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How Does Robotic Surgery Influence Communication, Leadership, and Team Outcomes? A Multimethod Examination.

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by

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Signature Page

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Abstract

The practice of delivering surgical care has evolved to be less invasive to the patients undergoing surgery. Minimally-invasive surgery can be practiced through traditional laparoscopic methods as well as with robotic technology that displaces the surgeon from the operating table. Robotic surgery has been cited to be safer and more effective than traditional laparoscopic surgery; however, little research has endeavored to investigate the role of surgical modality upon aspects of teamwork. This dissertation contributes to the human factors and teamwork literature by evaluating how surgical modality may influence communication, shared leadership, and team outcomes. Multiple methods were employed to study robotic and non-robotic (i.e., open and laparoscopic) surgical teams. Teams were evaluated through video analysis of surgical procedures as well as questionnaire methods. The results of this research revealed very few modality-specific differences which may represent the adaptive nature of teams and individuals. Robotic surgical team members did not perceive a statistically significant difference in communication quality which may indicate that the impact of the closed console design may be relatively benign in this regard. While there were no statistically significant differences between the degree to which robotic and non-robotic teams shared or perceived shared leadership, there were interesting role and leadership behavior type differences. For instance, the assists conducted significantly more leadership in robotic surgery than in laparoscopic surgery. In the video data, sharing leadership to a greater extent led to shorter operative durations. In the survey data, higher perceptions of communication quality and communication behavior significantly predicted higher perceptions of team effectiveness, indicating a strong positive relationship between perceived communication and perceived effectiveness. As robotic surgical systems and practices continue to inevitably advance in the coming years, developers should be keenly aware of the interdependencies between all aspects of the sociotechnical system including the providers and recipients of care, the environment and organization, and the tools and technologies.

Keywords: teamwork, communication, leadership, shared leadership, team performance, team effectiveness, minimally-invasive surgery, robotic surgery

"I think there is a tendency in science to measure what is measurable and to decide that what you cannot measure must be uninteresting." – Donald Norman

Dedication

Dedicated to Leah Elizabeth Jaquinta, my Nana, (1940-2010) for inspiring an interest in serving others through healthcare and an aspiration to be a lifelong learner. There is so much I wish I could tell you, show you, and experience with you.

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List of Acronyms and Abbreviations

1. Page (p.)
2. Pages (pp.)
3. United States (U.S.)
4. National Aeronautic Space Administration (NASA)
5. Stanford Research Institute (SRI)
6. Mobile Advanced Surgical Hospital (MASH)
7. Two-dimensional (2D)
8. Three-dimensional (3D)
9. Knowledge, skills, and attitudes (KSAs)
10. Team Leadership Questionnaire (TLQ)
11. Input-process-output (IPO)
12. Certified registered nurse anesthetist (CRNA)
13. Physician assistant (PA)
14. Analysis of variance (ANOVA)
15. Multivariate analysis of variance and covariance (MANOVA)
16. Multivariate analysis of covariance (MANCOVA)
17. Institutional review board (IRB)

Chapter 1: Introduction

Statement of the Problem

Technological advancements provide novel capabilities while simultaneously introducing dynamic limitations. Due to such advancements, minimally invasive surgery has radically transformed the nature of surgery. Significant clinical benefits have been realized, such as less postoperative pain, shorter hospitalization, decreased risk of infection, quicker return to normal function, and improved cosmetic effect (Bann et al., 2003; Dobson et al., 2011; Smith et al., 2006). Unfortunately, these benefits are entangled with associated trade-offs in both laparoscopic (i.e., minimally invasive surgery in which surgical instruments are inserted through ports that are placed in small incisions in the patient's body) and robotic surgery (i.e., minimally invasive surgery that utilizes a surgeon-controlled robotic system to control surgical instruments). Two-dimensional imaging, restricted instrument mobility, and poor ergonomic positioning have all been cited as limitations of laparoscopic surgery (Randell et al., 2017). Robotic surgery addresses these limitations by facilitating greater precision and control through three-dimensional imaging, motion scaling, greater instrument mobility, and improved ergonomic positioning (Corcione et al., 2005).

Given the limitations in traditional laparoscopic surgery, robotic surgery is being performed with growing frequency. In fact, in 2018 there were more than 5,000 surgical robots used in hospitals throughout the world (Smith, 2019), over one million robotic surgeries performed (Intuitive Surgical, 2019), and numerous new surgical robotic technologies in development (Brodie & Vasdev, 2018). Robotic technology is used in numerous specialties such as urology, general surgery, orthopedics, neurology, otolaryngology, thoracic, bariatric, rectal and colon, oncology, and even dental implants and hair transplants (Smith, 2019). However, robotic surgery has been accompanied by its own unique set of barriers as the introduction of new technology inevitably influences the manner in which work is performed. Notably, the surgeon operates at a console that is located away from the patient's bedside and is, therefore, physically distanced from the rest of the surgical team (Simorov et al., 2012). This structural change unavoidably influences the dynamics among surgical teams as they work to provide quality care to their patients.

Successful teams, including surgical teams, rely not only upon their technical competencies and available resources but also the effective usage of their non-technical skills and the processes they use to interact with each other to collectively accomplish tasks (Marks et al., 2001; Sharma et al., 2011). Interpersonal skills such as communication, effective decision-making, problem solving, and situation awareness are frequently leveraged and relied upon to appropriately deal with complex situations. Numerous investigations have demonstrated that a lack of proficiency in these skills may pose a threat to timely and efficient delivery of patient care (e.g., Suliburk et al., 2019). For example, Hull et al. (2012) conducted a systematic review to investigate the impact of nontechnical skills upon technical performance in surgery and demonstrated empirical evidence to support a strong relationship between teamwork deficiencies and technical error. More recently, Schmutz et al. (2019) performed a meta-analysis to investigate the impact of teamwork upon performance and also provided evidence that teamwork has a medium sized effect on clinical performance across various healthcare settings.

The case of robotic surgery is especially ripe for teamwork research for a variety of reasons. While the surgical team members who perform robotic surgery are consistent in terms of their titles (e.g., surgeon, circulating nurse, etc.), they may or may not possess congruent knowledge, skills, or attitudes relative to robotic surgery. Further, robotic surgery takes place in the operating room, an already complex working environment that has oftentimes been retro-fitted to accommodate the robotic system. The team's overarching goal is consistent with the non-robotic surgical modalities (i.e., open and laparoscopic): safely provide the relevant surgical intervention to the patient. However, the tasks the team must perform in order to accomplish this goal have been altered due the robotic approach. For example, the team is now required to appropriately position and sterilely drape the robotic patient-side console. In addition to taskwork being affected, how individuals work together (i.e., teamwork) is also impacted. For these reasons, among others, research regarding teamwork in robotic surgery is needed in order to better understand its associated implications.

Purpose of the Current Study

The present study aims to investigate the role of surgical modality (i.e., robotic vs. non-robotic) upon teamwork processes (i.e., communication and leadership) and team outcomes (i.e., operative duration and perceived effectiveness). A number of previous researchers have demonstrated a substantial impact to team communication in robotic surgery such that robotic surgical teams use more verbal and explicit communication (Nyssen & Blavier, 2009; Pelikan et al., 2018; Tiferes et al., 2016). The current study will further this area of research by examining how teams utilize specific communication behaviors such as names to indicate communication directionality, call outs to indicate task progression, and closed-loop-communication. The construct of leadership has been less thoroughly evaluated in robotic surgery. Consequently, the present research endeavors to investigate how leadership behaviors (e.g., train and develop team, provide feedback, monitor team, manage team boundaries, perform team task, solve problems, provide resources, support social climate) are shared among teams performing different modalities of surgery. Finally, team outcomes have been assessed in surgery in numerous fashions by countless researchers in order to explore the factors that lead to optimal outcomes (Hull et al., 2012; Stefanidis et al., 2010). The relationship between the use and perception of specific communication and leadership behaviors with operative duration and perceived effectiveness will be further explored in this dissertation. Extended operative durations have been associated with adverse outcomes and complications due to a variety of factors such as prolonged time under anesthesia and risk of surgical site infections (Cheng et al., 2018). Furthermore, perceived team effectiveness has been linked with other team constructs such as collective efficacy; in essence, teams that perceive that they are capable to perform their tasks are more likely to achieve optimal performance outcomes (Bandura, 2000; Gully et al., 2002; Mathieu et al., 2010).

The intent of this study is to investigate how surgical modality may influence communication, leadership, and team outcomes. Two distinct data collection and analysis approaches were utilized during this dissertation to yield greater insight into the research problem than would have been obtained through either type of data separately. The two approaches are referred to throughout this document as “study one” and “study two”. In study one, audiovisual data of laparoscopic and robotic surgical procedures was leveraged to explore the usage of effective communication behaviors, the enactment of leadership functions by various team members, and operative duration as a measure of team performance. In study two, surgical team member perceptions of communication, shared leadership, and team effectiveness were measured through a questionnaire. The resultant findings provide a basis from which the design and development of robotic systems may be influenced and the training of robotic surgical team members may be informed.

Chapter 2: Literature Review

This chapter begins by reviewing the evolution of surgery over time with respect to the different modalities of open, laparoscopic, and robotic surgery. Since this dissertation is greatly concerned with teams and the teamwork they employ, these concepts will be introduced next. This is followed by an introduction and description of each of the study constructs. These are each explained in detail, including definitions, relevance to surgical teams, and links to surgical modality. Additionally, theoretical rationale is provided relative to each construct in order to support the associated hypotheses. This chapter ends with a summary of the hypotheses that form the basis for this dissertation.

Evolution of Surgery

The medical field has evolved over time to provide safe and effective treatment of injuries, disorders, and other conditions. Of particular interest to the present research is the manner in which surgery has progressed throughout the years. At present, Americans will undergo an average of 9.2 surgical procedures in their lifetime with remarkably high chances of recovery and minimal pain (Lee et al., 2008; Melin, 2016). The surgical methods that are practiced today reflect the pinnacle of science and technology (Melin, 2016). There are three different surgical modalities, each encompassing unique techniques and technologies that are used to perform surgery; these are: open, laparoscopic, and robotic. Laparoscopic and robotic surgery are both considered to be "minimally invasive" because they require only one or several small incisions compared to the large incision that is used in open surgery. A comprehensive summary of the benefits and limitations of each surgical modality can be found in Table 1. Next, the evolution of surgery will be detailed by reviewing the inception, benefits, and limitations of each modality.

Open Surgery

Modern surgical practices are based upon the foundation that began in prehistoric times, with the earliest evidence of surgery dating back to 10,000 BC (Ellis, 2002). Before mankind could read or write, the most primitive surgeons performed trepanation procedures in which they cut rings or squares of bones in the skull; remarkably, archeologic evidence indicates that these patients survived and recovered from such procedures (Ellis, 2002). The practice of surgery originated and has evolved largely as a result of the innate instinct for self-preservation that is present among all mammals (Ellis, 2002).

Figure 1. Open surgery in the operating room (Oriez, 1990).

The discipline of surgery drastically advanced during the mid-19th century due to the advent of anesthesia and the introduction of aseptic technique (Melin, 2016). Reliable anesthesia radically reduces pain and allows physicians to perform more intricate operations in the internal regions of the human body (Melin, 2016). Likewise, the frequency of surgeries increased since patients were no longer had to endure antagonizing pain and, therefore, the surgeons were not restricted by completing the procedures as quickly as possible in order to limit pain (Melin, 2016). However, post-operative mortality rates continued to be high due to infections. Louis Pasteur's work on germ theory is credited with establishing the notion that microscopic life forms are carried through the air and unseen by the naked eye (Vallery-Radot, 1910). Joseph Lister, another scientist, applied Pasteur's work to medicine and surgery. Lister developed aseptic technique in order to limit the risk of surgical infection by sterilizing the operating field, surgical instruments, and surgeon's hands (Ellis, 2002). Pasteur and Lister's contributions were both critical in paving the way for a wide variety of new surgical techniques (Melin, 2016). The combination of anesthesia and aseptic techniques created entirely new avenues for surgical practice and surgery became less painful, safer, and more effective (Melin, 2016).

The above advancements undoubtedly changed the nature of surgery. However, while aseptic technique limited the risk of surgical infection, it did not reduce it entirely. In open surgery, the surgeon obtains access to his or her working area by using a scalpel to create a large incision (see Figure 1). Through this incision, the surgeon can directly access the surgical site to conduct the operation. One benefit of this approach is that the surgeon has direct visualization of the surgical site and can interact and manipulate anatomy directly. While the surgeon benefits from direct access to the surgical site, the large incision size leads to long recovery times and potential for infection. Open surgery has been utilized in every surgical specialty and is still used today in many specialties. The determination to conduct an open or a minimally-invasive surgery is dependent upon the associated benefits and limitations of each modality relative to the surgeon's assessment of the patient's condition.

Laparoscopic Surgery

With surgeries occurring more frequently and with increased complexity, the scientific and medical communities began to focus on limiting the opportunity for infection by reducing the incision size. Post-operative surgical site infections are one of the most common surgical complications; they cause physical discomfort of the wound and contribute to prolonged recovery time (Dobson et al., 2011). Kirkland et al. (1999) found that patients who develop surgical site infections are 60% more likely to spend time in the intensive care recovery unit, five times more likely to be readmitted to the hospital, and have twice the incidence of mortality. Because of the risk large infection sites pose, laparoscopic surgery was developed. In laparoscopic surgery, the surgeon obtains access to the surgical site through several ports placed in the patient's body (see Figure 2). The endoscope camera is inserted into one of these ports and the images are reproduced on a two-dimensional (2D) monitor in the operating room. The surgical instruments are inserted into the other ports and controlled by the surgeon while he or she performs the operation. By reducing the exposure to the internal organs by possible external contaminants, there is less risk to the patient of acquiring a surgical site infection.

In 1901, Georg Kelling of Dresden Germany, performed the first laparoscopic procedure on a dog, and subsequently in 1910, Swedish internist Hans-Christian Jacobaeus performed the first laparoscopic procedure on a human (Hatzinger et al., 2006). In Jacobaeus' 1910 publication "On the Possibility to Use the Cystoscopy in Investigations of Serous Cavities," he outlined his experiences with the first 17 laparoscopic procedures in humans. Notably, he recognized the diagnostic and therapeutic possibilities, the potential difficulties and limitations, and the need for appropriate training and specialized instrumentation (Hatzinger et al., 2006). In the decades that followed, laparoscopy was further developed and popularized. Particularly, the advent of computer chip-based television cameras provided the means by which a magnified view of the operative field could be projected onto a monitor for multiple viewers to observe (Soper et al., 1994).

Figure 2. Laparoscopic surgery in the operating room (Bendet, 2005).

The first laparoscopic cholecystectomy (surgery to remove the gallbladder) was performed in 1987 by French physician Dr. Philippe Mouret (Jones & Jones, 2001). This procedure was rapidly adopted by many surgeons and enthusiastically embraced by the public; more than an estimated 85% of all cholecystectomies performed 1993 were performed laparoscopically (Soper et al., 1994). Many believe that this marked the beginning of explosive growth in minimally invasive surgery (Soper et al., 1994). In the following years, the frequency and type of laparoscopic procedures increased alongside advances in technology and surgeons' growing proficiency and experience levels (Jones & Jones, 2001). Numerous studies have detailed the benefits of laparoscopic surgery. Research conducted by Allendorf et al. (1997) demonstrated that procedures done through smaller incisions resulted in greater preservation of the patients' postoperative immune function. Dobson et al. (2011) found that laparoscopic colorectal surgery patients experienced less morbidity and incurred less cost if they developed surgical site infections compared to open colorectal surgery patients. Other benefits include less postoperative pain, shorter hospitalization, quicker return to normal activity, and better cosmesis (Fuchs, 2002; Smith et al., 2006).

These benefits are unfortunately entangled with associated trade-offs. Smith et al. (2006) noted that in laparoscopy, the surgeon is dependent upon their assistant to provide a stable camera platform and assist in retraction. Along these same lines, Bann et al. (2003) critiqued laparoscopy for the inherent tremors that result from manually controlling and stabilizing the camera. Bann et al. (2003) further denoted how the rise of laparoscopic surgery caused a significant increase in the profile of surgeons' learning curves associated with the new technology. An additional limitation of laparoscopic surgery is decreased haptic feedback. There are two types of haptic feedback: kinesthetic (involving forces and positions of the muscles and joints) and tactile (involving cutaneous cues like texture, vibration, touch, and temperature) (Okamura, 2009). The lack of haptic feedback necessitates a greater reliance upon visualization for delicate tissue manipulations (Lanfranco et al., 2004). Further, physiological tremors from those that hold the instruments are transmitted through the length of the rigid instruments, making delicate dissections and anastomoses difficult if not impossible. Additionally, in laparoscopic surgery, the surgeon controls his/her instruments while watching a 2D video monitor. This is troublesome due to the ergonomic mismatch that is created by necessitating the surgeon to look up from where he/she is controlling his/her instruments to view the surgical site on the monitor. This is counterintuitive as the surgeon must move the instruments in the opposite direction from the desired target on the monitor in order to interact with the site of interest (Lanfranco et al., 2004). This compromise of the surgeons' hand-eye coordination is known as the *fulcrum effect*. Lastly, most laparoscopic instruments have four degrees of motion, representing a restricted degree of motion when compared to the seven degrees of freedom of the human wrist and hand (Meehan, 2008).

Robotic Surgery

The limitations of laparoscopic surgery provided the foundational motivation for the development of surgical robotics to expand the benefits of minimally invasive surgery. The concept of remote surgery, also known as telesurgery, was explored in the mid-1980s by a group of researchers at the United States (U.S.) National Aeronautics and Space Administration (NASA) Ames Research Center (Satava, 2002). In the early 1990s, multiple scientists from the NASA-Ames research team joined the Stanford Research Institute (SRI) to aid in the development of a dexterous telemanipulator for hand surgery (Satava, 2002). The surgeons and endoscopists who were involved in this effort began to realize the potential these systems had in mitigating the limitations of conventional laparoscopic surgery. Their research endeavor was noticed by the U.S. Army who subsequently began to fund the project. The U.S. Army was interested in decreasing wartime mortality through the prospect of using telepresence to provide surgical care to wounded soldiers on the battlefield (Satava, 2002). The research team developed a system in which a wounded soldier could be loaded into a vehicle and be operated on remotely by a surgeon at a nearby Mobile Advanced Surgical Hospital (MASH) (Satava, 2002). The primary objective was to prevent wounded soldiers from exsanguinating (i.e., bleeding out) prior to successful transportation to the hospital to receive care. The SRI research team successfully validated the system with animal models, but the U.S. Army did not implement it for battlefield casualty care (Satava, 2002). While telesurgery was initially intended to facilitate remote surgery on the battlefield, it was ultimately re-purposed to advance the state of minimally invasive surgical care. Several of the engineers and surgeons who collaborated on this effort went on to form commercial ventures that led to the introduction of surgical robotics to the civilian community (Satava, 2002). In robotic surgery, the surgeon obtains visual access to the surgical site through the surgeon console where he/she sits and controls the surgical instruments in the patient's body by manipulating the controls at the surgeon console (see Figure 3).

Figure 3. Robotic surgery in the operating room (*Montreal Heart Institute acquires da Vinci Xi for cardiac surgery in Canada*, 2017).

There are numerous benefits associated with robotic surgery that have led to its widespread usage in the U.S. and abroad. Foremost, the surgeon's visualization of the operative field is greatly improved through three-dimensional (3D) depth perception and the surgeon's ability to directly control the magnification and maneuverability of the visual field (Kim et al., 2002). As a result of this improved visualization, the *fulcrum effect* is eliminated and proper hand-eye coordination is restored, ultimately making instrument manipulation more intuitive (Lanfranco et al., 2004). With the surgeon seated at a console or control station, there is no longer a need for him/her to twist and turn in awkward positions to manipulate instrumentation and view the monitor (Lanfranco et al., 2004). In procedures that utilize X-ray equipment, radiation poses less of a risk to the surgeon as he/she is distanced from the patient bedside and X-ray equipment (Bonatti et al., 2014). Robotic surgical systems are equipped with advanced technology that provide greater dexterity and range of motion which contributes to enhanced operative capabilities. This technology scales movements and filters out physiological tremors to translate the surgeon's hand movements into more precise actions. These advances in instrumentation enhance the surgeon's ability to control instrumentation to manipulate tissues and achieve clinical functions. The advent of robotic surgery has made surgeries that were previously difficult and/or infeasible, possible (Lanfranco et al., 2004). Lastly, robotic surgery simulator training provides surgeons with the opportunity to practice in a simulated environment before performing an actual procedure.

Robotic surgery, like laparoscopic surgery, has been accompanied by its own unique set of barriers as new technology necessitates integration into an already-existing healthcare and surgical care ecosystem. Robotic surgical systems are associated with high capital investment costs; hospitals that acquire these systems work to ensure that the systems are utilized fully to achieve optimal return on investment. The systems are large and must be integrated into already-crowded operating rooms. Therefore, surgical teams and hospital administration have invested considerable time and effort into optimizing the usage of the operating rooms to maximize efficiency and space. During robotic surgery, the surgeon operates from a console that is typically located in the operating room but away from the patient and surgical team (Herron et al., 2008; Simorov et al., 2012). Additionally, similar to the laparoscopic approach, robotic systems offer decreased haptic feedback which necessitates greater reliance upon visualization for tissue manipulation. This feedback is critical in delicate procedures such as those involving fragile tissues like the bowel, heart, and lungs; to maximize surgical outcomes and avoid complications, the surgeon must be able to gauge how much pressure he/she is applying (Simorov et al., 2012). These changes may influence the potential challenges surgical teams face while providing patient care. In addition, there are risks inherent to the increased usage of technology as numerous components of the system have the potential to malfunction during surgery (Kirkpatrick & LaGrange, 2016).

Table 1. Surgical modality benefits and limitations.

	Open	**Laparoscopic**	**Robotic**	**Reference(s)**
Invasiveness	High	Reduced	Reduced	(Smith et al., 2006)
Blood loss	High	Reduced	Reduced	(Smith et al., 2006)
Recovery time	Long	Shortened	Shortened	(Smith et al., 2006)
Motion scaling and tremor reduction	Absent	Absent	Present	(Lanfranco et al., 2004)
Visualization of surgical site	Direct	2D camera-mediated	3D camera-mediated	(Kim et al., 2002)
Haptic feedback	Present	Decreased	Limited	(Lanfranco et al., 2004)
Surgeon's ergonomic positioning	Poor	Poor	Improved	(Catanzarite et al., 2018)
Surgeon location	Co-located with patient and team	Co-located with patient and team	At console away from patient and team	(Simorov et al., 2012)

Teams and Teamwork

Tracing major events and developments throughout our history as a civilization reveals an increased prominence of teamwork. Global and societal influences such as the Industrial Revolution and the first and second World Wars, among others, have led to the rise of individuals working together to combine their efforts to accomplish tasks that require the mental and/or physical contributions of multiple members. The utilization and study of collaborative work has expanded with irrefutable magnitude throughout the past few decades. The shift from individual to team-centric work has made team performance and effectiveness a salient organizational interest which has driven an ever-growing body of research. Behavioral scientists and psychologists have spear-headed the study of teams, and other disciplines and fields have come alongside them to more closely examine the teams that work together in their fields. Therefore, this area of research has been pushed forward and explored by the collective efforts of interdisciplinary groups.

Twenty years ago, Salas and Cannon-Bowers (2000) described four reasons why organizations are increasingly dependent upon teams to accomplish work. First, task complexity and work scope often mandate contributions from multiple people working together. Second, teams are better equipped than individuals to make difficult decisions since they share the responsibility and consequences for their choices. Third, teams can often outperform individuals due to their increased capacity for performance, also known as, the wisdom of the collectives (Salas et al., 2008). Fourth, in many organizations such as the military or healthcare, teams are a "way of life" due to the deeply rooted collaborative nature of the work. Considering surgical teams today, each of these holds true. The complexity of surgery requires contributions from multiple people, a surgical team with shared responsibility is better equipped to make difficult decisions, a surgical team representing multiple areas of expertise can outperform any one individual, and surgery is inherently collaborative due to the need for diverse skillsets.

Definitions

Operational definitions are needed in order to systematically study and understand teams and the work they perform. To define *teamwork*, one must first determine what constitutes a *team*. Many definitions for teams have emerged over the years that have varied in both scope and generalizability. One of the earliest definitions was proposed by Dyer (1984) who defined a team as a unit of “at least two people, who are working towards a common goal, where each person has been assigned specific roles or functions to perform, and where completion of the mission requires some form of dependency among the group members” (p. 286). Other early definitions were put forth by Hall and Rizzo (1975), Nieva et al. (1985), Morgan et al. (1986), and Modrick (1986). Based upon the foundation laid by those previous researchers, Salas et al. (1992) proposed the following well-known definition of a team, “a distinguishable set of two or more people who interact dynamically, interdependently, and adaptively toward a common and valued goal/objective/mission, who have each been assigned specific roles or functions to perform, and who have a limited life-span of membership” (p. 4).

Numerous subsequent definitions have emerged; many of which echo the major sentiments of the definition put forth by Salas et al. (1992) and some of which expand the definition in a limiting capacity. The definitions of a team become increasingly heterogeneous as they are geared toward specific teams. In an effort to parsimoniously consider the commonalities of these definitions in the literature, I have distilled them to their core. For the purposes of this dissertation, I will define a *team* as two or more individuals who interact through interdependent roles to achieve shared goals.

Similarly, the term *teamwork* has received due attention over the years with respect to its delineation. Salas et al. (2004) proposed the following definition of teamwork:

> Teamwork is a set of flexible behaviors, cognitions, and attitudes that interact to achieve desired mutual goals and adaptation to the changing internal and external environments. Teamwork consists of the knowledge, skills, and attitudes (KSAs) that are displayed in support of one's teammates, objectives, and mission. Essentially teamwork is a set of interrelated thoughts, actions, and feelings that combine to facilitate coordinated, adaptive performance and the completion of task work objectives (Salas et al., 2004; pp. 497-498).

More recently, Salas et al. (2009) advanced an earlier definition by Salas et al. (2007) and described teamwork as the "dynamic, simultaneous and recursive enactment of process mechanisms which inhibit or contribute to team performance and performance outcomes" (p. 41). Especially noteworthy is the notion that teamwork, whether effective or ineffective, may have associated consequences, in the form of either contributions or inhibitions to team performance and outcomes. Salas et al. (2005) noted that when compared to a single individual, teams are superiorly capable in creatively and productively solving and conquering problems. Salas et al. (2009) defined teamwork as "the means by which individual task expertise is translated, magnified, and synergistically combined to yield superior performance outcomes" (p. 42). For the purposes of this dissertation, I will define *teamwork* as the knowledge, skills, and behaviors that are enacted among team members as they work toward their shared goals.

Team Typology

Researchers note that even in the presence of an overarching definition, teams are unique entities and must be examined and regarded as such; this can be accomplished by considering teams with regard to their type (Salas et al., 1992). Understanding team typology is especially important in regard to assessing the predictive validity of theories or study results as team type can influence how team processes and outcomes manifest (Devine et al., 1999; Salas et al., 2005). Considering this, it is important to study teams in light of their "type" which may include aspects related to how power is distributed (i.e., their hierarchical structure), how skills are differentiated, and how they exist and perform over time, for example. Salas et al. (2005) noted that, "as one begins to examine the team literature, it becomes clear that the types of teams are as varied as the number of authors who have discussed them" (pp. 562-563).

To advance the current understanding of team typology, Hollenbeck et al. (2012) proposed a dimensional approach to compare and contrast teams with respect to three critical dimensions: skill differentiation, authority differentiation, and temporal stability. Throughout their review of existing team typologies, they identified and reviewed 42 distinct team types. They, along with other researchers, found little consensus regarding team typology. They were, however, successful in discovering three fundamental dimensions that consistently underlie different team types. *Skill differentiation* involves "the degree to which members of a team have specialized knowledge or functional capabilities that may make it more or less difficult to substitute members" (Hollenbeck et al., 2012, p. 84). *Authority differentiation* refers to "the degree to which decision-making responsibility is assigned to individual members, subgroups of the team, or the team as a whole" (Hollenbeck et al., 2012, p. 84). Lastly, *temporal stability* involves "the degree to which team members have a history of working together in the past and their expectation of working together in the future" (Hollenbeck et al., 2012, p. 84).

The dimensional approach put forth by Hollenbeck et al. (2012) reflects three primary characteristics of teams, however, it does not account for team distribution, or in other words, if teams interact face-to-face, virtually, or both. Team distribution has become a key area of teamwork research in recent years as remote work has become more popular. This is also a key tenet to this dissertation. Due to the nature of robotic surgery and how the surgeon works from a console that is physically located away from the patient and other team members, a careful examination of team distribution and its effects in robotic surgery is necessary. Pelikan et al. (2018) described robotic surgery as a “hybrid” form of distributed and collocated teamwork since the team is collocated in the same room but physically distanced when the surgeon is at the console.

Communication

Communication has been defined as the exchange of information occurring through either verbal and/or nonverbal channels between two or more people (Marlow et al., 2018). The role of communication among team members is especially important as the team works to coordinate interdependent actions, monitor progress, and achieve performance goals (Marks et al., 2001; Marlow et al., 2018). Empirical evidence suggests that effective communication is a key team process that distinguishes high from low performing teams (Entin & Serfaty, 1999). Consequently, deficiencies in communication have been linked to negative outcomes in several industries (e.g., aviation, healthcare, nuclear power; Helmreich et al., 1999; Lingard et al., 2004; Sasou & Reason, 1999). Ultimately, teamwork cannot occur without communication.

Shannon and Weaver's (1949) model of communication (Figure 4) describes the manner in which information travels from a source to a destination. Their model is linear and is comprised of five primary elements: information source, transmitter, channel, receiver, and destination. The *information source* is the sender from which the information originates. The *transmitter* transforms the message through a process known as encoding so that it can be sent through the communication channel; for example, how voice is converted into wave signals and transmitted through telephone cables. The *channel* refers to the medium that is used to transmit the message from the information source and the destination. The *receiver* decodes and reconstructs the original information and performs a reversal of the transmitter's processes. Lastly, the *destination* is the recipient of the information.

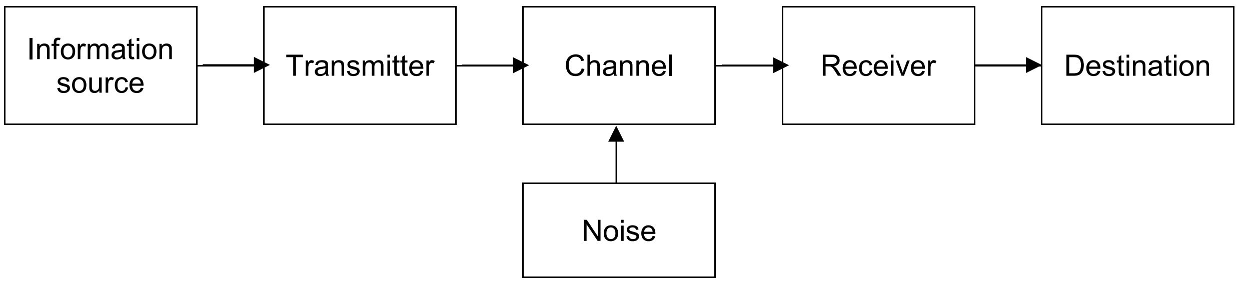

Figure 4. Model of communication, adapted from Shannon and Weaver (1949).

Of particular interest is the concept of *noise*, which Shannon and Weaver (1949) described as an effect upon communication that results in a disturbance such that the received message differs from the message that was sent. They posited that, in the presence of noise, communication accuracy can be increased by transmitting more redundant information or by improving decoding mechanisms (Shannon & Weaver, 1949). In their application, redundancy means replicating the message or otherwise improving the decoding mechanism. While their model is focused upon technical systems and explicitly excludes issues inherent in semantics (i.e., meaning) of communication, I postulate that if taken broadly, "mechanisms to improve decoding" include communication techniques that can be employed to reduce noise. In fact, when considering the term *redundancy* from an engineering perspective, it refers to the inclusion of additional components that may not be strictly necessary to ordinary functioning but serve as a back-up in case of failure in other components (Oxford Dictionary, n.d.).

Shannon and Weaver's (1949) model was developed specifically for technical communications but has been widely applied and amended for human-to-human communication.

A recent depiction (Figure 5) of the communication process (Robbins & Judge, 2008; p. 338) includes an additional element: feedback. Shannon and Weaver's (1949) model implies that the flow of communication is unidirectional, from sender to receiver; conversely, this model integrates feedback from the receiver to the sender. The process of feedback provides a means by which the receiver can indicate their interpretation and level of understanding, thereby providing the sender with an opportunity to adapt or elaborate their message. Thus, Robbins and Judge's (2008) model is more representative of the human-to-human communication process.

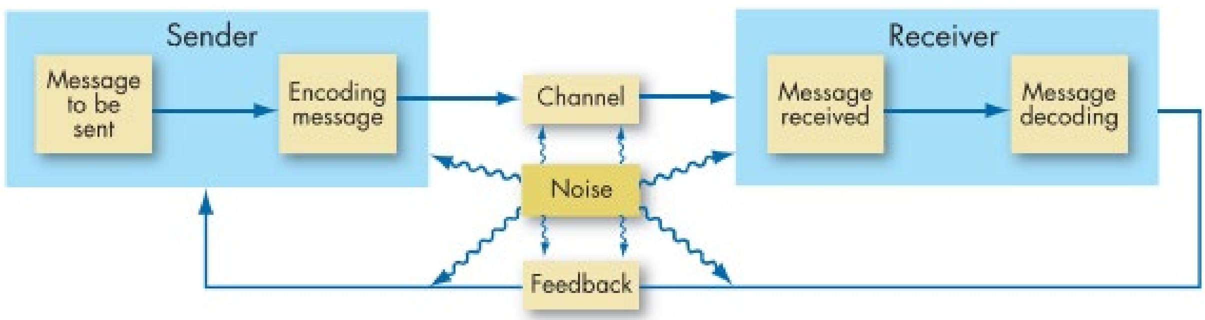

Figure 5. The communication process (Robbins & Judge, 2008).

Effective communication behaviors serve to enhance communication acts, thereby reducing noise by improving the decoding mechanism. One effective communication behavior is the act of addressing team members by their names. Gawande (2010) emphasized that team members who know and use each other's names in the operating room work better together in a number of ways. For example, teams who utilize each other's names perceive their level of communication to be higher. Further, they are better equipped to assign responsibilities and avoid responsibility diffusion, a phenomenon that occurs when individuals take less responsibility when others are present (Darley & Latané, 1968). Lastly, researchers even found that when nurses were invited to share their names and any concerns they had at the beginning of the case, they were more likely to share problems and offer solutions (Gawande, 2010). Another communication behavior that may improve the decoding mechanism by reducing noise is the usage of call outs (i.e., proactive updates). Team members frequently use call outs to share task progression or completion updates with the rest of the team and to increase situation awareness or anticipate next steps (Guerlain et al., 2008). A third communication behavior that enhances communication acts is closed-loop communication, which is also known as “read-back,” or “check-back” methods. Closed-loop communication is a strategy that has evolved from aviation and serves to ensure that both the sender and receiver of information have understood the information that has been shared. Weller et al. (2014) described closed-loop communication as a three-step strategy in which the sender conveys a message or instruction to the receiver, the receiver confirms that the message was heard by repeating it, and then the receiver seeks clarification if needed. Behavioral markers of closed-loop communication include following up with team members to ensure the message was received, acknowledging that a message was received, and clarifying with the sender of the message that the received message is the same as the intended message (Salas et al., 2005). In other words, closed-loop communication can take on various forms, ranging from an acknowledgement that the communication was received to ensuring that the intent of the message was understood. Conversely, in an “open loop”, there is no direct and relevant response following sent communication, for example, if someone asked a question and no one answered (Parush et al., 2011). The operating room is a complex environment characterized by multiple sources of information and multiple potential recipients; therefore, the utilization of these communication behaviors is especially valuable in this context.

Researchers posit that all communication and more broadly, collective action, is a derivative of the accumulation of common ground (Clark & Brennan, 1991). Common ground theory maintains that the driving force behind people’s interactions with one another is their assumptions about their mutual knowledge and beliefs (Clark & Brennan, 1991). This process by which individuals update and improve their common ground with others is referred to as *grounding*. Landmark researchers, such as Clark and Brennan (1991) hypothesized that communicators work to align on *process* and *content*. More recently, Jung (2017) introduced the term *affective grounding* to also encapsulate how individuals work together to build a shared understanding about the emotional meaning of each other's behavior.

Common ground is derived from general knowledge about individuals' backgrounds as well as through specific knowledge gleaned from individuals' appearance and behavior (Olson & Olson, 2000). Individuals build common ground from the cues that are available to them; when fewer cues are available it is more difficult to build common ground and misinterpretations are more likely (Olson & Olson, 2000). As such, distributed teams may encounter difficulty in maintaining common ground as the team members are no longer afforded the same opportunities to share the same cues (Cramton, 2001; Olson & Olson, 2000). A simple example of this is observed in the complete or partial elimination of nonverbal cues in distributed team settings (e.g., participants on a conference call cannot observe their team members and anticipate if someone is preparing to speak). The challenges experienced by distributed teams in maintaining common ground may also be experienced by robotic surgical teams during periods in which the surgeon is positioned in the console rather than at the operating table with the rest of the team.

