greater than 4.0. The highest level of agreement, was for "Nurses generally follow the drug administration guidelines and procedures set by the facility they work in" (*M* = 3.80) and "Instruments, such as a computer, are used as an aide to administer drugs" (*M* = 3.69). The lowest scores (< 2) corresponding to the lowest level of agreement were for "Nursing homes allow visitors to bring in over the counter medications for residents" (*M* = 1.89) and "Nursing homes allow doctors to bring in medications for residents" (*M* = 1.94).

Table 10

*Summary of Responses to Guidelines and Procedures Dimension of ADE Survey (*N = *102)*

Item Nbr	Item	M	SD
19	Nurses generally follow the drug administration guidelines and procedures set by the facility	3.80	0.68
20	Instruments, such as a computer, are used as an aide to administer drugs	3.69	0.87
21	Various policies and procedures contribute to drug administration errors	2.80	0.98
22	Decisions made by administrators contribute to drug administration errors	3.03	1.19
23	Nursing homes allow visitors to bring in prescription medications for residents	4.12	1.21
24	Nursing homes allow visitors to bring in over the counter medications for residents	1.89	1.23
25	Nursing homes allow doctors to bring in medications for residents	1.94	1.14
26	Nursing homes allow medication substitutes when the prescribed medication is unavailable	3.34	1.29

Descriptive statistics of the RT survey. The descriptive statistics for the baseline or pretest scores for the 10 items in the RT Survey (Figure B1), classified by the control group who did not view the demonstration (n = 51) and the treatment group who did view the demonstration (n = 51) are presented in Table 11. The differences between the mean scores for each item were due to random variation and sampling bias.

Table 11

Response of the Control Group and the Treatment Group to the RT Survey at the Pretest

Item Nbr	Item	Control Group		Treatment Group		Mean Difference
		M	SD	M	SD	
1	Nurses would use a robotic system to assist them with administering pills, tablets, and capsules, to prevent possible mistakes	3.53	1.05	3.29	1.28	0.24
2	Keeping medicines isolated in patient-specific containers could decrease the administration errors of solid drugs	4.04	0.72	4.08	0.84	-0.04
3	**A comprehensive interactive computer system will cause nurses to be less aware when administering medications**	3.59	0.96	3.08	1.37	0.51
4	Some new form of advanced technology is needed to reduce administration errors	3.94	0.93	3.88	1.05	0.06
5	**A robotic system would not be useful to assist in administering solid medications**	3.00	1.18	3.02	1.22	-0.02
6	A robotic system would be useful if it provided the right medication for each resident	3.75	1.06	3.27	1.17	0.48
7	A robotic system would be useful if it did not slow down the task of administering solid medicines	3.67	0.95	3.51	1.03	0.16
8	**A robotic system would decrease the success rate of administering medicines on time**	2.86	0.96	2.88	1.19	-0.02
9	A robotic system would help decrease administration of errors of solid medications	3.00	1.00	2.35	1.13	0.65
10	A robotic system would make my job of tracking what medicines I have administered easier	3.35	1.13	2.96	1.41	0.39

Note. **Bold** items 3, 5, and 8 were reversed-scored in the positive direction.

The descriptive statistics for the posttest scores for the 10 items in the RT Survey (Figure B1), classified by the control group who did not view the demonstration (n = 51) and the treatment group who did view the demonstration (n = 51), are presented in Table 12. On only two items were the mean responses for the treatment group lower than the control group. Specifically, "A comprehensive interactive computer system will cause nurses to be less aware when administering medications" and "A robotic system would not be useful to assist in administering solid medications." For the other eight items, the mean differences were negative, because the treatment group scored higher than the control group.

Table 12

Responses of the Control Group and the Treatment Group to the RT Survey at the Posttest

Item Nbr	Item	Control Group		Treatment Group		Mean Difference
		M	SD	M	SD	
1	Nurses would use a robotic system to assist them with administering pills, tablets, and capsules, to prevent possible mistakes	3.49	0.88	4.37	0.72	-0.88
2	Keeping medicines isolated in patient-specific containers could decrease the administration of errors of solid drugs	3.98	0.55	4.49	0.50	-0.51
3	**A comprehensive interactive computer system will cause nurses to be less aware when administering medications**	3.27	0.94	3.00	1.20	0.27
4	Some new form of advanced technology is needed to reduce administration errors	3.10	1.47	4.49	0.58	-1.39
5	**A robotic system would not be useful to assist in administering solid medications**	2.69	1.16	2.61	1.34	0.08
6	A robotic system would be useful if it provided the right medication for each resident	4.18	0.91	4.41	0.64	-0.23
7	A robotic system would be useful if it did not slow down the task of administering solid medicines	3.51	1.12	4.45	0.54	-0.94
8	**A robotic system would decrease the success rate of administering medicines on time**	3.00	1.15	3.45	1.08	-0.45
9	A robotic system would help decrease administration of errors of solid medications	3.24	1.09	4.53	0.50	-1.29
10	A robotic system would make my job of tracking what medicines I have administered easier	3.45	0.94	4.20	0.69	-0.75

Note. **Bold** items 3, 5, and 8 were reversed-scored in the positive direction.

Once reverse scoring of items 3, 5, and 8 was completed, the responses to the 10 items in the RT survey were averaged for each participant. Table B2 in Appendix B lists the original score (pretest) and final score (posttest) for the control group and Table B3 in Appendix B lists the original score (pretest) and final score (posttest) for the treatment group. The frequency distributions of the composited scores awarded by $N = 102$ participants in the RT survey at the pretest and posttest are illustrated in Figures 4 and 5, respectively. The majority of the participants ($n = 84$, 40.2%+31.4%+5.9%+4.9% = 82.4%) had an overall mean score above 3.0 to 5.0, trending above neutral toward the agreement end of the scale at the pretest. An even higher proportion ($n = 97$, 25.5%+40.2%+25.5%+3.9% = 95.1%) endorsed the agreement categories between 3.0 to 5.0 at the posttest.

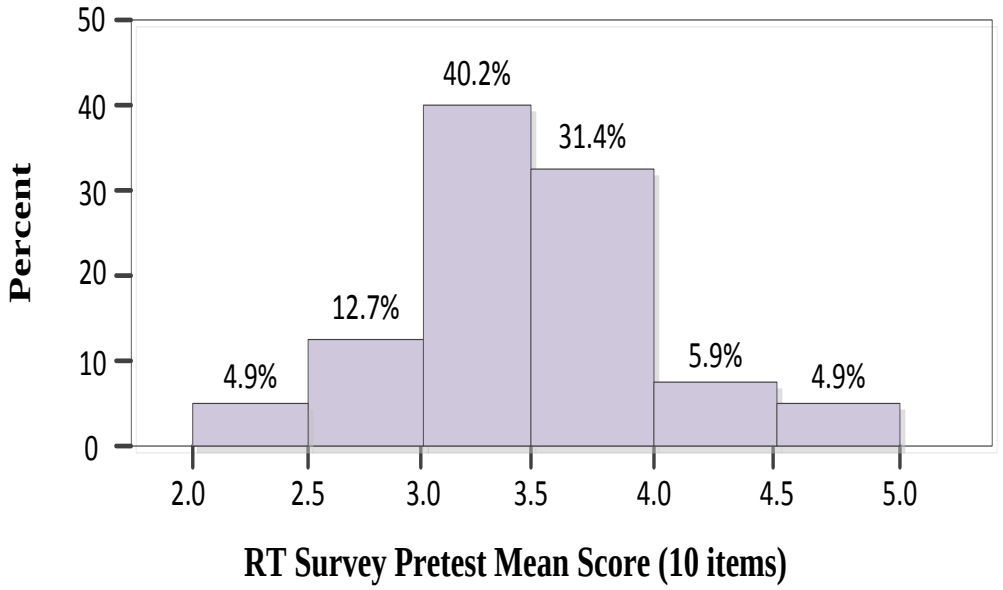


Figure 4. Frequency distribution of the mean pretest scores for the RT survey.

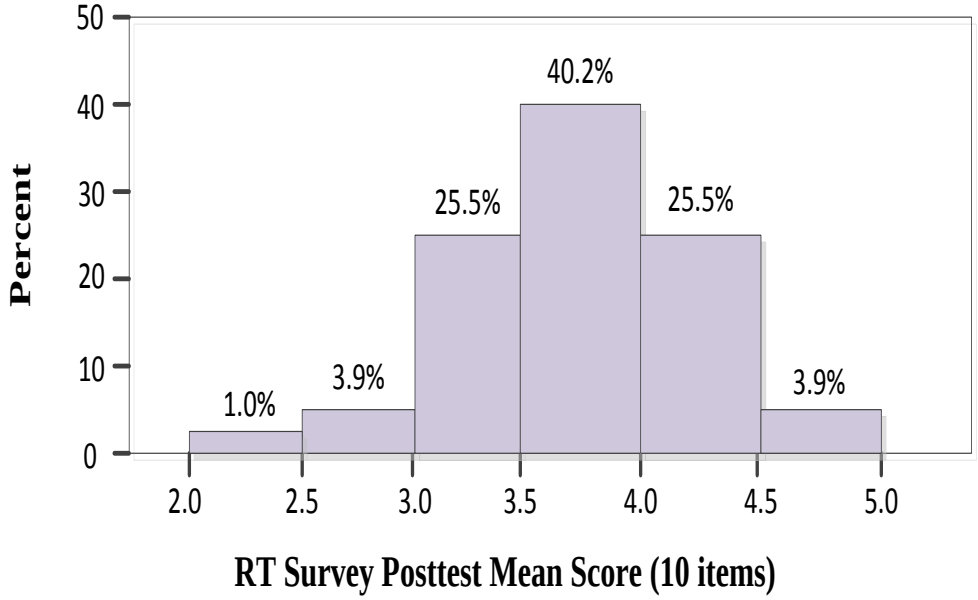


Figure 5. Frequency distribution to the mean posttest scores for the RT survey.

Research Results

Research Question 1

How are drugs administered in the participating facility? The data acquired from the focus group sessions exposed the fact that the administration of medications is mostly a non-technology assisted task. Primarily, nurses were required to go to a single location, interfacing with a medication dispensing system, to acquire medications for their resident assignments as a first step. Secondary steps involved sorting the medications per resident to assure accuracy and prioritizing administrations based on administration orders and situational circumstances within the NH. In other words, *distractions* and *too busy* were noted as significant events that contributed to ADEs.

Distractions and *too busy* correlate with lack of attention. When distractions are present or nurses engage in too many overlapping tasks, the potential possibility for an

ADE increases, especially when they are required to care for a high number of residents on a given shift or pressured to meet time constraints to administer medications according to doctor orders to multiple residents simultaneously. The participants acknowledged this possibility with the strong score they gave to item 4 of the ADE survey ("Administration mistakes are commonly caused by a lack of attention." $M = 3.82$). In fact, item 4 received the highest score among the items in the experience dimension, which suggests that even with experience, losing focus during drug administrations can still lead to ADEs.

Nurses realize the complexity of managing medications in the systems they have. Many medications look alike. Medication orders change frequently. New medications can be present on any given day for any resident. If nurses are not familiar with these aspects of medication administration, an ADE could occur because they are not keenly in tune to their dynamic environment as it relates to medications. According to item 7 of the ADE survey ("When a drug appears inappropriate for a resident, nurses question transcription orders made by doctors." $M = 3.41$), nurses understand the importance of asking questions related to unfamiliar medications, and rarely administer medications that were not ordered by a doctor as indicated by the low score for item 8 ("Nurses administer prescription medications to residents that were not prescribed by a doctor." $M = 2.21$). In contrast, administrators do encourage their nurses to ask questions about prescribed orders as indicated by the high score for item 17 ("Nurses are encouraged to ask questions about prescribed orders that appear inappropriate for a resident." $M = 4.02$).

Administrators also realize the complexity of managing medications in the systems they have. Evidence lies in the positive scores for items 14 ("Educational

seminar's related to new drugs are available in nursing homes." *M* = 3.59), items 15 ("Nurses are required to attend educational seminars on new drugs." *M* = 3.58), and item 16 ("Adequate information about drugs readily exist on nursing home wards." *M* = 3.56). Ongoing education related to medications and how they are administered is an essential part of medication safety.

