A Superior Touch:

A Socio-Technical Study of Humans, Robotic Surgical Assistants, and Touch

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DISSERTATION

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TABLE OF CONTENTS

CHAPTER PAGE

TABLE OF CONTENTS (continued)

<u>CHAPTER</u> <u>PAGE</u>

TABLE OF CONTENTS (continued)

CHAPTER PAGE

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANT	Actor-Network Theory
dVSS	da Vinci Surgical System
hHCI	haptic Human Computer Interaction
hHRI	haptic Human Robot Interaction
HMC	Human Machine Communication
HMS	Haptic Media Studies
OR	Operating Room
QDA	Qualitative Data Analysis
RAMIS	Robotically Assisted Minimally Invasive Surgery
RSA	Robotic Surgical Assistant
SCOT(t)	Social Construction of Technology (touch)
UIC	University of Illinois at Chicago

SUMMARY

The following study approaches the da Vinci Surgical System (dVSS), a robotic surgical assistant (RSA), as a case study to explore the co-construction of touch and technology. It focuses on how haptic engineers, surgical teams, and the RSA co-shape touch, from labs to the OR, and it explores the formation and implication of haptic imaginaries associated with the da Vinci and other emerging robotic surgical assistants.

My study is based on the idea that touch is socially and technically co-constructed. It posits that the meanings, values, experiences, and practices we associate with touch, and that guide our touch actions, are negotiated between social and material actors. Going further, it draws on a media ecological tradition that theorizes the way media technologies shape the sensorium — meaning they shape the way we feel, experience, perceive, and understand our worlds. Finally, I situate this study in conversation with the conceptual orientations and theoretical commitments of human-machine communication and haptic media studies which offer rationales for engaging machines as communicative agents and treating touch as having a cultural life of its own.

I use actor-network theory and social construction of technology to frame my mixed qualitative methods approach to identifying relevant social and material actors involved in the co-construction of touch and the dVSS, including haptic engineers, surgical teams, and the robotic surgical assistant. Semi-structured and unstructured interviews were conducted with robotic surgeons, residents, fellows, nurses, and medical technicians. Forty hours of observations took place in the OR and an additional twelve hours took place in the surgical training lab. Finally, I interviewed six leading haptics engineers, two of whom worked on the original da Vinci, and three of whom have worked on haptic projects related to RSAs.

In this study I provide an analysis of my findings over three interconnected chapters. Chapter 5 explores how touch is co-constructed as both profound and mundane in the OR. The dVSS reshapes touch practices in the OR and those shifts lead to changes in relationships between the surgeon, the rest of the surgical team, and the patient. The act of doing surgery with the device flattens touch, situates vision as the primary mode of doing surgery, and shifts the locus of control to the robot. By providing ergonomic comfort and control, the surgeon is put in the care of the device and allowed to operate within the physical and visual constraints of a system that diminishes the skilled sensory work of surgical touch. Chapter 6 traces the development of the daVinci and explores haptic ambiguities that both obscure touch and bring it to the surface. It suggests the construction of touch in the da Vinci is regarded as error in need of control and transforms surgical touch through a series of sociotechnical translations. Haptic engineers, treating touch from a functionalist and instrumentalist perspective, ultimately reduce touch to forces, which renders the surgeon's touch as desirable but not essential. Chapter 7 scrutinizes how haptics and surgical robotic futures are imagined, exposing the way that design decisions and operating the RSA situate and reinforce the nonnecessity of human touch in surgery, ultimately paving the way for surgeons to embrace the potential automation of surgery and the rise of a "superior" touch.

In the concluding chapter, I summarize my findings, offer four theoretical contributions regarding the co-construction of touch and technology, and argue that the findings from this study add to an emerging research orientation for communication and media studies scholars.

1. Introduction

1.1. Beyond the Limits of the Human Hand™

A hulking piece of machinery rests against the wall of the operating room. Sitting silently with its four mechanical arms pulled tight to its core, it waits to be draped, moved into position, and woken by the surgical team. Once the team makes incisions, places metal tubes in them, and sets the target, the metal arms are fitted with instruments and lowered into place manually, but with the memory to return to prior positions later. A surgeon sits in a chair, pulls it up to a piece of furniture that looks like a flight training simulator, and enters a code that allows the console to readjust to their preset preferences. Pressing their head against a headset and grasping two control grips with index finger and thumb, they make graceful movements with their hands and the machine moves in syncopated time, exaggerating the surgeon's motions through the exterior arms while miniaturizing the motions inside the patient's body. So begins a robotically assisted operation using the da Vinci Surgical System, a robotic surgical assistant whose creators, Intuitive, advertise the device as providing surgery that goes "beyond the limits of the human hand."

The suprahuman orientation is not unique to Intuitive. Discourses about transhumanism and posthumanism push claims about the ability of technology to take humans beyond their own physical limits. Framing the da Vinci specifically around the idea that it gets beyond the limits of the human hand clearly centers the labor of skilled human hands as paramount to surgical practice. Taken literally, the frame points to a disruption in surgical practice and a reshaping of surgical touch. The entry of machinery that can go beyond human hands is not novel, as Capuano (2015) points out:

> The Victorians were highly cognizant of the physicality of their hands precisely because unprecedented developments in mechanized industry and new advancements in evolutionary theory made them the first people to experience a radical disruption of this supposedly distinguishing mark of their humanity (p. 2).