The communication medium profoundly impacts the process of grounding and the amount of effort involved. This is especially relevant when considering teams who function in distributed or otherwise computer-mediated environments. Team interactions, the resources that support team activities, and the richness of communication depend upon the communication medium (Driskell & Salas, 2006). Clark and Brennan (1991) introduced eight factors that affect the nature of communication in collocated and distributed team settings. Priest et al. (2006)

summarized these factors as: (a) copresence (i.e., team members share the same physical space), (b) visibility (i.e., team members can see each other), (c) audibility (i.e., team members can hear each other), (d) contemporability (i.e., team members receive communication at approximately the same time it is sent), (e) simultaneity (i.e., team members can communicate simultaneously), (f) sequantiality (i.e., team members must communicate in sequence), (g) reviewability (i.e., team members can review each other's messages), and (h) revisability (i.e., team members can revise their messages before sending). Table 2 presents characteristics of certain communications and the associated grounding constraints put forth by Clark and Brennan (1991) and later adapted by Priest et al. (2006).

Table 2. Communication characteristics of collocated and distributed teams, adapted from Clark and Brennan (1991) and Priest et al. (2006).

		Medium / Environment				
		Face-to-face	Real time audio and video	Real time audio only	Instant messaging	Email or letter
Communication Characteristics	Copresence	X				
	Visibility	X	X			
	Audibility	X	X	X		
	Contemporality	X	X	X	X	
	Simultaneity	X	X	X	X	
	Sequentiality	X	X	X	X	
	Reviewability				X	X
	Revisability				X	X

The context of robotic surgery encompasses characteristics of both collocated and distributed teamwork. Robotic surgical teams are collocated during certain points at the beginning and end of the surgery but distributed throughout the robotic portion. For the purposes of this dissertation, I will consider the surgical team to be collocated from the time the surgeon enters the operating room to the time when the surgeon sits at the console. Once the surgeon is seated at the console and throughout the surgical operation performed at the console, the team will be considered to be distributed. And lastly, from the time the surgeon leaves the console to the time when the surgeon leaves the operating room, the team will be considered to be collocated. It is important to note that throughout any of these three "phases" of time, the surgeon may deviate such that the surgeon might leave the room to conduct sterilization activities or the surgeon may come "head out" of the console to visualize the room. Figure 6 layers these three "phases" on top of work by Cunningham et al. (2013) and Enright & Patane (2018) to describe workflow in robotic surgery. It is important to reiterate that robotic teams are not collocated throughout the entirety of the operation like open and laparoscopic teams.

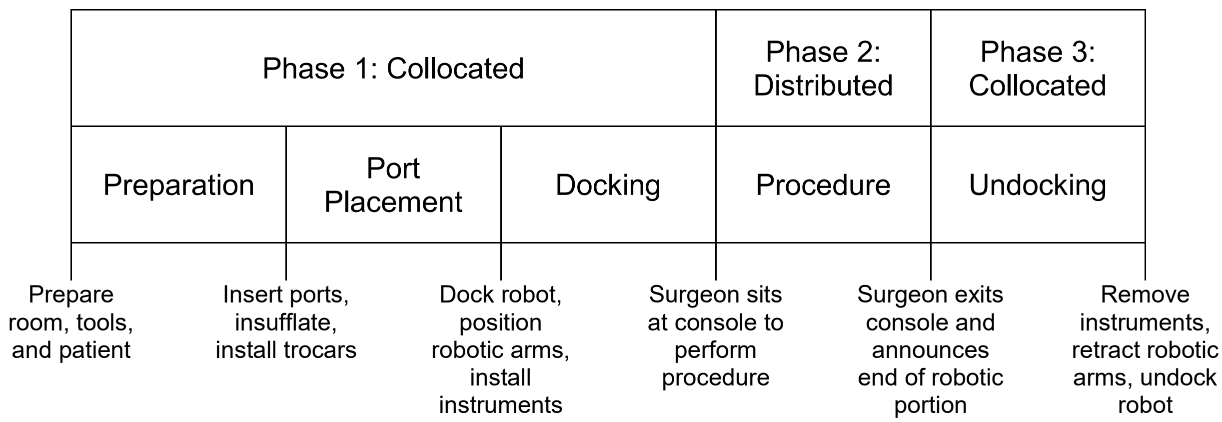

Figure 6. Workflow in robotic surgery, adapted from Cunningham et al. (2013) and Enright and Patane (2018).

In addition to changes regarding the maintenance of common ground, distributed teams are also affected by other communication differences. As previously noted, the equipment and technology involved in robotic surgery changes the traditional layout of the operating room along with the arrangement of the surgical team, whereby the console surgeon no longer has physical proximity to the patient and surgical team. Numerous researchers have discussed the implications of this concerning the information that is passed between the surgeon and team as well as the manner in which it is passed. Notably, in robotic surgery, the surgeon lacks access to what is happening at the patient bedside and, therefore, relies upon team members to communicate this information (Lai & Entin, 2005; Randell et al., 2017). In fact, Nyssen and

Blavier (2009) found a significant increase in verbal communication amongst teams performing robotic surgeries compared to laparoscopic.

The impact of communication medium on team interactions in robotic surgery has been empirically documented. Pelikan et al. (2018) observed teams huddling before docking the robot in order to establish rapport and monitor affective well-being to compensate for the distance that would be created once the robot is docked and the surgeon is seated at the console. In addition, Pelikan et al. (2018) observed that, although, the surgeon was not needed for the closing procedure, he or she would join the team at the patient bedside after the robot was undocked. Research on distributed teamwork has pointed to the importance of face-to-face interactions for relationship building and communication of complex messages (Maznevski & Chudoba, 2000). Globally dispersed teams who are highly effective prioritize rhythmically interspersing their remote collaborations with face-to-face meetings (Maznevski & Chudoba, 2000). Findings by Pelikan et al. (2018) suggest that this holds true for shorter distances as well, like in the operating room when robotic teams huddle before the surgeon separates to the console. This may indicate potential value for robotic teams leveraging their face-to-face interactions.

Interestingly, researchers have noted that due to the physical separation and decreased common ground between the surgeon and team, more explicit communication may be needed, which oftentimes results in improved communication and coordination (Pelikan et al., 2018; Randell et al., 2017). Interview research with anesthesia providers with experience in robotic surgery identified a lack of direct communication as a potential barrier or challenge (Myklebust et al., 2020). Randell et al. (2016) suggested that robotic surgical teams may successfully adjust their communication practices in order to mitigate challenges in grounding during the distributed portion of surgery. Specifically, using a person’s name, especially when making a request, helps to capture the attention of the intended recipient and further serves to avoid confusion as to who should respond or take responsibility for a request (Guerlain et al., 2008). Using a team member's name may also diminish the need to repeat requests multiple times before getting a response (Guerlain et al., 2008). In the context of robotic surgery, Randell et al. (2017) found that surgeons in robotic surgery often used team members' names to indicate the intended directionality of the communication. Additionally, using call outs to indicate when a task has been completed serves to notify other team members and maintain/increase their situation awareness (Guerlain et al., 2008). There are several other communication skills that may be particularly useful for robotic surgical teams. For instance, closed-loop communication and the "readback" method both provide benefits to the team such as increasing situation awareness, reducing anxiety that a request may have not been heard, and reducing the likelihood of forgetting the request (Guerlain et al., 2008 as cited by Randell et al., 2016). Randell et al. (2017) noted the importance of verbal acknowledgement in the context of robotic surgery, stating that without it, the surgeon would not be able to tell if the request was being actioned.

The reviewed findings reflect how teams have adapted their communication in an environment void of feedback typically generated by face-to-face interactions. As has been observed in a range of other industrial applications, increasing technology and automation places new demands on teams and their communication. As a result of such significant changes in the work system, differences are expected in terms of communication behaviors during surgery and team members' perceptions of communication. Given that team distribution results in decreased common ground due to the reduction of available shared cues, and because robotic surgical teams are distributed throughout the "procedure" phase of surgery, robotic teams may more frequently employ effective communication behaviors such as names, call outs, and closed-loop communication. Additionally, due to the challenges inherent in dispersed work and communication, non-robotic (i.e., open and laparoscopic) team members who interact face-to-face, may perceive higher communication quality than robotic team members. Lastly, due to the discussed challenges in maintaining common ground and reducing noise, robotic team members may perceive higher utilization of effective communication behaviors. Therefore, I hypothesize the following (Figure 7):

Study 1: Video Analysis of Robotic and Laparoscopic Procedures

H1a: Robotic teams will more frequently state team member names to indicate communication directionality, as compared with non-robotic teams.

H1b: Robotic teams will more frequently utilize call outs to notify team members of task status, as compared with non-robotic teams.

H1c: Robotic teams will more frequently utilize closed-loop communication, as compared with non-robotic teams.

Study 2: Survey Analysis of Surgical Team Members Perceptions

H2a: Non-robotic team members will perceive higher communication quality, as compared with robotic team members.

H2b: Robotic team members will perceive higher utilization of communication behaviors (names, call outs, and closed-loop communication), as compared with non-robotic team members.

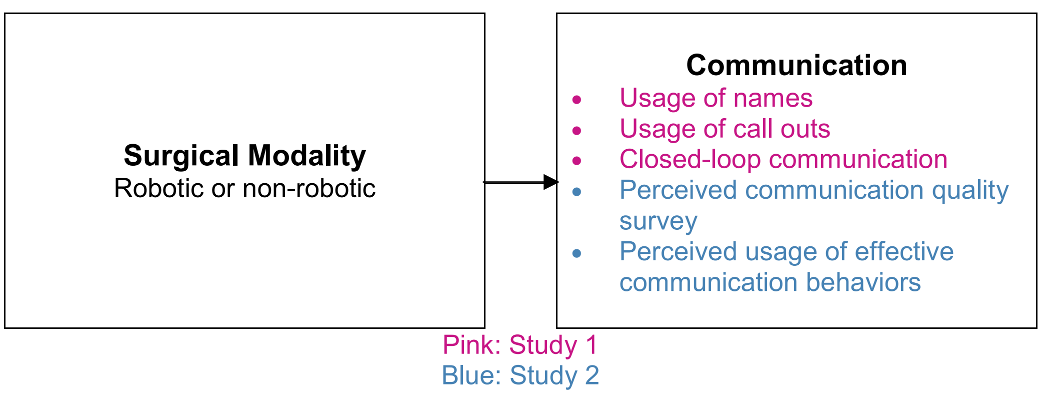

Figure 7. Hypotheses 1 and 2.

Leadership

The construct of leadership is vast, permeates many aspects of our lives, and has been defined in several ways. Anecdotally, the concept of leadership is associated with numerous components of the professional sphere, from mentorship programs that serve to promote leadership development to performance reviews that highlight leadership capabilities. Our understanding of leadership has grown and shifted over the years due to insights generated through increased empirical investigations and research. At its basic foundation, leadership involves satisfying team needs and enhancing team effectiveness (Morgeson et al., 2010). Leadership has also been defined as "the ability to influence a group toward the achievement of a vision or set of goals (Robbins & Judge, 2008, p. 359). This dissertation will leverage Yukl's (2008) definition of leadership because it describes leadership as an influence or process as opposed to the actions or behaviors of a formal leader. Yukl (2008) described leadership as "the process of influencing others to understand and agree about what needs to be done and how to do it, and the process of facilitating individual and collective efforts to accomplish shared objectives" (p. 7). This view of leadership is inclusive, in that, whoever takes responsibility for satisfying team needs is considered to be enacting leadership. Therefore, this perspective aligns closely with functional leadership theory which suggests that the role of a leader is, "to do, or get done, whatever is not being adequately handled for group needs" (McGrath, 1962; p. 5). Viewing the leader in this way further promotes that leadership is oriented toward the satisfaction of team needs.

Sources of Leadership

Leadership can come from a variety of sources. For instance, consider the structured working relationship between a manager and his or her team; the manager holds a specific title that establishes him or her as the formal leader. With that said, not all leaders hold a managerial rank, nor do all managers lead effectively. With this in mind, consider the working relationships between students who have been tasked with a group project in which no specific student has been designated as the team leader. Informal leadership is likely to arise in this situation as one or more students may emerge as informal leaders to guide their group toward achieving their objectives. The above examples illustrate internal leadership; however, leadership can also come from sources that are external from the team and do not perform any of the team's day-to-day tasks, such as a company's executive leadership or an external mentor or sponsor.

Morgeson et al. (2010) established a conceptual framework of leadership sources that is based upon the dimensions of locus of leadership (internal vs. external) and formality of leadership (formal vs. informal), see Figure 8. Leaders are considered to be internal if they are actively involved in the team's day-to-day activities whereas external leaders are not. Formal leaders are organizationally responsible for the team whereas informal leaders are not. Morgeson et al. (2010) posited that these four dimensions interact to produce four distinctive origins of team leadership. First, internal and formal leaders are involved in the team's day-to-day activities and hold direct responsibilities for the team's performance; these individuals might be referred to as the team leader or project manager. Second, external and formal leaders are not involved in the team's routine activities but do provide specific, organizationally-relevant oversight; such individuals may be called sponsors, coaches, or advisors. Third, internal and informal leaders are active members of the team who engage in leadership; they might be known as emergent leaders. Fourth, external and informal leaders are outside of the team and engage in leadership; these individuals may be called mentors, champions, or executive coordinators (Morgeson et al., 2010).

Formality of Leadership

Locus of Leadership	Formal	Informal
Internal	*Team leader* *Project manager*	*Shared* *Emergent*
External	*Sponsor* *Coach* *Team advisor*	*Mentor* *Champion* *Executive coordinator*

Figure 8. Sources of leadership in teams, adapted from Morgeson et al. (2010).

Theories of Leadership

As previously mentioned, the construct of leadership is immense; as such, there are numerous theories surrounding it. Many researchers have sought to understand leadership in light of the personality traits associated with leaders, such as charisma, enthusiasm, and courage (Judge et al., 2002). Additional research has focused on the behavioral strategies employed by effective leaders (Judge et al., 2004). The majority of existing leadership research is concerned with the role of the individual leader; however, there is a growing body of work that has begun to examine the role of co-leaders, followers, and even communities in the leadership process (Pearce & Sims, 2000).

Of particular relevance to the present research is the concept of shared or distributed leadership. Shared leadership and distributed leadership are often used interchangeably due to their similar nature (Day et al., 2004). For the purposes of this dissertation, the term *shared leadership* will be utilized in order to avoid any confusion to the reference of physical team distribution that was detailed in the team type section. Shared leadership differs from the traditional hierarchical *vertical* or *top-down* approach in that it acknowledges social sources of leadership across a *horizontal* view of a team. From a shared leadership perspective, leadership exists on a shared, or social, group level rather than with a specific individual (Pearce & Sims, 2000). Shared leadership has been defined by Pearce and Conger (2002) as, "a dynamic, interactive influence process among individuals in groups for which the objective is to lead one another to the achievement of group or organizational goals or both" (p. 2). Wang et al. (2014) differentiated *shared leadership* from *teamwork* by describing shared leadership as involving distributed influence and responsibility among team members and teamwork as a set of cooperatively oriented cognitions, attitudes, and actions through which team members transform member inputs to team outputs.

To further illustrate and contrast leadership models, Figure 9 depicts four models of leadership: (a) top down, (b) bottom up, (c) shared leadership, and (d) an integrated model. In the top down model, influence flows from the leader to the subordinate(s) and conversely, in the bottom up model, leadership flows from the subordinate(s) to the leader. Locke's (2003) depiction of shared leadership illustrates that leadership flows between subordinates in the absence of a formal leader. Locke (2003) asserts that the integrated model effectively exemplifies how influence can flow from the top, bottom, and among the team. Other researchers have defined shared leadership in accordance with the integrated model, for example, Conger and Pearce (2003) stated that shared leadership involves "peer, lateral, upward or downward influences of team members" (p. 286). The integrated model is thus in line with the definition of shared leadership that is utilized in this dissertation.

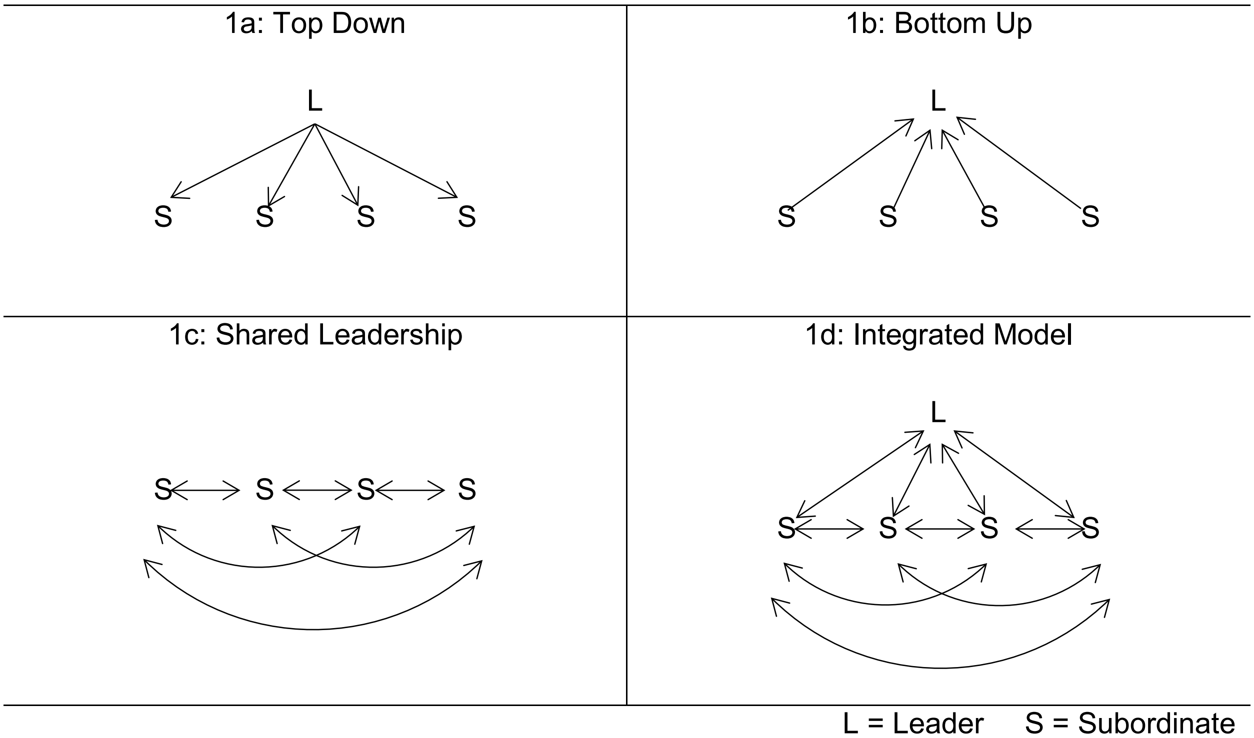

Figure 9. Four leadership models, adapted from Locke (2003).

Most leadership research conducted in the operating room has focused on the surgeon (Henrickson Parker et al., 2011; Stone et al., 2017). Surgery is characterized by a long-standing division of labor in which team members rely on each other's contributions; there is also a distinct hierarchy in which the surgeon holds authority (Hirschauer, 1991; Pelikan et al., 2018). Although most medical curriculums do not include leadership training, surgeons are considered and perceived to be the "de facto" team leaders (Pasarakonda et al., 2020; Stone et al., 2017). However, there are inherent limitations imposed upon the surgeon's leadership capabilities due to the nature of surgery. For instance, throughout the course of the operation, the surgeon is largely engaged with the actual task of conducting surgery which limits his or her ability to lead the rest of the team. Additionally, the surgeon is mostly absent during the pre- and postoperative phases as other team members conduct critical tasks before and after the procedure.

Therefore, in order to best grasp how leadership is conducted throughout surgery, some researchers posit that it should be studied across the team rather than by focusing unilaterally.

Only a few researchers have approached leadership in surgery with this perspective; for instance, Rydenfält et al. (2015) conducted a study on distributed leadership in the operating room. They developed nine leadership behavior categories based upon audiovisual data from ten surgical procedures. These researchers found that while the surgeons in their sample exhibited the most leadership, the other team members (nurse anesthetists and scrub nurses) exhibited leadership as well but to a lesser degree. Interestingly, the distribution of leadership differed from previous studies of surgeons' leadership alone such that some behavior categories were more associated with specific professions while others were more distributed over the team. Importantly, leadership behaviors associated with patient safety (e.g., conducting the timeout, sharing relevant patient safety information) appeared to be more distributed across the surgical team, indicating that a distributed leadership perspective provides a more holistic view of work processes. In addition, Pasarakonda et al. (2020) collected observational data in surgical teams to examine how leadership is shared.

Seers et al. (2003) postulated that the greater dispersion of power among a team, the greater likelihood of shared leadership. As previously mentioned, surgery has been historically characterized by a division of power and hierarchy in which the surgeon resides at the top. However, in specific consideration of robotic surgery, researchers have noted that there are significant implications to the distribution of power throughout the team (Pelikan et al., 2018). By positioning the surgeon in a remote capacity, the power structure is affected such that the rest of the team gains in autonomy since the surgeon is more dependent on them to communicate crucial information and to carry out tasks more independently (Lai & Entin, 2005). Thus, Pelikan et al. (2018) asserted that the integration of the robotic system changes power dynamics and new dependencies are created. With regard to physical proximity, Cox et al. (2003) theorized that the sharing of leadership among distributed teams may be particularly valuable since team members can swiftly respond to opportunities or dilemmas by enacting leadership functions.

These findings suggest that the integration of a robotic system into the operating room and the resultant distance between the surgeon and team may affect the power dynamics such that power may be more distributed, providing a foundation for shared leadership to occur. Furthermore, previous research points to the value of shared leadership among distributed teams. As a result of significant changes in the work system due to the integration of robotic surgery, differences are expected in terms of actual shared leadership behaviors as well as team members' perceptions of shared leadership. The specific functions of leadership that team members may engage in will be described in the next section in addition to rationale for whether they are relevant to surgical teamwork. Given that power may be more distributed in robotic teams due to new dependencies between the surgeon and other surgical team members, and given that team distribution increases the need for shared leadership, I hypothesize the following (Figure 10):

Study 1: Video Analysis of Robotic and Laparoscopic Procedures

H3: Robotic teams will exhibit a higher degree of shared leadership through the increased dispersion of leadership functions among the team, as compared with non-robotic teams.

Study 2: Survey Analysis of Surgical Team Members Perceptions

H4: Robotic team members will perceive a higher degree of shared leadership, as compared with non-robotic team members.

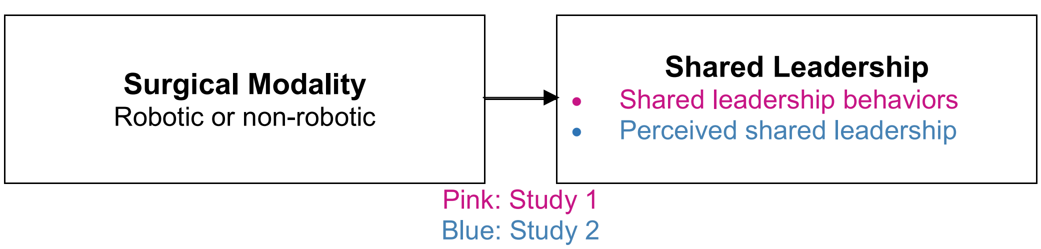

Figure 10. Hypotheses 3 and 4.

Functions of Leadership

Regardless of the source, leadership is considered to be the conduit through which team needs are satisfied. Leadership functions are the behaviors and activities that leaders (formal or informal) engage in to enhance performance and promote the satisfaction of team needs (Morgeson et al., 2010). Team performance is enhanced, and needs are satisfied when leadership functions are effectively enacted. Countless researchers have studied leadership functions to understand what behaviors make leaders effective and thereby increase team performance.

One issue in leadership research is the diverse and numerous sets of leadership behavior taxonomies that have been developed. Since as early as 1944, researchers have been organizing activities and behaviors into taxonomies of leadership functions (Coffin, 1944). Nearly thirty years ago, Fleishman et al. (1991) reviewed existing schemes for classifying leader behavior and discovered over 65 distinct taxonomies. Yukl (2008) outlined a multitude of reasons why it is difficult to make comparisons across and integrate findings from such varied taxonomies. First, different terms are sometimes used to describe the same behavior. Second, sometimes the same term is defined differently in different taxonomies. Third, a behavior that is considered to be a general category in one taxonomy is viewed as two or three separate categories in another. Finally, key concepts in certain taxonomies are entirely absent from others. Unfortunately for the sake of simplicity and homogeneity, behavior categories are not objective or tangible attributes of the real world; rather, they represent organized perceptions of behavior (Yukl, 2008). As a result, a “correct” or “perfect” taxonomy to describe leadership behavior will never and cannot exist; conversely, taxonomies will vary dependent upon their purpose and scope (Yukl, 2008).

Key tenants of many leadership behavior taxonomies are behaviors related to *task* and *relations*. This is based upon early theoretical work that was done by researchers at the Ohio

State University during the 1950's in which Stogdill and Coons (1957) identified *initiating structure* and *consideration* as two independent dimensions that substantially accounted for the majority of leadership behavior that was described by employees in questionnaire responses. Leaders who *initiate structure* enact behaviors that organize work, work relationships, and goals, such as assigning members to tasks or emphasizing standards or deadlines. Leaders who embody *consideration* demonstrate respect for employee's ideas and regard for their feelings through actions such as being friendly and approachable as well as expressing appreciation and support. In a similar effort to determine the behavioral characteristics of effective leaders, Judge et al. (2004) described qualities of *production-oriented* and *employee-oriented* leaders. *Production-oriented* leaders were described very similarly to leaders who *initiate structure* such that they are leaders who focus on accomplishing the group's tasks by emphasizing the technical or task aspects of the job. Conversely, the behaviors of *employee-oriented* leaders are similar to those of the *consideration* dimension in that they involve taking a personal interest in the needs of the employees and emphasizing interpersonal relationships.

Morgeson et al. (2010) put forth a framework of fifteen distinct leadership functions, see Table 3. The framework is organized according to the previously-discussed sources of leadership in addition to team performance cycles of transition and action phases that were established by Marks et al. (2001). During transition phases, teams conduct evaluation of past and future performance as well as planning tasks. Throughout action phases, teams perform tasks that directly lead to goal accomplishment. Therefore, it makes sense that the leadership functions that are enacted by a single or multiple team member(s) may differ depending upon the current "phase" of performance. For instance, an effective leader will likely behave differently while setting expectations throughout planning as compared with solving problems and challenging the team throughout performance. Morgeson et al. (2010) developed this framework into the Team Leadership Questionnaire (TLQ), a survey measure for each of the functions and accompanying sub-functions (see Appendix A).

Table 3. Team leadership functions by leadership sources, adapted from Morgeson et al. (2010).

	Formality of Leadership			
	Informal		Formal	
Leadership Function	Locus: Internal	Locus: External	Locus: Internal	Locus: External
Transition phase				
Compose team			++	+++
Define mission	++	+++	+++	+++
Establish expectations and goals	++		++	+++
Structure and plan	+++	+	+++	+
Train and develop team	+	+++	++	++
Sensemaking	+	+++	++	+++
Provide feedback	+++	+++	+++	+++
Action phase				
Monitor team	++	++	++	+++
Manage team boundaries	+	+	++	+++
Challenge team			++	+++
Perform team task	+++	+	+++	++
Solve problems	+++	++	+++	++
Provide resources			++	+++
Encourage team self-management			+	+++
Support social climate	+++		+++	++

Note: Cell entries reflect the source of leadership best positioned to perform a particular team leadership function, ranging from "good" (+), to "better" (++), to "best" (+++) positioned. Empty cells suggest that a particular source is not well-positioned to perform that leadership function.

Considering the context of surgery, teams engage in both transition and action phases. The team is engaged in the action phase as they are involved in executing the task at hand and there are also periods in which the team engages in evaluation and/or planning to guide their task accomplishment. For example, teams establish and review expectations and goals during the time-out period before the operation begins. In addition, training and development activities may occur throughout the surgery for newer or less experienced team members. Having said this, there are certain leadership functions that may be out of scope when considering a surgical team.

Therefore, several leadership functions have been excluded from the focus of this dissertation. Next, each leadership function will be discussed and the inclusion or exclusion rationale provided. The inclusion criteria includes the behaviors and activities that leaders may engage in to enhance performance and promote the satisfaction of team needs *during a surgical procedure*. A list of the functions that are in and out of scope can be found in Table 4.

Compose Team. This leadership function involves the selection of team members (Morgeson et al., 2010). In surgery, team composition is largely determined by the qualifications and roles that individuals hold (e.g., medical degree, nursing license). Many surgeons may have input into their team composition; however, hospital administration and logistical factors like scheduling play a role as well. Regardless of the key decision-makers involved, team composition is determined ahead of most scheduled procedures, so this leadership function is considered to be *out of scope*.

Define Mission. The leadership function of defining mission involves determining and communicating the team's purpose (Morgeson et al., 2010). Healthcare is a mission-driven field and surgery specifically places a distinct emphasis upon the importance of patient safety. Due to the background, training, and cultural emphasis placed upon the mission of surgery, I argue that this leadership function is *out of scope*.

Establish Expectations and Goals. The next leadership function involves identifying what the team is expected to accomplish (Morgeson et al., 2010). This leadership function is similar to "define mission," but there may be specific expectations and goals for each surgery based upon relevant patient factors. Oftentimes teams may establish these patient-specific expectations and goals during the time-out procedure before the operation begins. However, the present analysis is focused upon teamwork that occurs during the procedure; therefore, this leadership function is *out of scope*.

Structure and Plan. This leadership function works hand-in-hand with the previous function, establish expectations and goals; however, it is more so focused on determining how work will be accomplished (e.g., method), who will do which aspects of the work (e.g., role clarification), and when the work will be done (e.g., timing, scheduling, work flow) (Morgeson et al., 2010). While various patient factors that impact the overall expectations may flux, I argue that the structure and plan will remain relatively constant. For instance, the methods, roles, and overall workflow are determined prior to surgery so it is rare that these would need to be reviewed throughout an operation. Therefore, this leadership function is *out of scope*.

Train and Develop Team. This leadership function involves the training and development of technical skills and interpersonal skills (Morgeson et al., 2010). All team members in an operation are required to be appropriately trained and qualified. However, there are exceptions in the event that a staff member is new or less experienced in a certain procedure. After all, incoming healthcare practitioners such as residents and student nurses gain on-the-job experience and proficiency by performing tasks under more experienced practitioners' supervision. Therefore, this leadership function is *in scope*.

Sensemaking. The leadership function of sensemaking involves identifying critical external events that affect the team and then communicating them to the team how the event might impact team functioning (Morgeson et al., 2010). Morgeson et al. (2010) discussed the relevance of events that impact team functioning such as changes related to team size, team task, leadership structure, and organizational environment. Changes such as these would very likely not be communicated during surgery but rather during a staff meeting. Therefore, this leadership function is *out of scope*.

Provide Feedback. The next leadership function involves reviewing past or current performance so that the team can make improvements (Morgeson et al., 2010). In the context of surgery as a whole, this could occur at the beginning during the “prebrief” timeout while the team reviews previous performance, during the surgery to review a performance event that just occurred, and/or at the end if the team holds a “debrief” to review events that transpired during surgery. Specifically, in the context of the present study, we are focusing on the feedback that occurs intraoperatively to review an event that just occurred. In the literature, this type of feedback is commonly referred to as *team self-correction*. In team self-correction instances, after an event or error occurs, it is identified, corrected, and steps are taken to avoid it in the future (Salas & Cannon-Bowers, 2000; Wilson et al., 2005). This leadership function is *in scope*.

Monitor Team. This leadership function occurs during the action phase and involves actively monitoring the team during task performance. Team monitoring is situationally dependent and may include requesting task-relevant updates from team members or evaluating the team’s progress toward goals. Morgeson et al. (2010) noted that different leadership sources are able to monitor different aspects of the team’s environment and internal sources of leadership are best positioned to monitor team performance and the resources needed. Monitoring may take place in the operating room as members evaluate progress toward their goals and request task-relevant updates from one another; therefore, this leadership function is *in scope*.

Manage Team Boundaries. This leadership function involves managing the boundary between the team and the larger organizational context (Morgeson et al., 2010). As mentioned in the sensemaking category, it is rare that organizational updates would be communicated to teams during surgery. However, surgical teams may interface with individuals or teams outside of the surgical team for logistical reasons. For instance, the circulating nurse may communicate with the surgical logistics desk to secure a hospital bed to transfer the patient to after surgery. Additionally, surgical teams typically perform multiple operations per day, and there are external schedules and resources that they may need to be coordinated while in one operation. Therefore, this leadership function is *in scope*.

Challenge Team. The leadership function of challenging team involves confronting the team's assumptions, methods, and processes in order to improve how they are accomplishing work (Morgeson et al., 2010). For the most part, surgery is a standardized process in which the team comes together to perform a scheduled operation. For such an operation, there are policies and procedures in place that mandate how the instruments should be sterilized and prepared, how the anesthesia should be administered, and how the actual surgical intervention should be performed. Therefore, it would not be necessarily appropriate for a surgical team to be engaging in this leadership function during surgery, as such, it is *out of scope*.

Perform Team Task. The next leadership function involves participating, intervening, or otherwise performing some aspect of the team's task (Morgeson et al., 2010). All team members in surgery hold specific task responsibilities and there are certainly activities that required shared responsibility from multiple team members (e.g., moving a patient from the hospital bed to the operating table). Therefore, this leadership function is *in scope*.

Solve Problems. The leadership function of solving problems pertains to a leader's ability to diagnose and develop solutions to problems the team is facing (Morgeson et al., 2010). In surgery, complex problems may involve patient status as well as more logistical issues like not having the necessary equipment readily available. Therefore, this leadership function is *in scope*.

Provide Resources. This leadership function encompasses the obtainment and provision of informational, financial, material, and personnel resources for the team (Morgeson et al., 2010). Considering the context of surgery, material resources are the most relevant as teams require a great sum of equipment, instrumentation, and other supplies to complete their tasks. Personnel resources are also needed, but as discussed in the team composition function, personnel selection and scheduling occurs separately and before surgery begins. Most needed materials are prepped and made available before surgery starts. However, some resources are not kept near the patient table and may be stored elsewhere in the operating room or nearby. Based upon the team's need for material resources during surgery, this leadership function is *in scope*.

Encourage Team Self-Management. The next leadership function involves a leader encouraging the team to manage itself and become more autonomous (Morgeson et al., 2010). The different disciplines within surgery (e.g., surgeon, nurses, and anesthesia) are mostly distinct entities that manage their specific roles and the surgeon is perceived to reside as the hierarchical leader. Further, the work performed by a surgical team is highly coupled and interdependent. Due to the deeply collaborative nature of surgery, encouraging surgical team members to operate autonomously would not be appropriate. Therefore, this leadership function is *out of scope*.

Support Social Climate. The last leadership function involves supporting the team's social climate (Morgeson et al., 2010). Research has indicated that multiple sources among the team can perform this function and it is heavily associated with performance outcomes such as productivity and satisfaction (Morgeson et al., 2010). It is difficult to imagine a team that does not include some form of social component; surgical teams are no different and thus must work to maintain a positive social climate. As such, this leadership function is *in scope*.

Table 4. Summary of scope of leadership functions.

	Relevance to Surgical Teams	
Leadership Function	In Scope	Out of Scope
Transition phase		
Compose team		X
Define mission		X
Establish expectations and goals		X
Structure and plan		X
Train and develop team	X	
Sensemaking		X
Provide feedback	X	
Action phase		
Monitor team	X	
Manage team boundaries	X	
Challenge team		X
Perform team task	X	
Solve problems	X	
Provide resources	X	
Encourage team self-management		X
Support social climate	X	

Team Outcomes

Teams are increasingly performing work in organizations around the world. Kozlowski and Ilgen (2006) stated, “teams are at the center of how work gets done in modern life” (p. 78); therefore, salient team successes and failures alike make the concepts of team performance and team effectiveness relevant. Both concepts are largely based on the input-process-output (IPO) framework put forth by McGrath in 1964. In this framework, *inputs* refer to antecedents to team interactions and may include team member characteristics, team-level factors, and organizational contextual factors. These are the factors that culminate to “set the stage” for team *processes*, which involve how team members work together toward task accomplishment. Lastly, the resultant *outputs* include both factors related to performance (e.g., speed, quality, error rates) as well as other team outcomes (e.g., member satisfaction, team cohesion). Team performance and team effectiveness are sometimes used interchangeably; though, they reflect two very different concepts. Salas et al. (2005) differentiated the two terms as follows, "Team performance accounts for the outcomes of the team's actions regardless of how the team may have accomplished the task. Conversely, team effectiveness takes a more holistic perspective in considering not only whether the team performed (e.g., completed the team task) but also how the team interacted (i.e., team processes, teamwork) to achieve the team outcome" (p. 557).

Said differently, team performance is representative of what a team has accomplished and team effectiveness is a criteria or benchmark that performance can be compared against. In essence, when team processes and outcomes are aligned with organizationally-driven task demands, the team is considered to be effective and when they are not, the team is considered to be ineffective (Kozlowski & Ilgen, 2006). Therefore, team effectiveness must be considered in light of organizational and contextual factors. Kozlowski and Ilgen's (2006) conceptual framework (Figure 11) illustrates a reciprocal and ongoing cycle in which organizational factors drive team task demands, team members combine efforts and resources to resolve task demands, and the resultant team outcomes feed back into the organizational system.