Information accumulated during the focus group sessions revealed that once medications were dispensed from the centralized system, such as the MAR, EMAR, or ADU, the administration task was solely dependent on the nurse. This task was complicated by the fact that (a) *the medication dispensing system was not mobile*, (b) *the medication dispensing system was not centrally located to make acquisition of the medication easier*, and (c) *the medication dispensing system allowed acquisition of multiple medications for multiple residents simultaneously*. Further complications involved (a) *delayed updates of medication orders in the system*, (b) *the medication order was not in the system*, or (c) *the medication order was updated in the system after dispensing of the medications was completed*. At the end-point of administering the medication to the resident, the nurse could possibly unknowingly commit an ADE due to non-notification or late notification of medication changes in the system.

Perhaps this is why item 5 of the ADE survey ("When administration errors occur they are reported." *M* = 3.48) scored toward the agreement end of the scale. This could mean that nurses and administrators are aware of the possibility that an ADE can occur due to other factors beyond their control moments before actually administrating the medication. In such a case, the mistake was due to an issue with the system, not the

person. It could also mean that nurses may fear dire consequences related to their career, which may encourage them to report ADEs especially if witnesses or evidence are present. In my research, half the participants in my study stated that errors are reported. But, that means that half the participants stated that errors are not reported. That, plus the slightly above median score obtained for item 5, aligns with the claim made by Sawarkar et al. (2012) that many ADEs are not reported. If many ADEs are not reported then the problem of ADEs is more severe than what is currently being reported. It is impossible to say how much more severe, because it is unknown how many ADEs go unreported.

A contributing factor to this situation lies in the administration techniques nurses use for some residents. This is indicated by the median score obtained for item 10 of the ADE survey ("Nurses vary administration techniques based on the resident." $M = 3.35$). If a resident is uncooperative when it comes to taking solid medications, the nurse may mix the medication with food versus just administering with water. If a resident is mentally challenged (for example, dementia) the urge to resist taking medications is common. In such cases, the nurse may administer multiple medications one pill or tablet at a time over an extended period of time to minimize the residents' anxiety. If a resident is physically challenged (for example, difficulty swallowing large pills) the nurse may crush the medication into smaller pieces so that it is easier to swallow. While the action to ensure uncooperative, mentally, or physically challenged residents take their medication is admirable, a nurse could unknowingly cause an ADE when the medication is administered contrary to manufacturer instructions. Since it is unknown that an ADE

could have occurred, it is difficult to track and report the occurrence of an ADE from the perspective of varying administration techniques.

Nurses and administrators agree that policies and procedures are not leading contributors to ADEs as indicated by the low score obtained for item 21 of the ADE survey ("Various policies and procedures contribute to drug administration errors." M = 2.80) and the stronger score obtained for item 19 ("Nurses generally follow the drug administration guidelines and procedures set by the facility they work in." M = 3.80). In contrast, nurses and administrators felt that while policies and procedures are satisfactory, administration errors can occur due to direct decisions made by administrators. The responses were virtually neutral for item 22 ("Decisions made by administrators contribute to drug administration errors." M = 3.03), which may indicate a deeper issue to investigate or that sometimes administrators simply make inadvertent mistakes that are not challenged by a nurse.

While the centralized system contained safeguards against ADEs at the dispensing stage, such as *notifying the nurse if the medication had already been given or if it was too early/late to carry out the administration*, the only safeguard at the administration stage was the selection of the correct medications for the correct resident by the nurse. The participants mentioned, however, that *dispensing systems could cause some nurses to lessen their checks when administering medications*, losing reference to the universally adopted concept of the 5 rights of medication administration (right patient, right drug, right dose, right route, and right time).

In contrast to the use of technology at the dispensing stage, technology at the administration stage in the participating NHs was not used. Nurses may inappropriately associate technology at the dispensing stage with technology at the administration stage, but no evidence of this was present in the data. Similarly, nurses may use some other form of technology, such as barcode technology, to assist at the administration stage, but again no evidence was present in the data. Despite these possibilities, many nurses (and administrators) believe that they are already assisted by computer technology at the administration stage as indicated by the above average score obtained for item 20 ("Instruments, such as a computer, are used as an aide to administer drugs." $M = 3.69$). Therefore, an enhanced technology, such as RT, designed specifically for the administration stage would readily be accepted by nurses.

Research Question 2

How do ADE errors in the form of pills, tablets, or capsules occur in nursing homes? From the data gathered to answer this RQ, I did not discover any new causes to ADEs. The reasons noted were consistent with existing literature where the most frequent reasons mentioned were related to the administration stage of the medication-use process. Participants overwhelmingly mentioned that the NH environment often r*equires nurses to have responsibility for a large patient load*. This caused *stress and fatigue,* and when medications have to be delivered to all assigned residents within a certain time limit (usually one hour before or one hour after the scheduled administration time) *nurses often rush in order to meet this standard timeframe*. This was further complicated by *high*

turnover rates, where when new nurses began working they were required to begin administering medications during their first week to residents they were unfamiliar with.

Measures to prevent ADEs at the dispensing stage were present in the participating NHs, however, potential issues at other stages of the medication-use process were also mentioned. For example, at the prescription stage the participants mentioned that it was *common for pharmacy personnel to misinterpret, due to the doctor's handwriting, the type of medication or the quantity of medication ordered*. This leads to a transcription error from the pharmacy that could lead to an ADE at the administration stage. Errors at the beginning of the medication-use process can be amplified in later stages especially if personnel at earlier stages are unaware of the resident's medical history. The potential for contradicting medications becomes possible.

Education did not appear to be a significant contributing factor to ADEs. The responses from the training dimension of the ADE survey indicated that a majority of currently employed nurses believed first-time nurses (less than 1 year) receive adequate training in schools, but with experience (greater than 3 years) they become more adept at administering all classes of medications in a NH setting. This perspective was supported by four items from the training dimension which had the lowest level of agreement, but still trended toward the agreement end of the scale. Specifically stated, "Nurses with less than 1 year of experience are adequately trained to administer drugs" (M = 3.58), "Nurses are required to attend educational seminars on new drugs" (M = 3.58), "Educational seminars' related to new drugs are available in nursing homes" (M = 3.59), and "Adequate information about drugs readily exist on nursing home wards" (M = 3.56).

Therefore, it can be said that new nurses are better with drug administrations after 3 years of on-the-job experience.

Experience also did not appear to be a significant contributing factor to ADEs. When the participants were asked about administering multiple solid medications to the same resident, the number of different medications NH residents typically take was not a leading factor. Item 3 ("Administration errors are common because of the number of drugs prescribed to nursing home residents." $M = 2.90$) scored below neutral which suggests nurses and administrators become somewhat accustomed to administering multiple medications. Support for this claim lies in item 1 ("A nurse with less than 1 year of experience is likely to make a drug administration mistake." $M = 3.45$) as compared to item 2 ("A nurse with more than 3 years of experience is likely to make a drug administration mistake." $M = 2.90$) where nurses and administrators may believe more years of experience could lower the likelihood of an ADE related to multiple medications. Regardless, the neutral score expressed by the participants in item 6 ("Solid medications, like pills, tablets, and capsules, are more prone to administration errors than other forms." $M = 3.04$) clearly indicates that ADEs are equally possible with all forms of drugs, not just pills, tablets, and capsules.

Research Question 3

What knowledge do managers have of existing practices to reduce ADEs? The technologies expressed in the focus group sessions indicated that NH managers were familiar with some of the most widely used technologies (MAR, EMAR, and ADU) in the NH industry. Although, at the administration stage the participants did not mention

the usage of any technologies, such as barcodes. The participants from one NH described a two-step process at the administration stage.

> *A night nurse would fill the medication trays, containing medications for a group of residents (those assigned to a nurse) for the upcoming day, and the day nurse would verify the medications on the tray based a report generated by the system* [*MAR*].

The participants from another NH encouraged their nurses *to practice the five rights of drug administration*, which is a universally adopted practice to help decrease ADEs in all healthcare settings (Otto, 2015).

Closely associated with the familiarity of widely used technologies is training. There is no guarantee that training will reduce ADEs, but it is essential for nurses to receive some kind of training related to new technologies, techniques, medications, and policies. Items 11 ("Agency nurses are adequately trained to administer medications common in nursing homes." $M = 3.67$), 12 ("Nurses with less than 1 year of experience are adequately trained to administer drugs." $M = 3.58$), and 13 ("Nurses with more than 3 years of experience are adequately trained to administer drugs." $M = 3.90$) indicate that nurses agree that they receive sufficient training to perform their duties, regardless of title, experience, or employment status. While more stringent training may be applied to nurses with one year of experience due to advancements in medications, techniques, and education, the participants indicated that training coupled with experience better prepares nurses for the rigors of drug administrations as indicated by the mean score of 3.58 for item 12 and the higher mean score of 3.90 for item 13.

Item 23 (“Nursing homes allow visitors to bring in prescription medications for residents.” *M* = 4.12) draws particular interest because it was the highest scored item in the guidelines & policies dimension. It is common for family members, and sometimes friends, to pick up prescribed medications for family members living in NH quarters. While the gesture is genuine, it does not come without risk. Since the medication does not come from the pharmacy, the history and handling of the medication is unknown to the NH. If managers realize this risk and insist that medications come via the pharmacy, this practice could possibly prevent an ADE. Perhaps it is guidelines and policies that discourages doctors from bringing in prescription medications for residents as indicated by the low score obtained for item 25 (“Nursing homes allow doctors to bring in medications for residents.” *M* = 1.94) or which disallows family and friends from bringing in over the counter medications that may conflict with prescribed medications as indicated by the lower score obtained for item 24 (“Nursing homes allow visitors to bring in over the counter medications for residents.” *M* = 1.89).

A key defense against ADEs for administrators lies in the cooperation of nurses. If administrators demonstrate to nurses that they realize the reality of ADEs and are willing to combat them with positive actions, nurses may be more willing to report ADEs that they commit without fear of negative repercussions. Sawarkar et al. (2012) claimed that many ADEs are not reported, but administrators realize that encouraging nurses to report ADEs is a best practice. This may explain why nurses and administrators scored item 18 (“Nurses are encouraged to report adverse drug events that they are aware of.” *M* = 4.20) with strong agreement. However, the fear nurses may realize associated with an

ADE can be tremendous, which could very easily over rule any positive measures that administrators may have in place.

Based on the feedback from the ADE survey and the focus group discussions, nurses and administrators alike understand the severity and danger of ADEs. What the participants realized, after the demonstration of the model, was the potential benefit of a patient-specific technology-assisted approach at the administration stage. The participants acknowledged that this kind of technology could possibly enhance medication safety at the administration stage in addition to streamlining the drug administration process to make it more efficient. These efficiencies may increase the focus factor from nurses, because for each administration, interaction with the RT system would be necessary. The participants believed that such a system could possibly have the capacity to reduce turnover, where frustration and stress due to having responsibility to administer medications to residents they were not acquainted with, is greatly reduced.

Research Question 4

Do nursing home professionals have a favorable perception about the potential for RT to reduce ADEs?

Hypothesis 1 (H1): Pertained to the favorability of all participants (prior to the demonstration) from all three NHs collectively.

H_{10}: $\mu_{1A} \leq 3$

$H_{1a:}$ $\mu_{1A} > 3$

This RQ was answered quantitatively using the survey results from the RT Survey (Figure B1). Associated with this RQ was one hypothesis (*H1*), which I evaluated with

the *t* test. Table 13 presents the results of the one-tailed, one-sample *t* test that compared the pretest RT survey scores ($M = 3.36$, $SD = 0.52$) against a neutral response ($M = 3.0$) for all participants ($N = 102$). The mean pretest RT survey score was greater than 3.0. The $t_{statistic} = 6.972 > t_{critical} = 1.66$, and the *p*-value < .001. Therefore, I reject the null hypothesis and conclude that there is sufficient evidence that nursing home professionals have a favorable perception about RT.