However, the adaptation of machinery into professional medical settings to replace, or at least augment, surgical hands is a relatively recent transition. What does the integration of surgical robots mean for surgeons' sense of their professional identity? What does it really mean to go beyond the limits of the human hand? I pose these important questions as rhetorical examples meant to generate interest in the relationship between touch and technology.

1.2. Human Touch, Machine Touch, and Why They Matter

The development of robotic surgical assistants (RSAs) alter our notions of human and human-machine touch in medical settings. The most ubiquitous robotic assistant on the market, the da Vinci Surgical System (dVSS)[1] directly modifies what it means for the hands to act as healing agents, not only by removing them from direct contact with the patient but also by anesthetizing the felt epistemologies of operating. With the heat, resistance, and tackiness of the patient's body removed, what remains for the doctor to touch are the control side grips of a robot, grips which glide easily in the hands but give very little indication of a body being manipulated. Emerging RSAs attempt to recover some sense of feeling through haptic feedback, but these devices also alter touch in both technical and social ways.

RSAs created for human-machine interaction constitute an important focal point for understanding the co-construction of touch and technology. The values and meanings associated with these systems orient around the development of a haptic realities, a phrase I explicate in more

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[1] Through 2019, the da Vinci had been used in 7.2 million operations worldwide according to Intuitive's website.

depth in the next section. These systems are defined by their haptic materiality, shifting touch practices, and the associations of touch that arise with their development, use, and reception. I focus on the dVSS and the imaginaries corresponding to the development of novel RSAs that incorporate haptics because they alter the sociotechnical relationship between touch, machines, and surgery. Using a mixed-methods qualitative approach, I consider how surgical touch is configured with the rise of RSAs. I observe and interview engineers and surgical teams associated with the development and use of Intuitive's dVSS and other haptic tools for surgical intervention.

The growth of haptic human computer interaction (hHCI) and haptic human robot interaction (hHRI) requires attention from Communication, Media Studies, and Technology scholars as these devices present critical problems for the construction of touch and technology. At the heart of haptic communication technologies is the drive to erase them as mediating devices between humans, machines, and the environment, inspired by HCI logics argued for by Mark Weiser (1991). These logics are encapsulated in the concept of "transparency," which is the goal of adding haptic feedback to RSAs to make surgeons "feel as though they are directly operating on the patient rather than having a robot mediate the interaction" (Sauser, 2006). Ideations about the naturalness, immediacy, and intimacy of touch forward notions that communicating via touch, with and through machines, is necessarily intuitive, somehow unmediated, and potentially more direct than other forms of communication. However, touch also tends to be treated as ancillary to the process of communication, serving to heighten experience in combination with other senses rather than being treated as a meaningful site of communication itself. A paradoxical relationship results as device designs tend to treat touch as secondary while their imagined qualities place a premium on touch as the prime point of interfacing — of establishing direct, unmediated, intimate, and caring connections. These ideas about touch rest on an ingrained sense that touch communication is primordial (Hansen, 2006), ancillary, and resistant to mediation (Peters, 1999). Inculcating a naturalized notion of haptic communication undermines the processes and values involved in making touch, touch — thus hiding the social construction touch involves and creating a distance that undermines our ability to be critical about what that construction might mean.

This project pushes back against this framing of touch by providing empirical evidence about its construction that is additive to the work done in Haptic Media Studies (HMS) and by scholars like David Parisi in his 2018 book, *Archaeologies of Touch*. My investigation of touch, as it takes shape in the OR and design spaces, also situates this research alongside sociotechnical studies of work and workplaces (Knorr-Cetina, 1983, 1999; Orr, 1996; Suchman, 2007). It contributes to these classic workplace studies by centering the sociotechnical and material dimensions of touch and touch technologies in exploring emerging relationships and practices. I focus on understanding how meanings and practices of touch are being altered in the operating room and the lab with the development and introduction of RSAs. The introduction of new technologies, like robotic surgical assistants beg new questions about these relationships and serve as case studies for understanding the intersections of touch and technology. The overarching question I ask from a sociotechnical perspective is, *how is touch socially and materially co-constructed between the dVSS, engineers, and surgical teams in the operating room?* With the development of haptic systems to aid the dVSS and the emergence of competitor systems, I ask the secondary question, *how do imaginings about haptics and emerging RSAs co-construct surgical touch?*

HMS nods to a tradition of Media Studies focused on the co-constructive role we play with our technologies and recognizes media as the use of materials to “manage time, space, and power” (Peters, 2015, p. 20). This perspective orients my project and provides critical insights about how haptic media alter, control, and manage emerging forms of touch. Integrating human-machine communication (HMC) to theorize the construction of human-machine touch positions scholars and artists to intervene in ways that help us think and feel in new ways. By bringing co-constructed touch to the fore, I hope to push conversations about communication and technology in new and productive directions that question the historical, material, and social conditions leveraged to make and manage our touch worlds.