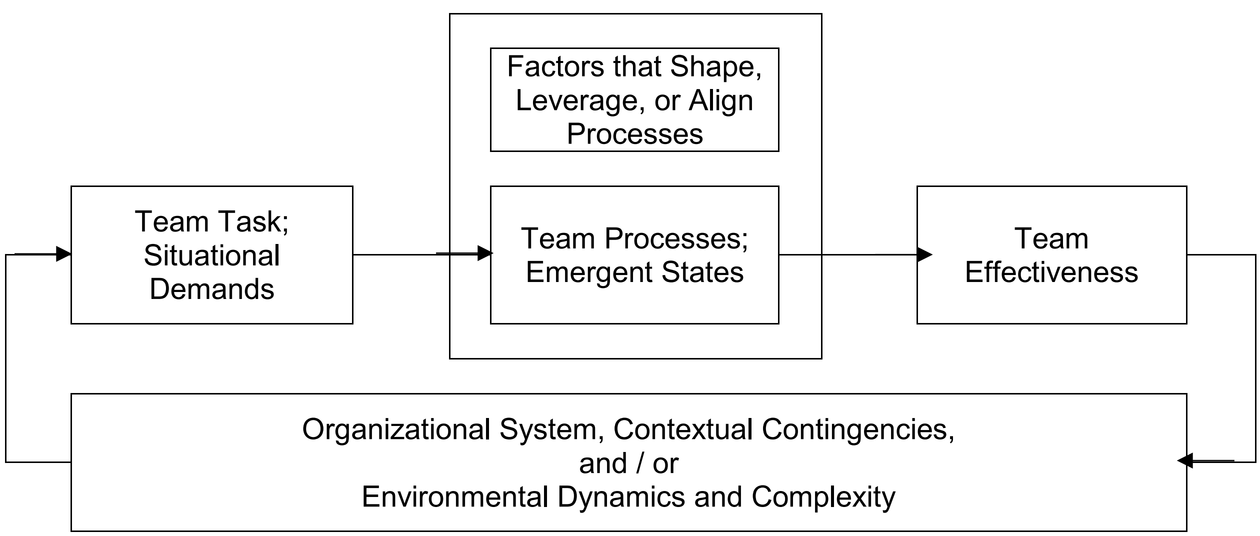

Figure 11. Conceptual framework, adapted from Kozlowski and Ilgen (2006).

Team effectiveness includes a number of different dimensions. Pearce and Sims (2002) put forth an overall scale of effectiveness (see Appendix B) that includes dimensions of output effectiveness, quality effectiveness, change effectiveness, organizing and planning effectiveness, and interpersonal effectiveness, value effectiveness, and overall effectiveness. Pearce and Sims (2002) combined the process and performance measures from Ancona and Caldwell (1992) and the effectiveness measures from Manz and Sims (1987) and Cox (1994) to develop this scale.

Communication and Team Outcomes

Communication is central to teamwork as it is the means by which teams translate individual-level understanding into team-level knowledge (Cooke et al., 2004). Intuitively, teams' coordination and collaboration efforts are guided by their communication (Salas et al., 2005). Empirical evidence suggests that effective communication is a key team process that distinguishes high from low performing teams (Entin & Serfaty, 1999). A meta-analysis conducted by Mesmer-Magnus and Dechurch (2009) demonstrated a significant positive relationship between information sharing and team performance. Kozlowski and Ilgen (2006) posited that communication supports both task-related and teamwork processes. Effective communication drives better performance for a number of reasons. For instance, communication can buffer the effect of interruptions by facilitating a common awareness of team member actions and intentions (Orasanu, 1994). Fundamentally, communication strengthens team performance because it allows team members to engage in other team processes more effectively (Kozlowski & Ilgen, 2006).

Communication facilitates the creation and maintenance of *shared mental models*. Mental models are simplified constructions humans create of their worlds (Johnson-Laird, 1983) in order to describe, explain, and predict their surroundings (Rouse & Morris, 1986). At the team level, shared mental models reflect the level of common understanding team members possess regarding team and task-level characteristics of their work (Klimoski & Mohammed, 1994). Cannon-Bowers et al. (1993) defined shared mental models as,

> "Knowledge structures held by members of a team that enable them to form accurate explanations and expectations for the task, and in turn, to coordinate their actions and adapt their behavior to demands of the task and other team members" (p. 236).

Many researchers have postulated that shared mental models lead to effective team coordination because when knowledge and understanding are shared, team members are better able to anticipate the behavior of their team members (Cannon-Bowers et al., 1993; Rentsch et al., 1994). In fact, shared mental models have been linked to team performance in a number of industries (DeChurch & Mesmer-Magnus, 2010). In complex work settings such as surgery, communication and the resulting construction of shared mental models has been linked to improved team performance (Weller et al., 2014). Leonard et al. (2004) posited that effective communication strategies and protocols are essential to fostering an environment in which clinicians can speak up and share concerns, and thereby facilitate safer and more effective patient care. For example, Mazzocco et al. (2009) demonstrated that increased information sharing during surgery was associated with lower probabilities of complications and death. In addition, among a large and diverse sample, Haynes et al. (2009) found that surgical teams who used a surgical safety checklist to consistently communicate key information resulted in decreased surgical complications. An important mechanism for this enhanced performance may be due to the reduction in uncertainty, which is facilitated by shared mental models (Fiore et al., 2017).

Along these same lines, effective communication behaviors such as using names to indicate direction, call outs to share task progression updates, and closed-loop communication all fundamentally serve the purpose of reducing uncertainty and facilitating shared mental models. When surgical team members have a shared mental model, they have a common understanding of the situation, the plan for treatment, and the roles and tasks of the team members (Weller et al., 2014). Therefore, these effective communication behaviors facilitate shared mental models and thereby promote effective information sharing and team performance. In the context of surgery, advantageous team outcomes may translate to more efficient operation durations.

Communication has been highlighted as especially influential in complex work settings such as surgery in which team members must share relevant information in a timely fashion. The relationship between communication and the development of shared mental models suggests that effective communication among a team will contribute to more effective teamwork, which in turn, may result in quicker and more efficient operative durations. In addition, team members who perceive higher quality communication may also perceive higher team effectiveness. Furthermore, team members who perceive the occurrence of effective communication behaviors may also associate their experience with higher effectiveness. Given the strong linkage between effective communication and team outcomes, I hypothesize the following (Figure 12):

Study 1: Video Analysis of Robotic and Laparoscopic Procedures

H5: Surgical teams with a higher frequency of communication behaviors (names, call outs, closed-loop communication) will experience a shorter operative duration.

Study 2: Survey Analysis of Surgical Team Members Perceptions

H6a: Surgical team members who perceive high communication quality will also rate their team effectiveness higher.

H6b: Surgical team members who perceive higher utilization of communication behaviors (names, call outs, closed-loop communication) among their team will also rate their team effectiveness higher.

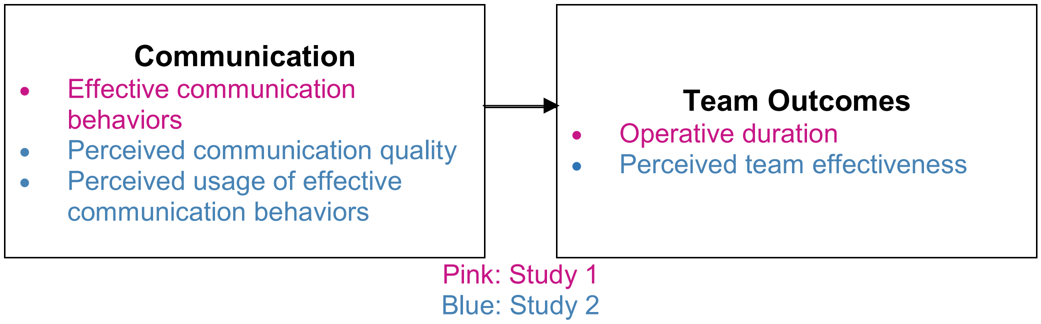

Figure 12. Hypotheses 5 and 6.

Shared Leadership and Team Outcomes

Initial studies on shared leadership provide evidence for a significant positive relationship between shared leadership and outcomes such as team morale and performance (Avolio et al., 1996; Pearce & Sims, 2000). In other words, scholars posit that in many cases, the most effective leadership is shared. Recent research has demonstrated that shared leadership shows positive effects on team performance in high-risk situations. For instance, Bienefeld and Grote (2011) discovered that shared leadership among aircraft crews undergoing a simulated emergency correlated with decision quality and crew performance. Additionally, similar results were found while researching firefighting teams (Baran & Scott, 2010) and anesthesia teams (Klein et al., 2006; Künzle et al., 2010).

Shared leadership may proliferate team outcomes as a result of increased empowerment and development of transactive memory systems. Historically, models of management have emphasized the centralization of power at the top of an organization; conversely, the concept of empowerment emphasizes the decentralization of power (Pearce & Conger, 2003). The underlying principle that promotes empowerment is that the individuals who are most familiar with certain situations are the most qualified to make decisions. This notion leans on the concept of the *law of the situation* which states that the demands of a situation should drive leadership (Follett, 1924). In other words, the ideal leader is the person who encompasses the most relevant knowledge and experience to lead the team through a given task or challenge. Naturally, this promotes the achievement of team outcomes. In addition, shared leadership may result in increased cooperative attitudes among teams that may lead to teams feeling like they have more influence. This is important because team members who perceive greater empowerment are more likely to effectively engage in collaboration, coordination, and the development of innovative solutions (Cox et al., 2003). Empowerment leads to increased satisfaction as well as additional responsibility (Hoch & Dulebohn, 2013). In addition, as a result of shared leadership, individual team members have increased understanding and knowledge that may promote team outcomes. For instance, when leadership functions are shared, team members are more familiar with what work needs to be accomplished and how it will be accomplished. The level of knowledge team members possess about their other team members (i.e., who knows what, who is skilled at what) is known as *transactive memory systems* (Lewis, 2003). Involvement in leadership functions increases individuals' knowledge of work as a whole as well as knowledge about their team. Teams with high transactive memory systems have been linked with high performance. For this reason, teams that share leadership to a greater degree may have greater transactive memory systems and, therefore, work more efficiently.

Further, Pearce (1997) found shared leadership to be a strong predictor of team self-ratings of effectiveness. Pearce and Sims (2002) determined that team members' perceptions of team leadership behavior predicted self-ratings of effectiveness and accounted for more variance than formal leadership. Hiller et al. (2006) postulated that conceptually, shared leadership is beneficial in all types of teams because the shared enactment of leadership provides an increased capacity for "getting things done," regardless of the task. These findings suggest that shared leadership increases team effectiveness. Given that greater shared leadership may contribute to increased team effectiveness, I hypothesize the following (Figure 13):

Study 1: Video Analysis of Robotic and Laparoscopic Procedures

H7: Surgical teams with a higher degree of shared leadership will experience a shorter operative duration.

Study 2: Survey Analysis of Surgical Team Members Perceptions

H8: Surgical team members who perceive leadership to be more shared among their team will rate their team effectiveness higher.

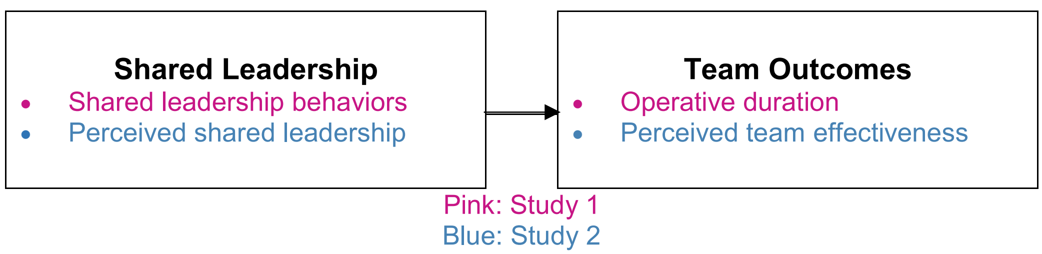

Figure 13. Hypotheses 7 and 8.

If surgical modality profoundly impacts teamwork as suggested by existing research, then gaining better understanding of how it impacts communication, leadership, and team outcomes is important. Researchers have discovered that robotic teams communicate differently than non-robotic teams (Nyssen & Blavier, 2009; Wang, 2017), but little work exists that examines the usage of specific communication strategies. There is a marked shift in leadership literature to studying the concept of shared leadership and this has been scarcely investigated in surgical teams (Rydenfält et al., 2015). Team outcomes are key tenants of teamwork research; less explored, however, is the relationship between the use and perception of specific communication and leadership behaviors with operative duration and perceived effectiveness. With these constructs in mind, it is the goal of this dissertation to focus on the behaviors and perceptions of surgical team members to gain greater insight into the usage of specific communication behaviors, the distribution of leadership, and team outcomes.

To summarize the above review, I expect that surgical modality will influence actual and perceived communication and leadership. I posit that robotic surgical teams will more frequently utilize and perceive effective communication behaviors. In addition, I hypothesize that robotic surgical teams will engage in and perceive more shared leadership. Further, I predict that communication and leadership will influence team outcomes such that teams who more frequently engage in effective communication behaviors will experience shorter operative durations. Similarly, I expect that teams who share leadership to a greater extent will experience shorter operative durations. Lastly, I hypothesize that surgical team members who perceive higher communication behaviors, higher communication quality, and greater shared leadership will also perceive higher team effectiveness. For a summary of these proposed hypotheses, refer to Table 5. In addition, for a summary of all study constructs and accompanying measurement methods, see Table 11.

Table 5. Summary of proposed hypotheses.

H1a.	Study 1	Robotic teams will more frequently state team member names, as compared with non-robotic teams.
H1b.	Study 1	Robotic teams will more frequently utilize call outs, as compared with non-robotic teams.
H1c.	Study 1	Robotic teams will more frequently utilize closed-loop communication, as compared with non-robotic teams.
H2a.	Study 2	Non-robotic team members will perceive higher communication quality, as compared with robotic team members.
H2b.	Study 2	Robotic team members will perceive higher utilization of communication behaviors (i.e., names, call outs, and closed-loop communication), as compared with non-robotic team members.
H3.	Study 1	Robotic teams will exhibit a higher degree of shared leadership through the increased dispersion of leadership behaviors among the team, as compared with non-robotic teams.
H4.	Study 2	Robotic team members will perceive a higher degree of shared leadership, as compared with non-robotic team members.
H5.	Study 1	Surgical teams with a higher rate of communication behaviors (i.e., names, call outs, and closed-loop communication) will experience a shorter operative duration.
H6a.	Study 2	Surgical team members who perceive high communication quality will also rate their team effectiveness higher.
H6b.	Study 2	Surgical team members who perceive higher utilization of communication behaviors (i.e., names, call outs, and closed-loop communication) will also rate their team effectiveness higher.
H7.	Study 1	Surgical teams with a higher degree of shared leadership will experience a shorter operative duration.
H8.	Study 2	Surgical team members who perceive leadership to be more shared among their team will rate their team effectiveness higher.

Chapter 3: Methods

This dissertation leveraged two data collection and analysis approaches in order to best understand, address, and test the research hypotheses. In study one, robotic and non-robotic (laparoscopic) surgical team member behaviors were assessed through audiovisual data of actual surgical procedures. In study two, robotic and non-robotic (open and laparoscopic) surgical team member perceptions were gleaned through questionnaire methods. Comparisons were made across both studies comparing "robotic" and "non-robotic" teams and team members. The two research approaches were conducted in parallel and the resultant findings were interpreted separately. Finally, similarities and differences between the two approaches were considered to compare the two sets of findings.

Study 1: Video Analysis of Robotic and Laparoscopic Procedures

Participants

A convenience sample of 22 surgeries was collected in which a total of 127 healthcare practitioners were involved. All participants were over the age of 18 and had direct involvement in either laparoscopic or robotic surgery. Each of the recorded procedures included a team composed of five to seven (M = 5.82, SD = 0.59) healthcare practitioners representing the following roles: surgeon, resident, physician assistant (PA), scrub nurse, scrub technician, anesthesiologist, certified registered nurse anesthetist (CRNA), and circulating nurse. Each surgery included one surgeon, either one PA or resident to act as the assist (with the exception of four cases with both), one scrub nurse or technician (with the exception of one case without a scrub where the PA fulfilled both roles), one anesthesiologist or CRNA, and one circulating nurse. In addition, 14 of the 22 cases included students who were shadowing surgical team members. Overall, the sample of observed healthcare workers included 22 surgeons, 11 residents, 15 PAs, 22 anesthesia providers, 21 scrub nurses/techs, 22 circulating nurses, and 14 students representing different disciplines. Demographic data such as age, race, and ethnicity were not collected.

Several a priori power analyses were conducted based upon the planned analyses of a multivariate analysis of variance and covariance (MANOVA) (for H1a, H1b, and H1c), an independent samples t-test (for H3), and a multiple linear regression (for H5 and H7). These analyses were conducted in order to determine the appropriate sample size, or in other words, the number of surgeries (teams) that are needed since the focus of the present study is at the team-level. The software G*Power 3.1.9.4 (Faul et al., 2007) was used to perform these analyses. First, for the MANOVA, the input parameters included a planned effect size of $f = 0.15$, alpha level of significance = 0.05, power (beta) = 0.80, two groups, and three response variables; these were used to calculate the output parameters of a critical F value of 2.73 and a minimum sample size of 78 participants. Next, for the independent samples t-test, the input parameters included one tail, a planned effect size of $d = 0.8$, alpha level of significance = 0.05, power (beta) = 0.8, and an allocation ratio of 0.6; these were used to calculate the output parameters of a critical t value of 1.68 and a minimum sample size for group one of 28 and a minimum sample size for group two of 16, resulting in a total minimum sample size of 44. Lastly, for the multiple linear regression, the input parameters included a planned effect size of $f = 0.25$, alpha level of significance = 0.05, power (beta) = 0.80, and two predictors; these were used to calculate a critical F value of 3.24 and a minimum sample size of 42 participants. Considering each planned analysis independently, the total minimum sample size is 164.

Of the 22 recorded procedures, 14 were completed robotically and eight were completed laparoscopically. The robotic system used in the robotic cases was the da Vinci Xi, a surgical robot with four arms that is operated remotely by a surgeon who is seated at a console with video-assisted visualization. The surgeries occurred at three different medical institutions (i.e., sites) within the U.S. with ten being from site A, eight being from site B, and four being from site C. In addition, the data set includes two different procedure types (i.e., inguinal hernias and right colectomies) with a total of 14 inguinal hernias and eight right colectomies. Details for each case are available in Table 6; the cases are numbered in the order in which they were recorded.

Table 6. Audiovisual data details.

Case #	Modality	Procedure	Site	Team Size
1	Laparoscopic	Inguinal hernia	A	6
2	Laparoscopic	Inguinal hernia	A	6
3	Robotic	Inguinal hernia	A	6
4	Laparoscopic	Inguinal hernia	A	5
5	Robotic	Inguinal hernia	B	6
6	Robotic	Inguinal hernia	B	5
7	Robotic	Inguinal hernia	C	6
8	Robotic	Inguinal hernia	C	7
9	Laparoscopic	Inguinal hernia	B	5
10	Laparoscopic	Inguinal hernia	B	6
11	Robotic	Inguinal hernia	C	5
12	Robotic	Inguinal hernia	B	5
13	Laparoscopic	Inguinal hernia	A	6
14	Laparoscopic	Inguinal hernia	A	6
15	Laparoscopic	Right colectomy	A	6
16	Robotic	Right colectomy	A	6
17	Robotic	Right colectomy	A	6
18	Robotic	Right colectomy	B	6
19	Robotic	Right colectomy	B	6
20	Robotic	Right colectomy	C	7
21	Robotic	Right colectomy	B	5
22	Robotic	Right colectomy	A	5

Procedure

Data Collection. The audiovisual data set was collected from January 2018 to August 2018 as part of a larger study examining human factors in the operating room. Institutional Review Board (IRB) approval was obtained from Allendale IRB and all participating hospitals, surgeons, and patients signed informed consent forms. Audiovisual data was collected during 22 surgical procedures in three medical institutions in the U.S. which yielded nearly 68 hours of audiovisual data. Four video cameras and a room microphone were used to capture a total view of the operating room, the surgical site, and adequate audio. Recording began during pre-operative preparation and ended during post-operative cleaning. A human factors consultancy collected the data and redacted all patient faces and identifying information (e.g., name, date of birth) before the research team for this project obtained access to the data.

Data Coding. I trained two graduate-level human factors research assistants (RAs) to code the data for a period of approximately 25 hours over a four-week period. Training included familiarizing the RAs with the three surgical modalities (i.e., open, laparoscopic, and robotic), the team roles involved in surgery (e.g., surgeon, scrub), the layout of and equipment in the operating room, and the two procedure types in the sample (i.e., inguinal hernia and right colectomy). After establishing this foundation, I introduced the RAs to the 11 communication and leadership behaviors (described in the Measures section) that we would be coding. I provided the RAs with each behavior's definition, operationalization, and an example from the data. In addition, I described how we would be viewing the videos in VLC media player and using an Excel spreadsheet to document these behaviors along with contextual information such as surgery phase beginning and end times.

Toward the end of the training period, the two RAs and I watched and coded one video in real-time as a group. After coding this video as a group, I had each RA independently code a second video and then we met as a group and we came to agreement on any inconsistencies. Next, each RA and I independently coded a third video. For this video, we followed the formal coding processes that we would utilize throughout the remainder of video coding. The formal coding process for each video included four main steps: (a) the RA and I independently coded the same video, (b) I combined all behavioral descriptions, (c) the RA and I independently coded any behavior descriptions that we did not originally capture, and (d) the RA and I met in-person to come to consensus on any inconsistencies.

For the third training video, each RA and I independently watched the video, described and transcribed behaviors, and selected the appropriate codes. After we had each coded this video, I combined our behavior descriptions in order to generate a comprehensive list of all behavior descriptions that were captured between the three of us. For the majority of behavior descriptions, the RAs and I described the same behaviors at the same time points. However, there were numerous instances in which I captured behavior descriptions that the RAs did not and vice versa. Therefore, the process of combining our behavior descriptions ensured that we captured as many behavior descriptions as possible. After I combined our lists of behavior descriptions into one comprehensive list, step three involved the RAs and I independently coding all behavior descriptions that we did not initially describe and subsequently code. Once the RAs and I had coded the combined list of behavior descriptions into specific communication and leadership behaviors, I calculated our total frequencies for each of the 11 behaviors. I used our total frequencies for each case and each variable to calculate interrater reliability. The reliability at the training stage was deemed excellent at an ICC value of .990 for the three raters (i.e., myself and the two RAs) and the full coding procedure continued. Next, we met as a group to discuss and arrive at consensus. Due to our high inter-rater agreement and the proficiency and understanding that both RAs demonstrated, we moved into the formal coding process to code the remaining 19 videos. During the formal coding process, one RA coded nine of the videos, the other RA coded 10 of the videos, and I coded all of the remaining 19 videos. Therefore, for each video, there were at least two coders.

Measures

The communication and leadership behaviors were systematically coded to record the frequency of effective communication behaviors and enactment of leadership functions. Phase times were used to measure the operative duration of the procedures.

Communication. Communication was assessed according to the frequency with which team members used names to indicate communication direction, utilized call outs, and engaged in closed-loop communication. To control for the impact of operative duration, the rate of each communication behavior was used for analysis. The rate was developed for each video by dividing the frequency of each behavior by the operative duration during which the behavior was being evaluated. The resultant rate represents the frequency of the behavior per hour as this was the most understandable unit of time given the nature of the data.

Usage of Names. Directed communication occurs when the sender verbally or non-verbally indicates who the communication is intended for (Parush et al., 2011). Using someone's name is a common manner in which communication direction is portrayed verbally. Non-verbally, communication direction may be depicted through eye-contact or through other forms of gesturing. The present coding effort focused specifically upon instances in which communication direction is established *verbally*. Communication direction may be verbally expressed by using the intended recipient's name, title, or through other means. An example of a directed verbal communication instance can be found in Table 7.

Table 7. Usage of names operationalization.

	Definition	**Example**
Directed verbal communication	Sender verbally indicates who the communication is intended for when relaying a task-related request or question.	Sender: Melissa, what are the patient's vitals?

Call Outs. Call outs are a strategy team members use to communicate task progression and other critical information to the rest of the team (Guerlain et al., 2008). Call outs therefore facilitate a shared mental model and help the rest of the team anticipate next steps. Team members utilize call outs to notify their team members of task progress or completion. An example of a call out can be found in Table 8.

Table 8. Call outs operationalization.

	Definition	**Example**
Call out	Sender verbally shares relevant information regarding safety, task progression, or task completion.	Sender: "Room is prepped, we can dock the robot"

Closed-Loop Communication. In addition to the other communication behaviors outlined above, closed-loop communication was also coded. Frequency of closed-loop communication was recorded for each instance that participants closed the loop in a conversation. Generally, closed-loop communication involves the transmission, acknowledgement, and potentially correction/clarification of a message between at least two parties.

As previously mentioned in Chapter 2 (Literature Review), closed-loop communication is multi-faceted and as such, is enacted in multiple different fashions and to varying extents. At a minimum, the recipient may simply acknowledge that the message was received through a verbal response such as "got it" or "okay". The next level, so to speak, would be for the recipient to conduct a "read-back" by repeating a portion or the entirety of the message to indicate that the content of the message was received. It is possible that the recipient may require clarification or desire verification; in these instances, the recipient may verbally request clarification from the sender by asking a question or verifying the details of the request. All three of these described communication behaviors involve the recipient's response to the sender's message as this is a form of closing the loop. However, a more conservative view of closed-loop communication portrays a three-step process in which the sender sends the message, the receiver acknowledges, repeats, and/or requests clarification of the message, and then the sender responds accordingly. For the purposes of this dissertation, acknowledgement, read-back, and clarification acts will be considered to be closed-loop communication in the event that neither the sender nor receiver are awaiting additional information or clarification. For instance, if the receiver acknowledges the message, the sender is not required to acknowledge the receiver's acknowledgment for the loop to be considered closed. On the other hand, if the sender requests clarification, but does not receive it, the loop will not be considered closed. Examples of each can be found in Table 9.

Table 9. Closed-loop communication operationalization.

	Definitions	**Examples**
Acknowledgment	Recipient verbally acknowledges that the task-related message was received.	Sender: "I need you to hold on" Recipient: "Okay"
Read-back	Recipient verbally repeats a portion or the entirety of the task-related message.	Sender: "I need 20ml of saline" Recipient: "I'll get 20ml saline"
Clarification	Recipient verbally requests clarification or verification from the sender regarding their task-related message.	Sender: "I need gauze" Recipient: "What kind of gauze?" Sender: "Wrapping gauze" Recipient: "Sounds good"

Shared Leadership. Shared leadership was assessed according to the dispersion of frequency with which team members engage in leadership functions. In chapter two (Literature Review), rationale was provided for the inclusion of eight out of the fifteen leadership functions described by Morgeson et al. (2010) relative to the context of surgery. In Table 10, these leadership functions are defined again and operationalized with respect to observable behaviors that may occur in the surgical environment. For each leadership behavior, the role that initiated the behavior was coded and the overall frequency for each team member was recorded. To compare cases as parsimoniously as possible, data from the five "core" surgical team members was analyzed to generate the shared leadership score. These roles included the surgeon, the primary assist (either the resident or PA), the scrub nurse or tech, the anesthesia provider, and the circulating nurse.

Much of the research on shared leadership has measured it through questionnaire methods (Small & Rentsch, 2011; Pearce & Sims, 2002). Researchers who have endeavored to measure shared leadership with observational data have reported the frequencies for leadership behaviors and the roles who conducted them (Rydenfält et al., 2015), measured “shared leadership behaviors” and compared the total frequency of these between teams (Bienefeld & Grote, 2011), and utilized a social network analysis approach (Pasarakonda et al., 2020). To my knowledge, no other research has developed and/or utilized an approach that quantitatively measures observational shared leadership.

In order to assess the level of “shared-ness”, the index of dispersion (i.e., variance to mean ratio) was calculated for each team. The index of dispersion is also commonly referred to as the coefficient of variation and has been applied in numerous domains such as economics, chemistry, and sociology (Abdi, 2010; Martin & Gray, 1971; Walker, 1999). The index of dispersion takes both the variance and mean into account in order to quantify whether a set of numbers are clustered together or dispersed apart. For this study, accounting for the mean was critical since the number of team members and the total frequency of behaviors varied between the videos in our sample. The formula for the index of dispersion can be found below. The denominator is the mean and the numerator is the standard deviation. In this study, the index of dispersion was calculated for each team, so the standard deviation was the variance between the total frequencies of leadership behaviors exhibited by each role and the mean was the total of all the leadership behaviors divided by the number of team roles.

$$D = \frac{\sigma^2}{\mu}$$

Table 10. Leadership behavior operationalization.

Behavior Type	Definitions	Observable Behaviors in Surgery
Train and develop team	This leadership function involves the training and development of task-relevant technical skills as well as interpersonal skills that enable the team to work well together.	• Explains and/or queries the technical aspects (surgery, medicine, anatomy) of surgery (e.g., "What do you think that anatomical structure is?") • Explains and/or queries the interpersonal aspects (e.g., communication, coordination) of surgery • Provides guidance or instruction in a teaching manner (e.g., "first you need to ensure you have all the equipment you need")
Provide feedback	This leadership function involves reviewing past or current performance so that the team can make improvements.	• Provides positive, negative, and/or corrective commentary about a previous decision or action (e.g., "Try it like this instead.") • Provides suggestions and/or directions for how to improve performance (e.g., "Surgeon says to resident "so I wouldn't particularly grab that bowel like you are")
Monitor team	This leadership function involves actively monitoring the team during task performance.	• Requests task-relevant updates (e.g., "Are you finished docking the robot yet?")
Manage team boundaries	This leadership function involves managing the boundary between the team and the larger organization.	• Communicates with individuals to coordinate details (e.g., schedule, room, equipment) for another patient's procedure
Perform team task	This leadership function involves participating, intervening, or otherwise performing some aspect of the team's task.	• Provides directions, instructions, orders, and/or requests to others to facilitate task performance. • Verbalizes willingness to provide assistance to other team members (back-up behavior) to carry out task work (e.g., "I can help you with that.")
Solve problems	This leadership function involves diagnosing and developing	• Verbalizes that there is a problem (may involve patient, equipment, etc.)

	solutions to problems that the team is facing.	• Seeks other perspectives to aid in problem-solving • Communicates solution(s)
Provide resources	This leadership function involves the obtainment and provision of informational, financial, material, and personnel resources for the team.	• Responds (verbally or behaviorally) to requests for needed equipment
Support social climate	This leadership function involves supporting the team's social climate.	• Responds to team member concerns • Encourages or reassures others • Inclusively uses humor • Says "I'm sorry", "thank you", "you're welcome", "please", or other polite phrases • Engages in small talk
Note: Definitions adapted from Morgeson et al. (2010).		

Operative Duration. Phase times were analyzed in order to assess team performance from the audiovisual data. The time between the first cut and the final closure was used to calculate the operative duration. The first cut was marked by the surgeon and/or PA applying their chosen method of entry (e.g., trocar) to make the first cut. The final closure was distinguished by the surgeon and/or PA completing the final closure of the surgical sites with either staples, sutures, and/or adhesives. The resultant time period reflects the operative duration, i.e., the "cut to close" time.

Study 2: Survey Analysis of Surgical Team Member Perceptions

Participants

This study included a convenience sample of 144 surgical healthcare practitioners from an 886-bed, non-profit, academic hospital in California, U.S. Overall, the sample included 35 attending surgeons, 23 residents, 21 anesthesiologists, 17 scrub techs, and 48 circulating nurses. An email memorandum (see Appendix C) was used to advertise the survey among a hospital's surgical staff. Participation was incentivized through a choice between compensation and a donation to a charity of their choice. In addition, participants had an option to be notified of the study results. Attrition was expected to be relatively low since the questionnaire required one-time participation and was expected to last approximately 10 minutes.

Three a priori power analyses were conducted based upon the planned analyses of a MANOVA (for H2a, H2b), an independent samples t-test (for H4), and a multiple linear regression (for H6a, H6b, H8). These analyses were conducted in order to determine the appropriate sample size, or in other words, the number of team member participants that are needed since the focus of the present study is at the individual level. The software G*Power 3.1.9.4 (Faul et al., 2007) was used to perform these analyses. First, for the MANOVA, the input parameters included a planned effect size of $f = 0.15$, alpha level of significance = 0.05, power (beta) = 0.80, two groups, and two response variables; these were used to calculate the output parameters of a critical F value of 3.14 and a minimum sample size of 68 participants. Next, for the independent samples t-test, the input parameters included one tail, a planned effect size of $d = 0.5$, alpha level of significance = 0.05, power (beta) = 0.8, and an allocation ratio of 1; these were used to calculate the output parameters of a critical t value of 1.66 and a minimum sample size for 51 for each group, resulting in a total minimum sample size of 102. Last, for the multiple linear regression, the input parameters included a planned effect size of $f = 0.15$, alpha level of significance = 0.05, power (beta) = 0.80, and three predictors; these were used to calculate a critical F value of 2.73 and a minimum sample size of 77 participants. Considering each test independently, the total minimum sample size is 247.

Procedure

The questionnaire was electronically hosted on Qualtrics and was released on January 13th, 2020 and subsequently closed on February 17th, 2020. IRB approval was obtained from the participating hospital's IRB committee. Responses were elicited via email from healthcare practitioners with surgical experience in open, laparoscopic, and/or robotic operations. Participants reviewed and electronically signed an informed consent form before beginning the questionnaire.

The survey began with a surgical experience screener (see Appendix D). In this screener, participants were asked if they currently work on a surgical team that performs open, laparoscopic, or robotic surgery. Next, they were asked to indicate what their primary role during surgery is (e.g., surgeon, circulating nurse) and the amount of time they have been in their role. Following this, they were prompted to indicate the approximate number of cases they perform of each modality during a typical 30-day period. Last, they were asked to rank the modalities in order of most performed/assisted with during a typical 30-day period. Their response to this question was used to format the remainder of the survey based upon the modality they ranked as the modality they most commonly perform. For instance, if a participant indicated that they most commonly performed/assisted with robotic surgery, the following scales were framed with "thinking about the most typical robotic surgery you have worked on…"

After completing the surgical experience screener, participants were directed to complete the main portion of the survey. The questionnaire consisted of three constructs that were measured by a total of 40 items. Respondents' perceptions and attitudes about their surgical experiences with regard to communication (see Appendices E and F), leadership (see Appendix G), and effectiveness (see Appendix H) were measured. The questionnaire was expected to take approximately 10 minutes to complete.

At the conclusion of the main portion of the questionnaire, participants completed the demographic (see Appendix I) and compensation (see Appendix J) portions. The demographic section queried participants about their age, gender, ethnicity, and race. In addition, participants were asked what their specialty is, if applicable. Participants were also asked to indicate if they frequently work with the same individuals (e.g., surgeon, scrub) and if so, how long they have worked with those individuals. Lastly, participants were asked if they had ever received any type of team training during medical school or at their hospital, and if so, they were asked to indicate how long it has been since they received the team training. After completing the demographic questions, participants were asked about their compensation preferences. Participants were given a choice between either an Amazon gift card or a donation to a charity of their choice.

The amount of time between a participant taking a survey and the surveyed experience affects the quality of self-reports such that the longer the interval between the event and the survey, the less likely the event is to be recalled or reported accurately (Lavrakas, 2008a). This is due to memory decay and the possibility of resultant recall error (e.g., forgetting an event all together, recalling an event inaccurately, or time error; Dex, 1995). To elicit accurate responses, appropriate reference periods should be chosen and communicated to respondents. As defined by Lavrakas (2008b), reference periods are "the time frame for which survey respondents are asked to report activities or experiences of interest" p. 699. In general, research regarding memory decay with regard to the occurrence of an event indicates that the likelihood of forgetting or incorrectly recalling increases with time (Dex, 1995). For the present study, a reference period of 30 days was chosen, meaning that participants were prompted to reflect upon their surgical experiences during the previous 30 days and answer the survey items accordingly. This reference period was chosen to limit recall error and accommodate for the variable volume in surgeries that hospitals might experience.

Measures

Questionnaire respondents indicated their level of agreement regarding perceptions of communication, leadership, and team effectiveness. In addition, participants completed several demographic questions (see Appendix I). To measure perceived team familiarity, demographic questions 7 to 18 queried participants on their familiarity with the surgical team member roles. Participants were asked to indicate how frequently they work with the same role (e.g., attending surgeon) by responding to a Likert scale that ranged from “never,” to “always.” If the participant selected “sometimes,” “often,” or “always,” they were prompted to indicate how long they have worked with that individual over the course of their career. Participants’ responses to these items were quantified to yield a “team familiarity” score.

Communication. Participants responded to items that assess perceived communication quality and items that measure participant perception of the occurrence of specific effective communication behaviors.

Communication quality was measured with the five-item communication quality scale developed by González-Romá and Hernández (2014) (see Appendix E). A classification reliability of 0.82 was calculated for this scale by using Cohen’s kappa coefficient (González-Romá & Hernández, 2014). The items in this scale assess participants’ perceptions of their team’s communication quality regarding clarity, effectiveness, completeness, fluency, and timeliness. For example, the first item is “to what extent was the communication between you and your teammates clear?” Participants responded on a five-point scale with the response format labeled as follows: “1” = strongly disagree, “2” = disagree, “3” neither agree nor disagree, “4” agree, and “5” strongly agree (with a sixth response category labeled “N/A” = not applicable or do not know).

Utilization of effective communication behaviors was measured with six items that assess the perception of the usage of names, call outs, and closed-loop communication (see Appendix F). This scale was developed specifically for this dissertation. The six items assess self-report perceptions as well as perceptions of the team's behavior. The first item is "how commonly does your team use each other's names to indicate who their communication is intended for?" Participants responded on a five-point scale with the response format labeled as follows: "1" = strongly disagree, "2" = disagree, "3" neither agree nor disagree, "4" agree, and "5" strongly agree (with a sixth response category labeled "N/A" = not applicable or do not know).

Shared Leadership. Leadership functions were measured with selected items from the self-report TLQ scale put forth by Morgeson et al. (2010) (see Appendix G). The complete TLQ scale (Appendix A) contains numerous items for each of the 15 leadership functions, resulting in a total of 82 items. In chapter 2 (Literature Review), rationale for inclusion/exclusion was provided to focus upon eight of the leadership functions. The eight leadership functions include train and develop team, provide feedback, monitor team, manage team boundaries, perform team task, solve problems, provide resources, and support social climate. In the TLQ, each of these eight leadership functions contain five items, resulting in a total of 40 items. In order to increase the brevity of the questionnaire and ensure that all items are highly relevant to surgical teams, the 40 items were reduced to a 16-item scale (two items for each leadership function) for use in this dissertation. An example item from the train and develop team leadership function is, "helps new team members to further develop their skills".