Table 13

Comparison of Mean Pretest RT Index vs. Neutral Response

t	*df*	*p*	Mean Difference	95% Confidence Interval of the Difference	
				Lower	Upper
6.972	101	<.001	0.36	0.31	0.41

Research Question 5

Do nursing home professionals have a more favorable perception about RT to reduce ADEs after viewing a demonstration of that technology?

This RQ was answered quantitatively using the survey results from the RT Survey (Figure B1). Associated with this RQ were five hypothesis tests (*H2*, *H3*, *H4*, *H5*, and *H6*), which I tested individually with the *t* test.

Hypothesis 2 (H2): Pertains to comparing the treatment group with the control group from all three NHs collectively, after the treatment group has viewed the model.

H_{20}: $\mu_{2T} \leq \mu_{2C}$

H_{2a}: $\mu_{2T} > \mu_{2C}$

Table 14 presents the results of a one-tailed independent sample *t* test that compared the posttest RT survey scores (M = 3.984, SD = 0.27) of the treatment group (n = 51) vs. the posttest RT scores (M = 3.398, SD = 0.39) of the control group (n = 51), assuming equal variances. The mean posttest RT survey score of the treatment group was greater than the mean posttest RT survey score of the control group. The $t_{statistic} = 8.612 > t_{critical} = 1.66$, and the p-value < .001. Therefore, I reject the null hypothesis and conclude that there is sufficient evidence that the treatment group had a more favorable perception about RT at the posttest than the control group.

Table 14

Comparison of Mean Posttest Scores of Treatment Group vs. Control Group

t	*df*	*p*	Mean Difference	95% Confidence Interval of the Difference	
				Lower	Upper
8.612	100	<.001	0.58	0.56	0.60

Hypothesis 3 (H3): Pertains to all treatment group participants (after viewing the model) from all three NHs collectively.

H_{30}: $\mu_{2T} \leq 3$

$H_{3a:}$ $\mu_{2T} > 3$

Table 15 presents the results of a one-tailed one-sample *t* test that compared the mean posttest RT survey score (M = 3.984, SD = 0.27) of the treatment group (n = 51) vs. a neutral response (M = 3.0). The mean pretest RT survey score was significantly greater than 3.0. The $t_{statistic} = 25.815 > t_{critical} = 1.66$, and the p-value < .001. Therefore, I reject

the null hypothesis and conclude that there is sufficient evidence that the treatment group had a favorable perception about RT at the posttest.

Table 15

Comparison of Mean Posttest RT Survey Score vs. Neutral Response

t	*df*	*p*	Mean Difference	95% Confidence Interval of the Difference	
				Lower	Upper
25.815	50	<.001	0.98	0.95	1.02

Hypothesis 4 (H4): Pertains to the perception of the treatment group (after and before viewing the model) from all three NHs collectively.

H_{40}: $\mu_{DT} \leq 0$

H_{4a}: $\mu_{DT} > 0$

Table 16 presents the results of a paired *t* test that compared the RT survey scores of the treatment group at the pretest vs. the posttest ($n = 51$). The average paired difference in responses from the treatment group before and after viewing the demo ($M = 0.73$) was significantly greater than zero. The $t_{statistic} = 8.280 > t_{critical} = 1.66$, and the *p*-value < .001. Therefore, I reject the null hypothesis and conclude that there is sufficient evidence that the treatment group had a more favorable perception about RT at the posttest compared to the pretest.

Table 16

Comparison of Mean Pretest vs. Posttest RT Survey Scores of Treatment Group

Paired Differences					*t*	*df*	*p*
Mean	SD	SE	95% Confidence Interval of the Difference				
			Lower	Upper			
0.73	0.22	0.03	0.69	0.76	8.280	50	<.001

Hypothesis 5 (H5): Pertains to the perception of the control group (after and before the treatment group viewed the model) from all three NHs collectively.

$H_{50}: \mu_{DC} = 0$

$H_{5a}: \mu_{DC} \neq 0$

Table 17 presents the results of the paired *t* test that compared the RT survey scores of the control group at the pretest and posttest (n = 51). The average paired difference in responses from the control group before and after viewing the demo (M = -0.07) was greater than zero. The $t_{statistic}$ = -1.137 > $t_{critical}$ = -1.98, and the p-value = .130 > .05. Therefore, I fail to reject the null hypothesis and conclude that there is not sufficient evidence that the control group experienced any change in their perception about RT from the first survey to the second.

Table 17

Comparison of Mean Pretest vs. Posttest RT Survey Scores of Control Group

Paired Differences					*t*	*df*	*p*
Mean	SD	SE	95% Confidence Interval of the Difference				
			Lower	Upper			
-0.07	0.14	0.02	0.05	0.07	-1.137	50	.130

Hypothesis 6 (H6): Pertains to the perception of the treatment group (before and after viewing the model) as compared to the control group (before and after the treatment group views the model) from all three NHs collectively.

$H_{60}: \mu_{DT} \leq \mu_{DC}$

$H_{6a}: \mu_{DT} > \mu_{DC}$

Table 18 presents the results of a one-tailed independent sample *t* test that compared the mean paired difference (M = 0.73, posttest minus pretest) of the treatment group (n = 51) vs. the mean paired difference (M = -0.07, posttest minus pretest) of the control group (n = 51), assuming equal variances. The average paired difference from the treatment group was significantly greater than the average paired difference from the control group. The $t_{\text{statistic}} = 7.86 > t_{\text{critical}} = 1.66$, and the p-value < .001. Therefore, I reject the null hypothesis and conclude that there is sufficient evidence that the treatment group had a greater change in perception about RT as compared to the control group, from the first survey to the second.

Table 18

Comparison of Mean Paired Differences of Treatment Group vs. Control Group

t	*df*	*p*	Mean Difference	95% Confidence Interval of the Difference	
				Lower	Upper
7.86	100	<.001	0.79	0.77	0.73

Evidence of Trustworthiness

To confirm that the research design employed in this research encompassed a high degree of trustworthiness, I considered value, credibility, transferability, dependability, and confirmability. Shenton (2004) mentioned that qualitative studies must address the validity and reliability concerns of positivists since qualitative outcomes are not definitive in nature, unlike quantitative outcomes. Common strategies, such as the usage of multiple methods, triangulation of multiple data sources, and the random selection of participants were utilized to ensure credibility, transferability, dependability, and confirmability.

A random selection of participants (nurses involved with direct resident care and administrators) at the participating NHs were summoned to participate in this research. I asked all participants, via the ADE survey (Appendix A), to share their honest thoughts and opinions on why ADEs occurred. Likewise, I asked three groups of four administrators (and nurse supervisors) to share their opinion on the open-ended questions listed in Appendix D, along with secondary questions that arose during a focus group session. In addition to the qualitative data, the RT survey (Figure B1) provided a means to statistically test the participant's perception of RT for the purpose of assisting with

patient-specific drug administrations. Out of 102 participants, there were no results from either survey that were exactly the same. Thus, there was no reason to believe the information the participants provided did not adequately reflect their honest opinion about RT and how ADEs occurred in NHs. Consequently, the data were exposed in the findings, which lessens concerns of credibility, especially since the datum was taken at face value.

I confirmed the reported findings directly with the physical surveys and the focus group recordings, and found similar and some repeating content in both sources. Therefore, the themes extracted from the data can be generalized to a larger population of NHs, thus supporting transferability to other NH settings. This assumes, however, that the research participants (nurses and administrators) would be of the same profession, and of the same size of NHs (small, medium, and large based on number of beds) to acquire similar results to maintain external validity. If the type of participants change, for example the inclusion of social workers, dieticians, or physical therapist, the results may change as their outlook upon ADEs would most likely be different than nurses. Obviously, they have no direct or indirect relationship with medications in the NH. The same can be said of administrators, although, administrators do carry responsibility of ADEs which makes their perspective relevant.

I excluded the data acquired from one participant, because the individual was not a nurse or an administrator. Perhaps this individual was eager to take part in this research, but to avoid possible distortion of the results from the intended participants (nurses and administrators only), I eliminated the results from that individual. I eliminated two other

participants because, in both cases, all of their answers to every survey (both RT and ADE) question were the same in contrast to the diverse answers among 102 other participants. Again, I eliminated the results from those two participants to avoid possible distortion of the overall results. To further aid in dependability, I checked the survey results entered into the SPSS application three times to ensure accuracy. As a result of these actions, the data collection and analysis process were consistent and accurate.

Since literature related to the use of RT in a NH environment to assist with drug administrations did not exist (Van den Bemt, 2011), it was not possible to collaborate the findings from the RT aspect of this research with other researchers to support confirmability. Although, all of the findings, except the perceptions of RT, were common and published throughout existing literature. For example, the reasons for ADEs captured in this research were also present in other works.

I conducted this research exclusively. Since an assistant was not involved to validate the quality of the results, the research design included measures to support confirmability further in terms of data validity. For example, the physical surveys were scanned onto a hard drive while the focus group recordings were saved. Therefore, evidence is available to confirm that the findings were reflective of the data and were void of any bias from the researcher.

Summary

The mixed methods approach for this research required an assessment of the researcher-created survey instruments through the use of a Pilot Study. I assessed reliability and validity of the surveys to justify their usage using a group of eight nurses

in Chesapeake, VA. Also, I carried out an evaluation of the robotic model to assess its fidelity, verification, and validation for usage in this research. In addition to researcher testing, I summoned a group of IT professionals to evaluate the model independently.

The mixed methods results collected for this research were extensive. I collected qualitative data via the survey method (ADE survey) and the focus group method, and quantitative data via the survey method (RT survey). Overall, 105 participants took part in this research; however, I eliminated three participants due to questionable survey answers or due to job title. I gathered and presented information related to the sample population (NHs) and the participants in Table 5.

To carry out the qualitative analysis, I used the NVivo software where six primary themes (and 29 subthemes) emerged from the data: reasons for ADEs, process of drug administration, use of technology, training, financial incentives, and cost savings. I presented details related to each theme with direct quotations from the participants. I triangulated this data (themes), the reported ADEs acquired from each NH, and the ADE survey results to confirm validity and understanding of the reasons behind ADEs. I used this collection of data to answer RQs 1, 2, and 3.

To carry out the quantitative analysis, I used the SPSS software explicitly with the data acquired from the RT survey (Figure B1). I evaluated a total of six hypotheses using the *t* test and the paired *t* test. In addition, I composed descriptive statistics of both the ADE and RT survey responses to better understand the overall perspective of the participants. I answered RQ4 using the results from *H1* and RQ5 using the results from *H2, H3, H4, H5,* and *H6.* Overall, I rejected each of the null hypotheses, except for *H5*,

which tested the average paired difference in responses from the control group before and after viewing the demo.

In this research, I intended to understand the cause of ADEs more deeply and to assess perceptions of using RT to reduce ADE numbers in a NH environment. In Chapter 5, I will interpret the findings on both points. Specifically, an in-depth discussion covering my interpretation of the findings, limitations of the research, implications, and recommendations for further research and professional practice will be presented.

Chapter 5: Conclusion

The intent of this mixed methods research was to assess the causes of ADEs from a diverse perspective (qualitatively) in addition to exploring how NH professionals (nurses and administrators) felt about using RT to assist at the drug administration stage (quantitatively). This investigation was important because the reasons behind ADEs are still elusive (Aljadhey, 2013; Weiss and Elixhauser, 2013; Sawarkar, 2012), illustrated by the high numbers that continue rising throughout the healthcare industry. This implies that our knowledge related to the causes of ADEs is lacking and that our current technologies are not capable of reducing these high numbers down on a broad scale.

Regardless of either implication, ADEs are a significant problem that will continue to grow until more advanced technological solutions are created to begin trending ADEs down. Tremendous challenges exist in every stage of the medication-use process to safeguard against ADEs, but the latter stage of the process (administration) is perhaps the most vulnerable, where medications are passed from the care-giver directly to the care-receiver. In many cases, it is nearly impossible to extract a drug from within the human body once the drug has been taken, especially if harm or death has already taken place. Thus, errors at the other stages have a greater opportunity to be caught prior to harm or death.