1.2.1. Touch Matter(s)

The title of this section, *Touch Matter(s)*, is meant to invoke a double meaning. In this dissertation, I explore matters of touch and technology and make an argument for why they matter. The significance of touch in social rituals, as socially constructed, as a way of communicating, and as a way of understanding and expressing agency in the world, almost always plays a secondary role to verbal or visual forms of communication. The relationship between touch and technology has received some technical attention, mostly from areas of engineering, but research addressing the sociotechnical relationship has only recently sprouted (see Cranny-Francis, 2013; Parisi, et. al., 2017; Parisi, 2018; and Plotnick, 2018). I place touch at the center of my inquiry in order to show how orienting communication research from the position of touch offers critical insights to understanding the role of communication and media technologies in medical spaces. These findings also suggest that centering touch could provide important insights to communication researchers beyond the medical domain. Exploring nontraditional media and communication technologies like RSAs and nontraditional modes of communication, like touch, widens the horizons of the field but also offers the potential to provide new insights on traditional technologies by suggesting an alternative focal point. I deal with matters of touch and technology that offer insights about their role and development that are germane to communication and media studies, in general, and human-machine communication more specifically. My dissertation offers ideas for haptic engineering by providing a sociotechnical account that could help guide the development of haptic technologies. And the empirical analysis from this project provides social and material accounts of touch and the dVSS that could be useful for the medical humanities. The project pulls evidence from each of these areas and is concerned with how touch is constructed between these communities. This construction necessarily concerns disparate disciplines and fields of study. The values laden in the practices of touch, and touch devices, in the operating room and training labs, and in their imaginaries, express and reify value systems developed between engineers, surgical teams, and robotic assistants. By considering these various stakeholders, this dissertation explicates ideas and practices of touch that are often obfuscated. Bringing these concerns to the surface establishes foundational evidence to help create productive links between different areas.

1.2.1.1. The Significance of Touch

It has become a rhetorical cliché that touch is the most significant sense for humans even though it is rarely elevated in study, or technological development, to a place of primacy (Montagu, 1978; Field, 2003; Lafrance, 2009). The rhetoric surrounding studies of touch emphasize that it is the first to develop, it connects a person to the world in the most fundamental ways, and it serves as a system of orientation, connection, and control in a chaotic world. McLuhan (1962) suggests that all senses are touch-oriented. In some sense, touch is the primary mode and medium of our existence. Photons don't just pass through the retina, they touch it, articulating the colors and contours we make sense of in the brain. Soundwaves, invisible to the eyes, hit the ear drums, which turn those invisible waves into audible sound. Taste requires the touch of taste buds on the tongue and smell requires molecules coming into contact with receptors in our nose. Our whole sensory system really is touch-oriented. Yet, the touch system, delineated as a separate sensory apparatus consisting of multiple sub-systems, to sense pain, pleasure, force, temperature, texture, and to orient our bodies in space, emerges from The Enlightenment to turn toward measurement, segmentation, and ultimately reduction. Identifying these narrow channels of sensation, and operationalizing them for machine learning and machine interaction, turns them into a system for exploitation, pleasure, capital gain, control, and other pursuits.

In a purely physiological sense, then, we might say that touch truly is our primal and most important sense for perceiving and interacting with the world, but of course, this framing also has political and social implications. Part of this framing stems from attempts to bring back an air of respectability to touch that the visual and auditory senses have received for well over a century. Touch has often been considered the sense unworthy of scholarly pursuit either because it seemed inconsequential, hard to study, or beyond the scope of theorization.

The point is that touch is significant, whether it is due to its physiological primacy or due to the fact that we are constantly touching to make sense of the world. Making sense of touch informs how we touch, why we touch, what we touch, how we feel about touch, and how we experience touch collectively. Touch, despite its ubiquity, or perhaps because of it, remains insufficiently studied in certain academic areas. But a dearth of research in an area, and the novelty that exploratory studies might offer, is not enough of a rationale for pursuit in and of itself. There are more significant reasons for studying touch and technology in general, and in medical settings, specifically.

Touch is the basis for epistemological work in the operating room (OR) and for working with patients, whether this is acknowledged or not. Researching touch in the OR, with robotic surgical assistants and the engineers who design haptics, offers significant insights into the discursive ideas and experiential practices that make up, are passed on, are rejected, or are reinforced within these systems. Understanding their co-construction provides necessary empirical evidence to better understand the cultural and sociotechnical status of touch in the OR, in engineering labs, and in society. Touch matters.