In order to assess the degree to which the leadership functions are perceived to be shared, participants responded based upon their perception of which individuals on their team typically engage in the leadership behaviors. The response format for this scale was a check-box response in which participants indicated which roles commonly perform the behavior in question. Participants were instructed to select as many roles that were relevant to each item. This approach reflects what Conger and Pearce (2003) described as measuring shared leadership as the "group as a sum of its parts," by using items with each of the team members measured separately as sources of influence. Similar to the approach utilized to develop a shared leadership "score" for the video data behaviors, the index of dispersion was calculated for each respondent, resulting in a shared leadership perception "score".

Team Effectiveness. Team effectiveness was measured with a modified scale of seven variables and a total of 13 items. The total scale established by Pearce and Sims (2002) (Appendix B) was reduced based upon relevance to surgical teams (see Appendix H). An internal consistency reliability of 0.85 was calculated for this scale for team self-ratings. The seven variables include output effectiveness, quality effectiveness, change effectiveness, organizing and planning effectiveness, interpersonal effectiveness, value effectiveness, and overall effectiveness. An example item is "the quality of the team's output is very high". Participants responded on a five-point scale with the response format labeled as follows: "1" = strongly disagree, "2" = disagree, "3" neither agree nor disagree, "4" agree, and "5" strongly agree (with a sixth response category labeled "N/A" = not applicable or do not know).

Table 11. Summary of study constructs and measurement methods.

Construct	Sub-construct	Definition	Measurement/ Scale	Sample Items	Reference(s)
Communication	Effective communication behaviors	Instances of using names, call outs, and closed-loop communication.	• Frequency of effective communication behaviors • Perception of effective communication behavior frequency with three items	"How commonly does your team use each other's names to indicate who their communication is intended for?"	N/A
	Communication quality	Communication that is clear, effective, complete, fluent, and on time.	• Perceived communication quality scale with five items	"To what extent was the communication between you and your teammates… clear?"	(González-Romá & Hernández, 2014)
Shared Leadership	Dispersion of leadership behaviors	Instances of train and develop team, provide feedback, monitor team, manage team boundaries, perform team task, solve problems, provide resources, and support social climate.	• Variance of frequency of leadership behaviors enacted by team members • Perception of which team member roles enact leadership behaviors	"Provides team members with task-related instructions"	(Morgeson et al., 2010)
Team Outcomes	Operative duration	The time between the first cut and the final closure.	• Duration of time between when the surgeon applies method of entry and closes all surgical sites.	N/A	N/A
	Perceived effectiveness	The extent to which a team accomplishes its goals.	• Modified Perceived Team Effectiveness scale with 13 items	"The team delivers its commitments on time."	(Pearce & Sims, 2002)

Pink: Study 1
Blue: Study 2

Chapter 4: Results

The purpose of this dissertation was to investigate how surgical modality might influence communication, leadership, and team outcomes. The previous chapter (Methods) outlined the multi-method approach that was employed for this dissertation. In study one, robotic and laparoscopic surgical team member behaviors were assessed through an archival video analysis of actual surgical procedures. In study two, open, laparoscopic, and robotic surgical team member perceptions were gleaned through questionnaire methods. In both studies, communication, leadership, and team outcomes were measured. This chapter details reliability statistics, hypothesized analyses, and exploratory analyses for both studies. All analyses were conducted using IBM's SPSS statistical package version 26. All appropriate assumptions tests were carried out for each analysis and any violations that occurred are detailed for the relevant analysis. In addition, it should be noted that the hypotheses appear in the order they were presented at the end of Chapter 2 (Literature Review). This chapter describes the results for study one (hypotheses 1, 3, 5, and 7) and then for study two (hypotheses 2, 4, 6, and 8) as well as exploratory hypotheses for both studies (all results are summarized in Tables 27 and 28).

Study 1: Video Analysis of Robotic and Laparoscopic Procedures

As detailed in the methods, 22 videos of surgeries were coded for communication behaviors (names, call outs, and closed-loop communication), leadership behaviors (train and develop team, provide feedback, monitor team, manage team boundaries, perform team task, solve problems, provide resources, and support social climate), and operative duration from first cut to final closure. Table 12 presents a summary of the means, standard deviations, and correlations for all analyzed variables. Table 13 and 14 provide frequency counts for all of the coded behaviors across the 22 videos.

Table 12. Summary of variable means, standard deviations, and correlations for Study 1.

Variable	1	2	3	4	5	6
1. Rate of names per hour						
2. Rate of call outs per hour	0.39					
3. Rate of closed-loop communication per hour	0.53*	0.38				
4. Rate of leadership behaviors per hour	0.59*	-0.09	0.60*			
5. Shared leadership score	0.37	-0.01	0.10	2.61		
6. Operative duration in hours	0.34	0.28	0.16	-0.18	0.16	
M	4.43	11.40	29.61	90.67	1.19	1.58
SD	4.12	7.70	12.82	43.16	0.31	0.87

Note: *Indicates significant correlations ($p < .05$).

Table 13. Leadership behavior frequency counts for Study 1.

Leadership Behavior Types	Surgeon	Assist	Scrub	Anesthesia Provider	Circulating Nurse	Total
1. Train and develop team	464	4	0	8	8	484 (16%)
2. Provide feedback	237	16	1	2	2	258 (9%)
3. Monitor team	63	22	12	3	11	111 (4%)
4. Manage team boundaries	12	1	3	3	11	30 (1%)
5. Perform team task	704	175	81	9	36	1,005 (33%)
6. Solve problems	62	63	11	14	25	175 (6%)
7. Provide resources	2	117	181	4	59	363 (12%)
8. Support social climate	298	136	56	47	38	575 (19%)
Total	1,842 (61%)	534 (18%)	345 (12%)	90 (3%)	190 (6%)	N = 3,001

Table 14. Communication behavior frequency counts.

Communication Behaviors	Frequency Counts
1. Names	179
2. Call outs	435
3. Closed-loop communication	1,065
Total	1,679

Rater Reliability

To calculate interrater reliability, at the conclusion of data coding, I calculated intra-class correlation coefficient (ICC) estimates and their 95% confidence intervals. I calculated ICC estimates for the 10 videos that I (i.e., Rater 1) coded with one RA (i.e., Rater 2) and for the nine videos that I coded with the other RA (i.e., Rater 3). These calculations were based on a single rater, consistency, 2-way random effects model to allow for measurements to be used from both raters (compared to the mean), account for consistency rather than absolute agreement, and because the raters were chosen from a larger population with similar characteristics. ICC Values less than 0.50 are considered poor, values between 0.50 and 0.75 are considered moderate, values between 0.75 and 0.90 are considered good, and values greater than 0.90 are considered excellent (Koo & Li, 2016). Table 15 presents a summary of the ICC values for each variable by the rater pairs and the overall mean; the full SPSS output is available in Appendix K.

Table 15. Results of ICC calculation in SPSS using single-rating, consistency, 2-way random-effects model.

	Rater 1 & 2	Rater 1 & 3	Mean
Variable 1: Names	0.81	0.96	0.89
Variable 2: Call out	0.81	0.95	0.88
Variable 3: Closed-loop communication	0.96	0.97	0.96
Variable 4: Train and develop team	0.92	0.59	0.75
Variable 5: Provide feedback	0.65	0.86	0.76
Variable 6: Monitor team	0.55	0.41	0.48
Variable 7: Manage team boundaries	0.90	0.59	0.74
Variable 8: Perform team task	0.92	0.96	0.94
Variable 9: Solve problems	0.53	0.62	0.56
Variable 10: Provide resources	0.88	0.87	0.87
Variable 11: Support social climate	0.78	0.88	0.83
Mean	0.79	0.79	

Hypothesized Results

This section presents each of the originally posed hypotheses and their analyses.

Hypotheses 1a, 1b, and 1c and Corresponding Results. Hypothesis 1a proposed that robotic teams would more frequently state team member names to indicate communication directionality. Hypothesis 1b proposed that robotic teams would more frequently utilize call outs to notify team members of task status. Hypothesis 1c proposed that robotic teams would more frequently utilize closed-loop communication. To test these three hypotheses, a one-way MANOVA was performed to assess the effect of surgical modality on the frequency rate of names, call outs, and closed-loop communication. These hypotheses were tested together since they are conceptually related and moderately correlated. Surgical modality included robotic and laparoscopic procedures. Frequency rates of the three communication behaviors were used for analysis to control for the impact of operative duration. The frequency rates were developed for each video by dividing the frequency of each communication behavior by the operative duration. The resultant rates represent the frequency of the behaviors per hour as this was the most understandable unit of time given the nature of the data. Data was not normally distributed for the frequency rate of names as assessed by Shapiro-Wilk test ($p > .05$); no modifications were made.

Data are expressed as mean ± standard deviation. The frequency rate per hour for names was very similar between the robotic (4.44 ± 3.69) and laparoscopic (4.40 ± 5.07) cases. The frequency rate per hour for call outs was higher in the robotic cases (14.19 ± 7.51) than in the laparoscopic cases (6.52 ± 5.51). The frequency rate per hour for closed-loop communication was very similar between the robotic (29.41 ± 10.40) and laparoscopic cases (29.97 ± 17.09). The differences between the modalities on the combined dependent variable was not statistically significant, $F(3, 18) = 2.656$, $p = .080$, Wilks' $\Lambda = 0.693$; partial $\eta^2 = 0.307$ (see Figure 14 for a bar graph of means and standard deviations). Since there was not a statistically significant difference between group means ($p > .05$), we cannot reject the null hypothesis or accept the alternative hypothesis. Although the MANOVA omnibus test failed, the partial eta squared value was moderate and the mean difference between the modalities on the rate of call outs was quite large; this justified the following-up these results by evaluating the post-hoc results for the rate of call outs. The univariate one-way analysis of variance (ANOVA) post-hoc test revealed that there was a statistically significant difference in the rate of call outs between the two modalities, $F(1, 20) = 6.329$, $p = .021$; partial $\eta^2 = 0.240$.

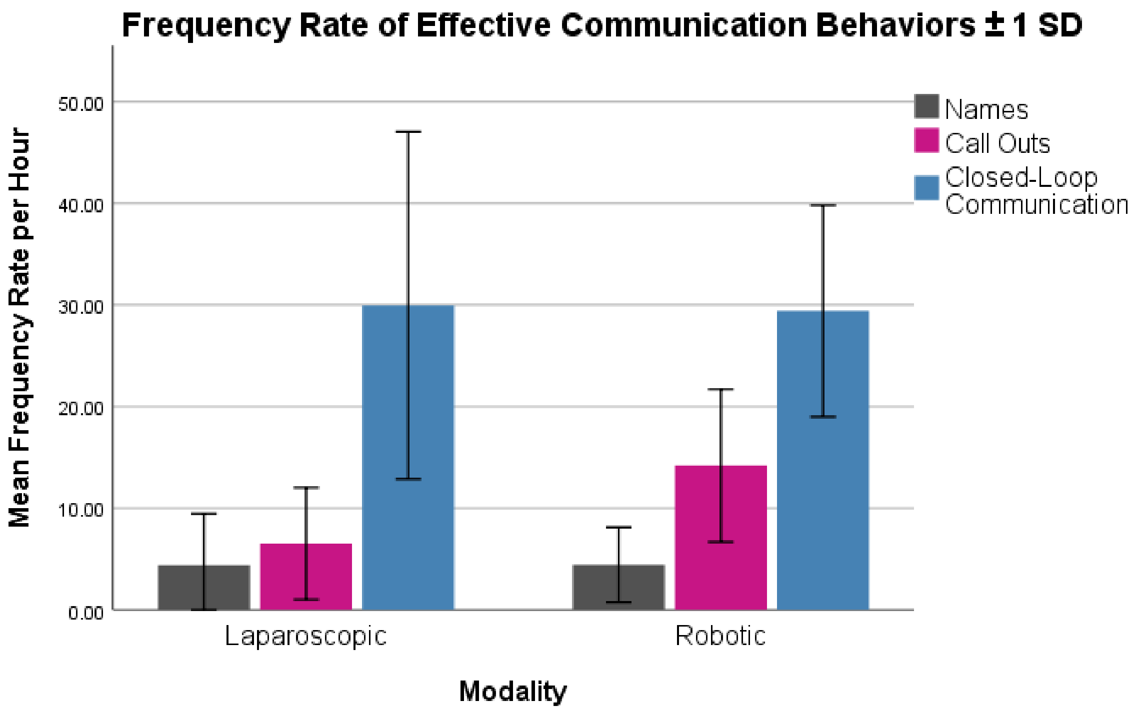

Figure 14. Results of hypotheses 1a, 1b, and 1c.

Hypothesis 3 and Corresponding Results. Hypothesis 3 proposed that robotic teams would exhibit a higher degree of shared leadership, as compared with non-robotic teams. To test this hypothesis, an independent-samples t-test was performed to determine the effect of surgical modality on shared leadership scores. Surgical modality included robotic and laparoscopic procedures. Shared leadership scores were calculated by dividing the standard deviation of the frequency of leadership behaviors exhibited by the five core team members (surgeon, assist (resident or PA), scrub, anesthesia provider, and circulating nurse) by the mean number of leadership behaviors (i.e., the index of dispersion calculation that was described in the Methods chapter). It is important to note that a *higher* shared leadership score is representative of more *centralized* leadership while a *lower* shared leadership score represents more *equal* leadership among the team members.

Data are expressed as mean ± standard deviation. The mean shared leadership scores were very similar between the laparoscopic (1.19 ± 0.45) and the robotic (1.19 ± 0.22) cases. The differences between the modalities on the dependent variable was not statistically significant, $t(20) = -0.030$, $p = .976$ (see Figure 15 for a bar graph of the means and standard deviations). Since there was not a statistically significant difference between group means ($p > .05$), we cannot reject the null hypothesis or accept the alternative hypothesis.

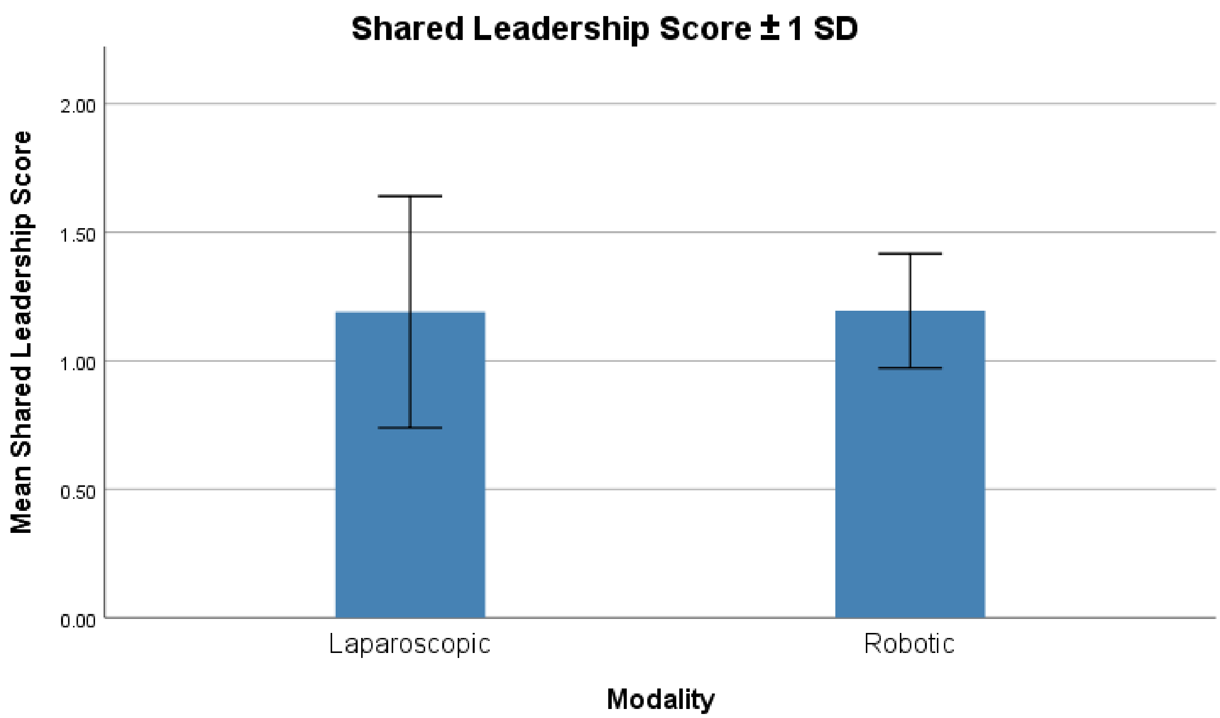

Figure 15. Results of hypothesis 3.

Hypotheses 5 and 7 and Corresponding Results. Hypothesis 5 proposed that surgical teams with a higher frequency of communication behaviors (i.e., names, call outs, and closed-loop communication) would experience a shorter operative duration. Hypothesis 7 proposed that surgical teams with a higher degree of shared leadership would experience a shorter operative duration. To test these hypotheses, a multiple regression was performed to determine if the frequency rate of names, frequency rate of call outs, frequency rate of closed-loop communication, and/or shared leadership score is/are related to operative duration. The communication frequency rates were developed for each video by dividing the frequency of each communication behavior by the operative duration. Shared leadership scores were calculated by dividing the standard deviation of the frequency of leadership behaviors exhibited by the five core team members (surgeon, assist, scrub, anesthesia provider, and circulating nurse) by the mean number of leadership behaviors (i.e., the index of dispersion calculation that was described in the Methods chapter). It is important to note that a *higher* shared leadership score is representative of more *centralized* leadership while a *lower* shared leadership score represents more *equal* leadership among team members. Operative duration was calculated by subtracting the time of *first cut* from the time of *final closure*. The multiple regression model did not significantly predict operative duration, $F(4, 17) = 1.107$, $p = .385$ (see Table 16 for the regression coefficients and standard errors and Figure 16 for the multiple regression scatterplot).

Table 16. Summary of multiple regression analysis for planned hypotheses 5 and 7.

Variable	B	Std. Error	Beta	Sig.
Constant	1.045	0.880		.251
Rate of Names	0.087	0.059	0.412	.158
Rate of Call Outs	0.037	0.027	0.332	.181
Rate of Closed-Loop Communication	-0.012	0.019	-0.184	.523
Shared Leadership Score	0.075	0.647	0.027	.909

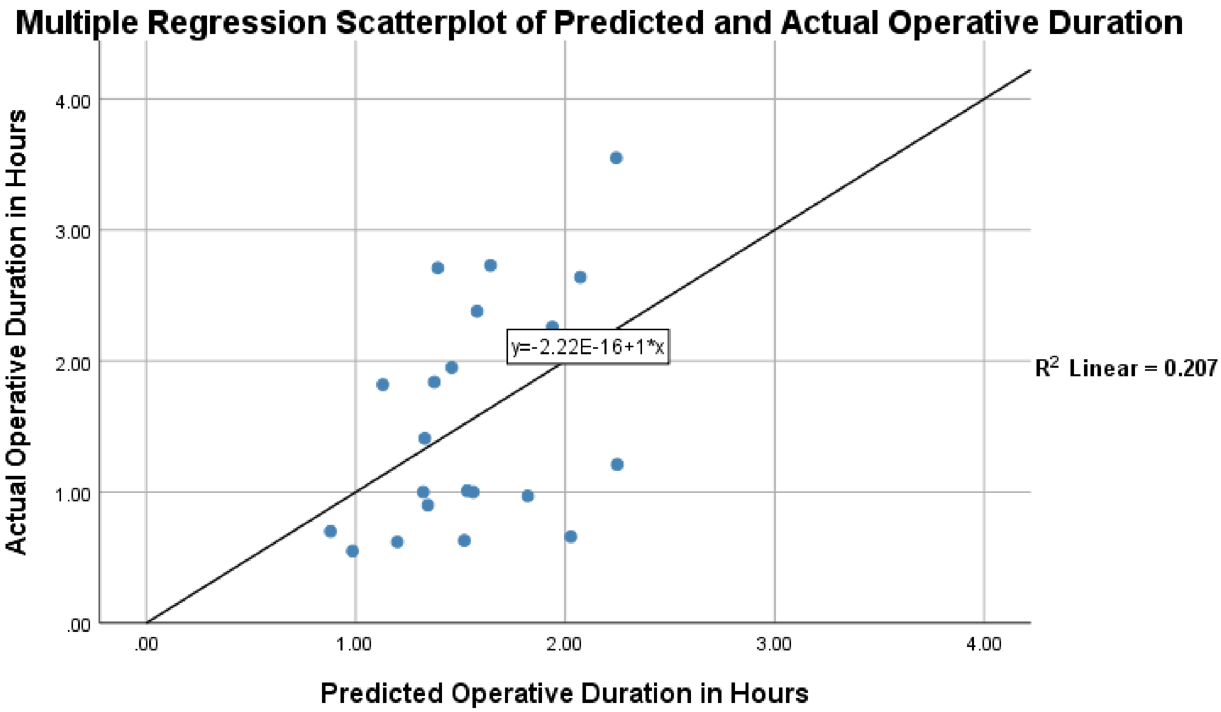

Figure 16. Results for hypotheses 5 and 7.

Exploratory Results

This section presents exploratory hypotheses and their corresponding analyses. These hypotheses were not originally posed when the study began. However, due to the non-significance of hypotheses 1a, 1c, 3, 5, and 7, additional analyses were carried out to further analyze the data. Exploratory hypotheses 9, 10, 11, and 12 build upon planned hypothesis 3 by further exploring leadership. Exploratory hypothesis 9 tests if modality influences the frequency rate of leadership behaviors. Exploratory hypothesis 10 evaluates if modality and role influence the percentage of leadership behaviors carried out by different team roles. Exploratory hypothesis 11 evaluates if team roles influences the leadership behavior *types* that are conducted and exploratory hypothesis 12 evaluates if modality influences the leadership behavior *types* that occurred. Exploratory hypothesis 13 extends planned hypotheses 5 and 7 with a revised regression model that includes modality, procedure type, frequency rate of communications, and shared leadership score. Lastly, exploratory hypothesis 14 is novel from the planned hypotheses and explores surgeon arrival and departure times.

Exploratory Hypothesis 9 and Corresponding Results. Exploratory hypothesis 9 (Figure 17) proposes that surgical modality will affect the frequency rate of leadership behaviors such that a higher rate will occur during laparoscopic surgeries.

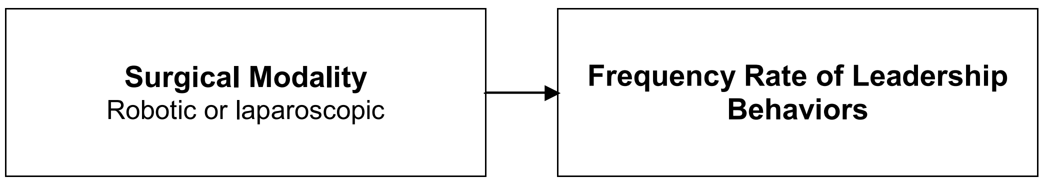

Figure 17. Exploratory hypothesis 9.

To test this hypothesis, an independent samples t-test was performed to determine the effect of surgical modality on the frequency rate of leadership behaviors. Surgical modality included robotic and laparoscopic procedures. The frequency rate of leadership behaviors was used for analysis to control for the impact of operative duration. The frequency rate was developed for each video by dividing the frequency of leadership behaviors by the operative duration. The resultant rate represents the frequency of leadership behaviors per hour as this was the most understandable unit of time given the nature of the data. The assumption of homogeneity of variances was violated, as assessed by Levene's test of equality (p = .038) so the Welch t-test results were evaluated.

Data are expressed as mean ± standard deviation. The frequency rate per hour of leadership behaviors was higher in the laparoscopic cases (124.36 ± 48.97) than in the robotic cases (71.41 ± 24.92), a statistically significant difference of 52.95 (95% CI, 11.07 to 94.83), $t(9.117) = 2.854$, $p = .019$ (see Figure 18 for a bar graph of the means and standard deviations). Since there was a statistically significant difference between means ($p < .05$), we can reject the null hypothesis and accept the alternative hypothesis.

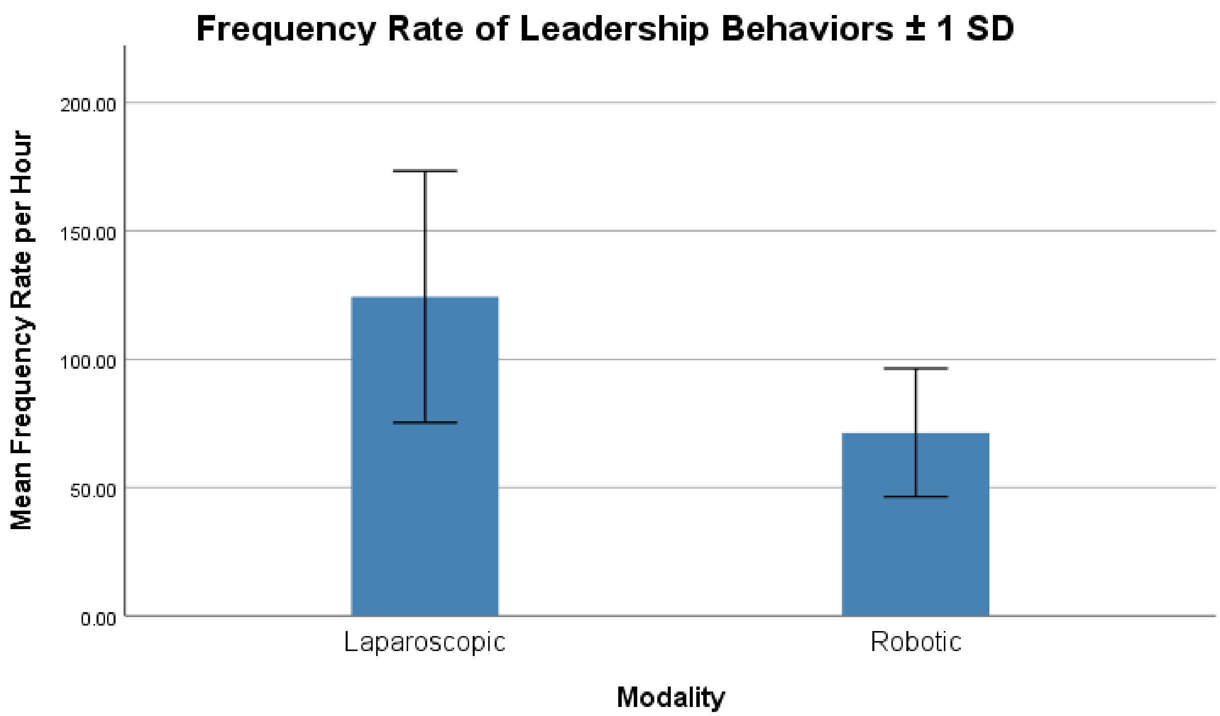

Figure 18. Results of exploratory hypothesis 9.

Exploratory Hypothesis 10 and Corresponding Results. Exploratory hypothesis 10 (Figure 19) proposes that modality and surgical team member role will affect the percentage of the leadership behaviors conducted by each role.

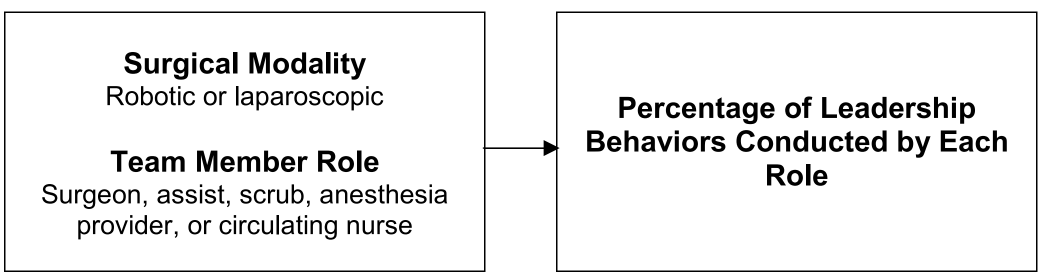

Figure 19. Exploratory hypothesis 10.

To test this hypothesis, a two-way between-groups ANOVA was performed to determine the effect of modality and role on the percentage of leadership behaviors conducted by each role. Surgical modality included robotic and laparoscopic procedures. Team member role groups included surgeons (N = 22), assists (N = 22), scrubs (N = 22), anesthesia providers (N = 22), and circulating nurses (N = 22). The leadership percentages were developed for each role (surgeons, assists, scrubs, anesthesia providers, and circulating nurses) in each video by dividing the number of leadership behaviors carried out by each role by the total frequency of all leadership behaviors in that video. Percentages were chosen for this analysis, compared to the rate with which each behavior occurred, so that differences could be evaluated between roles, regardless of the overall quantity/rate of leadership behaviors carried out in different videos. Two univariate outliers were detected; they were deemed to be genuinely unusual values and kept in this analysis. Data was not normally distributed for all groups assessed by Shapiro-Wilk test ($p < .05$); no modifications were made. Homogeneity of variances was violated, as assessed by Levene's test of equality ($p < .0005$).

Data are expressed as mean ± standard deviation. The surgeon group performed the highest percentage of leadership in both the laparoscopic (59.43% ± 17.52%) and robotic (58.24% ± 11.26%) modalities. Regarding the assist group, the leadership percentage was higher in robotic cases (22.88% ± 11.80%) compared to laparoscopic cases (11.15% ± 8.61%). For the scrub group, the leadership percentage was higher in laparoscopic cases (17.00% ± 11.92%) compared to robotic cases (9.11% ± 6.50%). With reference to the anesthesia provider group, the leadership percentage was slightly higher in laparoscopic cases (4.33% ± 4.96%) compared to robotic cases (2.98% ± 2.45%). Concerning the circulating nurse group, the leadership percentage was slightly higher in laparoscopic cases (8.10% ± 6.74%) compared to robotic cases (6.81% ± 3.23%). There was a statistically significant interaction between modality and role on the percentage of leadership behaviors conducted by each role, $F(4, 100) = 3.112$, $p = .019$, partial $\eta^2 = .110$ (see Figure 20 for a bar graph of means and standard deviations). Therefore, the simple main effects were analyzed for surgical modality and team member role using a Bonferroni adjusted α level of .025.

Analyzing the simple main effects for *modality* demonstrated that there was a statistically significant difference in the percentage of leadership conducted by the assist role. The assist group's leadership percentage in the robotic cases was 11.73% higher than the assist group's leadership percentage in the laparoscopic cases (95% CI, 3.68% to 19.78%), $F(1, 100) = 8.363$, $p = .005$, partial $\eta^2 = .077$.

Analyzing the simple main effects for *role* demonstrated several significant differences. In the laparoscopic cases, the surgeon group performed significantly more leadership than the other four groups. The surgeon group's leadership percentage in the laparoscopic cases was 48.27% higher than the assist group (95% CI, 35.14% to 61.41%), 42.43% higher than the scrub group (95% CI, 29.29% to 55.56%), 55.10% higher than the anesthesia provider group (95% CI, 41.96% to 68.23%), and 51.33% higher than the circulating nurse group (95% CI, 38.19% to 64.46%). The differences between the surgeon and the other four groups were all statistically significant at the $p < .0005$ level. In the robotic cases, the surgeons performed significantly more leadership than the other four roles. The surgeon group's leadership percentage in the robotic cases was 35.36% higher than the assist group (95% CI, 25.43% to 45.28%), 49.13% higher than the scrub group (95% CI, 39.20% to 59.06%), 55.26% higher than the anesthesia provider group (95% CI, 45.33% to 65.18%), and 51.43% higher than the circulating nurse group (95% CI, 41.50% to 61.36%). The differences between the surgeon and the other four groups were all statistically significant at the $p < .0005$ level. In addition, the assists in the robotic cases performed significantly more leadership compared to the scrub, anesthesia provider, and circulating nurse groups. The assist group's leadership percentage in the robotic cases was 13.78% higher than the scrub group (95% CI, 3.85% to 23.70%), 19.90% higher than the anesthesia provider group (95% CI, 9.97% to 28.83%), and 16.07% higher than the circulating nurse group (95% CI, 6.14% to 26.00%). Differences were statistically significant between the assist and scrub ($p = .001$), assist and anesthesia provider ($p < .0005$), and assist and circulating nurse ($p < .0005$) groups.

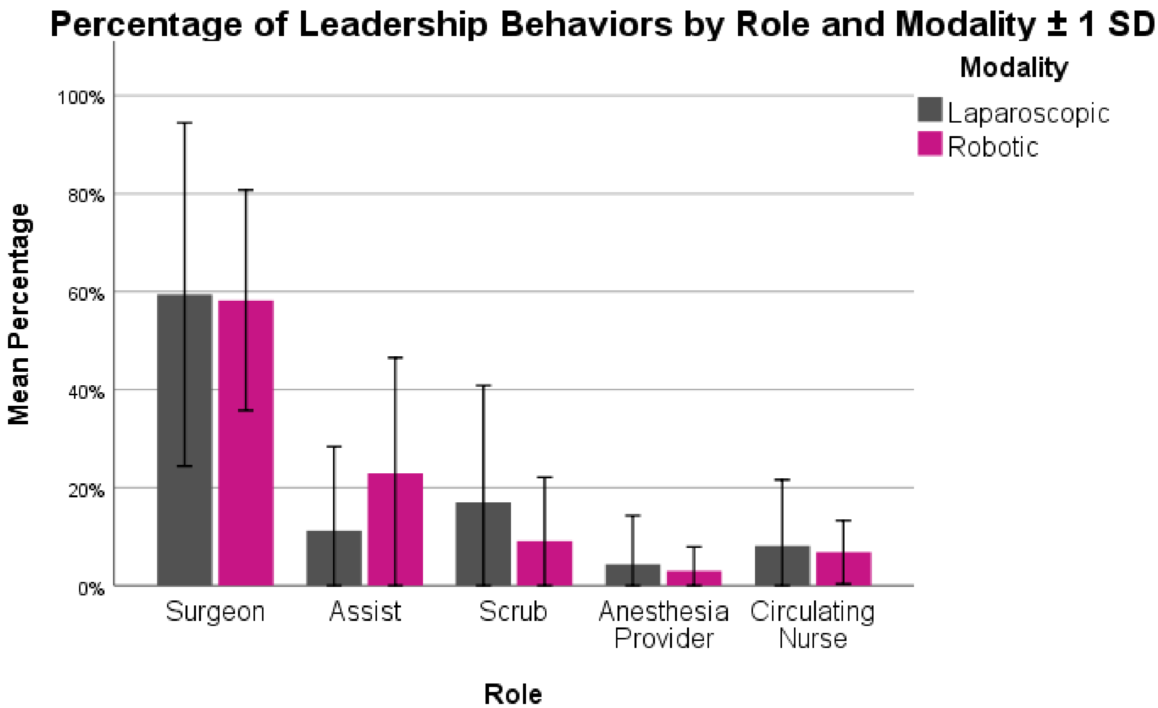

Figure 20. Results of exploratory hypothesis 10.

Exploratory Hypothesis 11 and Corresponding Results. Exploratory hypothesis 11 (Figure 21) proposes that surgical team member role will affect the leadership behavior types that are conducted by each role.

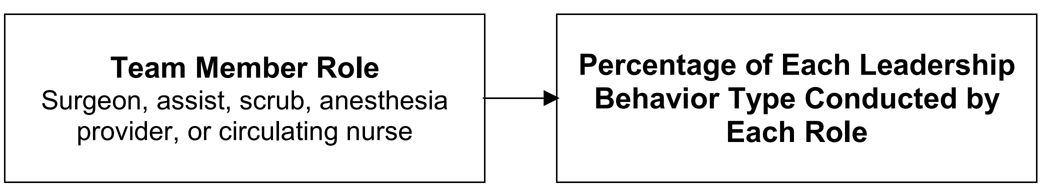

Figure 21. Exploratory hypothesis 11.

To test this hypothesis, a one-way MANOVA was performed to determine the effect of surgical team member role on the percentage of each of the eight leadership behavior types conducted by their role. Team member role groups included surgeons (N = 22), assists (N = 22), scrubs (N = 22), anesthesia providers (N = 22), and circulating nurses (N = 22). The leadership behavior type percentages were developed for each role (surgeons, assists, scrubs, anesthesia providers, and circulating nurses) for each of the eight leadership behavior types (train and develop team, provide feedback, monitor team, manage team boundaries, perform team task, solve problems, provide resources, and support social climate). These percentages were developed for each role in each video by dividing the number of each type of leadership behavior they conducted by the total frequency of that leadership behavior type. Percentages were chosen for this analysis, compared to the rate with which each behavior occurred, so that differences could be evaluated between roles, regardless of the overall quantity/rate of leadership behaviors carried out in different videos. There were numerous univariate outliers and four multivariate outliers; all were deemed to be genuinely unusual values and retained for analysis. Data was not normally distributed for most of the variables; no modifications were made. There was possible multicollinearity between *train and develop team* and *perform team task* ($r = 0.77$); no modifications were made. Homogeneity of variances was violated, as assessed by Levene's test of equality ($p < .0005$), therefore, Pillai's Trace and Games-Howell post-hoc multiple comparisons were evaluated.