Chapter 5 contains a thorough interpretation of the findings and the limitations that potentially had an effect on this research. Also included in Chapter 5 are recommendations for extending this research and the implications of this research in the

NH environment. This chapter ends with a succinct summary of the research and its results.

Interpretation of Findings

Provisions and systems are in place to mitigate ADEs at all stages of the medication-use process, yet it is still common for NH residents to be unwilling victims of ADEs (Harris-Kojetin et al., 2013). Nurses are the last line of defense for preventing ADEs at the administration stage (Kruer, 2014), which is a heavy burden to carry. As other research has pointed out, the causes are varying and divergent among and within each phase of the medication-use process (AHRQ, 2001) which complicates the creation of a universal solution. Although, within this research the causes of ADEs noted from three focus group sessions, the ADE surveys, and the historical data from three NHs were not new discoveries. This comprehensive view did highlight the main concerns related to circumstances that could lead to ADEs at the administration stage, information that will be useful in advancing the conceptual utilization of RT at the administration stage in NHs.

Mainly, human environmental factors affect the correct administration of medications. Reasons cited such as not paying attention, too busy, numerous distractions, limited time, stress, and fatigue were among the leading factors. The data indicated that these factors can be somewhat mitigated by offering financial incentives or by deploying a newer technology at the administration stage that interacts with existing technologies at other stages comparable to what Bates and Slight (2014) suggested. Most NHs are not able to offer financial incentives nor is it feasible to do so, because currently a newer

technology does not exist to offset these factors. Thus, errors related to these factors will remain the same.

Based on my research results, skills and knowledge factors do not have a significant impact on ADEs. Perhaps this is because ADEs at the administration stage are associated with human environmental factors, which could leave nurses and administrators to believe that skills and knowledge are not significant contributors to ADEs. For example, a nurse with one year of experience administered a wrong medication because she was not paying attention. RT, as presented in this research, would have the functionality to diminish not paying attention which would highlight opportunities related to lacking skills and knowledge. Stated another way, human environmental factors would be offset by a technological aid that would most likely decrease administration errors (Garroustte-Orgeas et al., 2012).

Dahl and Boulos (2014) acknowledged that any new technology must be vetted with its intended end-user, not its designer, to determine acceptability and ultimate functionality. This is why I wanted to gauge the perception of nurses and administrators, those who are involved or who have responsibility for ADEs, on the possibility of tailoring a noninvasive, self-guided, resident-specific RT system to assist at the administration stage. The perception of NH professionals about this RT concept was more important, because there is an insufficient understanding about whether innovations in RT can improve upon human-initiated ADEs of solid medications in NHs (Van den Bemt et al., 2011; Wild, 2011).

Before any of the participants viewed the model, they were intrigued from the introduction of the research about the potential contributions of RT at the administration stage as indicated by the rejection of the null hypothesis for *H1*. Alone, this hypothesis test was quite profound, because it implies that, overall, nurses and administrators would embrace a new technology (RT) that would potentially help them reduce ADEs. This means that they realize the benefits of an enhanced technological aid at the administration stage.

The isolation of participants into the two groups (control and treatment) supports this claim further. When I assessed the treatment group at the posttest as compared to the control group at the posttest (*H2*), the treatment group's view of RT was more favorable. A more favorable outcome also resulted when I assessed the treatment group independently at the posttest (*H3*), and at the posttest as compared to the pretest (*H4*). Further statistical testing revealed that when I compared the change in response for the treatment group from the first to the second survey with the change in response for the control group from the first to the second survey, the treatment group had a greater change and a more favorable perception of RT as compared to the control group.

Based on the results from these hypothesis tests, I conclude that the demonstration of the model influenced the treatment group's view of RT, since the null hypotheses for *H2*, *H3*, and *H4* were rejected. The lack of influence from the model explains why the null hypothesis for *H5* was not rejected, where the control group showed no significant change in their perception from the first survey to the second. Since the control group did not see the model in action, it was not possible for them to be influenced by it.

Prior to conducting this research, I did not know if the pretest and posttest results from the control group would vary due to an unexpected phenomenon regarding taking the survey twice. Therefore, *H5* was conducted specifically to make this determination. Since the treatment group changed from the pretest to posttest and the control group did not (*H5),* I can rule out that taking the survey twice as influential and that an unexpected phenomenon was not present.

Overall, indications from the data revealed that nurses have an optimistic view of the RT concept presented in this research. Complexities associated with other phases of the medication-use process dictate that it must be coupled with existing technologies to cover a greater range of causes. Ranji, Rennke, and Wachter (2014) found that combining systems designed to reduce ADEs is no easy task, but they recognized that assembling a single comprehensive system connecting all phases of the medication-use process would most likely yield the greatest results. My RT concept could potentially be the final component of this comprehensive system.

By isolating solid medications for one resident into a single cabinet only accessible via individualized barcodes, the chances of a nurse giving the wrong medication or wrong quantity to a resident greatly diminishes the potential for an ADE. This view aligns with Wittich, Burkle, and Lanier's (2014) assertion that improving the selection of the right drug and right quantity for the right patient is paramount in reducing ADEs. This view also aligns with research by Samaranayake et al. (2014) where barcode technology was instrumental in reducing medication errors in the administration stage. Applying the same barcode concept at a resident-specific level versus a medication-

specific level would most likely yield greater results, since the usage is elevated from general to specific. Looking further, if the number of wrong drug errors and wrong quantity errors, a total of five out of seven from the collected historical ADE data, were eliminated by using barcodes associated with resident-specific drug cabinets, ADEs would have been reduced in the participating NHs by 71% (5/7 * 100 = 71%).

If the assertion by Sawarkar et al. (2012) that ADEs at the administration stage rank in the top three categories is indeed true, then it is plausible to generalize one third of 71% to the 105,000 deaths reported by Aljadhey et al. (2013). In other words, if the RT application presented in this research was fully operational, approximately 24% (71/3 = 24%) or 25,200 (105,000 x .24 = 25,200) people would not have died at the hands of an ADE.

Even with the proposed RT application presented in this research, medication errors would still be possible, because human-interaction would still be necessary. It would remain a human task to place medications and the correct quantities into the system correctly. It would remain a human task to confirm that what is in the system matches current drug orders for individual residents at the time of administration. Similarly though, human interaction is also necessary for existing systems to function. For example, as noted from the research results the MAR and EMAR systems must be manually loaded by a nurse upon receipt of medications from the pharmacy and manually confirmed by the nurse during extraction in preparation for administration.

Regardless, it is evident from existing literature that cost savings from preventing ADEs can be substantial. USDHHS (2014a) estimated the cost of ADEs in hospitals and

NHs at $5 billion a year. If approximately 24% of $5 billion could be saved, assuming errors in other NHs are also mainly related to wrong drug and wrong quantity, an additional $2 billion would be available annually to handily support the kind of RT system presented in this research.

As an alternative to various forms of traditional ambulatory error-reporting systems, an RT system, which is nothing more than a complex computer system capable of movement, would have the capacity to track medications from the time of entry into the system to the time of exit out of the system, along with system generated inquiries. Stated differently, RT can electronically record all activities associated with error-reporting and alignment with medication changes, thus eliminating much of the manual aspect of medication management at the administration stage, thereby producing an intelligent decision support arrangement. If a drug regimen is modified prior to extraction of the medications from the system, a system alert would be generated prompting the nurse to continue with the appropriate action. Because of the limitations associated with the human brain and general human effort, manual processes of incident reporting drastically reduce the rate of accuracy. However, with a computerized system, efficiency and effectiveness are typically better, assuming there are no significant issues in the system, and that the system is utilized properly for its intended purpose.

This assumption can be made because computerized systems can be fully automated. So, the chances that the automatic performance of roles would be disrupted can be minimized. Indeed, when an automated system is used to detect errors, the error margin of the system is negligible. What this means is that there would virtually be no

errors taking place that would be uncounted for by the system. As effective error-reporting and tracking processes take place, a greater portion of potential medication errors leading to ADEs will be detected and prevented. At this point, it must be emphasized that the use of RT is one of the most effective computerized error-reporting and tracking systems available. Therefore, an optimized RT application should be considered at the administration stage to decrease ADEs (Kruer, 2014) in the NH environment.

Limitations of the Study

The limitations that could have impacted the outcome of this research were thoroughly discussed in Chapter 1. There were no changes in these limitations even though the participants were curious as to why the model was limited to only 10 solid drugs. Further curiosity from the participants on how the model would work with other categories of drugs other than in solid form extended the explanation of the model. The participants understood that the model designed for this research was a first of its kind. However, the limitations set within the model did not hinder the demonstration to acquire data on how NH professionals felt.

The most significant limitation of this study was the usage of a model in lieu of a real-world robotic system. I specifically designed the model to be simple where it only contained a small quantity (10) of one class of fictitious medications (in solid form such as tablets, capsules, and pills) for a small number of residents (10). Participants who viewed the model could only base their opinion on their understanding of the model which could generate a different appeal from a real system. Despite this limitation, the

participants were still eager to participate due to their curiosity of an assistive technology to assist at the administration stage.

At the onset of this research, I predicted that the information from the focus group sessions and the surveys may not be 100% accurate. Participants were encouraged to use their assigned number to maintain confidentially, but some participants still placed their name on the surveys which may have influenced the results they provided. This limitation was not expected because the research design had provisions to prevent it.

Recommendations

A key component in introducing assistive RT in NHs at the drug administration stage is to thoroughly assess how nurses and administrators who would be tasked to use the technology feel about it. It is simply not enough to create a technology that accomplishes its intended purpose without making sure it would be acceptable by its end-user. Without this confirmation, the usefulness of the system would not foster maximum effectiveness; thus, the problem that it was intended to solve remains the same in addition to the possibility of new causes because of a new system.

I recommend that the research design employed in this research be repeated in other settings and with other sample sizes to determine if similar results would be obtained. Perhaps there are additional causes of ADEs associated with solid medications in the NH environment that did not surface in this research. More importantly, these causes may be instrumental in the future development of RT for assisting nurses at the administration stage in NHs. Publishing this research would facilitate future development of RT for this purpose.

I also recommend expanding upon the RT survey with additional questions to acquire a greater depth of perceptions related to the use of this proposed RT application. Administering the survey was not a simple task as it took multiple trips to the NHs to acquire the required number of completed surveys. This was mainly due to the ever-changing dynamics of the NH on a daily basis, which was dictated mostly by resident needs, family needs, and state government needs. To overcome this issue, I recommend that an expanded version of the RT survey be conducted through an online survey service with no regards to the Medicare/Medicaid quality rating of where the participant works. The most frequent causes that could potentially aid in an ADE were relative to person, not the NH. For instance, stress and fatigue are common among nurses regardless of the quality rating of the NH.

A repeat of this research or additional investigation into the perceptions of RT at the administration stage will require the usage of a model. Since this domain of research is relatively new, knowledge related to its efficacy is unknown. So, it would be immature at this point to create an actual RT system designed to assist with the drug administration task in NHs. To this end, the presentation of the model could be demonstrated more extensively if it were done via a video that could be viewed online. Additional aids, such as manikins representing NH residents with uniquely assigned wristband barcodes (a staged environment) and an attached multidrawer cabinet affixed to the platform of the mobile cart can be incorporated to enhance the visual presentation. Another benefit of an online video would be that the demonstration of the model would only be done one time, which means all the participants would see the exact same thing. Since the video could be

accessible within and outside of the NH, the participant would have the opportunity to view it at their leisure, which eliminates working around their schedule at work and possible influences in the workplace. An enhanced model would enhance the authenticity of this RT concept.

Implications

This is the first research study to investigate assistive RT to be used at the administrative phase of the medication use process in NHs. Technological advances have been made in the transcription, prescribing, and monitoring phases, yet ADEs are still a significant problem in all healthcare settings. While the RT application presented in this research will not eliminate ADEs, it has the potential to greatly add to the progress that has already been made in other phases, especially since it has been reported that most ADEs occur in the administration phase.

Since this research took into consideration perceptions of RT only at the administration stage, as a first step, a tremendous amount of research lies ahead before this kind of RT can become a reality. However, the outcome of this first step showed that nurses and administrators have a favorable perception of RT. Perhaps the research community will be inspired by this outcome and continue extending this domain of research. After all, resident-specific technology isolating multiple medications for one resident in an individual cabinet appears to improve safety, assuming medications are loaded into the cabinets correctly.