1.2.1.2. Significance for Human-Machine Communication

The world is increasingly inundated with machines that humans communicate with wittingly or not. Human-machine communication (HMC) addresses these communicative moments by opening new avenues for inquiry about communication, technology, and society. It recognizes that "many emerging technologies no longer readily fit into the role of medium only. They are designed to function as things with which people interact" (Guzman, 2018). While the focus in human-machine communication centers visual and auditory interactions of humans and machines, a growing area of research into the mundane, ordinary, and imagined interactions involving touch largely fly under the radar (Barker, et. al, 2020; Richardson & Hjorth, 2017; Richardson & Hjorth, 2018). Communication, as it develops theory for emerging technologies and relationships, is in danger of repeating tropes about what counts as communication in a time when HMC is nascent. This study serves as a corrective to that impulse. It explores the ways that perceptions and practices of touch, by both humans and machines, are implicated in the process of communication. These articulations of touch have consequences for what counts as human-machine communication. Designing machines to provide haptic feedback via vibrations or forces or furriness alters how we perceive our interactions with devices. These decisions should not be diminished as we pursue an understanding of human-machine communication. Nor should we overlook the ways that devices become the embodiment of those ideas as they have social and political ramifications that we will fail to recognize if we overly emphasize interlocution through the lens of visual and verbal interactions. In addition to providing a touch-oriented frame for human-machine communication, my research also adds a methodological approach and empirical data that should be useful to HMC researchers interested in medical robotics.

1.2.1.3. Significance for Haptic Engineering

The significance of this study goes beyond pushing theoretical boundaries of human-machine communication and understanding the role and construction of touch in those relations. There are, in fact, practical points of significance to this study for both engineers and surgeons, surgical teams, and hospitals. The findings of this study offer at least two clear contributions to the field of haptic engineering. The study provides empirical data about how some surgeons think about touch, and the touch interfaces of robotic medical devices, in a way that could help better understand what types of touch matter to surgeons when developing surgical robots. It also pushes theoretical boundaries of what is possible for haptic engineers to consider when determining what counts as touch and what matters in haptic interfaces. It uncovers haptic ambiguities and suggests how they might be made productive.

On the first point, the data collected in this study through interviews with haptic engineers, provide an outsider perspective to experts and novices in the field. Talking to engineers to gain insights into their understanding of touch, haptics, and technology, this study provides a reflexive analysis which gives engineers a perspective on how values are embedded, expressed, and reified in the construction of haptic interfaces that they may not have otherwise considered. Moreover, the interviews reveal the sociotechnical work being done by engineers designing for robotic assistants and for haptic interfaces in general.

On the second point, this study provides practical theoretical benefits to the field of haptic engineering by articulating a theory of touch and haptics that could inform their design decisions. By showing how touch is not merely instrumental, but social and relational, the results of this study provide a wider range of potential ways for the field of haptic engineering to think about what it means to touch, and how various ideas of touch could inform the design and physical construction of apparatuses for haptic interaction.

1.2.1.4. Significance for Medical Humanities

Finally, the significance of this study extends to the field of medicine in general and into operating rooms with robotic surgical assistants more specifically. There is a growing body of research into the impacts of adding robotic surgical assistants into the OR, both in terms of disrupting, or reorganizing the flow of work in the OR, and in terms of the efficacy of doing surgery with the device. Some studies have begun to mention the role the device plays in changing notions of touch in the OR (Olsen, 2009; Sergeeva, et. al, 2018). And literature investigating medicine has long understood the role of the body in medical and surgical practice (Porter, 1993; Prentice, 2005; Reiser, 1978). The OR is a hyperspecialized space for the study of touch, but one where touch, from the mundane to the profound, plays organizing roles in the social interactions of surgical staff and the curing of patients. The role of the surgeon's touch has often been granted an almost reverential power, as the life of a patient is put in the hands of the surgeon, and with that power has come an elevated professional status. The integration of RSAs into the OR potentially diffuses that power and the status attached to it. Understanding how that is happening, and the extent to which it is happening, could be important for surgeons and the surgical team as they negotiate their roles with RSAs, their patients, and their institutions.

These intersecting areas inform the formation of my study, and I believe the data and analysis I provide in this dissertation can serve the empirical, theoretical, and practical pursuits of these fields. Considering how these intersecting areas form the backdrop of how touch takes shape in relation to human-machine communication and surgery, my dissertation focuses on the dVSS and the imaginaries of emerging Haptic RSAs. Each represent sites ripe for inquiry to understand how constructions of touch develop with certain technologies. Laying a conceptual framework helps orient the process.

2. LITERATURE REVIEW

Trying to position my research on the relationship between touch, communication and media studies, haptic engineering, and robotic surgery, requires a literature review that covers a great deal of ground. The review begins by taking a broad perspective that situates my research within a media ecological tradition that argues for the role communication technologies play in shaping our experiences of the world. I move to providing a brief history of the ways touch and vision have shifted with the introduction of new technologies before narrowing in on the cultural formation of touch and healing and shifts in medical knowledge and the authority of touch with the introduction of new medical instruments. Honing in even further, I discuss literature that has currently made claims about how the da Vinci reshapes the OR, arguing that the studies largely miss the importance of how the dVSS shapes touch and reorients the surgical space via touch. In order to understand the development of touch in the da Vinci and to provide a way of understanding the co-construction of touch and technology that leads to my research questions, I present literature that explores the way touch and haptics develop from a complex set of historical and sociotechnical conditions. Finally, I return to situating my project within communication and media studies by focusing on how the aims of this project are framed by human-machine communication and haptic media studies.