Data are expressed as mean ± standard deviation. There was a statistically significant difference between the roles on the combined dependent variables, $F(32, 404) = 7.425$, $p < .0005$; Pillai's Trace = 1.481; partial $\eta^2 = 0.370$ (see Figure 22 for a bar graph of means and standard deviations). Follow-up univariate ANOVAs showed that there were statistically significant differences in the *train and develop team* ($F(4, 105) = 67.162$, $p < .0005$; partial $\eta^2 = 0.719$), *provide feedback* ($F(4, 105) = 7.547$, $p < .0005$; partial $\eta^2 = 0.223$), *monitor team* ($F(4, 105) = 5.723$, $p < .0005$; partial $\eta^2 = 0.179$), *perform team task* ($F(4, 105) = 168.809$, $p < .0005$;

partial $\eta^2 = 0.865$), *solve problems* ($F(4, 105) = 6.594$, $p < .0005$; partial $\eta^2 = 0.201$), *provide resources* ($F(4, 105) = 16.869$, $p < .0005$; partial $\eta^2 = 0.391$), and *support social climate* ($F(4, 105) = 39.071$, $p < .0005$; partial $\eta^2 = 0.598$) leadership behavior types between the different team roles, using a Bonferroni adjusted α level of .025. The only leadership behavior type that was not statistically significant different between the different team roles was *manage team boundaries*.

Regarding the leadership behavior type *train and develop team*, Games-Howell post-hoc tests revealed that the surgeon group conducted the highest percentage of this leadership behavior type (74.17% ± 41.57%) followed by the circulating nurse group (1.55% ± 4.93%), then the anesthesia provider group (0.91% ± 3.16%), then the assist group (0.64% ± 1.67%), and lastly, the scrub group (0.00% ± 0.00%), representing respective decreases of 72.61% (95% CI, 46.09% to 99.14%), 73.26% (95% CI, 46.81% to 99.14%), 73.53% (95% CI, 47.11% to 99.94%), and 74.17% (95% CI, 47.77% to 100.57%). There were statistically significant differences between the surgeon group and the other four groups ($p < .0005$).

With consideration of the leadership behavior type *provide feedback*, Games-Howell post-hoc tests revealed that the surgeon group conducted the highest percentage of this leadership behavior type (25.74% ± 37.38%), followed by the assist group (9.45% ± 19.32%), then the circulating nurse group (0.59% ± 2.07%), then the anesthesia provider group (0.41% ± 1.36%), and lastly, the scrub group (0.17% ± 0.82%), representing respective decreases of 16.29 (95% CI, -9.66% to 42.24%), 25.15% (95% CI, 1.38% to 48.92%), 25.32% (95% CI, 1.57% to 49.08%), and 25.56% (95% CI, 1.82% to 49.31%). There were statistically significant differences between the surgeon and the circulating nurse group ($p = .035$), between the surgeon group and the anesthesia provider group (p = .033), and between the surgeon group and scrub group (p = .031).

Referencing the leadership behavior type *monitor team*, Games-Howell post-hoc tests revealed that the surgeon group conducted the highest percentage of this leadership behavior type (28.09% ± 31.46%), followed by the assist group (17.53% ± 23.31%), then the scrub group (8.48% ± 18.27%), then the circulating nurse group (8.01% ± 12.33%), and lastly, the anesthesia provider group (1.52% ± 4.90%), representing respective decreases of 10.56% (95% CI, -13.32% to 34.43%), 19.61% (95% CI, -2.74% to 41.95%), 20.08% (95% CI, -0.94% to 41.11%), and 26.58% (95% CI, 6.44% to 46.72%). There were statistically significant differences between the surgeon group and the anesthesia provider group (p = .006) and between the assist group and the anesthesia provider group (p = .033).

Referencing the leadership behavior type *manage team boundaries*, Games-Howell post-hoc tests revealed that the surgeon group conducted the highest percentage of this leadership behavior type (11.36% ± 21.45%), followed by the circulating nurse group (7.20% ± 16.32%), then the anesthesia provider group (3.79% ± 14.49%), then the scrub group (2.65% ± 8.68%), and lastly, the assist group (2.27% ± 10.66%), representing respective decreases of 4.17% (95% CI, -8.39% to 16.72%), 7.58% (95% CI, -4.98% to 20.13%), 8.71% (95% CI, -3.84% to 21.27%), 9.09% (95% CI, -3.46% to 21.65%). There were no statistically significant differences between any of the groups ($p < .05$).

With regard to the leadership behavior type *perform team task*, Games-Howell post-hoc tests revealed that the surgeon group conducted the highest percentage of this leadership behavior type (69.97% ± 16.71%), followed by the assist group (17.45% ± 12.79%), then the scrub group (8.76% ± 8.30%), then the circulating nurse group (4.02% ± 4.06%), and lastly, the anesthesia provider group (0.76% ± 1.47%), representing respective differences of 52.52% (95% CI, 39.70% to 65.35%), 61.22% (95% CI, 49.69% to 72.74%), 65.95% (95% CI, 55.13% to 76.78%), and 69.22% (95% CI, 58.57% to 79.86%). There were statistically significant differences between the surgeon group and the other four groups ($p < .0005$), between the assist group and circulating nurse group ($p = .001$), between the assist group and the anesthesia provider group ($p < .0005$), between the scrub group and the anesthesia group ($p = .002$), and between the circulating nurse group and the anesthesia provider group ($p = .012$).

Considering the leadership behavior type *solve problems*, Games-Howell post-hoc tests revealed that the surgeon group conducted the highest percentage of this leadership behavior type (25.12% ± 20.78%), followed by the assist group (22.92% ± 22.35%), then the circulating nurse group (9.00% ± 13.16%), then the scrub group (7.32% ± 12.71%), and lastly, the anesthesia provider group (5.63% ± 12.82%), representing respective differences of 2.20% (95% CI, -16.35% to 20.75), 16.12% (95% CI, 1.06% to 31.19%), 17.80% (95% CI, 2.87% to 32.74%), and 19.49% (95% CI, 4.52% to 34.46%). There were statistically significant differences between the surgeon group and the circulating nurse group ($p = .031$), between the surgeon group and the scrub group ($p = .013$), between the surgeon and the anesthesia provider group ($p = .006$), and between the assist group and the anesthesia provider group ($p = .027$).

With reference to the leadership behavior type *provide resources*, Games-Howell post-hoc tests revealed that the scrub group conducted the highest percentage of this leadership behavior type (41.91% ± 32.25%), followed by the assist group (33.68% ± 32.02%), then the circulating nurse group (23.39% ± 16.52%), then the anesthesia provider group (0.68% ± 2.26%), and lastly, the surgeon group (0.34% ± 1.29%), representing respective differences of 8.24% (95% CI, -19.37% to 35.85%), 18.53% (95% CI, -3.82% to 40.88%), 41.23% (9%% CI, 20.72% to 61.75%), and 41.57% (95% CI, 21.08% to 62.06%). There were statistically significant differences between the scrub group and the anesthesia provider group ($p < .0005$), between the scrub group and the surgeon group ($p < .0005$), between the assist group at the anesthesia provider group ($p = .001$), between the assist group and the surgeon group ($p = .001$), between the circulating nurse group and the anesthesia provider group ($p < .0005$), and between the circulating nurse group and the surgeon group ($p < .0005$).

Regarding the leadership behavior type *support social climate*, Games-Howell post-hoc tests revealed that the surgeon group conducted the highest percentage of this leadership behavior type (47.31% ± 18.27%), followed by the assist group (23.29% ± 14.64%), then the scrub group (10.75% ± 13.54%), then the anesthesia provider group (8.53% ± 8.18%), and lastly, the circulating nurse group (5.58% ± 5.56%), representing respective differences of 24.02% (95% CI, 9.77% to 38.28%), 36.57% (95% CI, 22.70% to 50.44%), 38.79% (95% CI, 26.38% to 51.19%), and 41.74% (95% CI, 29.78% to 53.70%). There were statistically significant differences between the surgeon group and the other four groups ($p < .0005$), between the assist group and the scrub group ($p = .039$), between the assist group and the anesthesia provider group ($p = .002$), and between the assist group and the circulating nurse group ($p < .0005$). Since there was a statistically significant difference between means ($p < .05$), we can reject the null hypothesis and accept the alternative hypothesis.

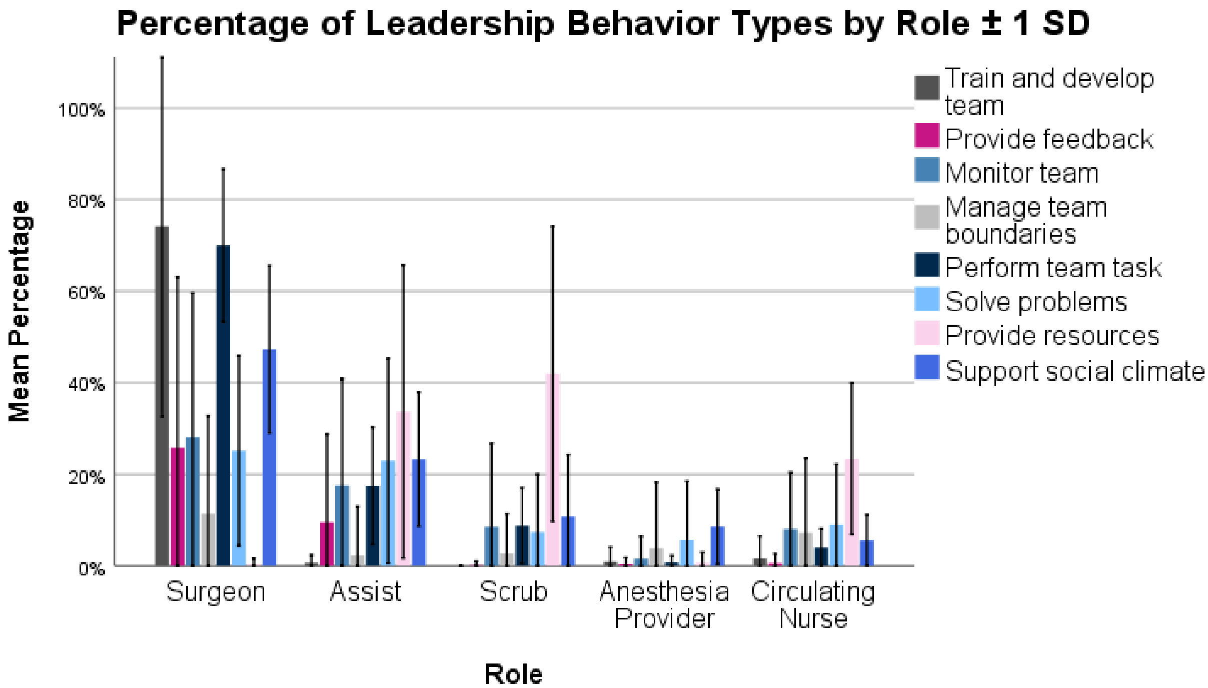

Figure 22. Results of exploratory hypothesis 11.

Exploratory Hypothesis 12 and Corresponding Results. Exploratory hypothesis 12 (Figure 23) proposes that surgical modality will affect the leadership behavior types that are conducted.

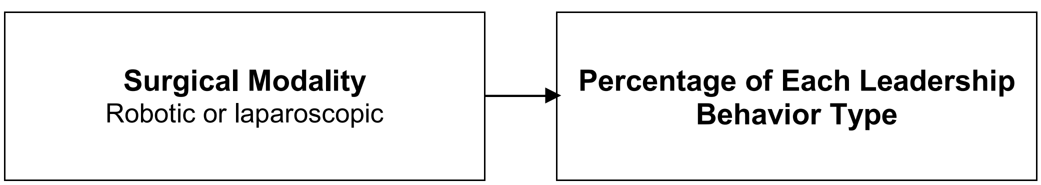

Figure 23. Exploratory hypothesis 12.

To test this hypothesis, a one-way MANOVA was performed to determine the effect of surgical modality on the percentage of each of the eight different leadership behavior types relative to the total number of leadership behaviors that occurred. Surgical modality included robotic and laparoscopic procedures. Percentages for each leadership behavior type were developed for each video by dividing the frequency of each leadership behavior type (train and develop team, provide feedback, monitor team, manage team boundaries, perform team task, solve problems, provide resources, and support social climate) by the total frequency of all leadership behaviors for that video. Percentages were chosen for this analysis, compared to the rate with which each behavior occurred, so that differences could be evaluated between modality, regardless of the overall quantity/rate of leadership behaviors. There were several univariate outliers and data was not normally distributed for all variables; no modifications were made. This analysis barely met the sample size requirement since there are eight cases in the laparoscopic condition and there are eight dependent variables (i.e., the leadership behavior types). Homogeneity of variance-covariance matrices was violated, as assessed by Levene's test of equality ($p < .0005$), therefore, Pillai's Trace was used instead of Wilk's Lambda.

Data are expressed as mean ± standard deviation. The leadership behavior type *perform team task* was the most prevalent leadership behavior type in both modalities and accounted for more of the total leadership observed in the robotic cases (38.07% ± 7.56%) than the laparoscopic cases (27.38% ± 8.80%). The leadership behavior type *support social climate* also occurred frequently in both modalities and accounted for more of the total leadership in the laparoscopic cases (23.87% ± 14.13%) than in the robotic cases (19.71% ± 7.87%). The leadership behavior type *train and develop team* also occurred frequently and accounted for more of the total leadership in the laparoscopic cases (20.38% ± 16.12%) than in the robotic cases (9.79% ± 8.96%). The leadership behavior type *provide resources* occurred with similar frequency in both modalities and accounted for slightly more of the total leadership in the laparoscopic cases (11.88% ± 5.46%) than in the robotic cases (11.57% ± 3.52%). The leadership behavior type *provide feedback* accounted for more of the total leadership in the laparoscopic cases (10.12% ± 9.67%) than in the robotic cases (6.07% ± 2.76%). The leadership behavior type *solve problems* occurred relatively infrequently and accounted for more of the total leadership in the robotic cases (8.14% ± 4.24%) than in the laparoscopic cases (2.25% ± 2.71%). The leadership behavior type *monitor team* also occurred relatively infrequently and accounted for more of the total leadership in the robotic cases (5.36% ± 2.68%) than in the laparoscopic cases (1.25% ± 1.39%). The leadership behavior type *manage team boundaries* occurred least frequently and accounted for more of the total leadership in the laparoscopic cases (1.75% ± 3.41%) than in the robotic cases (0.86% ± 1.29%).

There was a statistically significant difference between the modalities on the combined dependent variables, $F(8, 13) = 5.745$, $p = .003$; Pillai's Trace = 0.780; partial $\eta^2 = 0.780$ (see Figure 24 for a bar graph of means and standard deviations). Since there was a statistically significant difference between means ($p < .05$), we can reject the null hypothesis and accept the alternative hypothesis. Follow-up univariate ANOVAs demonstrated that the differences were statistically significant for the leadership behavior type percentages for *monitor team* ($F(1, 20) = 16.095$, $p = .001$; partial $\eta^2 = 0.446$), *perform team task* ($F(1, 20) = 9.067$, $p = .007$; partial $\eta^2 = 0.312$), and *solve problems* ($F(1, 20) = 12.397$, $p = .002$; partial $\eta^2 = 0.383$), using a Bonferroni adjusted α level of .025.

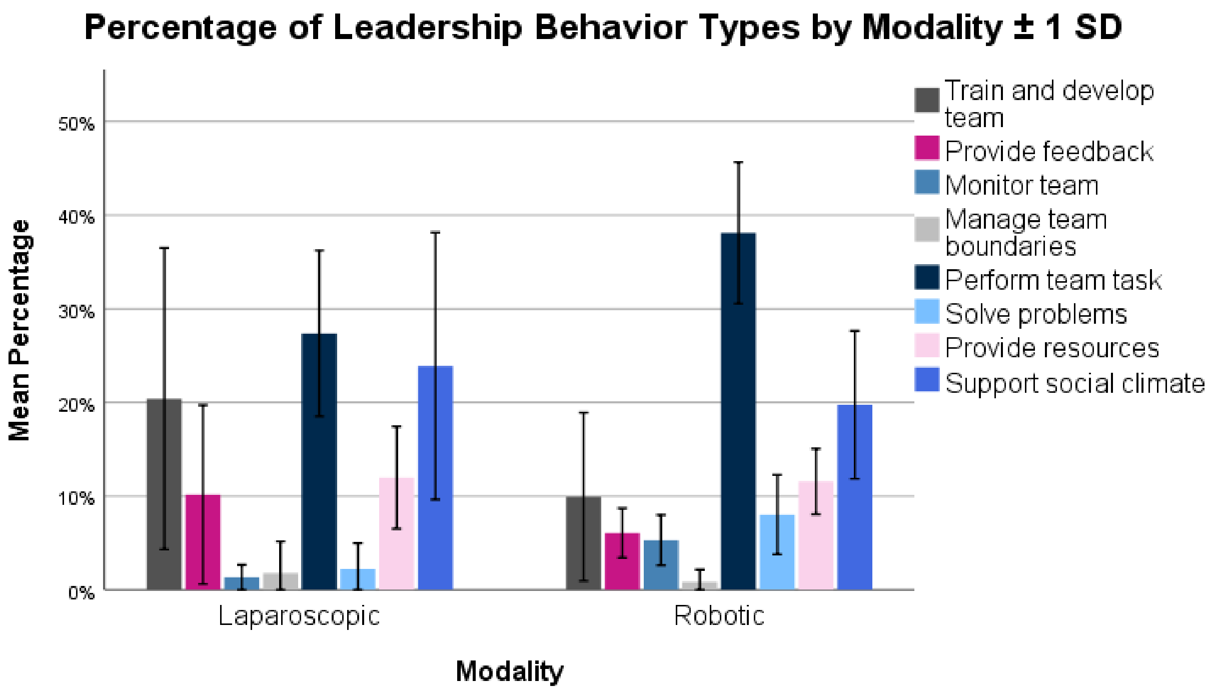

Figure 24. Results of exploratory hypothesis 12.

Exploratory Hypothesis 13 and Corresponding Results. Exploratory hypothesis 13 (Figure 25) proposes that modality, procedure type, frequency rate of communication behaviors, and shared leadership score will predict operative duration such that laparoscopic hernias with higher rates of communication and greater shared leadership will experience shorter operative durations.

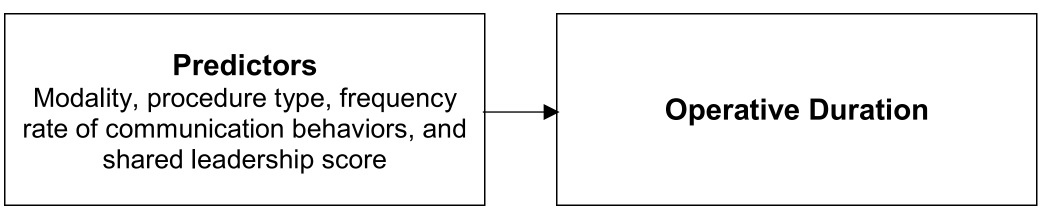

Figure 25. Exploratory hypothesis 13.

To test this hypothesis, a multiple linear regression was performed to determine if procedure type, modality type, frequency of communication behaviors and/or shared leadership score is/are related to operative duration. Procedure type included inguinal hernia repairs and right colectomies. Surgical modality included robotic and laparoscopic procedures. The overall communication behavior frequency rate was developed for each video by dividing the frequency of all communication behaviors by the operative duration. Shared leadership scores were calculated by dividing the standard deviation of the frequency of leadership behaviors exhibited by the five core team members (surgeon, assist, scrub, anesthesia provider, and circulating nurse) by the mean number of leadership behaviors (i.e., the index of dispersion calculation that was described in the Methods chapter). It is important to note that a *higher* shared leadership score is representative of more *centralized* leadership while a *lower* shared leadership score represents more *equal* leadership among team members. Modality and procedure type were entered as covariates to see if the frequency rate of communicate behaviors and/or the shared leadership score added significantly to the model while controlling for modality and procedure type. The R^2 value increased from 0.797 to 0.846 when the rate of communication behaviors and shared leadership variables were added to the model, representing an R^2 increase of 0.049. The multiple regression model significantly predicted operative duration, $F(4, 17) = 23.333$, $p < .0005$ (see Table 17 for the regression coefficients and standard errors and Figure 26 for the multiple regression scatterplot). Modality, procedure type, and shared leadership score significantly contributed to the model while rate of communication behaviors did not ($p < .05$).

Table 17. Summary of multiple regression analysis for exploratory hypothesis 13.

Variable	B	Std. Error	Beta	Sig.
Constant	-1.764	0.458		.001
Modality	0.504	0.190	0.775	.000
Procedure	1.366	0.181	0.286	.013
Shared Leadership Score	0.622	0.268	0.225	.033
Rate of Communication Behaviors	-0.002	0.005	-0.043	-.679

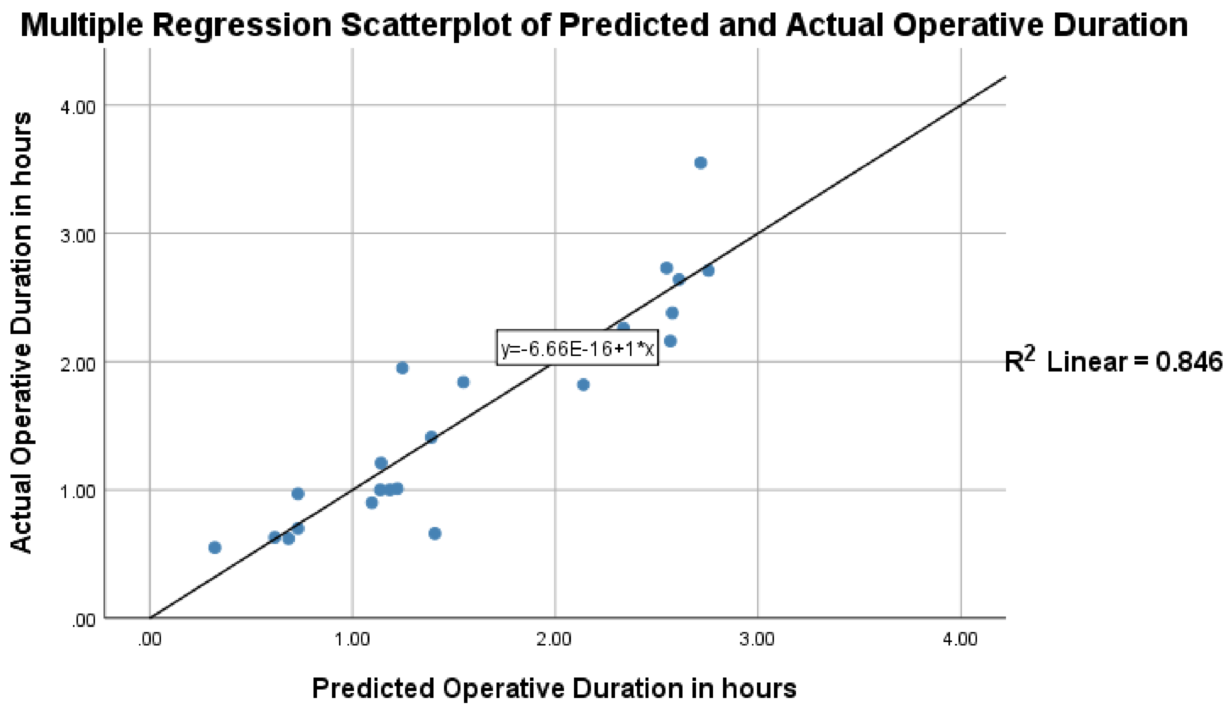

Figure 26. Results of exploratory hypothesis 13.

Exploratory Hypothesis 14 and Corresponding Results. Exploratory hypothesis 14 (Figure 27) proposes that the surgeons in the robotic cases will arrive earlier and stay later, as compared with the surgeons in the laparoscopic cases.

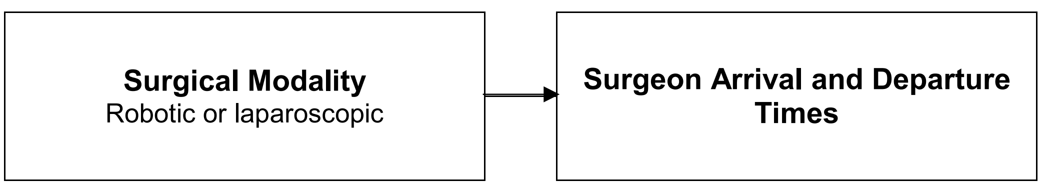

Figure 27. Exploratory hypothesis 14.

To test this hypothesis, a one-way MANOVA was performed to compare the time between surgeon arrival and the first cut and the time between surgeon departure and final suture. It should be noted that all surgeons arrived prior to first cut, however, most surgeons left before final closure since oftentimes the assist completed final closure, therefore, the arrival relative to first cut is a positive duration while the departure relative to final closure is a negative duration that indicates the time between surgeon departure and final closure.

Data are expressed as mean ± standard deviation. On average, the surgeons in the robotic cases arrived more minutes earlier (9.59 ± 6.79) than the surgeons in the laparoscopic cases (8.22 ± 5.94). The surgeons in the laparoscopic cases departed the room more minutes (4.70 ± 4.58) before final closure, compared with the surgeons in the robotic cases who stayed longer and left less minutes (2.96 ± 6.86) before final closure. The differences between the modalities on the combined dependent variable was not statistically significant, $F(2, 19) = 0.235$, $p = .793$; partial $\eta^2 = 0.024$ (see Figure 28 for a bar graph of means and standard deviations). Since there was not a statistically significant difference between group means ($p > .05$), we cannot reject the null hypothesis or accept the alternative hypothesis.

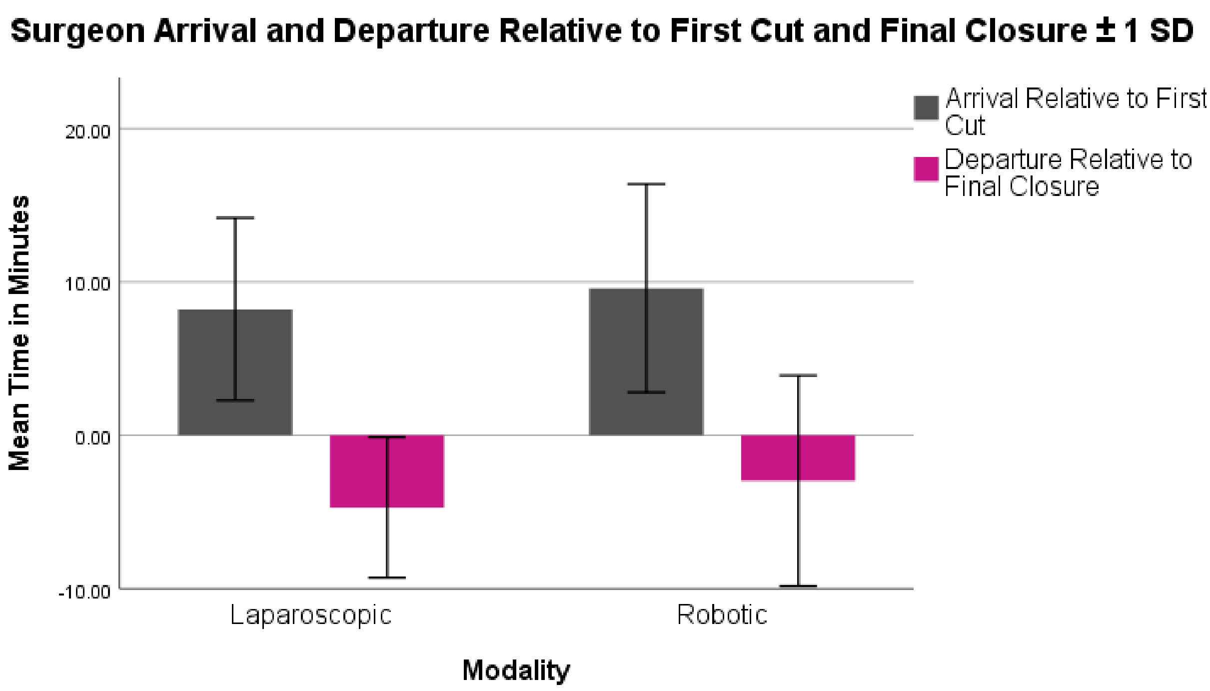

Figure 28. Results of exploratory hypothesis 14.

Summary

In total, twelve analyses were carried out to analyze the data from study one. Support was only provided for one of the six planned hypotheses. Conversely, five of the six exploratory hypotheses were supported. The significance or lack of significance for each analysis is discussed in Chapter 5 (Discussion).

Study 2: Survey Analysis of Surgical Team Member Perceptions

As detailed in Chapter 3 (Methods), 144 surgical team members responded to an online survey regarding their perceptions of communication, leadership, and team effectiveness. Participants also answered several demographic, surgical experience, and team familiarity questions. Table 18 presents means, standard deviations, and correlations for all analyzed variables. Table 19 provides an overview of the demographic data for gender, age, and duration in current role. Table 20 presents the primary modality data.

Other demographic questions queried participants about their race, area of specialty, the robotic system they typically use (if applicable), and the number of people on their team for a typical surgery. In terms of race, 63 participants selected "White," 58 participants elected to not respond, 16 participants selected "Native Hawaiian or Other Pacific Islander," five participants selected "Black or African American," and two participants selected several races. Participants represented a broad range of specialties including general surgery, obstetrics and gynecological, ophthalmic surgery, orthopedic surgery, urology, thoracic surgery, cardiac surgery, colon and rectal surgery, vascular surgery, neurological surgery, trauma, transplant, pediatric surgery, otolaryncgology, oral, plastic and maxiollofacial surgery. Most (78.79%) of the participants who indicated that they perform or assist with robotic surgery also indicated that they utilize the da Vinci Xi robotic surgical system. Only a few (12.12%) indicated that they use the da Vinci Si robotic surgical system and several (9.09%) indicated that they use both the da Vinci Xi and Si robotic surgical systems. On average, participants indicated that they work with a team of about five people (M = 5.49, SD = 2.90) during a given surgery.

Table 18. Summary of variable means, standard deviations, and correlations for Study 2.

Variable		1	2	3	4	5	6	7
1.	Perception of communication quality	(0.95)						
2.	Perception of communication behaviors	0.59*	(0.94)					
3.	Perception of shared leadership	0.18*	-0.11	(n/a)				
4.	Perception of team effectiveness	0.83*	0.62*	-0.13	(0.97)			
5.	Duration in current role in years	0.01	-0.16	0.33*	-0.05	(n/a)		
6.	Perception of team familiarity	0.21*	0.23*	-0.03	0.33*	-0.04	(n/a)	
7.	Age in years	0.00	-0.18*	0.26*	-0.05	0.87*	0.03	(n/a)
	M	4.17	4.11	0.71	4.07	9.29	3.20	39.52
	SD	0.84	0.93	0.59	0.85	10.19	0.70	11.85

Note: The diagonal contains Cronbach's Alpha reliability estimates. *Indicates significant correlations ($p < .05$).

Table 19. Demographic data for Study 2.

	Gender			Age (in years)	Duration in Current Role (in years)
	Male	Female	Prefer not to say		
Surgeons (N = 35)	80% (N = 28)	20% (N = 7)	-	47.4 ± 11.96	14.81 ± 12.62
Residents (N = 23)	69.6% (N = 16)	26.1% (N = 6)	4.3% (N = 1)	30 ± 2.73	2.13 ± 1.38
Anesthesiologists (N = 21)	42.9% (N = 9)	52.4% (N = 11)	4.8% (N = 1)	41.28 ± 8.74	9.55 ± 7.66
Scrubs (N = 17)	58.8% (N = 10)	41.2% (N = 7)	-	36.12 ± 10.19	10.31 ± 11.30
Circulating Nurses (N = 48)	12.5% (N = 6)	85.4%) (N = 41)	2.1% (N = 1)	38.79 ± 12.50	8.23 ± 9.06
Total (N = 144)	47.9% (N = 69)	50% (N = 72)	2.1% (N = 3)	39.52 ± 11.85	9.29 ± 10.19

Table 20. Primary modality data for Study 2.

	Primary Modality		
	Open	Lap	Robotic
Surgeons (N = 35)	40% (N = 14)	40% (N = 14)	20% (N = 7)
Residents (N = 23)	13% (N = 3)	69.6% (N = 16)	17.4% (N = 4)
Anesthesiologists (N = 21)	33.3% (N = 7)	66.7% (N = 14)	-
Scrubs (N = 17)	64.7% (N = 11)	23.5% (N = 4)	11.8% (N = 2)
Circulating Nurses (N = 48)	41.7% (N = 20)	16.7% (N = 8)	41.7% (N = 20)
Total (N = 144)	38.2% (N = 55)	38.9% (N = 56)	22.9%) (N = 33)

Survey Reliability

In order to ensure that the items for each scale reliably measure the same latent variable, their internal consistency was evaluated by calculating the Cronbach's alpha for each scale (Appendix L). A Cronbach's alpha value of 1.0 indicates perfect association (DeVellis, 2016). The Cronbach's alpha value was 0.95 for the communication quality scale, 0.94 for the communication behaviors scale, and 0.97 for the team effectiveness scale. Since all Cronbach's alpha values were higher than 0.70 and no item reduction led to a substantial increase in Cronbach's alpha, all items were included in the analyses. Cronbach's alpha was not calculated for the Leadership scale due to the checkbox response format in which participants selected as many roles as relevant for each of the 16 leadership behavior items.

Dealing with Missing Data

A common problem with survey research is missing data. Among the 144 participants surveyed, 29 did not fully complete the questionnaire. The quantity of missing data among those 29 participants frequently only involved omitting one response in the entire survey (N = 15), with the majority of respondents omitting three items or less (N = 21). There were two participants who did not answer 15 of the 16 leadership items, one participant who did not answer five of the six communication behavior items, and four participants who did not answer three of the four team familiarity questions. Since these participants did not complete at least half of the scale, their responses to those scales were not used for analysis. For the other cases of missing data, we took the approach suggested by Shrive et al. (2006) to impute the participant's mean for the scale for the missing item(s) in that scale.

Preliminary Data Analyses

Several preliminary analyses were conducted to ensure that the primary modality groups of open, laparoscopic, and robotic were comparable in terms of the participants' experience level (i.e., duration in current role), team training background, and perceptions of team familiarity. Data are expressed as mean ± standard deviation. Reported duration in current role in years increased from the robotic group (8.71 ± 9.30), to the laparoscopic group (8.86 ± 9.34), to the open group (10.09 ± 11.57); there were no statistically significant differences between the three modalities. With regard to team training history, nearly sixty-percent of participants indicated that they had received some sort of team training and the majority (52%) of those participants reported that they received that training less than three years ago; there were no statistically significant differences between the modalities.

Perceived team familiarity was generated based on participants' responses to a series of questions that asked how frequently they work with different team roles. Response options ranged from never (value of 1) to always (value of 5); perceived team familiarity scores were computed by averaging the responses. Data are expressed as mean ± standard deviation. The robotic group perceived the highest degree of team familiarity (3.46 ± 0.73), followed by the open group (3.30 ± 0.60), and then the laparoscopic group (2.96 ± 0.70). A one-way ANOVA was performed and perceived team familiarity was found to be significantly different for the different modalities, $F(2, 137) = 6.633$, $p = .002$., partial $\eta^2 = 0.088$ (see Figure 29 for a bar graph of means and standard deviations). Tukey post-hoc tests revealed that the robotic group's perception of team familiarity was 0.50 (95% CI, 0.15 to 0.85) higher than the laparoscopic group ($p = .003$) and the open group's perception of team familiarity was 0.35 (95% CI, 0.04 to

0.65) higher than the laparoscopic group (p = 0.02). To control for this, primary modality was used as a covariate to test exploratory hypothesis 16.

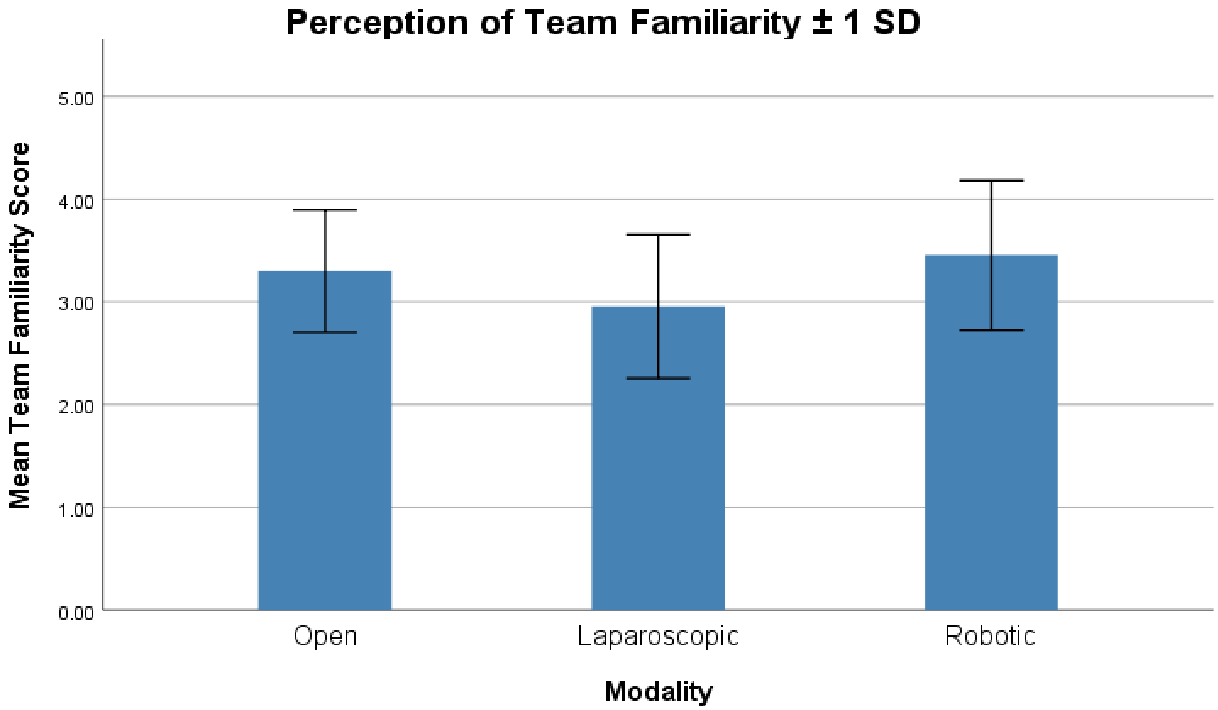

Figure 29. *Results of preliminary team familiarity analysis comparing open, laparoscopic, and robotic modalities.*

Since there were statistically significant differences between the three primary modality groups for perceived familiarity, an independent samples t-test was performed to determine if there were differences between the robotic and non-robotic (consisting of both the open and laparoscopic participants) groups. Data was not normally distributed, as assessed by Shapiro-Wilk test ($p > .05$) and no modifications were made. One univariate outlier was detected and removed from this analysis. Data are expressed as mean ± standard deviation. The robotic group perceived higher team familiarity (3.45 ± 0.73) than the non-robotic group (3.14 ± 0.64), a statistically significant difference of 0.31 (95% CI, 0.05 to 0.57), $t(137) = 2.355$, $p = .020$, d = 0.872 (see Figure 30 for a bar graph of means and standard deviations). To control for this, team familiarity was used as a covariate to test planned hypotheses 2a and 2b.