The healthcare industry is committed to improving the lives of the citizens it serves. With this domain of research tied to the healthcare industry, every technological

idea should be explored to the point where the idea is no longer feasible for continued development or it becomes a practical opportunity for continued development with the expectation of advancing new solutions to solve existing problems, especially long-standing problems. If thousands of lives can be saved or extended by some technological solution, such as RT, then the solution might be worthwhile, assuming its cost to purchase and maintain are reasonable. If three lives could be saved from each of 15,600 NHs in the U.S. (Centers for Disease Control and Prevention, 2016, p. 1) by some technological solution, 50% (3*15,600 = 46,800) of the 93,600 ADEs that occur annually (Handler, 2012) could be prevented.

My application of RT could become the technological solution that improves medication safety at the administration stage for NH residents. To this end, the positive social implications of saving lives by preventing or decreasing the frequency of ADEs via RT at the administration stage in NHs could be monumental. Continued research may make this a reality.

Conclusion

This research will add to the knowledge base on the use of RT at the administration stage in NHs. Specifically, this research will promote the feasibility that RT can save nurses valuable time and present medications in an untraditional manner that increases safety. Additionally, this kind of system will stimulate a behavior change in how nurses approach medication administration due to the intrinsic capability of error-reporting, medication tracking, and real-time updates and notifications that will be part of the system.

The healthcare industry has recognized and capitalized on the benefits of tailoring RT for specific medical issues. Over the last 10 years, numerous RT applications, mainly for surgical procedures and dispensing applications, have become practical and beneficial in many ways. These successes have spurred development of robotic applications in many other healthcare niches, like social robots, service robots, nanobots (related to diminishing end of aging), and nanotechnology (related to prevention and treatment of diseases). The RT application presented in this research addressed the need for assistive automation at the administration stage of the medication-use process in NHs.

In order for this RT application to become practical and effective, continued discovery of the causes of ADEs at the administration stage must occur and the acceptance of the technology by those who would be expected to use it must be well established. Without knowing the causes, the functionality of the system would likely miss the inclusion of critical components that would still allow ADEs. Without determining if the technology would be acceptable by nurses and administrators, the system may not become practical or it may be incorrectly used, causing a non-reduction in ADEs or an increase in ADEs. Ease of use and user acceptance are important factors of consideration, especially in a dynamic fast-paced environment such as a NH.

The results from this research did not reveal any causes of ADEs that have not been previously reported. Despite this finding, investigation into the causes should continue because the creation or evolution of various systems and processes may generate new reasons that were not evident in this research. Until a solution is found to begin

trending ADE occurrences down at the administration phase, researchers must continue evaluating the causes to assure that they are addressed in any potential solution.

The RT concept in this research, where solid medications (pills, capsules, and tablets) would only be accessible via a mobile RT unit one resident at a time, was rated positively by the participants. Perhaps this is because nurses and administrators recognize the challenges at the administration stage and the benefits this kind of system would bring. A reduction in time to acquire medications, a real-time tracking and update system, and the unique feature of keeping medications separate at the resident level could indeed increase efficiency at the administration stage. The bottom line is that RT will improve the effectiveness of drug safety by nurses and the quality of life for NH residents as it relates to solid medications.

References

Administration of Aging. (2014). Aging statistics. Retrieved from http://www.aoa.acl.gov/Aging_Statistics/index.aspx.

Agency for Healthcare Research and Quality (AHRQ). (2001). Reducing and preventing adverse drug events to decrease hospital costs: Research in action. AHRQ Publication Number 01-0020. Retrieved from http://www.ahrq.gov/legacy/qual/aderia/aderia.htm.

Aljadhey, H., Mahmoud, M., Mayet, A., Alshaikh, M., Ahmed, Y., Murray, M., & Bates. D. (2013). Incidence of adverse drug events in an academic hospital: A prospective cohort study. *International Journal for Quality in Health Care, 25*(6), 648-655.

Barker, K., Flynn, E., Pepper, G., Bates, D., & Mikeal, L. (2002). Medication errors observed in 36 health care facilities. *Archives of Internal Medicine, 162*(16), 1897-903.

Barnett, K., McCowan, C., Evans, J., Gillespie, N., Davey, P., & Fahey, T. (2011). Prevalence and outcomes of use of potentially inappropriate medicines in older people: Cohort study stratified by residence in nursing home or in the community. *BMJ Quality & Safety, 20,* 275-281.

Bates, D. & Slight, S. (2014). Medication errors: What is their impact? *Mayo Clinical Proceedings, 89*(8), 1027-1029.

Blackburn, D. (2007, July 13). Robotics added to OMHS pharmacy: System is designed to boost accuracy. *Messenger-Inquirer.* Retrieved from http://www.highbeam.

com/doc/1G1-166357089.html.

Borenstein, J. (2011). Robots and the changing workforce. *Artificial Intelligence & Society, 26*, 87-93.

Brandt, N. & Zarowitz, B. (2015) Aligning Care Initiatives to Reduce Medication Adverse Effects in Nursing Homes. *Journal of Gerontological Nursing, 41*(1), 8-13.

Campanelli, C. (2012). American geriatrics society updated beers criteria for potentially inappropriate medication use in older adults: The American geriatric society 2012 beers criteria update expert panel. *Journal of American Geriatric Society, 60*(4), 616-631.

Campbell, F., Karnon, J. Czoski-Murray, C., & Jones R. (2007). A systematic review of the effectiveness and cost effectiveness of interventions aimed at preventing medication error (medicines reconciliation) at hospital admission. *Report for the National Institute for Health and Clinical Excellence as Part of the Patient Safety Pilot.* Retrieved from http://www.nice.org.uk/nicemedia/pdf/PatientSafetyMedsSystematicReview.pdf.

Carlsen, B. & Glenton, C. (2011). What about n?: A methodological study of sample-size reporting in focus group studies. *BMC Medical Research Methodology, 11,* 26.

Centers for Medicare & Medicaid Services (CMMS). (2015). Five-star quality rating system. Retrieved from https://www.cms.gov/Medicare/Provider-Enrollment-and-Certification/CertificationandComplianc/FSQRS.html.

Centers for Medicare & Medicaid Services (CMMS). (2013). Official nursing home

compare data. Retrieved from https://data.medicare.gov/data/nursing-home-compare.

Centers for Disease Control and Prevention. (2016). Nursing home care. Retrieved from http://www.cdc.gov/nchs/fastats/nursing-home-care.htm.

Cohen, W. (1977). *Sampling techniques* (3rd.). New York: NY: John Wiley & Sons.

Craig, P., Dieppe, P., Macintyre, S., Michie, S., Nazareth, I., & Petticrew, M. (2008). Developing and evaluating complex intervention: The new medical research council guidance. *British Medical Journal, 337, 455-459.*

Crowe, S., Creswell, K., Robertson, A., Huby, G., Avery, A., & Sheikh, A. (2011). The case study approach. *BMC Medical Research Methodology, 11,* 100-108.

Cunningham, F., Ranmuthugala, G., Plumb, J., Georgiou, A., Westbrook, J., & Braithwaite. (2011). Health professional networks as a vector for improving healthcare quality and safety: A system review. *BMJ Quality & Safety Online First, 21*(3), 239-249.

Dahl, T. & Boulos, M. (2014). Robots in health and social care: A complementary technology to home care and telehealthcare? *Robotics, 3*(1), 1-21.

DePaulo, P. (2000). Sample size for qualitative research: The risk of missing something Important. *Quirks Marketing Research Review.* Retrieved from http://www.quirks.com/articles/a2000/20001202.aspx?searchID=215035&sort=5&pg=1.

Diaz Pavon, J. & de la Portilla, F. (2011). Robotic surgery: A present and future technological advance. *Cirugia Espanola (English Edition), 89*(10), 633-634.

Doody, O., Slevin, E., & Taggart, L. (2013). Preparing for and conducting focus groups in nursing research: Part 2. *British Journal of Nursing, 22*(1), 16-19.

Farquhar, M., Ewing, G., & Booth, S. (2011). Using mixed methods to develop and evaluate complex interventions in palliative care research. *Palliative Medicine 25(*8), 748-757.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A. (2009). Statistical power analysis using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods, 41,* 1149-1160.

Feinstein, A. & Cannon, H. (2001). Fidelity, verifiability, and validity of simulation: Constructs for evaluation. *Developments in Business Simulation and Experiential Learning, 28,* 57-67.

Francois, O., Carrez, L., Gschwind, L., Cingria, L., Vernaz-Hegi, N., & Bonnabry, P. (2013). Automation of drug distribution: Impact on error rate and distribution speed. *European Journal of Hospital Pharmacy, 20*(1), 88.

Gandhi, T., Weingart, S., Borus, J., Seger, A., Peterson, J., Burdick, E., . . . Bates, D. (2003). Adverse drug events in ambulatory care. *New England Journal of Medicine, 348*(16), 1556–1564.

Garrouste-Orgeas, M., Philippart, F., Bruel, C, Max, A., Lau, N., & Misset, B. (2012). Overview of medical errors and adverse events. *Annual of Intensive Care, 2,* 2.

Gibbs, A. (1997). Focus groups. *Social Research Update, 19,* 1-8.

Grinnell, R. & Unrau, Y. (2011). *Social work research and evaluation: Foundations of evidence-based practice* (9th ed.). New York, NY: Oxford University Press.

Handler, S. (2012). Enhancing the detection and management of adverse drug events in nursing homes. Retrieved from http://clinicaltrials.gov/ct2/show/study/NCT01531088?view=recrd.

Harris-Kojetin, L., Sengupta, M., Park-Lee, E., & Valverde, R. (2013). Long-term care services in the United States: 2013 overview. *National Center for Health Statistics, 3*(37), 1-93.

Herman, J. (2012). Medical robots: From mechanized lampreys to android nurses. Retrieved from https://www.patexia.com/feed/medical-robots-from-mechanized-lampreys-to-android-nurses-3624.

Heylen, D., Van Dijk, B., & Nijholt, A. (2012). Robotic rabbit companions: Amusing or a nuisance? *Journal of Multimodal User Interfaces, 5*, 53-59.

Horowitz, A. (2014). Prescription for safety: Strategies for avoiding medication errors improves resident care and reduces business risk. *Long-Term Living, 63*(1), 29.

Huston, C., (2013). The impact of emerging technology on nursing care: Warp speed ahead. *The Online Journal of Issues in Nursing,* 18(*2*), Manuscript 1.

Institute of Medicine. (2004). *Patient safety: Achieving a new standard for care*. Washington, DC: National Academies Press.

Kiekkas, P., Karga, M., Lemonidou, C., Aretha, D., & Karanikolas, M. (2011). Medication errors in critically ill adults: A review of direct observation evidence. *American Journal of Critical Care, 20*(1), 36-44.

Kirschling, T., Rough, S., & Ludwig, B. (2009). Determining the feasibility of robotic courier medication delivery in a hospital setting. *American Journal of Health-*

System Pharmacy, 66, 1754-1762.

Krueger R. & Casey M. (2000). *Focus groups: A practical guide for applied research* (4th ed.). Thousand Oaks, CA: Sage Publications.

Kruer, R., Jarrell, A., & Latif, A. (2014). Reducing medication errors in critical care: A multimodal approach. *Clinical Pharmacology. 6,* 117-126.

Lauer, P. (2004). A policymaker's primer on education research: How to understand, evaluate, and use-it. *Mid-Continent Research for Education and Learning.* Retrieved from http://ecs.org/html/educationIssues/Research/primer/appendixA.asp.

Law, A. & Kelton, W. (2000). *Simulation modeling and analysis*. Boston: McGraw-Hill.

Liu, X. (2012). Sample size for the z test and its confidence interval. *International Journal of Mathematical Education in Science and Technology, 43*(2), 266-270.

Mangan, J., Lalwani, C., & Garnder, B. (2004). Combining quantitative and qualitative methodologies in logistics research. *International Journal of Physical Distribution & Logistics Management, 34*(7), 565-578.