2.1. The Cultural and Sociotechnical Co-Construction of Touch and Technology

Much has been written about the morphing sensorium, especially with regard to the relationship between the emergence of optic technologies, instrumentalizations of vision, and the relationship between visual media, knowledge, and shifting social values. Jonathan Crary (1990) and Martin Jay (1993) offer two especially salient accounts, but a host of media theorists from Benjamin (1969[1935]) to Innis and McLuhan (1962, 1994), and beyond, have also provided rich theoretical and analytical accounts of these shifts and their social, economic, political, and cultural implications. While accounts of vision and visual culture have been thoroughly explored and continue to dominate the field of media studies, accounts of touch remain more disparate. This short section is thus meant to provide some evidence concerning the historical development of the sensorium in the West, as technologies of vision, along with ideas about epistemology, began to emerge, displacing rituals of touch as verifiers of knowledge and sanctity. This section also shows some of the ways that touch and vision took on different cultural valences. The examples attest to the cultural and sociotechnical life of touch and suggest that a new era of touch technologies may reconfigure our senses once again.

2.2. A Very Brief Cultural History of Touch and Vision

> When technology extends one of our senses, a new translation of culture occurs as swiftly as the new technology is interiorized (McLuhan, 1962, p. 40).

In order to understand how society perceives in any given time we must understand how they value the senses, how the senses are arranged, and what senses are given precedence over others. The variability in the formation of the senses constitutes the variability of our perceptions of the world. "Each of us has a somewhat different experience of reality, owing to the differing combination of the five senses" (Lowe, 1982, p. 7). But while each of us has a different experience of reality based on how we, as individuals, value our senses, a step back reveals that a societal shift in the sensorium, granting the eye primacy, has also helped reshape our larger social experience of reality in the West since at least the 13th century.

Visual metaphors abound in 21st century language but their association with progress is especially apparent. From vision statements to data visualizations, the eye defines the modern condition. But reality defined by the eye is a modern innovation for the majority of the population, the world over. The visual turn accelerated in the 17th century with the slow spread of literacy, but the values associated with the eye and its placement on top of the hierarchy of the senses began well before the 17th century. The roots of the visual turn started when humans decided to represent animals from the hunt on cave walls, mark rituals with pictorial inscription, and to capture sounds in the static medium of writing.

The shift from orality to chirography marked "a new translation of culture." The shift was not necessarily met with open arms. For Plato, the encroachment of writing over orality meant the end of memory and the displacements of dialog between the author and the audience (Nicholson, 1999). Ironic then that Plato's laments are only known because they were written down. Contrary to Plato, Aristotle exulted the eye. Regardless of philosopher quarrels, the invention of the alphabet affirmed the domination of the eye and transformed hearing-dominated cultures to sight-dominated cultures. From that moment on, "vision became the most important means of acquiring knowledge" (Classen, 1993, p. 5), at least for philosophers and the literate class – reifying positions of power. Not only did written language reinforce vision as an important means of acquiring knowledge, it also "made possible the discovery of a formal abstract logic, apart from speech and memory" (Lowe, 1982, p. 4).

Mediums that supported writing also played vital roles in the visual turn. From clay to papyrus to paper, the materials that stored written words changed over time and with their changes came greater diffusion of written knowledge. The durability and lightness of paper made the dispersion of ideas over great distances possible. Spreading from China, paper "hastened the growth of commerce in Italy and northern Europe" (Innis, 2008, p. 20). It spread Greek science, Arabic numerals, and a host of philosophical, religious, and technological ideas.

In *Orality and Literacy: The technologizing of the Word,* Walter Ong (2002) describes the transition of oral sounds to written language, but the interiorization of the technology took time to catch on for a majority of humans. Highly trained scribes passed down written knowledge from generation to generation. They spread ideas across lands by meticulously hand copying written works. In the West scribes were often Monks in the monastery. Much knowledge was lost or censored by those in political power. Because only few could read, written texts were not visual for a majority of the population. Books were not read privately but read aloud in public places (Fischer, 2003). Thus, visual texts remained aural for most people. Still, the seeds for the primacy of the eye and the association of sight with knowledge took root.

In early medieval Europe, relics and other religious artifacts were associated with mystical powers that could only be gained through coming into direct contact with them, either through touch or ingestion. Direct encounters decreased after the 13th century. Even though the host is still ingested, it became spectacle in the 13th century and conventions of raising the host, hoisting the eyes upward, symbolizing the raised status of the church and its closeness to god, began to gain social currency. The importance of seeing thus manifested itself in a shift from touching relics to viewing them (Classen, 2012, p. 149).

The Age of Enlightenment ushered in an era of new technologies of vision. Individuals, especially intellectuals in the academy, saw the world in new ways with the increasing proliferation of telescopes and microscopes, maps and books, and eyeglasses and eye-operations. Scholars observed the universe of the very big with more precision and discovered the world of the very tiny for the first time. They wrote and recorded events of the day and the spread of literacy, due to recent innovations in printing technology, created a public and intellectual curiosity thirsted for through the eyes. The magic lantern illuminated walls with pictures and invoked an inner world of visual dreams.