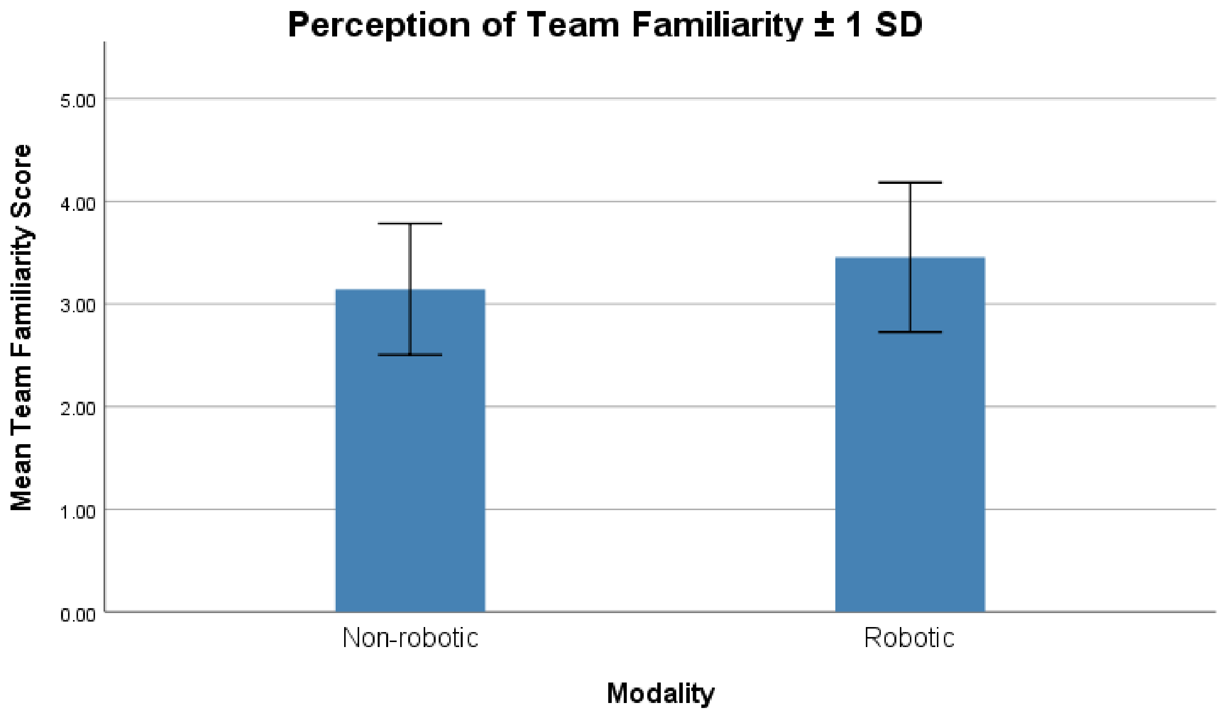

Figure 30. Results of preliminary team familiarity analysis comparing non-robotic and robotic modalities.

Hypothesized Results

This section presents each of the originally posed hypotheses and their analyses.

Hypotheses 2a and 2b and Corresponding Results. Hypothesis 2a proposed that non-robotic team members would perceive higher communication quality, as compared with robotic team members. Hypothesis 2b proposed that robotic team members would perceive higher utilization of communication behaviors (i.e., names, call outs, and closed-loop communication), as compared with non-robotic team members. To test these hypotheses, a one-way multivariate analysis of covariance (MANCOVA) was run to determine the effect of surgical modality (robotic vs. non-robotic) on the perception of effective communication behaviors and perceived communication quality while controlling for the effect of perceived team familiarity. Participants selected whether they primarily perform open, laparoscopic, or robotic procedures and the participants who selected open or laparoscopic were combined to create the non-robotic group that was compared to the robotic group. Two measures of communication were assessed: perceived effective communication behaviors and perceived communication quality. Perceived team familiarity scores were generated for each participant based upon how frequently they reported working with the same team roles. Since perceived team familiarity significantly differed between modalities, it was entered as a covariate for this analysis. Nine multivariate outliers were detected and subsequently removed from this analysis. Data was not normal for all variables as assessed by Shapiro-Wilk test ($p > .05$) and no modifications were made. There was homogeneity of regression slopes, as assessed by the interaction term between primary modality and perceived team familiarity, $F(2, 125) = 0.289$, $p = .749$.

Means and adjusted means were relatively similar (see Table 21) and perceptions of communication behavior were slightly higher in the robotic group; however, there was no statistically significant difference between the modalities on the combined dependent variable after controlling for team familiarity, $F(2, 125) = 0.289$, $p = .749$,Wilks' $\Lambda = 0.995$, partial $\eta^2 = 0.005$. Since there was not a statistically significant difference between group means (p > .05), we cannot reject the null hypothesis or accept the alternative hypothesis.

Table 21. Means, adjusted means, standard deviations, and standard errors for each modality group.

	Communication Quality		Communication Behaviors	
Group	*M (SD)*	M_{adj} *(SE)*	*M (SD)*	M_{adj} *(SE)*
Non-robotic	4.28 (0.59)	4.31 (0.06)	4.25 (0.59)	4.28 (0.05)
Robotic	4.36 (0.52)	4.30 (0.11)	4.53 (0.43)	4.46 (0.10)

Hypothesis 4 and Corresponding Results. Hypothesis 4 proposed that robotic team members would perceive a higher degree of shared leadership, as compared with non-robotic team members. To test this hypothesis, an independent-samples t-test was performed to determine the effect of surgical modality (robotic vs. non-robotic) on perceived shared leadership scores. Perceived shared leadership scores were calculated by dividing the standard deviation of the frequency of leadership behaviors selected for the five team roles (surgeon, resident, scrub, anesthesia provider, and circulating nurse) by the average number of leadership behaviors (i.e., the index of dispersion calculation that was described in the Methods chapter). It is important to note that a *higher* shared leadership score is representative of more *centralized* leadership while a *lower* shared leadership score represents more *equal* leadership among team members. Participants selected whether they primarily perform open, laparoscopic, or robotic procedures. The participants who selected open or laparoscopic were combined to create the non-robotic group that was compared to the robotic group. Fifteen outliers were detected; these values were determined to be genuinely unusual values and kept in this analysis. Data was not normal as assessed by Shapiro-Wilk test ($p > .05$) and no modifications were made.

Data are expressed as mean ± standard deviation. Individuals who perform primarily non-robotic (i.e., open or laparoscopic) surgery perceived a lower shared leadership score (indicative of *greater* shared leadership) (0.69 ± 0.61) than individuals who perform primarily robotic surgery (0.72 ± 0.59). The difference between the modalities on the dependent variable was not significantly significant, $t(125) = -0.219$, $p = .827$ (see Figure 31 for a bar graph of means and standard deviations). Since there was not a statistically significant difference between group means ($p > .05$), we cannot reject the null hypothesis or accept the alternative hypothesis.

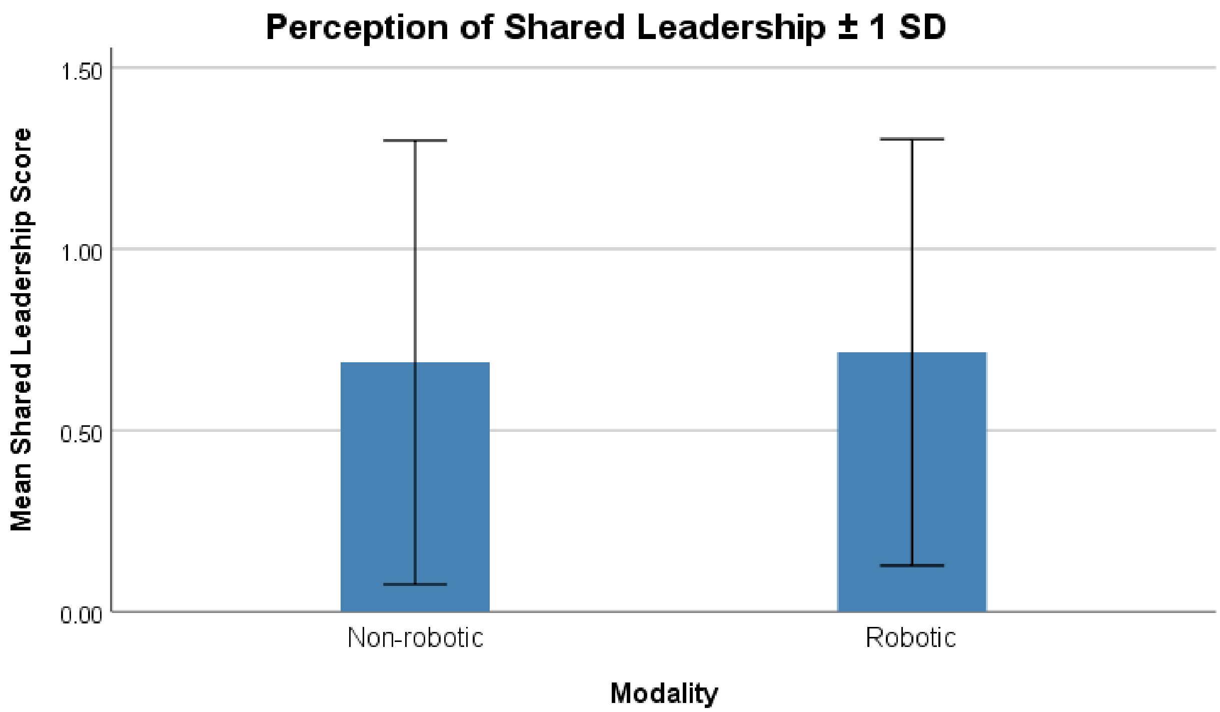

Figure 31. Results of hypothesis 4.

Hypotheses 6a, 6b, and 8 and Corresponding Results. Hypothesis 6a proposed that surgical team members who perceive high communication quality would also rate their team effectiveness higher. Hypothesis 6b proposed that surgical team members who perceive higher utilization of communication behaviors (i.e., names, call outs, and closed-loop communication) among their team would also rate their team effectiveness higher. Hypothesis 8 proposed that surgical team members who perceive leadership to be more shared among their team would rate their team effectiveness higher. To test these hypotheses, a multiple regression was performed to identify if perceived communication behaviors, communication quality, and/or shared leadership is/are related to perceived team effectiveness. Assumptions testing revealed heteroscedastic residuals and a weighted least squares regression was carried out to remediate the effects of this violation. One potential outlier was identified as having a studentized deleted residual greater than ±3 standard deviations and was subsequently removed from this analysis.

The model yielded an R^2 value of 0.755. The weighted least squares multiple regression significantly predicted perceived effectiveness, $F(3, 122) = 126.653$, $p < .0005$ (see Table 22 for the regression coefficients and standard errors and Figure 32 for the multiple regression scatterplot). Perceptions of communication behaviors and communication quality significantly contributed to the model while perceptions of shared leadership did not significantly contribute to the model ($p < .05$).

Table 22. Summary of multiple regression analysis for planned hypotheses 6a, 6b, and 8.

Variable	B	Std. Error	Beta	Sig.
Constant	0.460	0.223		.041
Communication Behaviors	0.180	0.060	0.178	.003
Communication Quality	0.697	0.056	0.741	.000
Shared Leadership Score	-0.006	0.057	-0.005	.919

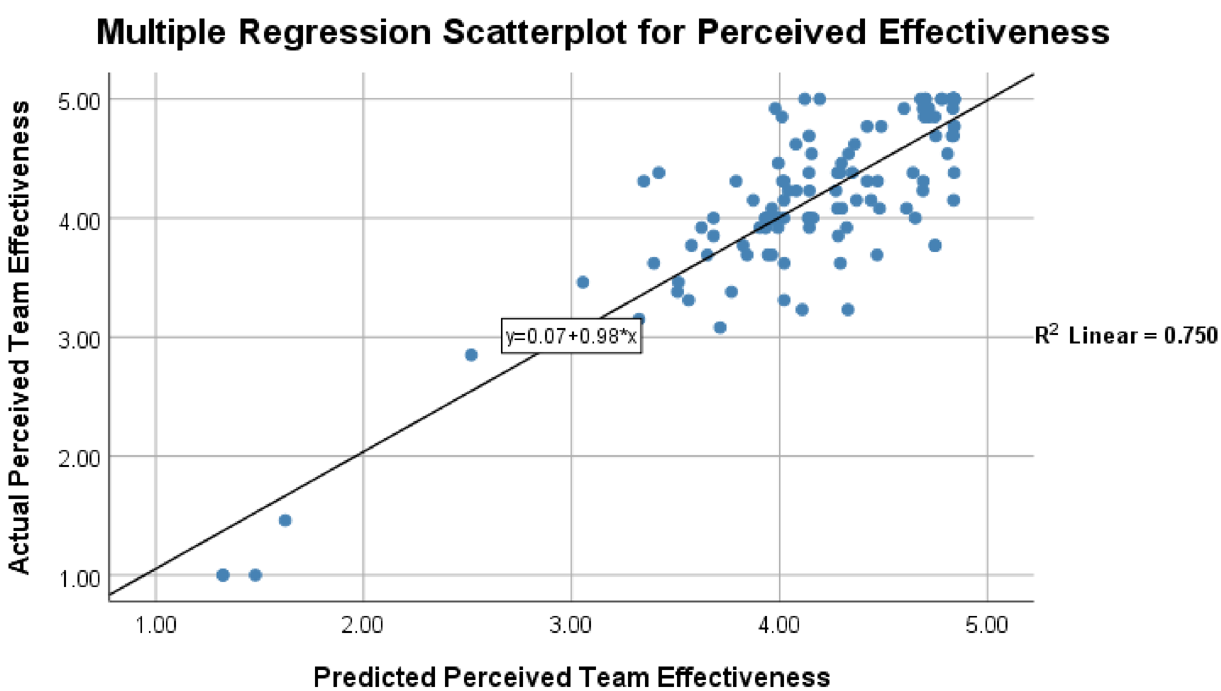

Figure 32. Results of hypotheses 6a, 6b, and 8.

Exploratory Results

This section presents exploratory hypotheses and their corresponding analyses. These hypotheses were not originally posed when the study began. However, due to the non-significance of Hypotheses 2a, 2b, and 4, additional analyses were warranted. Exploratory hypothesis 15 extends planned hypotheses 2a and 2b by evaluating perceptions of communication while considering the three modality groups (open, laparoscopic, robotic) separately as opposed to a composite non-robotic (consisting of open and laparoscopic) and robotic group. Similarly, hypothesis 16 extends hypothesis 4 by evaluating perceptions of shared leadership while considering the three modality groups (open, laparoscopic, robotic) separately as opposed to a composite non-robotic (consisting of open and laparoscopic) and robotic group. Exploratory hypotheses 17, 18, 19, 20, and 21 are all novel explorations. Exploratory hypothesis 18 evaluates if there are differences between participants' perceptions of communication behaviors that they themselves conduct compared to communication behaviors that their team conducts. Exploratory hypothesis 18 investigates if survey respondent role influences the percentage of leadership behaviors they attributed to each role. Lastly, exploratory hypotheses 19, 20, and 21 investigate if perceived team familiarity predicts perceived team effectiveness, perceived communication quality, and perceived communication behaviors, respectively.

Exploratory Hypothesis 15 and Corresponding Results. Exploratory hypothesis 15 (Figure 33) proposes that surgical modality will affect perceived communication behaviors and communication quality while considering the open and laparoscopic groups separately as opposed to a composite non-robotic group.

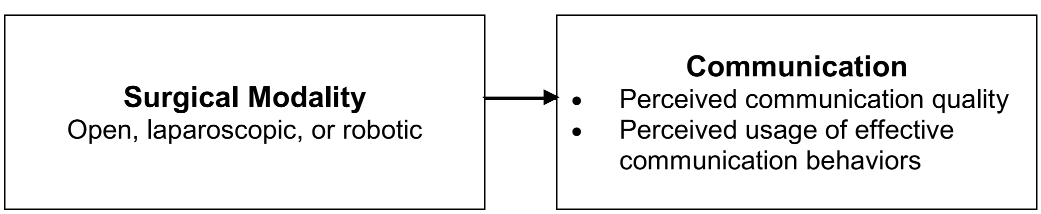

Figure 33. Exploratory hypothesis 15.

To test this hypothesis, a one-way MANCOVA was performed to determine the effect of surgical modality (open, laparoscopic, and robotic) on perceptions of communication quality and communication behavior while controlling for the effect of perceived team familiarity. Participants selected whether they primarily perform open, laparoscopic, or robotic procedures; this exploratory analysis compares these three groups. Two measures of communication were assessed: perceived effective communication behaviors and perceived communication quality. Perceived team familiarity scores were generated for each participant based upon how frequently they reported working with the same team roles. Since perceived team familiarity significantly differed between modalities, it was entered as a covariate for this analysis. Nine multivariate outliers were detected and subsequently removed from this analysis. Data was not normal for all variables as assessed by Shapiro-Wilk test ($p > .05$) and no modifications were made. There was homogeneity of regression slopes, as assessed by the interaction term between primary modality and perceived team familiarity, $F(4, 264) = 1.278$, $p = .279$.

Means and adjusted means were relatively similar (see Table 23) and perceptions of communication quality and communication behavior showed a general trend to be slightly higher in the robotic and open modality groups; however, there was no statistically significant difference between the modalities on the combined dependent variable after controlling for team familiarity, $F(4, 246) = 0.253$, $p = .907$,Wilks' $\Lambda = 0.992$, partial $\eta^2 = 0.004$. Since there was not a statistically significant difference between group means (p > .05), we cannot reject the null hypothesis or accept the alternative hypothesis.

Table 23. Means, adjusted means, standard deviations, and standard errors for each modality group.

	Communication Quality		Communication Behaviors	
Group	*M (SD)*	M_{adj} (*SE*)	*M (SD)*	M_{adj} (*SE*)
Open	4.36 (0.55)	4.34 (0.08)	4.39 (0.49)	4.37 (0.08)
Laparoscopic	4.20 (0.62)	4.29 (0.08)	4.12 (0.65)	4.20 (0.08)
Robotic	4.36 (0.52)	4.30 (0.11)	4.53 (0.57)	4.46 (0.10)

Exploratory Hypothesis 16 and Corresponding Results. Exploratory hypothesis 16 (Figure 34) proposes that surgical modality will affect perceived shared leadership while considering the open and laparoscopic groups separately as opposed to as a composite non-robotic group.

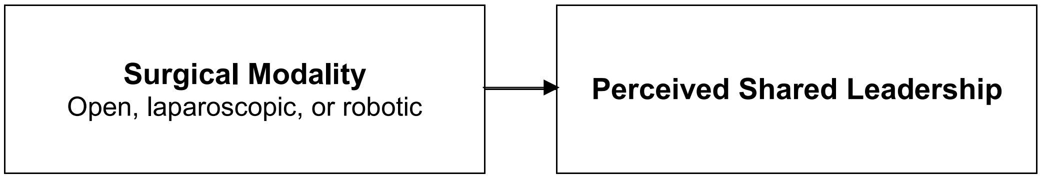

Figure 34. Exploratory hypothesis 16.

To test this hypothesis, a one-way between-groups ANOVA was performed to determine the effect of surgical modality on the shared leadership score. Participants selected whether they primarily perform open, laparoscopic, or robotic procedures; this exploratory analysis compares these three groups. Perceived shared leadership scores were calculated by dividing the standard deviation of the frequency of leadership behaviors selected for the five team roles (surgeon, resident, scrub, anesthesia provider, and circulating nurse) by the average number of leadership behaviors (i.e., the index of dispersion calculation that was described in the Methods chapter). It is important to note that a *higher* shared leadership score is representative of more *centralized* leadership while a *lower* shared leadership score represents more *equal* leadership among team members. Fifteen outliers were detected; these values were determined to be genuinely unusual and kept in this analysis. Data was not normal as assessed by Shapiro-Wilk test ($p > .05$) and no modifications were made. The assumption of homogeneity of variances was violated, as assessed by Levene's test of equality ($p = .003$), therefore, the results of the Welch ANOVA were evaluated

Data are expressed as mean ± standard deviation. Individuals who perform primarily laparoscopic surgery perceived the most shared leadership (represented by the *lowest* scores) (0.55 ± 0.49), followed by individuals who perform primarily robotic surgery (0.72 ± 0.59), and then individuals who perform primarily open surgery (0.83 ± 0.69). The difference between the modalities on the dependent variable was not significantly significant, Welch's $F(2, 71.3) = 2.901$, $p = .061$ (see Figure 35 for a bar graph of means and standard deviations). Since there was not a statistically significant difference between group means ($p > .05$), we cannot reject the null hypothesis or accept the alternative hypothesis.

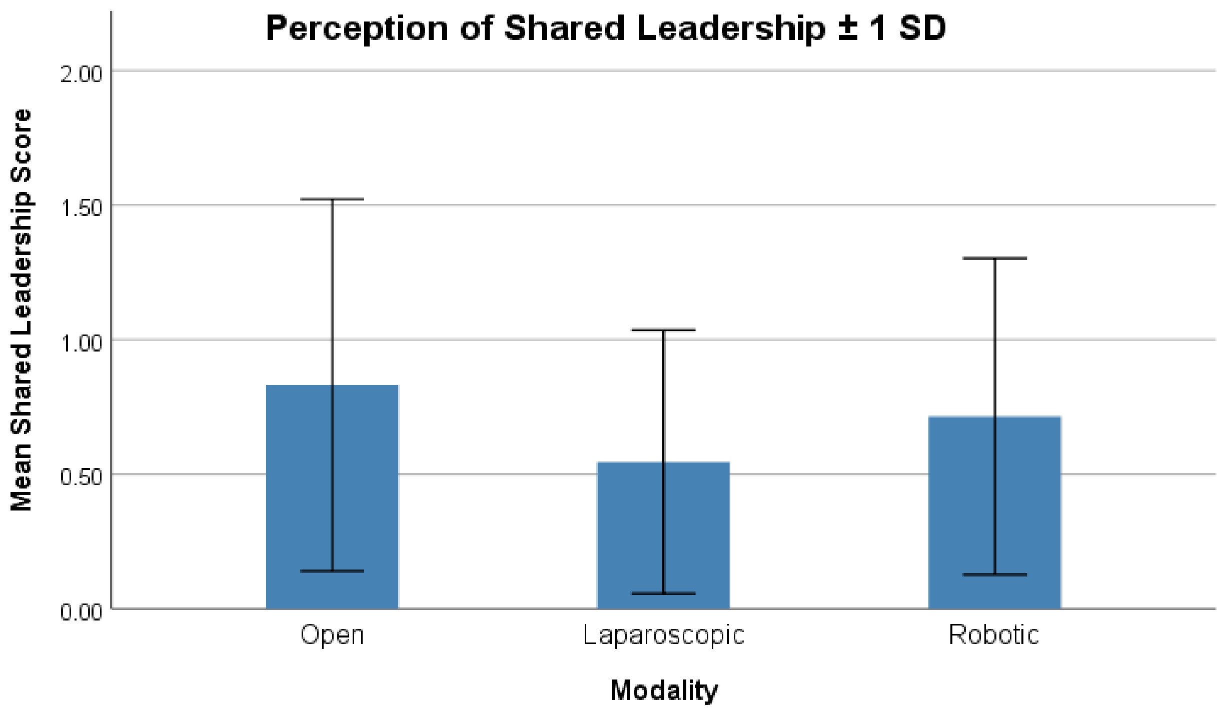

Figure 35. Results of exploratory hypothesis 16.

Exploratory Hypothesis 17 and Corresponding Results. Exploratory hypothesis 17 (Figure 36) proposes that participants will perceive differences between communication behaviors that they conduct compared to communication behaviors that their team conducts.

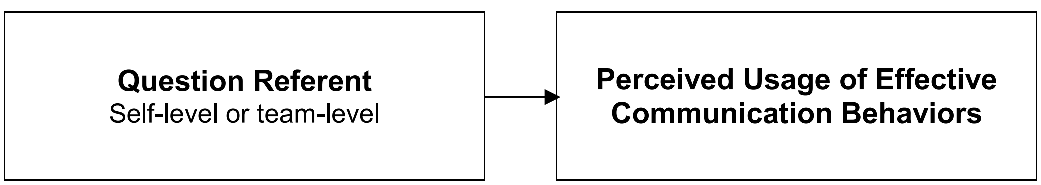

Figure 36. Exploratory hypothesis 17.

To test this hypothesis, a within-subjects t-test was performed to determine if there are differences between perceptions at the self and team levels. Participants' responses to the three questions in the communication behaviors scale that ask them if they themselves use names, call outs, and closed-loop communication with their team were averaged to generate the mean score for the *self*-level. Similarly, participants' responses to the three questions that ask if their team uses these communication behaviors with them were averaged to generate the mean score for the *team*-level. Fifteen univariate outliers were detected and removed from this analysis.

Data are expressed as mean ± standard deviation. Participants perceived that they themselves conducted more communication behaviors (4.48 ± 0.53) than their team (4.25 ± 0.59). One's perception of their own communication behaviors was 0.23 (95% CI, 0.14 to 0.31) higher than their perception of their team's communication behaviors, $t(127) = 5.114$, $p < .0005$, $d = 0.452$ (see Figure 37 for a bar graph of means and standard deviations). There was a statistically significant difference between means ($p < .05$), and therefore, we can reject the null hypothesis and accept the alternative hypothesis.

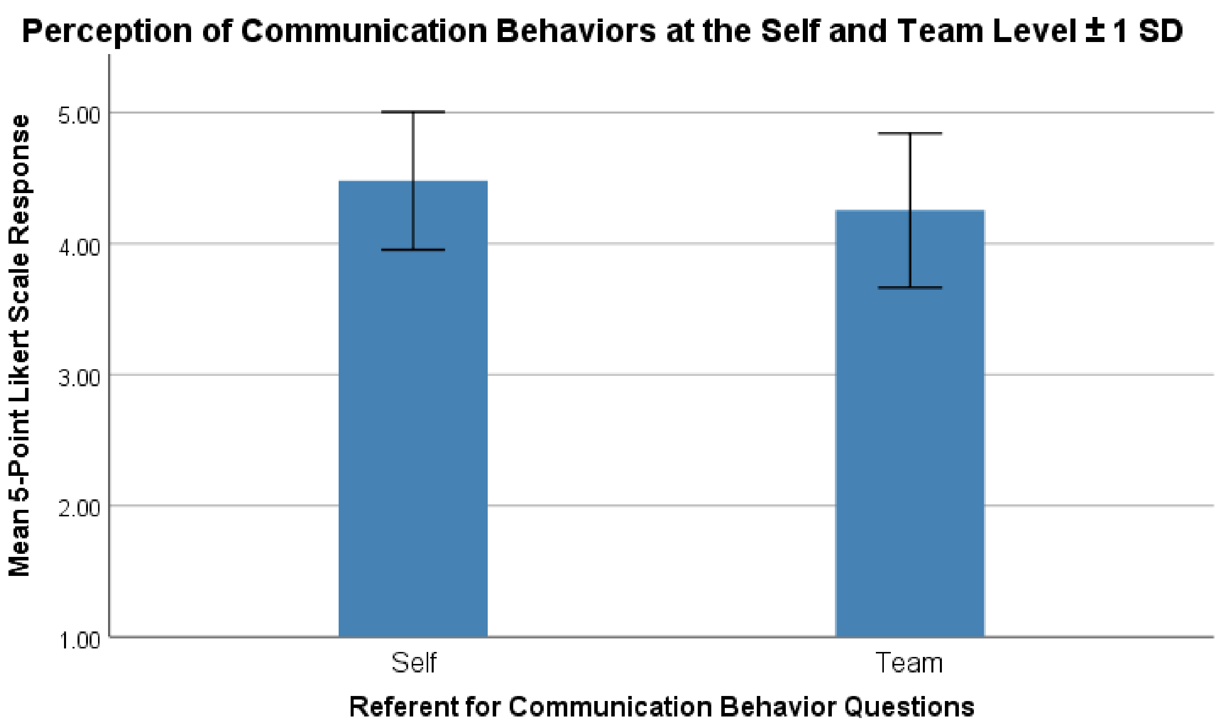

Figure 37. Results for exploratory hypothesis 17.

Exploratory Hypothesis 18 and Corresponding Results. Exploratory hypothesis 18 (Figure 38) proposes that survey respondent role will influence the percentage of leadership behaviors they attributed to each role.

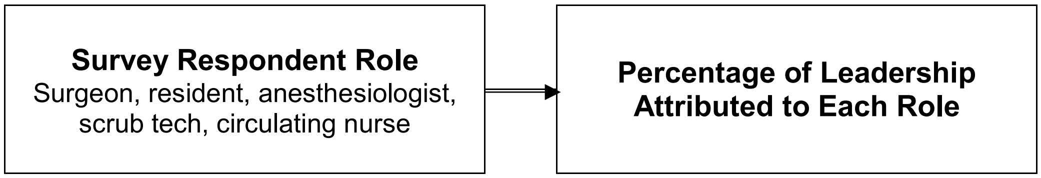

Figure 38. Exploratory hypothesis 18.

To test this hypothesis, a one-way MANOVA was performed to determine the effect of respondent role on the percentage of leadership behaviors they attributed to each role. Respondents were classified into five role groups: attending surgeons (N = 35), residents (N = 23), anesthesiologists (N = 21), scrub technicians (N = 17), and circulating nurses (N = 48). Respondents answered 16 leadership questions by indicating which team roles exhibited the behaviors in each item. Perceived leadership percentages were calculated for each respondent based on the percentage of time they chose each role relative to the total quantity of roles they chose. For example, if a respondent selected attending surgeon for all 16 questions and did not select any other roles, their perceived leadership percentage for attending surgeon would be 100% and the perceived leadership percentages for the other roles would be 0%. There were several univariate outliers and four multivariate outliers; all were deemed genuinely unusual and retained in this data analysis. Data was not normal as assessed by Shapiro-Wilk test ($p > .05$); no modifications were made. Homogeneity of variances was violated, as assessed by Levene's test of equality ($p < .0005$), therefore, Pillai's Trace and Games-Howell post-hoc multiple comparisons were evaluated.

Data are expressed as mean ± standard deviation. There was a statistically significant difference between the respondent role types on the combined dependent variable, $F(16, 488)$ =

11.160, $p < .0005$; Pillai's Trace = 1.071; partial $\eta^2 = 0.268$ (see Figure 39 for a bar graph of means and standard deviations). Since there was a statistically significant difference between means ($p < .05$), we can reject the null hypothesis and accept the alternative hypothesis. Follow-up univariate ANOVAs showed that there were statistically significant differences in surgeon ($F(4, 122) = 14.453$, $p < .0005$; partial $\eta^2 = 0.322$), resident ($F(4, 122) = 7.809$, $p < .0005$; partial $\eta^2 = 0.204$), anesthesiologist ($F(4, 122) = 19.876$, $p < .0005$; partial $\eta^2 = 0.395$), scrub tech ($F(4, 122) = 12.606$, $p < .0005$; partial $\eta^2 = 0.292$), and circulating nurse ($F(4, 122) = 15.277$, $p < .0005$; partial $\eta^2 = 0.334$) leadership role percentages between the respondent role types, using a Bonferroni adjusted α level of .025.

With regard to the surgeon leadership percentages, Games-Howell post-hoc tests revealed that surgeon respondents perceived the highest leadership percentages (40.14% ± 25.06%), followed by anesthesiologist respondents (26.75% ± 10.49%), then resident respondents (23.61% ± 6.35%), then circulating nurse respondents (15.36% ± 10.08%), and lastly, scrub tech respondents (14.23% ± 9.70%), representing respective decreases of 13.39% (95% CI, -1.21% to 28.00%), 16.53% (95% CI, 2.98% 30.09%), 24.78% (95% CI, 11.16% to 38.40%), and 25.91% (95% CI, 11.11% to 40.71%). Differences were statistically significant for the resident ($p = .010$), circulating nurse ($p < .0005$), and scrub tech ($p < .0005$) groups.

Considering the resident leadership percentages, Games-Howell post-hoc tests revealed that resident respondents perceived the highest leadership percentages (21.30% ± 8.20%) followed by surgeon respondents (13.66% ± 9.05%), then anesthesiologist respondents (12.97% ± 7.52%), then scrub tech respondents (10.97% ± 8.02%), and lastly, circulating nurse respondents (9.13% ± 7.93%), representing respective decreases of 7.64% (95% CI, 0.67% to 14.61%), 8.34% (95% CI, 1.01% to 15.66%), 10.34% (95% CI, 2.13% to 18.54%), and 12.18%

(95% CI, 5.89% to 18.46%). Differences were statistically significant for the surgeon (p = .025), anesthesiologist (p = .019), scrub tech (p = .008), and circulating nurse (p < .0005) groups.

Regarding the scrub tech leadership percentages, Games-Howell post-hoc tests revealed that scrub tech respondents perceived the highest leadership percentages (40.37% ± 26.53%), followed by circulating nurse respondents (20.29% ± 12.46%), then resident respondents (16.23% ± 3.07%), then surgeon respondents (14.26% ± 8.66%), and lastly, anesthesiologist respondents (13.49% ± 6.43%), representing respective decreases of 20.08% (95% CI, -2.60% to 42.75%), 24.13% (95% CI, 1.76% to 46.50%), 26.11% (95% CI, 3.54% to 48.67%), and 26.88% (95% CI, 4.33% to 49.43%). Differences were statistically significant for the resident (p = .032), surgeon (p = .020), and anesthesiologist (p = .016) groups.

For the anesthesiologist leadership percentages, Games-Howell post-hoc tests revealed that anesthesiologist respondents perceived the highest leadership percentages (26.75% ± 6.99%), followed by resident respondents (21.10% ± 9.14%), then surgeon respondents (12.47% ± 9.09%), then circulating nurse respondents (9.54% ± 7.87%), and lastly, scrub tech respondents (8.19% ± 6.99%), representing respective decreases of 5.64% (95% CI, -1.90% to 13.19%), 14.28% (95% CI, 7.68% to 20.88%), 17.21% (95% CI, 11.38% to 23.04%), and 18.55% (95% CI, 11.30% to 25.81%). Differences were statistically significant for the surgeon (p < .0005), circulating nurse (p < .0005), and scrub tech (p < .0005) groups.

With consideration to the circulating nurse leadership percentages, Games-Howell post-hoc tests revealed that circulating nurse respondents perceived the highest leadership percentages (45.68% ± 26.65%), followed by scrub tech respondents (26.24% ± 13.33%), then anesthesiologist respondents (20.05% ± 7.90%), then surgeon respondents (19.47% ± 11.13%), and lastly, resident respondents (17.75% ± 5.47%), representing respective decreases of 19.44%

(95% CI, 4.18% to 34.70%), 25.63% (95% CI, 13.15% to 38.11%), 26.21% (95% CI, 13.60% to 38.82%), and 27.93% (95% CI, 16.05% to 39.81%). Differences were statistically significant for the scrub tech (p = .006), anesthesiologist (p < .0005), surgeon (p < .0005), and resident (p < .0005) groups.

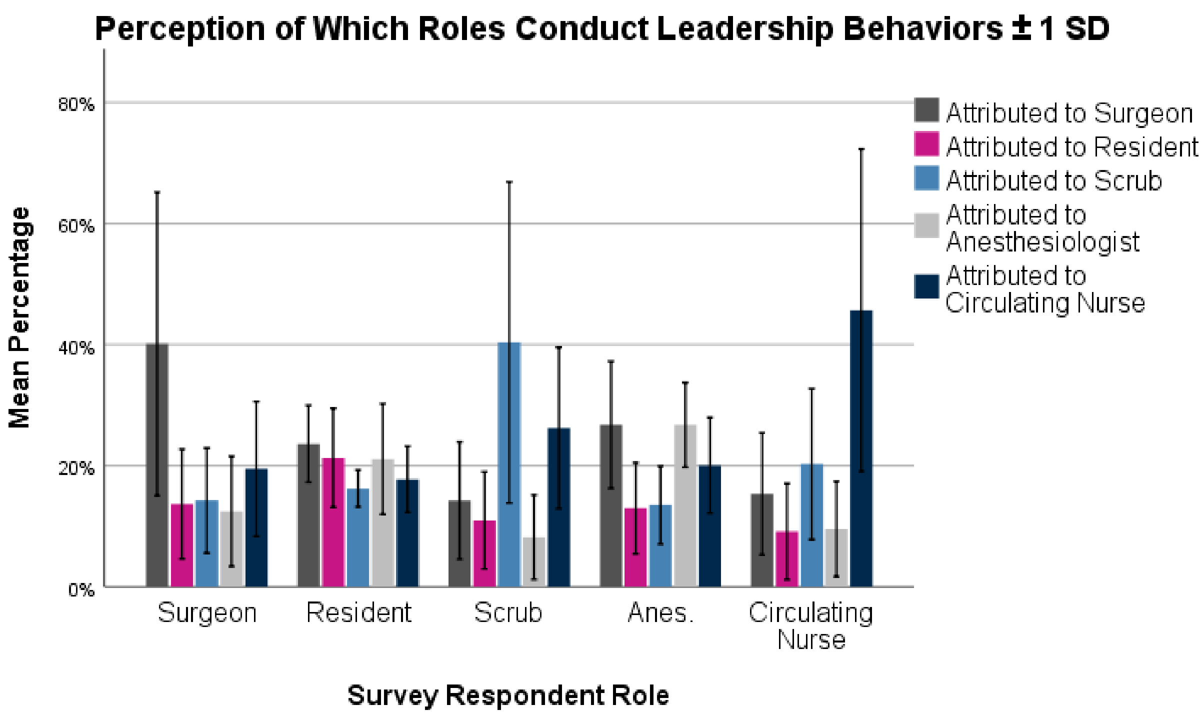

Figure 39. Results of exploratory hypothesis 18.