Mayer, M., Dowsett, S., Brahmavar, K., Hornbuckle, K., & Brookfield, W. (2010). Reporting adverse drug events. *US Pharmacy. 35,* 15-19.

Moore, T., Cohen, M., & Furberg, C. (2007). Serious adverse drug events reported to the food and drug administration. *Archives of Internal Medicine, 167*(16), 1752-1759.

Mowery, B. (2011). The paired t-test. *Pediatric Nursing, 37*(6), 320-321.

Murphy, B. & Wakefield, A. (2013). Early verification and validation using model-based design. *EDN, 54*(13), 39-41.

Nachmias, C. & Nachmias, D. (1992). *Research methods in the social sciences* (4th ed.). New York, NY: St. Martin's Press.

O'Byrne, P. (2007). The advantages of mixing methods: An analysis of combining traditional and autoethnographic approaches. *Qualitative Health Research, 17(*10), 1381-1391.

O'Shaughnessy, C. (2013). The basics: National spending for long-term services and supports (LTSS), 2011. *National Health Policy Forum,* Retrieved from http://www.nhpf.org/uploads/announcements/Basics_LTSS_02-01-13.pdf.

Otto, E. (2015). 5 rights of medication safety. Retrieved from http://www.livestrong.com/article/102785-rights-medication-safety/.

Parker-Pope, T. (2011, April 14). Medication-related injuries on the rise. *The New York Times.* Retrieved from http://well.blogs.nytimes.com/ 2011/04/14/medication-related-injuries-on-the-rise/.

Pedersen, C., Schneider, P., & Scheckelhoff, D. (2012). ASHP national survey of pharmacy practice in hospital settings: Dispensing and administration --- 2011. *American Journal of Health System Pharmacy, 69,* 768-785.

Philip, R. (2004). Occurrence of dispensing errors and efforts to reduce medication errors at the central arkansas verteran's healthcare system. *Drug Safety, 27*(4), 271-282.

Ranji, S., Rennke, S., & Wachter, R. (2014). Computerised provider order entry combined with clinical decision support systems to improve medication safety: A narrative review. *BMJ Quality & Safety, 23*(9), 773-780.

Samaranayake, N., Cheung, S., Cheng, K., Lai, K., Chui, W., & Cheung, B. (2014).

Implementing a bar-code assisted medication administration system: Effects on the dispensing process and user perceptions. *International Journal of Medical Informatics, 83*(2014), 450-458.

Samaras, N., Chevalley, T., Samaras, D., Gold, G. (2010). Older patients in the emergency department: a review. *Annals of Emergency Medicine, 56*(3), 261-269.

Sargent, R. (2013). Verification and validation of simulation models. *Journal of Simulation, 7,* 12-24.

Sawarkar, A., Keohane, C., Maviglia, S., Gandhi, T., & Poon, E. (2012). Adverse drug events caused by serious medication administration errors. *BMJ Quality & Safety, 21*(11), 933-938.

Sekhar, L., Tariq, F., Kim, L., Pridgeon, J., & Hannaford, B. (2013). Commentary: Virtual reality and robotics in neurosurgery. *Neurosurgery, 72,* A1-A6.

Shenton, A. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for Information, 22,* 63-75.

Sokolowski, J. & Banks, C. (2009). *Principles of modeling and simulation: A multidisciplinary approach.* Hoboken, New Jersey: John Wiley & Sons Inc.

Soler, M., Aguera-Ortiz, L., Rodriguez, J. Rebolledo, C., Munoz, A., Perez, I., . . . Martin, P. (2015). Social robots in advanced dementia. *Frontiers in Aging Neuroscience,* 7(133), 1-12.

Summerfield, M., Seagull, J., Vaidya, N., & Xiao, Y. (2011). Use of pharmacy delivery robots in intensive care units. *American Journal of Health-System Pharmacy, 68,* 77-83.

Sullivan, G. (2011). A primer on the validity of assessments instruments. *Journal of Graduate Medical Education, 3*(2), 119-120.

Tsao, N., Lo, C., Babich, M., Shah, K., & Bansback, N. (2014). Decentralized automated dispensing devices: Systematic review of clinical and economic impacts in hospitals. *Canadian Journal of Hospital Pharmacy, 67*(2), 138-148.

U.S. Census Bureau. (2012). Statistical abstract of the U.S. Retrieved from http://www.census.gov/compendia/statab/2012/tables/12s0020.pdf.

U.S. Department of Health and Human Services (USDHHS). (2014a). *HHS strategic plan and secretary strategic initiatives: Strategic plan fy 2014 –2018.* Retrieved from http://www.hhs.gov/about/strategic-plan/strategic-goal-1/index.html.

U.S. Department of Health and Human Services, Office of Disease Prevention and Health Promotion (ODPHP). (2014b). *National Action Plan for Adverse Drug Event Prevention.* Retrieved from http://libguides.scu.edu.au/content.php?pid=161580&sid=3666750.

Van den Bemt, P., Idzinga, J., Robertz, H., Kormelink, D., & Pels, N. (2011). Medication administration errors in nursing homes using an automated medication dispensing system. *Journal of American Medical Informatics Association, 16*, 486-492.

Van Sonderen, E., Sanderman, R., & Coyne, J. (2013). Ineffectiveness of reverse wording of questionnaire items: Let's learn from cows in the rain. *PLOS One*, *8*(9), 10.

Wakefield, D., Ward, M., Loes, J., & O'Brien, J. (2010). A network collaboration implementing technology to improve medication dispensing and administration in

critical access hospitals. *Journal of American Medical Informatics Association, 17*(5), 584-587.

Webster's Ninth New Collegiate Dictionary (1983). Springfield, MA: Merriam-Webster Inc.

Weekes, H. (2014). Hospital pharmacy practice: US versus UK. *Tomorrow's Pharmacist.* Retrieved from http://www.pharmaceutical-journal.com/sign-in?rtn=publications/tomorrows-pharmacist/hospital-pharmacy-practice-us-versus-uk/11138998.fullarticle.

Weiss, A. & Elixhauser, A. (2013). Characteristics of adverse drug events originating during the hospital stay, 2011. HCUP Statistical Brief #164. Retrieved from http://www.hcup-us.ahrq.gov/reports/statbriefs/sb164.pdf.

Westbrook, J., Rob, M., Woods, A., & Parry, D. (2011). Errors in the administration of intravenous medications in hospital and the role of correct procedures and nurse experience. *BMJ Quality & Safety Online First, 23*(4), 319-324.

Wild, D. (2011). New barcode checks help reduce drug round errors in care homes. *Nursing Management, 18*(5), 26-30.

Wittich, C., Burkle, C. & Lanier, W. (2014). Medication errors: An overview for clinicians. *Mayo Clinic Proceedings, 89(*8), 1116 -1125.

Zafar, A., Hickner, J., Pace, W., & Tierney W. (2008). An adverse drug event and medication error-reporting system for ambulatory care (meaders). *The American Medical Informatics Association Annual Symposium Proceedings, 6*, 839–843.

Appendix A: Adverse Drug Event Survey Instrument

Adverse Drug Event Survey

Thank you for taking the time complete this survey. Your responses are strictly confidential and will not be revealed to the administrators of your facility. Your honest feedback, based on your experience, is valuable to this research project. It should only take about 15 minutes of your time to complete. Please answer all questions.

Job Title: **Nbr Years of Experience:**	**Are you certified to administer drugs? (Y/N) _____**

For each question, mark one box with an X to represent your answer.

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	Example: Drug administration errors occur in the facility that I work at			X		
	Experience	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1.	A nurse with less than 1 year of experience is likely to make a drug administration mistake					
2.	A nurse with more than 3 years of experience is likely to make a drug administration mistake					
3.	Administrations errors are common because of the number of drugs prescribed to nursing home residents					
4.	Administration mistakes are commonly caused by a lack of attention					
5.	When administration errors occur they are reported					
6.	Solid medications, like pills, tablets, and capsules, are more prone to administration errors than other forms					
7.	When a drug appears inappropriate for a resident, nurses question transcription orders made by doctors					
8.	Nurses administer prescription medications to residents that were not prescribed by a doctor					
9.	Nursing home residents cause incorrect drug administrations					
10.	Nurses vary administration techniques based on the resident					

	Training	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
11.	Agency nurses are adequately trained to administer medications common in nursing homes					
12.	Nurses with less than 1 year of experience are adequately trained to administer drugs					
13.	Nurses with more than 3 years of experience are adequately trained to administer drugs					
14.	Educational seminar's related to new drugs are available in nursing homes					
15.	Nurses are required to attend educational seminar's on new drugs					
16.	Adequate information about drugs readily exist on nursing home wards					
17.	Nurses are encouraged to ask questions about prescribed orders that appear inappropriate for a resident					
18.	Nurses are encouraged to report adverse drug events that they are aware of					
	Guidelines and Policies	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
19.	Nurses generally follow the drug administration guidelines and procedures set by the facility they work in					
20.	Instruments, such as a computer, are used as an aide to administer drugs					
21.	Various policies and procedures contribute to drug administration errors					
22.	Decisions made by administrators contribute to drug administration errors					
23.	Nursing homes allow visitors to bring in **prescription medications** for residents					
24.	Nursing homes allow visitors to bring in **over the counter medications** for residents					
25.	Nursing homes allow doctors to bring in medications for residents					
26.	Nursing homes allow medication substitutes when the prescribed medication is unavailable					

In the space below, please share any way you think drug administration errors occur in nursing homes.

Appendix B: Robotic Technology Survey Instrument and Scores

1-1-5	**Robotic Technology Survey**					
Thank you for taking the time complete this survey. Your responses are strictly confidential and will not be revealed to the administrators of your facility. Your honest feedback, based on your experience, is valuable to this research project. It should only take less than 5 minutes of your time to complete. Please answer all questions.						
Job Title: **Nbr Years of Experience:**			**Are you certified to administer drugs? (Y/N) ___**			
For each question, mark one box with an X to represent your answer.						
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	Example: Drug administration errors occur in the facility that I work at			X		
	Robotic Technology	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1.	Nurses would use a robotic system to assist them with administering pills, tablets, and capsules, to prevent possible mistakes					
2.	Keeping medicines isolated in patient-specific containers could decrease administration errors of solid drugs					
3.	A comprehensive interactive computer system will cause nurses to be less aware when administering medications					
4.	Some new form of advanced technology is needed to reduce administration errors					
5.	A robotic system would not be useful to assist in administering solid medications					
6.	A robotic system would be useful if it provided the right medication for each resident					
7.	A robotic system would be useful if it did not slow down the task of administering solid medications					
8.	A robotic system would decrease the success rate of administering medications on time					
9.	A robotic system would help decrease administration errors of solid medications					
10.	A robotic system would make my job of tracking what medicines I have administered easier					

Figure B1. Robotic Technology Survey

Table B2

RT Survey Means Before and After Reverse Scoring for the Control Group

Item Nbr	Item	Control Group (Pretest) Original Score	Control Group (Pretest) Final Score	Control Group (Posttest) Original Score	Control Group (Posttest) Final Score
1	Nurses would use a robotic system to assist them with administering pills, tablets, and capsules, to prevent possible mistakes	3.53	3.53	3.49	3.49
2	Keeping medicines isolated in patient-specific containers could decrease the administration errors of solid drugs	4.04	4.04	3.98	3.98
3	**A comprehensive interactive computer system will cause nurses to be less aware when administering medications**	2.41	3.59	2.73	3.27
4	Some new form of advanced technology is needed to reduce administration errors	3.94	3.94	3.10	3.10
5	**A robotic system would not be useful to assist in administering solid medications**	3.00	3.00	3.31	2.69
6	A robotic system would be useful if it provided the right medication for each resident	3.75	3.75	4.18	4.18
7	A robotic system would be useful if it did not slow down the task of administering solid medicines	3.67	3.67	3.51	3.51
8	**A robotic system would decrease the success rate of administering medicines on time**	3.14	2.86	3.00	3.00
9	A robotic system would help decrease administration of errors of solid medications	3.00	3.00	3.24	3.24
10	A robotic system would make my job of tracking what medicines I have administered easier	3.35	3.35	3.45	3.45

Note. **Bold** items 3, 5, and 8 were reversed-scored in the positive direction. Listed is the original mean per item prior to reverse scoring and the final mean per item after reverse scoring for the control group pretest and posttest.