The opening of the first public museum in the late 1790s further solidified the place of visual experience in the history of Western thought and social practice. As the first public museum, the Louvre housed a wide variety of artistic works and cultural artifacts. The practice of collecting artifacts of ancient civilizations and recently colonized societies continued to spread throughout Europe and North America with the opening of more museums and public intellectual spaces. The museum enforced the taming of touch and helped solidify its increasingly irrelevant status in two ways. First, museums took tactile works like sculpture and crafts from more touch-oriented cultures and put them on display. The museum turned tactile art into visual art. Second, putting things on display to be seen resulted in the active educating of public patrons in the museum to touch with their eyes, not with their hands (Classen, 2012).

The rise of rationalism and its connection with visual experience also depicted women as unfit for scholarly endeavors. Some in The Enlightenment project suggested that women were more physically sensitive than men. This increased tactile and sensory sensitivity made women experience the world in more reactionary, emotional ways, all of which left women unfit for the world of rational scholarly pursuit (Jütte, 2005, p. 137). While they may not have been permitted to obtain medical degrees, their sensitive skin and tender touch apparently made them good subservient caretakers.

Objectivism rose out of a reaction to Kantian rationality, inspired by the Cartesian split of body and mind, in the late 19th century. It suggested that there was a world out there, independent of the human mind, that could be measured and taken account of. While objectivism rose as a philosophical reaction to pure rationality it also espoused The Enlightenment era’s turn toward science and extended Romanticism's engagement with the natural world. Although objectivism resulted in "hard" sciences that measured the material proprieties of objects, emerging social sciences took objective ideals to indicate the need for distancing. By taking a birds-eye view of culture and society and by observing their language and practices from outside, scholars could get at the objective reality of a culture. This idea also marked the rise of experimentalism. The eye, and perhaps the ear, as physical receptors associated with detached rationality, instead of emotion, provided the most objective view of these newly encountered subjects.

In tracing a very brief cultural history of touch and vision I have attempted to establish a broad survey for thinking about how touch has been constructed in Western culture and why those constructions matter. In the next section, I focus more narrowly on how constructions of touch have manifest in relation to medicine. Narrowing to focus on the relationship between touch and medicine, specifically ideas of healing associated with medicine, provides a context for thinking about what kinds of tensions and reformulations arise for the co-construction of touch with the introduction of RSAs.

2.3. On Touch and Healing

Touch has long been associated with notions of healing, although who could touch, who had the healing touch, where touch could be administered and when it could be delivered have shifted over time. The curative powers of touch have also long been associated with religion, spirituality, and superstition, notions that still echo through a variety of religious and secular practices today. While many of the superstitious associations between touch and healing have dissipated in mainstream culture, an almost mystical quality between touch and healing seems to remain in the practices and discourses of touch, even in implicit ways.

The Christian bible is littered with references to the healing power of touch, both through Jesus and through those who spread his word (Gospel of Mark). Throughout antiquity and into the Middle Ages, saintly objects were highly sought after to be touched or sometimes ingested because of their supposed healing properties (Classen, 2012). Physical and spiritual healing, up until the Reformation and Enlightenment Period, at least in the West, were predicated on practices of touch. These notions carried forward in the rites and rituals of Kings and Queens. The divine right of Kings and Queens meant they had the power to literally connect a person to God, promising to deliver healing touch as if by divine intervention. In his work, "Magical Healing: The King's Touch," Keith Thomas (2005) explains the popularity of the procedure after it was initiated by Edward the Confessor, stating, "Charles II is known to have ministered to 90,798 persons in the nineteen year, 1660 -64 and 1667-82" (p. 355). Beyond the Royal touch ceremony, folk healers also incorporated touch into curative rituals. However, unlike monarchs who were supposedly channeling a divine touch to heal, folk healers were often "accused of magic and witchcraft" (Thomas, 2005, p. 359). Ceremonies of royal touch were relatively short lived and gave way to the turn of Enlightenment, and a growing suspicion of divine right. Many were also accused of being frauds and hucksters, selling fake cures through their own hands "however, hopeful believers in the magical powers of touch have continued to abound" (Classen, 2005, p. 348). Indeed, a strong tradition of faith healing which includes the literally laying on of hands by a preacher or parishioner filled with the holy spirit, lives on today in some Evangelical religious traditions in the United States. The spike in hands-on faith healing may have dwindled after the Revival Period in the early 1900s, but the associations between touch and healing, and magic and religion, continue through other non-Western traditions of healing, into medicine, and through technological innovations, especially with electricity (de la Peña, 2003), which carried its own magical and divine associations.