Exploratory Hypothesis 19 and Corresponding Results. Exploratory hypothesis 19 (Figure 40) proposes that perceived team familiarity will predict perceived team effectiveness.

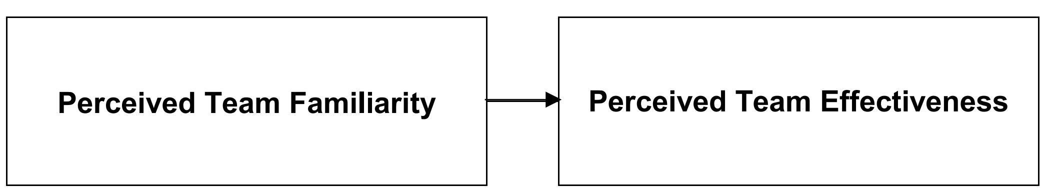

Figure 40. Exploratory hypothesis 19.

To test this hypothesis, a linear regression was performed to see if higher perceived team familiarity led to higher perceived team effectiveness. Four potential outliers were identified as having standardized residuals greater than three by examining the casewise diagnostics and were subsequently removed from analysis. After these outliers were removed, three additional variables were identified as having standardized residuals greater than three by examining the casewise diagnostics, however, these variables were retained for this analysis. The model yielded an R^2 value of 0.226. The linear regression significantly predicted perceived team effectiveness, $F(1, 134) = 39.217$, $p < .0005$ (see Table 24 for the regression coefficients and standard errors and Figure 41 for the linear regression scatterplot).

Table 24. Summary of linear regression analysis for exploratory hypothesis 19.

Variable	B	Std. Error	Beta	Sig.
Constant	2.768	0.230		.000
Team Familiarity Score	0.441	0.070	0.476	.000

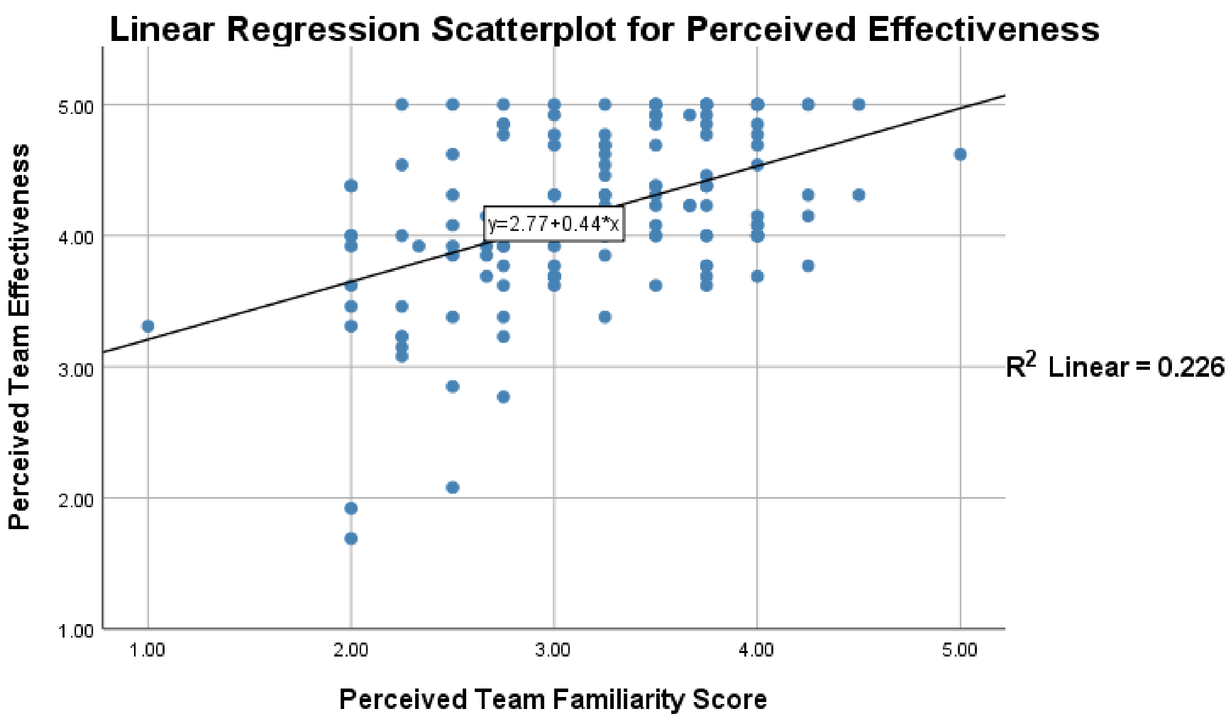

Figure 41. Results of exploratory hypothesis 19.

Exploratory Hypothesis 20 and Corresponding Results. Exploratory hypothesis 20 (Figure 42) proposes that perceived team familiarity will predict perceived communication quality.

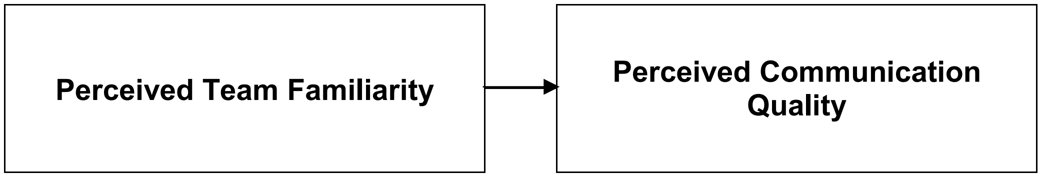

Figure 42. Exploratory hypothesis 20.

To test this hypothesis, a linear regression was performed to see if higher perceived team familiarity led to higher perceived communication quality. Four potential outliers were identified as having standardized residuals greater than three by examining the casewise diagnostics and were subsequently removed from this analysis. After these outliers were removed, one additional variable was identified as having standardized residuals greater than three by examining the casewise diagnostics, however, this variable was retained for this analysis. The model yielded an R^2 value of 0.121. The linear regression significantly predicted perceived communication quality, $F(1, 134) = 19.374$, $p < .0005$ (see Table 25 for the regression coefficients and standard errors and Figure 43 for the linear regression scatterplot).

Table 25. Summary of linear regression analysis for exploratory hypothesis 20.

Variable	B	Std. Error	Beta	Sig.
Constant	3.344	0.224		.000
Team Familiarity Score	0.294	0.069	0.347	.000

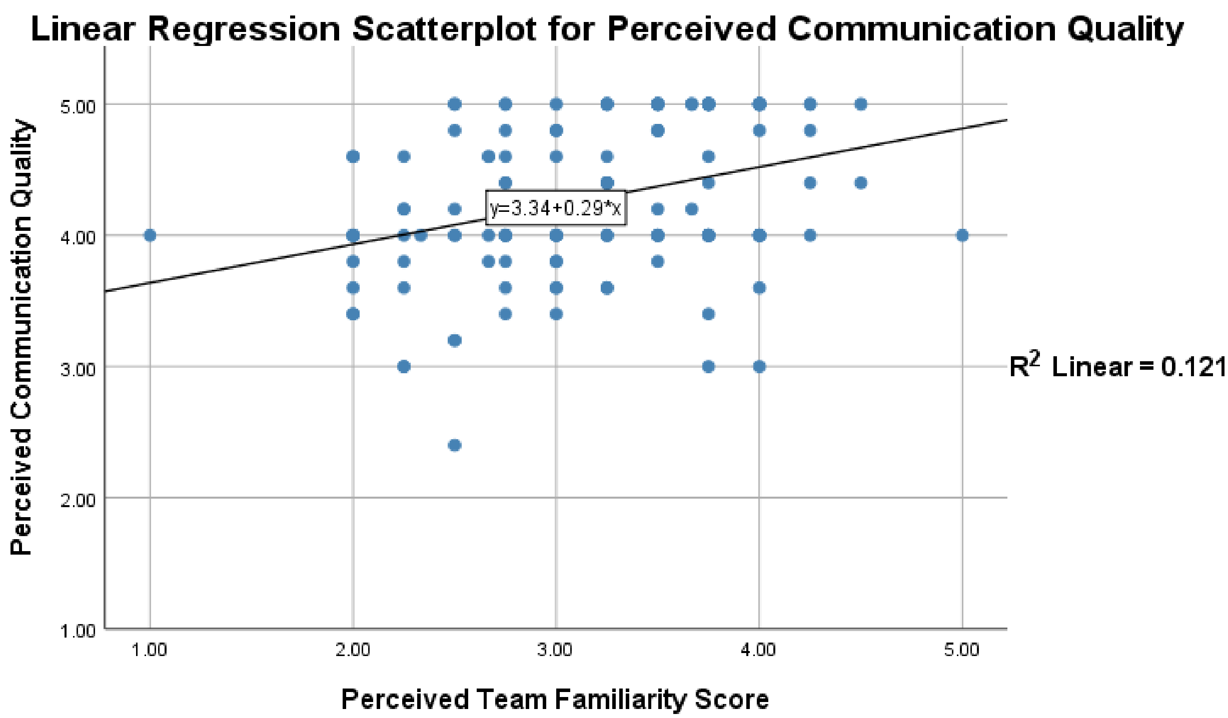

Figure 43. Results of exploratory hypothesis 20.

Exploratory Hypothesis 21 and Corresponding Results. Exploratory hypothesis 21 (Figure 44) proposes that perceived team familiarity will predict perceived communication behaviors.

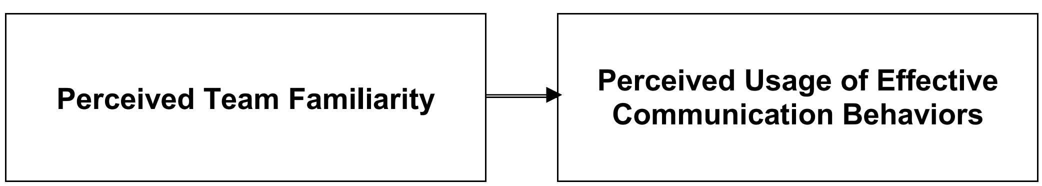

Figure 44. Exploratory hypothesis 21.

To test this hypothesis, a linear regression was performed to see if higher perceived team familiarity led to higher perceived communication behaviors. Five potential outliers were identified as having standardized residuals greater than three by examining the casewise diagnostics and were subsequently removed from analysis. After these outliers were removed, two additional variables were identified as having standardized residuals greater than three by examining the casewise diagnostics, however, these variables were retained for this analysis. The model yielded an R^2 value of 0.173. The linear regression significantly predicted perceived communication behaviors, $F(1, 132) = 27.581$, $p < .0005$ (see Table 26 for the regression coefficients and standard errors and Figure 45 for the linear regression scatterplot).

Table 26. Summary of linear regression analysis for exploratory hypothesis 21.

Variable	B	Std. Error	Beta	Sig.
Constant	2.946	0.254		.000
Team Familiarity Score	0.408	0.078	0.416	.000

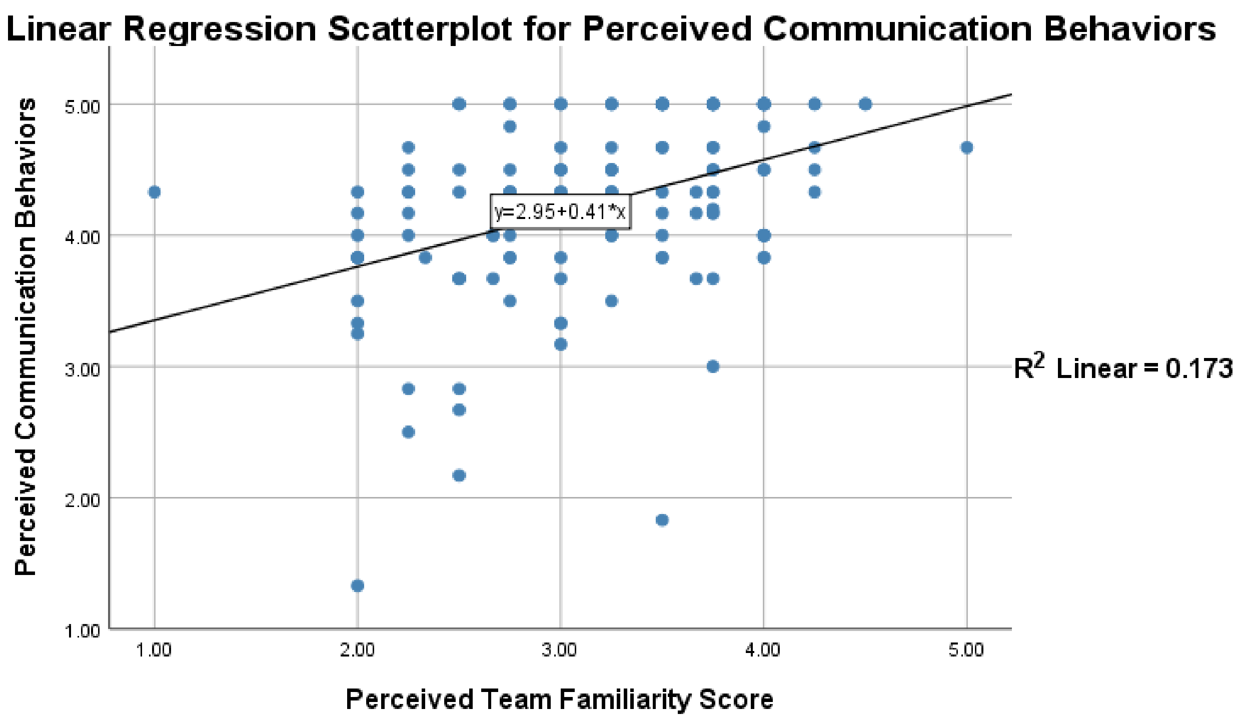

Figure 45. Results of exploratory hypothesis 21.

Summary

In total, thirteen analyses were carried out to analyze the data from study two. Support was only provided for two of the six planned hypotheses. Conversely, five of the eight exploratory hypotheses were supported. The significance or lack of significance for each analysis is discussed in Chapter 5 (Discussion).

Table 27. Summary of planned hypotheses and results.

H1a.	Study 1	Robotic teams will more frequently state team member names, as compared with non-robotic teams.	Not supported
H1b.	Study 1	Robotic teams will more frequently utilize call outs, as compared with non-robotic teams.	Supported
H1c.	Study 1	Robotic teams will more frequently utilize closed-loop communication, as compared with non-robotic teams.	Not supported
H2a.	Study 2	Non-robotic team members will perceive higher communication quality, as compared with robotic team members.	Not supported
H2b.	Study 2	Robotic team members will perceive higher utilization of communication behaviors (i.e., names, call outs, and closed-loop communication), as compared with non-robotic team members.	Not supported
H3.	Study 1	Robotic teams will exhibit a higher degree of shared leadership through the increased dispersion of leadership behaviors among the team, as compared with non-robotic teams.	Not supported
H4.	Study 2	Robotic team members will perceive a higher degree of shared leadership, as compared with non-robotic team members.	Not supported
H5.	Study 1	Surgical teams with a higher rate of communication behaviors (i.e., names, call outs, and closed-loop communication) will experience a shorter operative duration.	Not supported
H6a.	Study 2	Surgical team members who perceive high communication quality will also rate their team effectiveness higher.	Supported
H6b.	Study 2	Surgical team members who perceive higher utilization of communication behaviors (i.e., names, call outs, and closed-loop communication) will also rate their team effectiveness higher.	Supported
H7.	Study 1	Surgical teams with a higher degree of shared leadership will experience a shorter operative duration.	Partially supported
H8.	Study 2	Surgical team members who perceive leadership to be more shared among their team will rate their team effectiveness higher.	Not supported

Table 28. Summary of exploratory hypotheses and results.

H9.	Study 1	Surgical modality will affect the rate of leadership behaviors such that a higher rate will occur during laparoscopic surgeries.	Supported
H10.	Study 1	Modality and surgical team member role will affect the percentage of the leadership behaviors conducted by each role.	Supported
H11.	Study 1	Surgical team member role will affect the leadership behavior types that are conducted by each role.	Supported
H12.	Study 1	Surgical modality will affect the leadership behavior types that are conducted.	Supported
H13.	Study 1	Modality, procedure type, frequency rate of communication behaviors, and shared leadership score will predict operative duration such that laparoscopic hernias with higher rates of communication and greater shared leadership will experience shorter operative durations.	Supported
H14.	Study 1	The surgeons in the robotic cases will arrive earlier and stay later, as compared with the surgeons in the laparoscopic cases.	Not supported
H15.	Study 2	Surgical modality will affect perceived communication behaviors and communication quality while considering the open and laparoscopic groups separately as opposed to a composite non-robotic group.	Not supported
H16.	Study 2	Surgical modality will affect perceived shared leadership while considering the open and laparoscopic groups separately as opposed to a composite non-robotic group.	Not supported
H17.	Study 2	Participants will perceive differences between communication behaviors that they conduct compared to communication behaviors that their team conducts.	Supported
H18.	Study 2	Survey respondent role will influence the percentage of leadership behaviors they attributed to each role.	Supported
H19.	Study 2	Perceived team familiarity will predict perceived team effectiveness.	Supported
H20.	Study 2	Perceived team familiarity will predict perceived communication quality.	Supported
H21.	Study 2	Perceived team familiarity will predict perceived communication behaviors.	Supported

Chapter 5: Discussion

Study 1: Video Analysis of Robotic and Laparoscopic Procedures

Hypothesized Results

Hypotheses 1a, 1b, and 1c proposed that robotic surgical teams would more frequently engage in communication behaviors (i.e., names, call outs, and closed-loop communication) as compared with non-robotic teams. This was hypothesized as a result of robotic surgical teams' decreased common ground due to physical separation. The findings from this study partially support these hypotheses such that support is provided for only hypothesis 1b. The lack of support for hypotheses 1a and 1c may, in part, represent the adaptive nature of teams who conduct robotic surgery. Other researchers have discussed the concept of adaptation with respect to teams conducting robotic surgery. Specifically, Nyssen and Blavier (2009) and Wang (2017) cited instances of implicit communication (e.g., surgeons gesturing with instruments to indicate where he or she would like irrigation) in robotic surgery as evidence that teams have adapted to the new environment in robotic surgery. Interestingly, a team is commonly defined as a group of "two or more people who interact dynamically, interdependently, and *adaptively* toward a common valued goal/objective/mission…" (Salas et al., 1992). Furthermore, expert teams have been characterized by their ability to *adapt* their strategies. Individuals who work on robotic surgical teams may have adapted existing or developed new competencies that aid them completing work in this new setting. The support for hypothesis 1b may indicate the increased utility of calling out relevant information to bolster team situation awareness in a robotic surgery setting. Team situation awareness represents the collective understanding team members share about their environment and tasks (Salas et al., 1995) and is especially critical in the operating room (Parush et al., 2011).

Hypothesis 3 posited that robotic teams would exhibit a higher degree of shared leadership through the increased dispersion of leadership functions among the team, as compared with non-robotic teams. This hypothesis was based on the rationale that the "de facto" team leader is physically distanced from the other team members in robotic surgery, which may contribute to increased responsibility for the other team members and shifted power dynamics. In addition, shared leadership is more common is distributed team settings. The results from this study did not support this hypothesis. These findings illustrate that the surgeon's position as the "de facto" team leader is intact regardless of modality. While the surgeon is largely occupied with the task of performing surgery, the other roles are primarily focused on this task as well. These findings may also indicate the adaptive nature of teams performing robotic surgery such that despite the distributed setting, the surgeon is still executing the majority of the leadership behaviors.

Hypothesis 5 proposed that surgical teams with a higher frequency of communication behaviors (i.e., names, call outs, and closed-loop communication) would experience a shorter operative duration. The supporting rationale for this hypothesis was that teams who utilize these effective communication behaviors more frequently may communicate more effectively overall and thereby increase their shared mental model and operate more efficiently. The results from this study did not support this hypothesis. Other work (Baker, 2018) has illustrated that the use of communication behaviors such as closed-loop communication may actually contribute to longer task times due to the increased time that it may take to perform. However, what we did not directly capture is if any instances of miscommunication or delay would have resulted if the team did not use such communication behaviors. For instance, if the PA did not announce "the needle is out," the surgeon may have needed to ask later on if the needle had been removed which could have yielded a simple response of "yes" or conversely, the PA may not remember and this would necessitate an additional instrument count and/or search. The lack of significance for this finding is largely explained by the complex nature of surgery and the other factors that can influence operative duration. Patient factors, procedure complexity, unexpected events, and other factors largely affect operative duration. If we had evaluated the relationship between the use of these effective communication behaviors and task duration in a more controlled setting, it is possible that our findings would have been different.

Hypothesis 7 stipulated that surgical teams with a higher degree of shared leadership would experience a shorter operative duration. The reasoning behind this hypothesis was that shared leadership contributes to greater team performance, increasing the team's capacity for taskwork as well as facilitating greater familiarity with the task and team. The results from this study partially support this hypothesis. This hypothesis was tested along with hypothesis 5 with a multiple regression and the results were not significant. However, for exploratory hypothesis 14, a regression model was built with communication, shared leadership, procedure, and modality type to see if these variables would predict operative duration. This regression was significantly predictive and all variables except communication were significant. Therefore, procedure and modality type acted as suppressor variables; once they were added to the model, the contribution of shared leadership was evident. These results are discussed further below for hypothesis 10.

Exploratory Results

Exploratory hypothesis 9 proposed that surgical modality would affect the rate of leadership behaviors such that a higher rate would occur during laparoscopic surgeries. This hypothesis was based on the rationale that laparoscopic teams might interact more due to their collocated nature. The findings from this study support this hypothesis. Since the leadership behaviors we evaluated had to be observable and verbalized, it is possible that we saw a greater rate of leadership behaviors in the laparoscopic cases since these teams may have communicated more due to their face-to-face nature. On the other hand, the teams performing robotic surgery may be more siloed due to their distributed setting.

Exploratory hypothesis 10 suggested that modality and surgical team member role would affect the percentage of the leadership behaviors conducted by team roles. This hypothesis was based on the rationale that different roles are involved in executing leadership behaviors to varying extents and to explore if modality type influenced which roles engaged in leadership behaviors. The findings from this study support main effects for modality and role as well as an interaction effect between modality and role. With regard to modality, in general, the percentages of roles conducting leadership behaviors were very similar in the laparoscopic and robotic cases. In both modalities, the surgeons conducted the bulk of the leadership behaviors, echoing findings by Rydenfält et al. (2015). The main difference involved the amount of leadership behaviors conducted by the assists and scrubs. In the robotic cases, the assists performed significantly more of the leadership behaviors than the assists in the laparoscopic cases. This may be explained by the increased role assists play in robotic cases by inserting instruments into the robotic system. While not significant, the inverse was found for the scrub role such that scrubs performed more of the leadership behaviors in the laparoscopic cases than in the robotic cases. This may be because of their increased involvement in providing resources from the back table in laparoscopic cases. With regard to role, it makes sense that the surgeons conducted the bulk of the leadership behaviors as they are on the top of the hierarchy, hold clinical responsibility, and are the situationally-driven experts for the task of surgery. It is also makes sense that the assist acts as the “second-in-command” with the scrub following closely behind. These three roles are known as the "key triad" since they are most closely involved in the act of surgery (Sexton et al., 2018; Tiferes et al., 2016). The circulating nurse and anesthesia provider roles are both somewhat ancillary to most of the surgical tasks, though they are certainly involved in providing resources, administering medications, and fulfilling other important roles.

Exploratory hypothesis 11 proposed that surgical team member role would influence the leadership behavior types exhibited. The supporting rationale for this hypothesis was that different roles may be predisposed to conduct different leadership behavior types based on their role responsibilities and scope. The findings from this study support this hypothesis. In line with the finding that surgeons conducted the bulk of leadership behaviors (exploratory hypothesis 10), these findings illustrate that surgeons do the majority of all of the leadership behavior types, except for *provide resources*, which makes sense as this is more of a supporting role. In fact, this could represent a potential limitation of the manner in which the leadership behavior types were operationalized for this study.

Exploratory hypothesis 12 stipulated that surgical modality would affect the leadership behavior types conducted. This was hypothesized as a result of inherent differences between the two modalities that might lead to differences in leadership behavior types. The findings from this study support this hypothesis. Though not statistically significant, the leadership behavior types *train and develop team*, *provide feedback*, *manage team boundaries*, *provide resources*, and *support social climate* were more prevalent in laparoscopic surgery. Reaching statistical significance, the leadership behavior types *monitor team*, *perform team task*, and *solve problems* were more prevalent in robotic surgery. It is possible that teams performing robotic surgery utilized the leadership behavior type *monitor team* more frequently in order to increase their situation awareness. The increased usage of *perform team task* may represent an increased need to state task instructions or requests since team members are not as easily able to anticipate needs. Lastly, it is possible that the leadership behavior type *solve problems* was used more due to increased communication regarding troubleshooting since all team members are not in the same location.

Exploratory hypothesis 13 posited that procedure type, modality type, frequency rate of communication behaviors, and shared leadership would predict operative duration such that the hernia procedure, laparoscopic modality, higher rate of communication behaviors, and a smaller shared leadership score (representative of higher shared leadership) will contribute to a shorter operative duration. The supporting rationale for this hypothesis was that hernia repairs are generally quicker than right colectomies, robotic procedures include some additional tasks (e.g., docking robot), and that teams who utilize more effective communication behaviors and share leadership to a greater extent may perform more efficiently. The findings from this study support this hypothesis. The findings that procedure type and modality predicted operative duration were expected since these two factors are largely influential of operative duration. Conversely, the finding that more shared leadership led to shorter operative duration is novel. This finding may indicate that in surgical settings, shared leadership leads to increased efficiency. Other researchers have demonstrated the utility of sharing leadership to increase team performance in settings such as aircraft crews (Bienefeld & Grote, 2011), firefighting teams (Baran & Scott, 2010), and anesthesia teams (Klein et al., 2006; Künzle et al., 2010). The frequency rate of communication did not significantly add to the model; this may be explained by the rationale that was provided for hypothesis 5 that the usage of certain communication behaviors like closed-loop communication may actually lead to longer task times due to the time required (Baker, 2018).

Exploratory hypothesis 14 proposed that the surgeons in the robotic cases would arrive earlier and stay later, compared with the surgeons in the laparoscopic cases. This was hypothesized as a result of anecdotal findings put forth by Pelikan et al. (2018) that surgeons performing robotic surgery might arrive early and/or leave late in order to increase their opportunity for *affective grounding* (i.e., how individuals work together to build a shared understanding about the emotional meaning of each other's behavior; Jung, 2017) with their team. The findings from this study did not support this hypothesis. While the results did not reach statistical significance, the data did reflect that surgeons performing robotic surgery arrived earlier and left later, on average, when compared to the surgeons performing laparoscopic surgery. However, it is possible that there are other reasons why the surgeons conducting robotic surgery were arriving earlier and leaving later.

Limitations

The results gleaned from this study may be limited due to several factors. This study utilized real-world, applied data. Because of this, there were inherent differences between the cases that could not be controlled such as team familiarity, if anyone was being trained, experience levels, procedure difficulty, patient differences, and hospital-specific nuances. Furthermore, the nature of surgery is very procedural and encompasses specific sets of tasks; this may have limited the ability to discern differences based upon the modality. Since this study involved videotaping individuals at work, it is possible that their behaviors were impacted by Hawthorne effect (Landsberger, 1959), the notion that individuals behave differently while being observed. Some teams exchanged very little communication while others communicated more, across both modalities. This could be due to differing levels of Hawthorne effect or simply a result of the team's typical level of communication.

In addition, the sample size was somewhat limited due to the difficulty and logistics involved in collecting audiovisual data of surgical procedures. While similar research endeavors have used comparable amounts of audiovisual data (e.g., Pelikan et al., 2018; Randell et al., 2017; Sexton et al., 2018), it is possible that non-significant results were found due to insufficient power because of the small sample size (Pallant, 2016). Also regarding logistical limitations, the data was collected at three different hospital sites, therefore, the findings may not be generalizable to other hospitals. While the hospital site, modality, and procedure type were collected, very little other contextual data was collected. As a result, the research team lacked contextual and background information that could have been helpful (e.g., team familiarity and individual experience levels).

With regard to data quality and capture, there were several possible limitations. Multiple cameras were used to capture video of the room and surgical site; however, the visual data is limited such that all possible angles and views were not be captured. In addition, a room microphone was used to obtain audio, but there were several factors that contributed to audio limitations, such as quiet conversations, simultaneous conversations, music being played in the room, and noise from equipment. Especially in the context of surgery, the primary communications occur between the surgeon, assist, and scrub, otherwise known as the "key triad", therefore, other team members such as the circulating nurse and anesthesia provider may have engaged in quieter conversations. This may also be impacted by the expectations and norms that are developed by the team and surgeon.

Lastly, the specific communication and leadership behaviors that were measured inherently limit the scope and utility of the research findings. Considering the broad construct of communication, my scope was focused and, therefore, limited. If we had, for example, measured communication duration and collected team information such as familiarity and length of experience, we could have assessed these relationships. Elbardissi et al. (2008) found that surgical teams who were less familiar with one another experienced more communication failures. Furthermore, work on *implicit* or *tacit* team coordination indicates that high functioning teams are adept at anticipating needs and may, therefore, communicate less to coordinate work (Entin & Serfaty, 1999). Unfortunately, variables such as communication duration, team familiarity, and length of experience were not captured for this sample.

Validity

Internal Validity. Due to the empirical nature of this study, there were several threats to internal validity. Efforts were made to control factors between the surgeries as much as possible. Only hernia repair and right colectomy procedures were collected in order to limit the potential effects of procedure type. However, we did not control for factors that could have affected the data such as team familiarity, individual experience level, or hospital-specific nuances. Observer bias is also a potential threat to internal validity. By having multiple raters, the potential effect of observer bias was diminished. In addition, the research assistants were blinded to the study hypotheses. Also, the coding protocol was developed a priori, and all raters utilized the same protocol, behavior definitions, and exemplars.

External Validity. This study utilized audiovisual data from actual surgical procedures, bolstering its external validity. In contrast to studies that take place during simulations, the teams involved in this study were performing surgery with real patients and as a result, behaving in a representative manner. However, the cases were performed at three different sites within the U.S., so generalizability to surgical teams outside of the U.S. may be limited. In addition, the attending surgeon was male for every case in the sample, which could limit the generalizability of this research to surgeries with an attending female surgeon. Overall, the external validity is considerably strong due to the applied nature of the data.

Construct Validity. The selected measures for this study were chosen based on their ability to effectively assess the latent variables of interest: communication, shared leadership, and team performance. The coding scheme was designed to measure *behaviors* that team members performed, rather than *cognitions* that would not have been observable. The frequencies of specific communication behaviors (i.e., names, call outs, and closed-loop communication) were measured, however, these measures represent only a facet of the broad construct of communication. Shared leadership was measured by quantifying the degree to which team members equally enacted leadership behaviors. The leadership behavior types selected for measurement represent a sub-set of one leadership behavior taxonomy (i.e., the TLQ put forth by Morgeson et al., 2010); however, there are countless other leadership behaviors that were not measured in this study. In addition, it is possible that the way these leadership behaviors were operationalized for this research did not appropriately reflect the leadership behaviors.

Statistical Validity. The statistical validity of the findings from this study is moderate. For each statistical test that was performed, all relevant assumptions were evaluated to ensure that the results were significantly unlikely to be due to random variance. In addition, all 22 videos were coded by at least two researchers and ICC values were considered good or excellent for most variables, indicating high inter-rater reliability (see Appendix K for a summary of the ICC values for each variable by the rater pairs and the mean). However, due to logistical challenges, the small sample size of 22 cases did not meet the recommended sample size of 164 specified by G*Power.

Study 2: Survey Analysis of Surgical Team Member Perceptions

Hypothesized Results

Hypothesis 2a proposed that non-robotic team members will perceive higher communication quality, as compared with robotic team members. This hypothesis was developed based on how non-robotic team members work together face-to-face and do not have to compensate for decreased common ground. The results from this study did not support this hypothesis. These findings may also reflect the adaptive nature of teams performing robotic surgery, as discussed above with regard to hypotheses 1a, 1b, and 1c. The communication quality scale queried participants on their perceptions of communication clarity, effectiveness, completeness, fluency, and timeliness. It is possible that the robotic surgery environment augments certain aspects of communication perception. Considering non-robotic surgery environments, although the team members are at the bedside together and can see one another, there are still difficulties related to communication. For instance, all team members wear masks that cover their mouths. Foundational research (e.g., Erber, 1975) on auditory and visual cue perception illustrated that if the communication recipient is able to visualize the sender's mouth and facial movements, their understanding of the communicated message is improved. Furthermore, the OR can be a noisy environment due to loud equipment, music, multiple conversations, and other sources of noise. The robotic surgical system has a microphone and speaker system that increases the volume of the surgeon's voice at the bedside and similarly provides the surgeon audio from the bedside. It is possible that there are different communication limitations and benefits in robotic and non-robotic environments.

Hypothesis 2b posited that robotic team members would perceive higher utilization of communication behaviors (i.e., names, call outs, and closed-loop communication), as compared with non-robotic team members. This hypothesis was developed based on anecdotal evidence put forth by researchers (e.g., Pelikan et al., 2018; Randell et al., 2017) that demonstrated that robotic surgical teams may utilize certain communication behaviors to compensate for the lack of common ground. The results from this study did not support this hypothesis. When comparing participants who primarily perform non-robotic surgery with those who primarily perform robotic surgery, there were no statistically significant differences. These results indicate that despite modality, participants perceive the prevalence of these communication behaviors similarly. It is possible, therefore, that there are other factors such as team culture and norms that influence their usage of these effective communication behaviors.

Hypothesis 4 proposed that robotic team members will perceive a higher degree of shared leadership, as compared with non-robotic team members. This was hypothesized due to the rationale that the “de facto” team leader is physically distanced from the other team members in robotic surgery, which may contribute to increased responsibility for the other team members and shifted power dynamics subsequently. In addition, shared leadership is more common in distributed team settings. The results from this study did not support this hypothesis. It is possible that participants would have responded differently if they would have known they were indicating which roles perform *leadership*, rather than simply indicating which roles carry out various behaviors (that have been conceptualized as leadership for this study). Regardless, the lack of modality-specific differences may indicate that robotic technology does not influence how teams may share leadership.

Hypothesis 6a proposed that surgical team members who perceive high communication quality will also rate their team effectiveness highly. This hypothesis was based on the positive relationship between communication and team performance. To achieve positive team outcomes, teams must be able to communicate effectively. The results from this study support this hypothesis. These findings indicate that individuals who perceive high quality communication also perceive high team effectiveness, demonstrating a strong relationship between the two. Communication is foundational for teamwork and team performance (Marks et al., 2001). As such, it makes sense that individuals who perceive high-quality communication with their team members also perceive high team effectiveness.

Hypothesis 6b postulated that surgical team members who perceive higher utilization of communication behaviors (i.e., names, call outs, and closed-loop communication) among their team will also rate their team effectiveness highly. This hypothesis was established base on literature that demonstrated that teams who use these communication behaviors to bolster their shared awareness are more effective. The results from this study support this hypothesis; individuals who perceived that their team commonly uses these communication behaviors also perceived that their team is highly effective. The usage of these communication behaviors may lead to more clear communication that can eliminate the need to repeat information and minimize risks of miscommunication.

Hypothesis 8 proposed that surgical team members who perceive leadership to be more shared among their team will rate their team effectiveness highly. This hypothesis was developed based on research that indicates that team members who engage in shared leadership perceive increased influence and team morale. The results from this study did not support this hypothesis. One possible explanation for the lack of support for this hypothesis is that participants did not know that they were answering questions about leadership and the degree to which it is shared among their team. It is possible that if this had been clear to participants, they would have responded differently and that higher perceptions of shared leadership would have been linked to more favorable perceptions of team effectiveness. Regardless, the lack of significance in the current study's results illustrates that perceived shared leadership is not linked to perceived team effectiveness in surgical team settings.

Exploratory Results

Exploratory hypothesis 15 proposed that surgical modality would affect perceived communication behaviors and communication quality while considering the open and laparoscopic groups separately as opposed to a composite non-robotic group and while controlling for team familiarity. This hypothesis was developed to explore potential differences between open, laparoscopic, and robotic team members, rather than evaluating differences between the non-robotic and robotic groups. The results from this study did not support this hypothesis. These results provide further support for the notion that different modalities may offer different benefits and limitations with regard to communication and that there may be other factors within teams that influence perceptions of communication.

Exploratory hypothesis 16 proposed that surgical modality would affect perceived shared leadership while considering the open and laparoscopic groups separately as opposed to a composite non-robotic group. This hypothesis was developed to explore potential differences between open, laparoscopic, and robotic team members, rather than evaluating differences between the non-robotic and robotic groups. The results from this study did not support this hypothesis. This finding provides further evidence that surgical modality may not influence the degree to which leadership behaviors are perceived to be shared.