Table B3

RT Survey Means Before and After Reverse Scoring for the Treatment Group

Item Nbr	Item	Treatment Group (Pretest) Original Score	Treatment Group (Pretest) Final Score	Treatment Group (Posttest) Original Score	Treatment Group (Posttest) Final Score
1	Nurses would use a robotic system to assist them with administering pills, tablets, and capsules to prevent possible mistakes	3.29	3.29	4.37	4.37
2	Keeping medicines isolated in patient-specific containers could decrease the administration errors of solid drugs	4.08	4.08	4.49	4.49
3	**A comprehensive interactive computer system will cause nurses to be less aware when administering medications**	2.92	3.08	3.00	3.00
4	Some new form of advanced technology is needed to reduce administration errors	3.88	3.88	4.49	4.49
5	**A robotic system would not be useful to assist in administering solid medications**	2.98	3.02	3.39	2.61
6	A robotic system would be useful if it provided the right medication for each resident	3.27	3.27	4.41	4.41
7	A robotic system would be useful if it did not slow down the task of administering solid medicines	3.51	3.51	4.45	4.45
8	**A robotic system would decrease the success rate of administering medicines on time**	3.12	2.88	2.55	3.45
9	A robotic system would help decrease administration of errors of solid medications	2.35	2.35	4.53	4.53
10	A robotic system would make my job of tracking what medicines I have administered easier	2.96	2.96	4.20	4.20

Note. **Bold** items 3, 5, and 8 were reversed-scored in the positive direction. Listed is the original mean per item prior to reverse scoring and the final mean per item after reverse scoring for the treatment group pretest and posttest.

Appendix C: ADE Scorecard Instrument

ADE Scorecard of Historical Data

Facility _____ Quality Rating _____
Employee _____ Gender (M/F) _____
Status _____ Tenure (yrs) _____
Month _____ Tot Beds _____

Med Category: Pills, Capsules, Tablets

Error Type
- W - Wrong Medication
- Q - Improper Quantity
- L - Late Administration
- E - Early Administration
- N - No Administration
- T - Improper Technique
- O - Other

Prescribed Medication					Administration Activity			
Medication	Time	Freq	Med Category	Notes	Error (Y/N)	Error Time	Error Type	Error Description
Total Administrations:				**Total Errors:**				

Appendix D: Focus Group Questions

1. How do ADEs occur in nursing homes?

2. What do you think is the single most cause for ADEs in nursing homes?

3. Does your facility offer any ongoing training programs for staff nurses qualified to administer drugs?

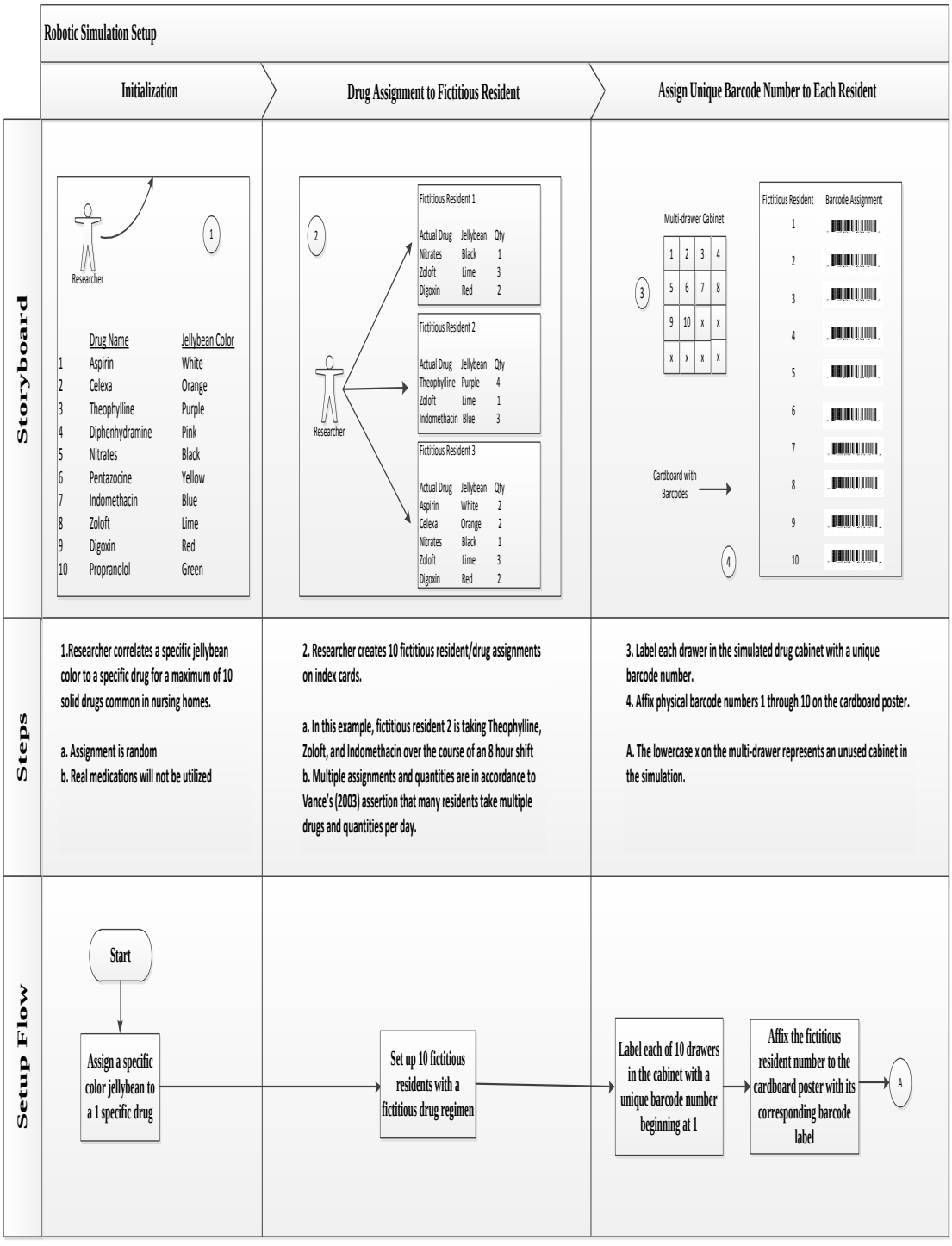
4. Would you be willing to offer a financial incentive if ADEs were less than 5% of all administrations in your facility?

5. Would a substantial decrease in ADEs cause your facility to save money in addition to improving care?

6. Does your facility currently use technology to assist in drug administrations?

7. Describe your current processes and procedures for administering drugs?

Appendix E: Robotic Simulation Storyboard



Robotic Simulation Setup Continued

Setup Simulation in MS Access Application – Step 1

Storyboard

(5)

Resident Landscape Table

Resident ID Nbr	Drug Regimen Nbr
1	2
2	7
3	9
4	10
5	11
6	12
8	13
10	14

Steps

5. Each resident is assigned to a "resident ID number" that corresponds to a specific "drug regimen nbr"

a. These are fields in a table referred to as Resident Landscape
b. Each "drug regimen nbr" equates to various drugs the resident is taking
c. Assignments are fictitious and do not represent any resident

Setup Flow

(A) → Set up Resident ID numbers 1 through 10 in the database with the corresponding drug regimen number

Setup Simulation in MS Access Application – Step 2

Storyboard

Drug Regimen Master Table

Drug Regimen Nbr	Drug Nbr	Qty	Start Time	End Time
6	130	1	7:30:00 AM	8:30:00 AM
6	192	1	7:30:00 AM	8:30:00 AM
(6) 7	131	4	7:30:00 AM	8:30:00 AM
7	143	3	7:30:00 AM	8:30:00 AM
7	145	1	7:30:00 AM	8:30:00 AM
8	192	2	10:00:00 AM	11:00:00 AM
8	143	1	10:00:00 AM	11:00:00 AM
9	143	1	12:00:00 PM	1:00:00 PM
10	142	1	12:00:00 PM	1:00:00 PM
11	130	2	12:00:00 PM	1:00:00 PM
12	130	1	12:00:00 PM	1:00:00 PM

Steps

6. For each drug regimen number, enter a pre-defined number that represents one particular drug.

a. In this example, fictitious resident 2 is assigned to drug regimen number 7. Drug regimen 7 illustrates that this resident is taking drugs 131, 143, and 145. See Step 7 for the actual drug name and the correlating jellybean.
b. This table is referred to as the Drug Regimen Master.

Setup Flow

Assign drug, quantity, and time to the drug regimen number

Setup Simulation in MS Access Application – Step 3

Storyboard

(7)

Drug Register Table

Drug Nbr	Drug Name	Drug Candy
129	Aspirin	White
130	Celexa	Orange
131	Theophylline	Purple
132	Diphenhydramine	Pink
141	Nitrates	Black
142	Pentazocine	Yellow
143	Indomethacin	Blue
145	Zoloft	Lime
146	Digoxin	Red
192	Propranolol	Green

Steps

7. For each drug number, assign the actual name of the drug and the corresponding jellybean color associated with the simulation.

a. For example, fictitious resident 2 is assigned to drug regimen number 7 with drug numbers 131, 143, and 145. Thus, this resident is taking 4 Theophylline (purple), 3 Indomethacin (blue), and 1 Zoloft (lime).
b. Thus, drawer number 2 will contain 4 purple jellybeans, 3 blue jellybeans, and 1 lime jellybean.

Setup Flow

Assign actual drug to a uniquely covered jellybean → End

Appendix F: Coded Transcript of Focus Group Discussions

Theme Code	Theme	Subtheme Code	Subtheme	Significant Statement
1	Reasons for ADEs	1.01	Not paying attention	I think the main reason is simply not paying attention.
1	Reasons for ADEs	1.01	Not paying attention	Not paying attention.
1	Reasons for ADEs	1.01	Not paying attention	Not paying attention.
1	Reasons for ADEs	1.01	Not paying attention	Not paying attention to what we're actually doing.
1	Reasons for ADEs	1.01	Not paying attention	There has been errors to occur because I have worked with a nurse who had medicine ready to go in one patient room then was called into another patient room, but she could not leave that medicine there. But in her haste went into this room with this medicine and administered this medicine to this patient, because she was not paying attention at the time at what she was doing, you know
1	Reasons for ADEs	1.02	Too busy	I would say being too busy
1	Reasons for ADEs	1.02	Too busy	Being too busy.
1	Reasons for ADEs	1.02	Too busy	I would say being too busy
1	Reasons for ADEs	1.02	Too busy	Just being too busy and rushing around the stuff
1	Reasons for ADEs	1.02	Too busy	Then too, because of patient load they want you to go here, here, here and here. Now you got everybody calling at one time wanting their medicine and everyone talking about everybody ready to go to sleep.
1	Reasons for ADEs	1.02	Too busy	The workload under the nurse.
1	Reasons for ADEs	1.03	Limited time	When you stock your cart to go out for that day, you need to have those medications on that cart already otherwise if your back in the hall you're having to walk all the way back up the nurse's station to supply room to get that extra applesauce or pudding. What you encounter from the end of that hall from the patient you're currently at, it may take you 20 or 30 minutes to get back depending on the circumstances that you ran into, which actually may become the priority. So, there's a lot of different factors.