In her essay, Classen (2005) argues that there are two historical constructions of therapeutic touch. The first treats touch as a medium of supernatural influence. These constructions are related to ideas like Royal Touch, faith healing, and Reiki, that believe the healing power of touch comes through its ability to act as a medium. The second constructs touch with a natural kind of healing ability, not tied to religion, magic, or superstition. In this thread, touch still has a kind of healing power or healing potential but one that is physiologically based. Here, the act of touching promotes biological and social responses that may aid in the healing process, even where the process produces a kind of placebo effect. Of course, more often than not, these constructions have been, and continue to be intertwined in some ways, moving back and forth, and potentially reinforcing the other. While the construction of a therapeutic idea of touch is more complex than the two strands Classen lays out, they provide a starting model to consider how, when, and why the two may bleed into each other and give way to other strands. In considering the da Vinci, we might ask whether it becomes the medium for supernatural influences remarked on in the first strand (e.g. do people ascribe a kind of religious or spiritual development to the device?) and/or does it work through the second strand, or perhaps through neither, standing apart in some way.

As one example of the way Classen's (2005) two strands may slip into each other, she says, "Franz Mesmer believed in apparent healing power of magnetic touch to be due to natural forces, his practice acquired the reputation of being supernatural or superstitious" (p. 348). And further, "within a non-Western medical context, distinguishing between the supernatural and the natural employment of healing touch is often misleading, as the distinction may not be meaningful within the culture itself" (p. 348).

While the connection between touch and healing has a long history in religious, spiritual, and supernatural contexts, it also has a long and evolving history in medicine, with some of the spiritual associations sometimes spilling over. A brief Western history of medical touch from the mid 1700s through today helps illustrate the shifting relations of touch within medicine. In her essay on "Educating the senses: students, teachers and medical rhetoric in eighteenth-century London," Lawrence (1993) explains norms surrounding touch in medicine. She states, "medicine has long abided by certain protocols in respect of the touching and grasping of another body. A barber-surgeon was normally permitted to touch all parts of a male or female patient's body — anywhere, that is, where it hurt" (p. 72). But norms concerning touch were quickly shifting in the 1700s. What had once been permissible contact between individuals and especially between doctors and patients was quickly giving way to new forms of touch etiquette, often driven by changes in religious ideals. As Jütte (2005) points out, shifting norms stemming mostly from religious ideals increasingly dictated not sleeping in the same bed, especially while naked, and turned even dance, an acceptable form of male-female contact, into a form which might arouse too much sexual temptation (p. 177). As further evidence, he points to a description left by Louis-Sébastien Mercier (1740 - 1814) on French etiquette, "'the man of delicate feelings abhors nothing so much as kissing a woman on the cheek in public. It is better to avoid even touching her hand or the hem of her gown to have witness'" (Jütte, 2005, p. 177).

In confirming the relationship between power and touch, Classen (2005), summarizing Porter states, "the routine of the modern physical examination — testing reflexes, taking the patient's blood pressure and so on — is not only a means of ascertaining the patient's state of health, it is also a performance in which the physician enacts his identity through a set of established procedures and confirms his right 'above all, to touch and penetrate the body' (Porter, 1993, p. 179)" (p. 349). Porter (1993) goes on to talk about the fact that the routine medical examination was so mundane at one point that records of how the exams were done is extremely limited. His focus on the 18th and 19th centuries in England, though, reveal that the "'hands-on' examination" which, if not administered today, would be perceived as "negligent," has mostly developed in the last 100 years or so (p. 179). Unlike today's medical exams which require touch as a diagnostic tool, doctors during the 18th and 19th century, at least in England, took a more hands-off approach, believing that diagnoses were possible, indeed best made, after a patient offered a detailed story about their daily lives and the ailment that was affecting them. The shift in acceptance of physical exams for doctors and patients may actually have corresponded to the rise in the use of instruments in examinations. As Porter (1993) points out, "many procedures involve the touching of body zones not normally exposed or handled, though the use of diagnostic instruments perhaps reduced the sense of violation and provides legitimation" (p. 179). This speculation is interesting because it suggests instruments do not transfer associations of human touch but render them mundane and neutral. But Porter's claim seems spurious given the lack of empirical evidence to support it and the strong theoretical evidence that technologies are never neutral.

Of course, touch in any setting, but especially a medical context, is not just about touch, it's about "confirming or challenging certain social orders and roles" (Classen, 2005, p. 349). It is this claim, in itself, that lays a justification for interrogating the way introducing new instruments into medicine alters those social orders and roles, thus altering the meanings of touch and vice versa. The authority granted to medical touch means that doctors are typically permitted to touch in ways that would be inappropriate in other contexts. In this light, it is worth considering how robotic touch may alter that authority and rearrange the social order.

In his book on medicalized touch, Stepansky (2016) makes the claim that, "allowing for the variegated meanings of touching and being touched—by doctors' hands, by nurses' hands, by instruments, as an aspect of medical procedures, as an expression of human connection—it is all about touch" (p. 1). Stepansky's work sometimes treats touch as purely metaphorical, in the sense that touching someone means forming an affective connection, e.g. her advice touched me deeply. But his work also takes seriously the social and physical construction of touch in the field of medicine. It explores the shifting and shaping of touch in relation to regulations, cultural shifts, and the introduction of new instruments. Much of the monograph focuses on the relationships between touch and care. While this relationship is slightly different from that of touch and healing, it is related in the sense that in order for touch to be effective in healing it must first be caring. Or, in other words, there cannot be proper healing without caring because healing is about more than suturing a physical wound, it is also about the psychological and emotional trauma that accompanies it.