Exploratory hypothesis 17 proposed that participants would perceive differences between communication behaviors that they conduct compared to communication behaviors that their team conducts. This hypothesis was developed to assess whether one's perceptions of themselves differ from their perceptions of others. The results from this study did support this hypothesis. Participants may have more favorably perceived their communication behaviors for a couple of different reasons. First, participants may be more aware of their actions compared to others. Second, it is inherent in human behavior to have a more favorable view of oneself than others due to a cognitive bias known as illusory superiority (Hoorens, 1993).

Exploratory hypothesis 18 proposed that survey respondent role would influence the percentage of leadership behaviors they attributed to each role. This was hypothesized to investigate if participants' roles influence their perceptions of leadership behaviors exhibited by other roles, including their own. The results from this study did support this hypothesis. Overall, each role group perceived that their role conducted the largest percentage of leadership behaviors, relative to the other roles. Following similar rationale outlined for exploratory hypothesis 17, it is possible that participants are more familiar with their own actions than others and that they view their role more favorably than other roles. While controlling for the Big Five personality traits, Judge et al. (2006) found that narcissism was related to enhanced self-ratings of leadership, indicating that narcissistic individuals perceive themselves to be stronger leaders.

Exploratory hypotheses 19, 20, and 21 proposed that perceived team familiarity would predict perceived team effectiveness, perceived communication quality, and perceived communication behaviors, respectively. These hypotheses were developed to investigate if higher perceptions of team familiarity led to higher perceptions of team effectiveness, communication quality, and communication behaviors. The results from this study support all three of these hypotheses. These findings suggest that individuals who perceive greater familiarity with their team members also perceive higher team effectiveness, communication quality, and communication behaviors. While this data is perceptual, it supports previous research that has illustrated that familiar teams outperform unfamiliar teams in a variety of settings (Harrison et al., 2003; Marlow et al., 2018). Researchers have theorized numerous reasons why team familiarity might beget superior performance. For instance, team familiarity may lead to reduced uncertainty and anxiety about social acceptance (Hinds et al., 2000). In addition, increased familiarity may allow team members to develop cognitive structures such as transactive memory and team mental models as they learn more about each other's roles and characteristics (Okhuysen & Waller, 2002) Furthermore, increased team familiarity may lead to higher trust and mutual expectations (Jones & George, 1998). Throughout team familiarization and development, teams are able to establish and cultivate more effective team processes, such as efficient communication practices (Katz, 1982; Littlepage et al., 1997; Marlow et al., 2018). These findings suggest that it is possible that these communication practices may include the usage of names, call outs, and closed-loop communication in a surgical team setting.

Limitations

The survey study findings may be limited for several different reasons. All data was obtained from one hospital system. Because of this, the results may not be generalizable to hospitals that are not located within the western U.S., have established open, laparoscopic, and robotic surgical programs, and engage in teaching. Furthermore, the percentage of respondents who indicated that they primarily perform or assist with robotic surgery was 23%, which is much less than the 77% of respondents who indicated that they primarily perform or assist with non-robotic surgery. This is, however, representative of the real world due to the smaller proportion of surgical team members who specialize in robotic surgery.

In addition, similar to all survey research, particularly online survey research, there is a possibility that participants did not complete the survey honestly and accurately. Participants may not have answered questions in an accurate manner due to their own idiosyncrasies and/or due to misreading an item. Additionally, since participants received compensation for their participation, it is possible that they could have skipped or arbitrarily chose responses in order to complete the survey quickly. The data was screened for outliers during the analysis process and completion times were reviewed in order to eliminate questionable participants. However, in general, it is difficult to distinguish which participants completed the questionnaire attentively and which did not. In addition, survey research may be limited because of missing data. As discussed in Chapter 4 (Results), 29 of the 144 participants did not fully complete the questionnaire and the majority of these participants omitted three items or less (N = 21). Nevertheless, the approach that was taken to deal with missing data may be limited in some regards.

Furthermore, perceptions are well-known to often differ from actual performance (Bowyer et al., 2015; Mullan & Kothe, 2010). For example, this is evidenced by the clear discrepancy between how the surgeons conducted the bulk of the leadership behaviors in the video data, but each role perceived that their role conducts the bulk of the leadership behaviors in the survey data. One of the reasons why this study was carried out in parallel to the video analysis was to allow for comparisons and similarities to be discovered between behavioral and perceptual data. Lastly, as mentioned as a limitation for study one, the procedural nature of surgery may have limited the ability to discern modality-specific differences.

Validity

Internal Validity. The online questionnaire format of this study ensured that all participants received identical recruitment material and access to the survey. However, because participants were free to complete the survey at their convenience and at any location, environment participants were in as they took the survey could not be controlled. In addition, participation was voluntary and compensated; it is possible that the participants were biased in that they all made the decision to participate. Furthermore, attrition occurred such that 44.8% of those who began the survey did not finish. This may have resulted in a biased sample of only participants who chose to complete the survey once they began.

External Validity. The individuals who completed the questionnaire were actual surgical team members with experience working with others to perform either open, laparoscopic, and/or robotic surgery. As a result, their perceptions are in line with the target population of individuals who perform or assist with surgical procedures. With that said, all participants were from one hospital system within the U.S., thus, the findings may not be generalizable to other hospital systems, especially those outside of the U.S.

Construct Validity. The selected measures for this study were chosen based on their ability to effectively assess the following latent variables of interest: communication, shared leadership, and team effectiveness. The questionnaire was designed to elicit *perceptions* of communication, leadership, and team effectiveness. The self-report nature of this study demonstrates strong construct validity since participants indicated their own perceptions. All items, except for the communication behaviors scale and the team familiarity questions, were leveraged from existing literature. It is possible that other scales would have more accurately captured perceptions of these constructs. For example, the communication quality scale includes five items that query five different elements of communication quality; other, more exhaustive scales may have yielded different results.

Statistical Validity. The statistical validity of the findings from this study is sound. For each statistical test that was performed, all relevant assumptions were evaluated to ensure that the results were significantly unlikely to be due to random variance. In addition, the survey scales utilized for this study were selected based on their previous validation and use in the literature to appropriately measure the related construct, with the exception of the communication behaviors scale and the team familiarity questions that were created for this research. All measures, with the exception of the Leadership scale (due to the checkbox response format), were tested for reliability and all were determined to hold a Cronbach's Alpha score of 0.70 or higher (see Appendix L for the Cronbach's alphas for each scale).

Future Research

This research was built upon a foundation of literature developed by copious other researchers. In turn, the methods and findings of the present studies can inform future work. There are a number of practical lessons learned as well as areas for future exploration that have been discovered through this process.

For both study one and study two, there are several practical considerations for future research. With regard to study one, the video analysis, researchers should consider the costs and benefits to real-time observational vs. video analysis data collection. Several research groups (e.g., Pelikan et al., 2018; Wang, 2017) captured videos of surgical procedures and benefited from the number of advantages afforded by video data, such as the ability to rewind and/or pause clips, have multiple coders, revisit scenes of interest, and general reproducibility (Heath et al., 2017; Knoblauch et al., 2013). However, there are limitations inherent in video analysis that may be remediated by real-time data collection, such as environmental context, full view of the space, ability to move around in the room, and the ability to hear simultaneous conversations, among others. Considering study two, the survey, future work aimed at examining surgical team member perceptions to assess differences based upon modality might benefit from considering the utility of other methods such as interviews and/or focus groups. Either of these methods would allow for within-subjects comparisons and therefore provide the researcher with an avenue to dig deeper into perceived differences between the modalities. In addition, survey length and possible attrition should be carefully considered. With regard to the multi-method approach, forthcoming research interested in evaluating both behavioral and perceptual data could assess the same teams and individuals rather than using separate samples, which was done in these studies due to logistical rationale.

There are numerous avenues for future research directions that may prove fruitful in advancing this research. Further work on communication in surgery could continue to investigate the usage of the three communication behaviors that this work evaluated (i.e., names, call outs, and closed-loop communication) with the objective of discerning if there are other communication behaviors that are similarly useful for distributed teamwork. While robotic and non-robotic teams and individuals utilized and perceived similar amounts of the examined communication behaviors (i.e., names, call outs, and closed-loop communication) in these studies, this does not indicate that these behaviors do not offer increased utility in a robotic surgery environment. There may be other communication strategies that are utilized by high-performance robotic surgical teams. Future research could investigate this in an effort to translate these best practices to newer or less experienced robotic surgical teams. In addition, other potential follow-up work could involve evaluating teamwork and team outcomes pre-training, providing communication training on these behaviors, and evaluating teamwork and team outcomes post-training. Team outcomes could include, for example, measures of efficiency (e.g., task duration) and/or team dynamics (e.g., perceptions of communication quality). Further, perceptions of the importance and utility of these communication behaviors could be investigated to assess if surgical team members perceive them to be helpful and/or useful. Lastly, future research could investigate the relationship between team familiarity with levels of communication, based on the concept that *intact* teams may rely on implicit coordination and, therefore, communicate less (Espinosa et al., 2007). In high-performing teams in which there is little communication, it would be interesting to evaluate which communication acts are occurring and their antecedents.

Additional research on leadership in surgery may benefit from a teams-perspective by considering how each role may enact leadership behaviors, rather than only assessing the surgeon. This approach would provide greater insight into how the *team* functions, rather than just one member. With regard to the leadership behaviors evaluated, future research may measure the leadership behaviors that were adapted from Morgeson et al. (2010) for these studies. However, there are numerous other leadership behavior taxonomies that could be leveraged. Stone et al. (2017) compared various existing teamwork-centric behavior coding taxonomies to generate a leadership behavior taxonomy to study surgeons. In addition, researchers may choose to carry out a grounded-theory approach to generate the leadership behaviors of interest, similar to the approach carried out by Rydenfält et al. (2015).

Broadly, it would be useful and interesting to evaluate teamwork and team outcomes with different robotic surgical systems, especially if researchers are able to compare open and closed console designs. In many ways, the lack of statistically significant modality-specific differences demonstrated by these studies indicates that human-robot teams are performing similarly to human-human teams. Future research may seek to unearth greater understanding regarding how human-robot team performance can be optimized over human-human team performance. As robotic surgery continues to evolve, so will the tools and technologies that teams use. One design consideration that may have a considerable impact to teamwork is whether the surgeon console is open to allow the surgeon to visualize the bedside as well as the operating room, or if the console is closed (like the da Vinci Xi system that was evaluated in this dissertation) to allow the surgeon to access a 3D visualization of the surgical site, but not the rest of the operating room. With an open console, the surgeon may gain awareness of the rest of the operating room, but may also lose a sense of immersion (Randell et al., 2014) that he or she may experience within a closed console. Understandably, there are numerous tradeoffs with either design. How this design choice may influence teamwork is certainly a ripe area for research.

Theoretical and Practical Implications

Theoretically, this work has provided several key advances. One of the more novel theoretical contributions of this research is the use of the index of dispersion calculation to quantify the degree to which teamwork behaviors, such as leadership in this application, are shared among team members. Previous work (e.g., Rydenfält et al., 2015) utilized frequency distributions to report the amount of leadership behaviors conducted by each team role. More recent research conducted by Pasarakonda et al. (2020) utilized social network analysis in a novel application to examine the linkages between team roles conducting leadership. The usage of the index dispersion calculation in the present study achieves the objective of quantifying variance (i.e., standard deviation of leadership frequency from each team member) while also accounting for the quantity of behaviors exhibiting by the team (i.e., mean of leadership frequency among team). Furthermore, this calculation proved applicable to survey data as well with a simple modification to quantify an individual's perception based on their responses to 16 items. Another important contribution made by this work involves the development and validation of an original questionnaire scale that assesses perceptions of specific communication behaviors. The scale queries individuals on how commonly they themselves utilize and how commonly their team utilizes names, call outs, and closed-loop communication with their team.

Practically, this work also makes numerous contributions. The findings of this research may be translated into medical device development as well as surgical team training. While the results of this study did not support that effective communication behaviors contribute to better team outcomes (i.e., shorter operative duration), the perceptual data indicates that team members who perceive higher communication quality and usage of effective communication behaviors, also perceive that their team is more effective. The practical importance of this is rooted in the concept of collective efficacy, the notion that teams who believe they have the necessary resources and skills to accomplish a goal, may exert more effort and are, thereby, more likely to achieve their objectives (Bandura, 2000; Gully et al., 2002; Mathieu et al., 2010). Thus, there is a link between teams' perceptions and their actual performance. This illustrates the importance of developing effective communication tools and strategies for surgical teams. Especially in the context of robotic surgery, teams may benefit from using each other's names, calling out relevant information, and closing the loop, as evidenced in the literature as potentially viable mechanisms by which communication can be improved in distributed team settings (e.g., Guerlain et al., 2008; Randell et al., 2017). In addition, to mitigate the potential impacts of team distribution in robotic surgery, medical device developers might benefit from considering ways in which they may be able to reinvent face-to-face interactions. For instance, perhaps a camera view of the surgeons' face could be captured and portrayed on one of the monitors in the room so that the other team members could access his or her facial movements and expressions. Similarly, perhaps a room camera could capture video of team members at the bedside to portray inside the surgeon console so that the surgeon could refer to this view to visualize what is happening at the bedside. Some researchers (Almeras & Almeras, 2019; Randell et al., 2014) have touted the benefits of a closed console design such that the surgeons are able to be more fully immersed in the task of surgery. These recommendations, therefore, are not to eliminate the closed console design and resultant team distribution, but rather to optimize this setup to increase the amount of information available on both sides about the other party.

The behavioral results of this work indicate that the attending surgeons enact the majority of the leadership behaviors. This preserves the historical perspective that surgeons are the team leaders. Based on this, along with work that indicates the precarious nature of poor leadership (e.g., Barling et al., 2018; Lagoo et al., 2019), increased attention and resources should be placed on providing focused and effective leadership training for surgeons, as this is not a core component of medical training (Stone et al., 2017). Furthermore, research on shared leadership as well as research on strategies to improve teamwork in robotic surgery indicate the importance of clarity in role responsibility (Myklebust et al., 2020; Toole et al., 2003). It may prove beneficial, especially in a technologically dynamic setting involving advances in surgical tools and approaches, to clearly communicate what responsibilities each team role is entrusted with, thus increasing the team's shared mental model of who is responsible for what in various situations. This approach may also be beneficial regarding the perceptual data gleaned from the present study which indicated that nearly all team roles perceived that their role conducts the majority of the queried leadership behaviors. Detailing role responsibilities and contingencies may lead to more shared perceptions among team members, and thus, more harmonious teamwork. This could be accomplished via team training and fostered within individual team cultures. In addition, role clarification could also result from guidance provided by the tools and technologies teams are using.

Conclusion

Medical device developers, clinicians, and the broader population are collectively invested in continuing to improve surgical practices and technologies. Robotic surgical approaches have been developed to address the risk of infection for the patient and to improve visualization and ergonomics for the surgeon. However, the impact of team distribution in robotic surgery on team dynamics and outcomes has not been fully investigated. The purpose of this research, therefore, was to better understand how robotic surgery might influence communication, shared leadership, and team outcomes. To unearth these relationships, a multi-method approach was taken. Behaviors were analyzed through video analysis of surgical procedures and perceptions were evaluated through a questionnaire completed by surgical team members.

The findings of this research did not uncover many modality-specific differences with regard to the communication, shared leadership, and team outcome constructs evaluated. This may represent the adaptive nature of teams and individuals. In addition, since robotic surgical team members did not perceive a statistically significant difference in communication quality, this may indicate that the impact of the closed console design may be relatively benign in this regard. Considering leadership, while there was no statistically significant difference between the degree to which robotic and non-robotic teams shared or perceived shared leadership, there were interesting role and leadership behavior type differences. A few important relationships between team dynamics and team outcomes were uncovered. In the video data, sharing leadership to a greater extent led to shorter operative durations. In the survey data, higher perceptions of communication quality and communication behavior significantly predicted higher perceptions of team effectiveness, indicating a strong positive relationship between perceived communication and perceived effectiveness.

Robotic surgical systems and practices will inevitably continue to advance in the coming years. There are numerous important overarching considerations that will need to be addressed involving console design, use of automation, and performing surgery from greater distances, among others. Would an open console design yield greater situation awareness and better teamwork? Should the surgeon be located in the operating room or is there potential for surgeons to deliver care over greater distances? The focus of this dissertation was on understanding how team dynamics and outcomes may differ in robotic surgical environments that utilize a closed console, limited use of automation, and had the surgeon in the operating room. Moving forward, these decisions should be made with respect to all aspects of the sociotechnical system, including the providers and recipients of care, the environment and organization, and the tools and technologies.

Appendices

Appendix A: Team Leadership Questionnaire (TLQ) (Morgeson et al. (2010).

Transition phase leadership functions and sub-functions	
1. **Compose team**	a. Selects highly competent team members b. Selects team members who have previously worked well together c. Selects team members that have previously worked well with the leader d. Selects team members so there is a mix of skills on the team
2. **Define mission**	a. Ensures the team has a clear direction b. Emphasizes how important it is to have a collective sense of mission c. Develops and articulates a clear team mission d. Ensures that the team has a clear understanding of its purpose e. Helps provide a clear vision of where the team is going
3. **Establish expectations and goals**	a. Defines and emphasizes team expectations b. Asks team members what is expected of them c. Communicates expectations for high team performance d. Maintains clear standards of performance e. Sets or helps set challenging and realistic goals f. Establishes or helps establish goals for the team's work g. Ensures that the team has clear performance goals h. Works with the team and individuals in the team to develop performance goals i. Reviews team goals for realism, challenge, and business necessity
4. **Structure and plan**	a. Defines and structures own work and the work of the team b. Identifies when key aspects of the work need to be completed c. Works with the team to develop the best possible approach to its work d. Develops or help develop standard operating procedures and standardized processes e. Clarifies task performance strategies f. Makes sure team members have clear roles
5. **Train and develop team**	a. Makes sure the team has the necessary problem solving and interpersonal skills b. Helps new team members learn how to do the work c. Provides team members with task-related instructions d. Helps new team members to further develop their skills e. Help the team learn from past events or experiences
6. **Sensemaking**	a. Assists the team in interpreting things that happen inside the team b. Assists the team in interpreting things that happen outside the team c. Facilitates the team's understanding of events or situations d. Helps the team interpret internal or external events e. Helps the team make sense of ambiguous situations
7. **Provide feedback**	a. Rewards the performance of team members according to performance standards

	b. Reviews relevant performance results with the team c. Communications business issues, operating results, and team performance results d. Provides positive feedback when the team performs well e. Provides corrective feedback
Action phase leadership functions and sub-functions	
1. Monitor team	e. Monitors changes in the team's external environment f. Monitors team and team member performance g. Keeps informed about what other teams are doing h. Requests task-relevant information from team members i. Notices flaws in task procedures or team outputs
2. Manage team boundaries	a. Buffers the team from the influence of external forces or events b. Helps different teams communicate with one another c. Acts as a representative of the team with other parts of the organization d. Advocates on behalf of the team to others in the organization e. Helps to resolve difficulties between different teams
3. Challenge team	a. Reconsiders key assumptions in order to determine the appropriate course of action b. Emphasizes the importance and value of questioning team members c. Challenges the status quo d. Suggests new ways of looking at things e. Contributes ideas to improve how the team performs its work
4. Perform team task	a. Will "pitch in" and help the team with its work b. Will "roll up his/her sleeves" and help the team do its work c. Works with team members to help do work d. Will work along with the team to get its work done e. Intervenes to help team members get the work done
5. Solve problems	a. Implements or helps the team implement solutions to problems b. Seeks multiple different perspectives when solving problems c. Creates solutions to work-related problems d. Participates in problem solving with the team e. Helps the team develop solutions to task and relationship-related problems
6. Provide resources	a. Obtains and allocates resources (materials, equipment, people, and services) for the team b. Seeks information and resources to facilitate the team's initiatives c. Sees to it that the team gets what is needed from other teams d. Makes sure that the equipment and supplies the team needs are available e. Helps the team find and obtain "expert" resources
7. Encourage team self-management	a. Encourages the team to be responsible for determining the methods, procedures, and schedules with which the work gets done b. Urges the team to make its own decisions regarding who does what tasks within the team c. Encourages the team to make most of its own work-related decisions d. Encourages the team to solve its own problems

	e. Encourages the team to be responsible for its own affairs f. Encourages the team to assess its performance
8. Support social climate	a. Responds promptly to team member needs or concerns b. Engages in actions that demonstrate respect and concern for team members c. Goes beyond own interest for the good of the team d. Does things to make it pleasant to be a team member e. Looks out for the personal well-being of team members

Appendix B: Team Effectiveness, (Pearce & Sims Jr., 2002).

Sub-Category of Effectiveness	Items
Output Effectiveness	1. The team delivers its commitments. 2. The team delivers its commitments on time. 3. The team provides a volume of work consistent with established standards. 4. The team is highly effective at implementing solutions. 5. The team delivers important changes.
Quality Effectiveness	6. The quality of the team's output is very high/ 7. The team performs duties accurately and consistently. 8. The team eliminates root problems, not just symptoms.
Change Effectiveness	9. The team faces new problems effectively. 10. The team changes behavior to meet the demands of the situation/ 11. The team copes with change very well.
Organizing and Planning Effectiveness	12. The team sets goals and priorities for maximum efficiency. 13. The team develops workable plans. 14. The team works on important problems. 15. The team has its priorities straight.
Interpersonal Effectiveness	16. The team communicates its progress. 17. The team proactively communicates its progress. 18. The team keeps everyone informed. 19. The team keeps everyone informed on its progress.
Value Effectiveness	20. The team's contribution to the company is very valuable. 21. The team makes valuable contributions to the company. 22. The contributions of this team are very valuable to the company.
Overall Effectiveness	23. The team is highly effective. 24. The team is making very good progress on the team's charter. 25. The team does very good work. 26. The team does a very good job.

Appendix C: Email Memorandum to Advertise Survey

Do you work on a surgical team?

Survey Participants Needed!

If you **currently work on a surgical team** (i.e., you are a surgeon, physician assistant, anesthesia provider, circulating nurse or scrub nurse) you are invited to participate in an **online survey**.

This research investigates how **surgical modality** (i.e., open, laparoscopic, robotic) may influence **team dynamics**. Your contributions may lead to **actionable insights** that may inform design or training improvements.

Online survey will take 10 minutes and pay $15

Your quick participation is kindly requested and appreciated. For your compensation, you will be able to decide between:

- Amazon gift card
- Charitable contribution in your name to charity of choice

First-come-first served! Survey will go offline once the target number of responses have been received.

Click Here to Access Survey

Appendix D: Surgical Experience Screener

Thinking about **all of the surgeries you work on in a typical 30-day period**, please answer the following questions. Your responses to these questions will be used to frame the rest of the survey.

1. Do you currently work on a surgical team that performs open, laparoscopic, or robotic surgery?
   - ◯ Yes
   - ◯ No **(send to end of survey)**
2. What is your primary role during surgery?
   - ◯ Surgeon – attending
   - ◯ Surgeon – fellow
   - ◯ Surgeon – resident
   - ◯ Physician assistant
   - ◯ Anesthesiologist – attending
   - ◯ Anesthesiologist – fellow
   - ◯ Anesthesiologist – resident
   - ◯ Certified registered nurse anesthetist (CRNA)
   - ◯ Circulating nurse
   - ◯ Surgical technician
   - ◯ Other: ________________
3. How long have you been in your current role?
   Text entry response
   ____
4. Please indicate the approximate number of cases you perform of each modality during a typical 30-day period.
   Text entry response
   Open _____
   Laparoscopic _____
   Robotic _____
5. Please rank the following modalities in order of most commonly performed/assisted with during a typical 30-day period (most performed at the top). **(sort to question blocks with appropriate framing based on primary modality)**
   Rank order response:

	1	2	3
Open	◯	◯	◯
Laparoscopic	◯	◯	◯
Robotic	◯	◯	◯

Appendix E: Communication Quality Scale, (González-Romá and Hernández, 2014).

Thinking about the **most typical [open / laparoscopic / robotic] surgery you have worked on**, please select the options that most closely reflect your level of agreement with each statement.

Response format:
◯ Strongly disagree
◯ Disagree
◯ Neither agree nor disagree
◯ Agree
◯ Strongly agree
◯ Not applicable or don't know

1. The communication between you and your teammates was CLEAR.
2. The communication between you and your teammates was EFFECTIVE.
3. The communication between you and your teammates was COMPLETE.
4. The communication between you and your teammates was FLUENT.
5. The communication between you and your teammates was ON TIME.

Appendix F: Effective Communication Behaviors Scale

Thinking about the **most typical [open / laparoscopic / robotic] surgery you have worked on**, please select the options that most closely reflect your level of agreement with each statement.

Response format:
◯ Strongly disagree
◯ Disagree
◯ Neither agree nor disagree
◯ Agree
◯ Strongly agree
◯ Not applicable or don't know

1. You commonly used your team members' names to indicate who your communication was intended for.
2. You commonly called out task progression/completion updates to notify your team of pertinent information.
3. You commonly used closed-loop communication to acknowledge, read-back, and/or clarify communication from your team members.
4. Your team commonly used each other's names to indicate who their communication was intended for.
5. Your team commonly called out task progression/completion updates to notify the rest of the team of pertinent information.
6. Your team commonly used closed-loop communication to acknowledge, read-back, and/or clarify communication from other team members.

Appendix G: Leadership Behaviors Scale, Adapted from Morgeson et al., (2010).

Thinking about the **most typical [open / laparoscopic / robotic] surgery you have worked on**, please select the team roles that consistently engaged in these behaviors.

Matrix response format:

- ☐ Attending surgeon
- ☐ Resident
- ☐ Anesthesia team member
- ☐ Circulating nurse
- ☐ Surgical technician
- ☐ No one

1. Provides team members with task-related instructions
2. Helps new team members to further develop their skills
3. Provides positive feedback when the team performs well
4. Provides corrective feedback
5. Monitors team and team member performance
6. Requests task-relevant information from team members
7. Acts as a representative of the team with other parts of the organization
8. Advocates on behalf of the team to others in the organization
9. Will "roll up his/her sleeves" and help the team do its work
10. Intervenes to help team members get the work done.
11. Participates in problem solving with the team
12. Helps the team develop solutions to task and relationship-related problems
13. Obtains and allocates resources (materials, equipment, people, and services) for the team
14. Makes sure that the equipment and supplies the team needs are available
15. Engages in actions that demonstrate respect and concern for team members
16. Looks out for the personal well-being of team members

Appendix H: Team Effectiveness Scale, Adapted from Pearce and Sims, (2002).

Thinking about the **most typical [open / laparoscopic / robotic] surgery you have worked on**, please select the options that most closely reflect your level of agreement with each statement.

Response format:
◯ Strongly disagree
◯ Disagree
◯ Neither agree nor disagree
◯ Agree
◯ Strongly agree
◯ Not applicable or don't know

1. The team delivers its commitments on time.
2. The team provides a volume of work consistent with established standards.
3. The quality of the team's output is very high.
4. The team performs duties accurately and consistently.
5. The team faces new problems effectively.
6. The team changes behavior to meet the demands of the situation.
7. The team sets goals and priorities for maximum efficiency.
8. The team works on important problems.
9. The team communicates its progress.
10. The team proactively communicates its progress.
11. The team's contribution to the company is very valuable.
12. The team is highly effective.
13. The team does very good work.

Appendix I: Demographics

Your completion of the following demographic and background questions will greatly aid in the analysis of the survey results.

1. What is your current age?
   Text entry response
   ____
2. What is your gender?
   ◯ Male
   ◯ Female
   ◯ Nonbinary
   ◯ Prefer not to say
   ◯ Other: _______________
3. Are you Hispanic or Latino (of Cuban, Mexican, Puerto Rican, South or Central American, or other Spanish culture or origin, regardless of race)?
   ◯ Yes
   ◯ No
4. What race(s) do you identify as?
   ☐ American Indian or Alaska Native
   ☐ Black or African American
   ☐ Native Hawaiian or Other Pacific Islander
   ☐ White
   ☐ Prefer not to say
5. What is your area of specialty?
   ◯ I don't have an area of specialty
   ◯ General surgery
   ◯ Thoracic surgery
   ◯ Colon and rectal surgery
   ◯ Obstetrics and gynecology
   ◯ Neurological surgery
   ◯ Opthalmic surgery
   ◯ Oral and maxillofacial surgery
   ◯ Orthopaedic surgery
   ◯ Otolaryngology
   ◯ Pediatric surgery
   ◯ Plastic and maxillofacial surgery
   ◯ Urology
   ◯ Vascular surgery
   ◯ Other: _______________
6. **(Only for participants who indicated robotic as their primary modality)** Thinking about the robotic surgeries you work on in a typical 30-day period, please indicate which surgical system(s) is/are used.

- ☐ Da Vinci Xi
- ☐ Da Vinci Si
- ☐ Da Vinci SP
- ☐ Other: _______________

7. Thinking about the **open surgeries you work on in a typical 30-day period**, please indicate how frequently you work with the same **attending surgeon** (e.g., Alex is usually the attending surgeon).
   - ◯ Never **(skip next question)**
   - ◯ Rarely **(skip next question)**
   - ◯ Sometimes
   - ◯ Often
   - ◯ Always
   - ◯ This is my role **(skip next question)**
   - ◯ Not applicable or don't know **(skip next question)**
8. How long have you worked with this **attending surgeon** over the course of your career? Text entry response

   ____
9. Thinking about the **open surgeries you work on in a typical 30-day period**, please indicate how frequently you work with the same **fellow or resident** (e.g., Bailey is usually the fellow or resident).
   - ◯ Never **(skip next question)**
   - ◯ Rarely **(skip next question)**
   - ◯ Sometimes
   - ◯ Often
   - ◯ Always
   - ◯ This is my role **(skip next question)**
   - ◯ Not applicable or don't know **(skip next question)**
10. How long have you worked with this **fellow or resident** over the course of your career? Text entry response

    ____
11. Thinking about the **open surgeries you work on in a typical 30-day period**, please indicate how frequently you work with the same **physician assistant** (e.g., Quinn is usually the physician assistant).
    - ◯ Never **(skip next question)**
    - ◯ Rarely **(skip next question)**
    - ◯ Sometimes
    - ◯ Often
    - ◯ Always
    - ◯ This is my role **(skip next question)**
    - ◯ Not applicable or don't know **(skip next question)**
12. How long have you worked with this **physician assistant** over the course of your career? Text entry response

    ____

13. Thinking about the **open surgeries you work on in a typical 30-day period**, please indicate how frequently you work with the same **anesthesiologist** (e.g., Taylor is usually the anesthesiologist).
    - ◯ Never **(skip next question)**
    - ◯ Rarely **(skip next question)**
    - ◯ Sometimes
    - ◯ Often
    - ◯ Always
    - ◯ This is my role **(skip next question)**
    - ◯ Not applicable or don't know **(skip next question)**
14. How long have you worked with this **anesthesiologist** over the course of your career?
    Text entry response

    ____
15. Thinking about the **open surgeries you work on in a typical 30-day period**, please indicate how frequently you work with the same **circulating nurse** (e.g., Jaden is usually the circulating nurse).
    - ◯ Never **(skip next question)**
    - ◯ Rarely **(skip next question)**
    - ◯ Sometimes
    - ◯ Often
    - ◯ Always
    - ◯ This is my role **(skip next question)**
    - ◯ Not applicable or don't know **(skip next question)**
16. How long have you worked with this **circulating nurse** over the course of your career?
    Text entry response

    ____
17. Thinking about the **open surgeries you work on in a typical 30-day period**, please indicate how frequently you work with the same **scrub tech or nurse** (e.g., Parker is usually the scrub tech or nurse).
    - ◯ Never **(skip next question)**
    - ◯ Rarely **(skip next question)**
    - ◯ Sometimes
    - ◯ Often
    - ◯ Always
    - ◯ This is my role **(skip next question)**
    - ◯ Not applicable or don't know **(skip next question)**
18. How long have you worked with this **scrub tech or nurse** over the course of your career?
    Text entry response

    ____

19. Thinking about the **[open / laparoscopic / robotic] surgeries you work on in a typical 30-day period**, please indicate the approximate number of people on your team.
    Text entry response

    ____

    ____

20. Have you ever received any type of team training in medical school and/or at your hospital or surgery center?
    - ◯ Yes
    - ◯ No **(skip next question)**
21. How long ago did you receive this team training?
    Text entry response

    ____

Appendix J: Compensation

Thank you very much for completing this survey. The data collected will be anonymous and your responses will remain confidential. Please complete the following questions regarding your compensation for completing this survey.

1. How would you like to be compensated?
   - ◯ An Amazon gift card **(send to question 2)**
   - ◯ A charity donation of my choice **(send to question 4)**
2. Please provide an email address where we can send your virtual Amazon gift card. This email address will not be associated with your survey data.
   Text entry response
   ____
3. Would you like to be notified of the research findings? A summary of the insights will be emailed to you at the conclusion of the study.
   - ◯ Yes, please send the results to the email address I provided above
   - ◯ Yes, please send the results to this email address: _______________
   - ◯ No
4. Which charity would you like your compensation to be donated to?
   - ◯ Option 1
   - ◯ Option 2
   - ◯ Option 3
5. Would you like a name to be associated with the donation? This name will not be associated with your survey data.
   - ◯ Yes, please associated with this name: _______________
   - ◯ No
6. Would you like to be notified of the research findings? A summary of the insights will be emailed to you at the conclusion of the study.
   - ◯ Yes, please send the results to this email address: _______________
   - ◯ No

Appendix K: ICC SPSS Output

Intraclass Correlation Coefficient

		Intraclass Correlation[b]	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound	F Test with True Value 0 Value	df1	df2	Sig
Variable 1: Names								
Rater 1 & 2	Single Measures	.811[a]	.408	.949	9.578	9	9	.001
	Average Measures	.896	.580	.974	9.578	9	9	.001
Rater 1 & 3	Single Measures	.961[a]	.840	.991	50.938	8	8	.000
	Average Measures	.980	.913	.996	50.938	8	8	.000
Variable 2: Call out								
Rater 1 & 2	Single Measures	.811[a]	.408	.949	9.578	9	9	.001
	Average Measures	.896	.580	.974	9.578	9	9	.001
Rater 1 & 3	Single Measures	.947[a]	.786	.988	37.045	8	8	.000
	Average Measures	.973	.880	.994	37.045	8	8	.000
Variable 3: Closed-loop communication								
Rater 1 & 2	Single Measures	.957[a]	.839	.989	45.865	9	9	.000
	Average Measures	.978	.912	.995	45.865	9	9	.000
Rater 1 & 3	Single Measures	.968[a]	.865	.993	61.007	8	8	.000
	Average Measures	.984	.927	.996	61.007	8	8	.000
Variable 4: Train and develop team								
Rater 1 & 2	Single Measures	.922[a]	.719	.980	24.629	9	9	.000
	Average Measures	.959	.837	.990	24.629	9	9	.000
Rater 1 & 3	Single Measures	.585[a]	-.005	.885	4.080	8	8	.032
	Average Measures	.738	-.010	.939	4.080	8	8	.032
Variable 5: Provide feedback								
Rater 1 & 2	Single Measures	.654[a]	.085	.901	4.775	9	9	.015
	Average Measures	.791	.157	.948	4.775	9	9	.015
Rater 1 & 3	Single Measures	.858[a]	.494	.966	13.102	8	8	.001
	Average Measures	.924	.662	.983	13.102	8	8	.001
Variable 6: Monitor team								
Rater 1 & 2	Single Measures	.554[a]	-.072	.867	3.484	9	9	.039
	Average Measures	.713	-.155	.929	3.484	9	9	.039
Rater 1 & 3	Single Measures	.411[a]	-.299	.828	2.394	8	8	.119
	Average Measures	.582	-.851	.906	2.394	8	8	.119
Variable 7: Manage team boundaries								

Rater 1 & 2	Single Measures	.897[a]	.641	.973	18.400	9	9	.000
	Average Measures	.946	.781	.987	18.400	9	9	.000
Rater 1 & 3	Single Measures	.585[a]	-.074	.889	3.822	8	8	.038
	Average Measures	.738	-.160	.941	3.822	8	8	.038
Variable 8: Perform team task								
Rater 1 & 2	Single Measures	.923[a]	.723	.980	25.016	9	9	.000
	Average Measures	.960	.839	.990	25.016	9	9	.000
Rater 1 & 3	Single Measures	.964[a]	.850	.992	54.744	8	8	.000
	Average Measures	.982	.919	.996	54.744	8	8	.000
Variable 9: Solve problems								
Rater 1 & 2	Single Measures	.527[a]	-.110	.857	3.225	9	9	.048
	Average Measures	.690	-.248	.923	3.225	9	9	.048
Rater 1 & 3	Single Measures	.622[a]	-.017	.900	4.285	8	8	.028
	Average Measures	.767	-.035	.947	4.285	8	8	.028
Variable 10: Provide resources								
Rater 1 & 2	Single Measures	.879[a]	.588	.968	15.508	9	9	.000
	Average Measures	.936	.740	.984	15.508	9	9	.000
Rater 1 & 3	Single Measures	.868[a]	.524	.969	14.191	8	8	.001
	Average Measures	.930	.688	.984	14.191	8	8	.001
Variable 11: Support social climate								
Rater 1 & 2	Single Measures	.777[a]	.329	.940	7.968	9	9	.002
	Average Measures	.874	.495	.969	7.968	9	9	.002
Rater 1 & 3	Single Measures	.877[a]	.550	.971	15.291	8	8	.000
	Average Measures	.935	.710	.985	15.291	8	8	.000

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

Two-way random effects model where both people effects and measures effects are random.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type A intraclass correlation coefficients using an absolute agreement definition.

Appendix L: Cronbach's Alpha SPSS Output

Reliability Statistics

	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
Communication Behaviors Scale	.940	.942	6
Team Effectiveness Scale	.968	.969	13
Communication Quality Scale	.954	.954	5

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