1	Reasons for ADEs	1.03	Limited time	The problem is that you have one hour before and one hour after and that what your JACO standards are, but it's absolutely impossible to pass those meds during that time specifically if you have the lead time of…. If one of your patients was let's say their a diabetic and you have test them and then you have to stay with that patient to make sure that blood sugar levels are decreasing based on the insulin level. You've already lost your time. Your testing q15, q20…. Ummm you can be up to 45 minutes with one patient. You're way pass your window of time to pass those meds
1	Reasons for ADEs	1.04	Stress and fatigue	A lot of times stress and fatigue
1	Reasons for ADEs	1.04	Stress and fatigue	You may have someone that may take an additional shift, because someone didn't come to work. That would cause the fatigue that she's speaking of. So yes, I think that would also have an impact on it as well.
1	Reasons for ADEs	1.05	Transcription errors	I will say a lot of them can occur by misreading a transcription wrong.
1	Reasons for ADEs	1.05	Transcription errors	Sometimes a doctor's handwriting can come to you and you can't quite read what he has written out or either you read it and it is typed in wrong.
1	Reasons for ADEs	1.05	Transcription errors	Transcription has been the majority of what I have seen.
1	Reasons for ADEs	1.06	Medicine not up from the pharmacy	The medicine not being up from the pharmacy usually is an issue
1	Reasons for ADEs	1.07	Unknown medical history of patients	I think the biggest reason is that we see adverse drug events with patients are their unknown medical history that contradict the use of certain medications and in turn we end up seeing the adverse drug event when it's too late.
1	Reasons for ADEs	1.08	Wrong patient, wrong drug	Wrong patient, wrong drug.
1	Reasons for ADEs	1.09	Drug received at wrong time	In some of your adverse med errors are strictly based on that the patient didn't receive the medication at the right time.

1	Reasons for ADEs	1.10	Updating MAR (Medical Administration Record)	The problem with the MAR is that if a physician comes in and updates a medication it may not be changed over into the MAR. So, that can lead to some adverse effect and disrupt medications. It was the correct medication at the time, however, because of their symptoms this medication has been changed…And to no fault of her own, she would be charged with the error. Yes, yes. She would because the information was not updated (in the MAR). Right.
1	Reasons for ADEs	1.11	Lack of continuity of care	I believe one of the largest indicators is the lack of continuity of care from caregivers in the nursing home. We have a high turnover rate and that umm… the orientation rate for the new nurses can be really stressful on them and I believe a lot of our errors are from that.
2	Process of drug administration	2.01	Time and effort	Then I would take those medications to the patients room, identify the patient, make sure they do have the order for the medication I have in hand, and proceed with the administration.
2	Process of drug administration	2.01	Time and effort	We have to come all the way down from B wing hall to all the way to A wing hall, cause A wing is the only one with the unit (medicine cart). In the middle of the med pass cause the resident want a pain pill, so I have to stop and come all the way down from the B wing hall to come all the way over to A wing to get a pain pill. 10 [minutes] is the max. That is a lot of time. With enough nurses using the machine or like if they are running meds a person would have to wait (on machine to retrieve meds).
2	Process of drug administration	2.01	Time and effort	After the prioritization I go to the medication room where I withdraw the medication by patient and by time individually.
2	Process of drug administration	2.01	Time and effort	That nurse, like I say, again she just goes and she pulls it cause it stripped by patients. It doesn't skip. It's by room, so all of section or room 1 would be here, room 2 would be here, room three would be here. So, when they pull the strip and it has the

				names and there's blocks in between, so you know that once you end that white section here this is starting a new room. So you know that way they not getting jumbled or mixed up.
2	Process of drug administration	2.01	Time and effort	So, I get my report on my patients. I make a list of all the medications that are to be administered throughout my shift and then I prioritize, you know the patients I need to see first.
2	Process of drug administration	2.01	Time and effort	Well normally you have patients in your undesignated space, which is normally one or two halls and those medications are on your med trays. On those med trays though each patient is different and individualized, so you have to ensure that… and this is where a lot of nurses loose time and where some errors may come in. Some of your patients can't chew medicine and so there gonna have to be crushed. So, you have to know (other participants agreeing) that and that has to be reported to you otherwise you're losing time.
2	Process of drug administration	2.02	Companywide process	I want to say that they started companywide. I know we have one. I'm not sure about a couple of the other areas, but I know we got approved for ours. So I'm just taking it that everybody else is using it
3	Use of Technology	3.01	MAR (Medication Administration Records)	We have like a scanning system. It's all computerized. So, it comes up on the MAR what the patient is supposed to take and we scan each medication. So, there's no paper charting or things like that. We pull all of our med's and then we scan them and administer them.
3	Use of Technology	3.01	EMR (Electronic Medical Records)	Our EMR is fully equipped with a scanning system as well as best practice alerts to let you know when there is medications being given to soon or the wrong medication that there's no order for.
3	Use of Technology	3.01	MAR (Medication Administration Records)	As far as what we have our MAR. That will tell us when we're giving a medication, if we're giving a medication too soon or if it's not scheduled or the wrong patient, wrong medication, whatever. It will catch us with that.

3	Use of Technology	3.01	MAR (Medication Administration Records)	Well, we currently use a cart that's in a MAR (Medication Administration Record).
3	Use of Technology	3.01	MAR (Medication Administration Records) EMAR (Electronic and ADU (Automated Dispensing Unit)	They moved everything to the electronic MAR or EMR, and the ADU automated dispensing unit
3	Use of Technology	3.02	ADU (Automated Dispensing Unit)	It [ADU] will stream out 24 hours' worth of medications and the 11 to 7 shift puts those medications in each individual patients slot. So for that 24 hour period, every medication that the patient has taken is put in that slot. So like 1:00pm today a RN will go in and dispense those medicines for that 24 hour period. And she will put them per unit… bag per unit and then the 11 to 7 nurse goes and take them to her unit and again put them in the slot cause by the time they come in for their shift the slots are empty, and it will start over like that every night.
3	Use of Technology	3.03	Best Practice Alerts	I do kind of have a feeling that this might be taking away the nurses responsibility of doing their checks, the patient identified and the five rights of medication administration.
3	Use of Technology	3.03	Best Practice Alerts	However, the good thing is that the scanning system does stop us from overriding the best practice alerts where there is something wrong with the administration.
3	Use of Technology	3.03	Best Practice Alerts	It [ADU] alerts you that it's not time. It would have a time on there that the last time. It would have the date and the time it was last given. So you know you can see in red the date and the time that it was given so you don't give it too early because it would have on their give every six hours or you know so you don't give it too early.
3	Use of Technology	3.04	PCAS (Patient	We also have things like our IV pumps or PCAS. Our PCAS will tell

			Controlled Analgesia System)	us if we were not administering a specific narcotic correctly with heparin for example. That's weight based so it's very specific. Stuff like that.
3	Use of Technology	3.05	Robotic Technology	If your robotic can effectively handle patient and med safety it would be an awesome addition to what we already have.
3	Use of Technology	3.05	Robotic technology	It's kind a cumbersome that you have to keep going back and forth to get medicine, go get the medicine and go back to the resident, get the medicine and go back to the resident. Yes it would be an improvement. If your robot can follow and go patient to patient I mean that works
3	Use of Technology	3.05	Robotic technology	Yes, it would [save a lot of time and effort] because right now if they don't have something cause with this ADU is setup if they don't have something they got to leave their unit and go get it.
3	Use of Technology	3.05	Robotic technology	Hopefully in the model that you have created… that will not stock the pills and the medicines it will also put in that drawer the applications of the pudding of what they supposed to take with those pills they giving. So, hopefully the model that you have those individualized trays would have like she said, the applesauce or the pudding in there with that already. Like in your model somehow you would have to work that into your robotic model.
3	Use of Technology	3.05	Robotic technology	I know Baptist pharmacy they have the robot that dispenses the medications, but it goes to the med cart and then after a pharmacist actually puts in a med cart. Then we take over the med cart. So, nothing actually administering it to us so there's still is error with that. But the robot in pharmacy at Baptist… that's the only one that I know of. But it is a stationary kind of deal.
4	Training	4.01	No training	No!
4	Training	4.01	No training	There's not. There's not enough time to do that.

4	Training	4.03	Training is adequate	I do believe that it's adequate to get the nurse or the certified medication administrator the ability to pass medications to patients
4	Training	4.03	Training is adequate	Yeh, I think so.
4	Training	4.02	Training is inadequate	Well in my experience the facility didn't have continuing education. Like if there was new equipment or new mediation. Now there would be (drug) reps that would come in and talk to us about certain medications or you know an IV pump…. They (drug reps) might come in and do an in service but it's only a short amount time and it's usually during our shift. We're pulling away from our patient to talk with them for about 10 to 15 minutes and then we go back
4	Training	4.04	Connect Care class	Like learning how, I mean, when you get accepted to being a new nurse you learn how to, you know, how to administer meds, you go to a Connect Care class on the computer to learn how to scan the medication.
4	Training	4.05	Health Stream	We have our annual medication requirements that we do on Health Stream. So yes, there are available for that.
4	Training	4.06	Medication tests	Every nurse in here takes a medication test and yeh as a matter of fact you got one coming up. Say it again. New and old nurses have to take a medication math test and I got a new one that's coming out. It's got IV's stuff on it so I hope you ready.
4	Training	4.07	Orientation	Well, all staff have to go through an orientation and they have go for training.
4	Training	4.08	Training for EMR (Electronic Medical Records)	There have been some trials though with new employees coming on to our electronic medical records system and having to correlate the training with the EMR and the medication administration.
4	Training	4.09	More training is needed	I think there's other education that is needed to be incorporated surrounding, not just surrounding the medication administration itself, but the rights of the patient when administering the medication, , right

				route, right dose, right time, and of course the right medication,
4	Training	4.09	More training is needed	I feel that we have things in place to help with that, such as if I try to give a med too soon and I scan it, the computer is actually going to tell me I'm giving it too soon or it would tell me this drug is not scheduled right now, stuff like that. Ummm, I don't think we actually have training for events for that.
4	Training	4.09	More training needed	I also think there's a lot of pharmacology re-education that needs to be done when people get out of school that we don't focus as much on because we rely too heavily on micro medics.
4	Training	4.09	More training needed	I think additional training may help with that. I think that is a possible yes.
5	Financial incentives	5.01	Agree	So, off the record I would love to give financial incentives to my nurses.
5	Financial incentives	5.01	Agree	Yes, money is a huge incentive to us I think.
5	Financial incentives	5.01	Agree	If we had a financial incentive I think we would do better. I mean I feel like a financial incentive is a big deal for us. So yea, I bet it would bring it down.
5	Financial incentives	5.01	Agree	I think it would motivate a person to do what they are supposed to do or actually focus more, let me say that.
5	Financial incentives	5.01	Agree	You have to budget it. If the budget allows for it, yes.
5	Financial incentives	5.01	Agree	That would raise the stakes. Well, I think it would actually lead to a lot of good things. If you had less adverse reactions, one you would retain your nurses because they would be working in an environment in which they will be happy. And that's your goal. And once you can achieve that environment you're going to retain that staff. Exactly! Totally agree with that. Totally agree with that.
5	Financial incentives	5.02	Other incentives	There is a certain sense of satisfaction you get when you make no mistakes at work and I am the type of manager that will acknowledge not only the mistakes at work but over acknowledge the accomplishments

				and the recognition that need to be had on the floor.
5	Financial incentives	5.02	Other incentives	Or even give them at the end of every quarter some kind of recognition, like a banquet or just know like a special dinner for them, a special catered lunch for them. So, they don't have to go out for lunch. We can get them a lunch.
5	Financial incentives	5.02	Other incentives	Well, I don't know if that… will it necessarily have to monetary. It can be like a day off or maybe an extra hour for lunch. I don't know about an extra hour for lunch, but…. You know some type of incentive other than monetary. I think any type of incentive would encourage or may make that employee feel more valued and more appreciated. So, yes I would definitely be willing to look at things like that.
6	Cost savings	6.01	Reduces costs	Yes, I am not 100% sure what the financial aspect that would affect, but as far as the numbers go I do believe that any decrease in any adverse event is going to save the facility medications. I think that because with medication…. I think seeing the cost saving on the treatment that are provided to reverse effects… Ummm, would be less costly if we prevented there ADEs.
6	Cost savings	6.01	Reduces costs	Yea, because when people make med errors people die and get sicker and we have to fix that. Yea, it would save everybody a lot of money.
6	Cost Savings	6.01	Reduces costs	Oh yeh, because I mean med errors can cause readmission and a lot of other problems. I think it would.
6	Cost savings	6.01	Reduces costs	Yeh
6	Cost savings	6.01	Reduces costs	Yes, most definitely. Money, time.