2.4. On Reshaping the Knowledge and Authority of Human Touch

In his work on phenomenology, Merleau-Ponty (1962) argues that perception is what connects humans to the world. It defines our place in and relation to the world. How we perceive is thus integral to making sense of the world around us. Figuring out the perceptual biases of an individual or a society or a thing is key to understanding the ideas and values they perpetuate. These ideas are manifest and made material in technological devices. Lowe (1982) proposes a theory to frame how perceptual changes take place in different places and periods:

> In each period, the culture of communications media frames the act of perceiving; the subject is delimited by a different hierarchical organization of sensing; and the content of the perceived is ordered by a different set of epistemic rules. Therefore, the perceptual field constituted by them is a historical formation, which differs from one period to the next (p. 12).

Applied to surgical robotic assistants, this means they reconfigure the importance of touch and vision, re-orienting the sensory arrangement. Surgical touch, the defining characteristic of surgeons, becomes subsumed to surgical sight. Surgery with the da Vinci means reorienting epistemologies of cutting and sewing away from the tactility of the hands to the optics of the eye. This shift aligns surgery with the trajectory of the medical field writ large, which has become more ocularcentric with the introduction of new technologies, altering what counts as diagnostic and curative knowledge.

The use of instruments is standard practice in Western medicine today. There is a reverence reserved for the knowledge produced by the instrument that is not conferred to the doctor or nurse alone. It is likely a patient would be suspect of medical advice offered without first having a machine record blood pressure, temperature, and other vital signs. Our orientation toward instruments, observations, and medical knowledge is a complete departure from the 17^{th} and 18^{th} centuries when "the coin of evaluation was words – the doctor learned about illness from the patient's story of the events and sensations marking its passage" (Reiser, 1978, p. 13). The introduction of the stethoscope "reformulated the relationship between doctors and patients, through the use of an instrument that took the mantel of illness out of the hands of patients and placed it in the doctor's orbit" (Reiser, 1978, p. 13). Taking Reiser's argument, the stethoscope granted the doctor increased authority to interpret the bodily condition because the doctor had specialized knowledge and training to make sense of the stethoscope signals. As Olson (2009) argues:

> the expertise and authority of the physician was cultivated through a sensibility of autonomy from the patient. The net effect of this emergent epistemology was to render a patient's narrative suspect in its subjectivity, unreliable and subject to distortions of overemphasis and omission (p. 2).

The introduction of these instruments also ushered in an era of segmenting and segregating the senses. In order for instruments to take sensory measurements that would be read and interpreted by doctors, it was necessary to turn the senses into a system that could be mapped and manipulated. Instruments and measurements distinguished the senses in order to make them knowable, but those same instruments reduced the senses into ever finer segmentations to make them more efficient tools (Sterne, 2003).

In altering the perception of the senses, these technologies also altered perceptions of the authority aligned with embodied senses as instruments for measurement. The physician's touch was made suspect. Thermometers, X-rays, and other emerging technologies, now considered mundane, offered a sense of objective measurement and displaced the authority of the physician's touch (Reiser, 1978). New media technologies like fitness trackers further erode the authority of human touch as a diagnostic tool, raising "anxiety over the potential sensory deskilling of medical practioners" (O'Neill, 2017, p. 1616 – 1617).

The reshaping of medical knowledge and the authority of human touch is not relegated to the realm of the medical doctor; it increasingly extends into the realm of the surgeon. While surgical instruments have always been part of the surgeon's trade, the increasing reliance on medical imagery and robotic tools break the traditional connection between surgeons, instruments, and bodies. As Olson (2009) notes concerning laparoscopic tools, but also applicable to the da Vinci:

> Touch is severely attenuated; the haptic feedback experienced through the laparoscopic tool handles in no way approximates the rich sensations received by the hand in open surgery. The resistance of tissue to the probing intervention of the instrument is felt, but radically diminished by the fulcrum physics of the rigid laparoscopic tools. And these instruments cannot transmit temperature, texture, viscosity — all the detailed qualities that once constituted the surgeon's tacit knowledge of the body (pg. 73).

2.5. da Vinci® Reshapes the OR and Surgical Touch

There are numerous studies concerning the da Vinci and other surgical robotic devices, but these studies tend to either focus exclusively on the technical aspects of the device or on surgical outcomes (some examples include: Lai, et. al., 2020; Vigneswaran, et. al., 2020; Wilensky, 2016; Zhou, 2011). There are studies that offer insights from personal experience (Giulianotti, et. al., 2004), but they are far fewer. This is not surprising since there is a desire to prove or disprove the effectiveness of the device in the OR. It is also not a surprise since those with access to the devices tend to be engineers designing the devices and doctors using them. The studies on the da Vinci reflect their concerns with designing and using it. However, an increasing number of studies have also considered the social and cultural impact of the system (Balkin, 2013; Beane, 2018; Pelikan, 2018; Olson, 2009; Sergeeva, et. al., 2018).

Each of the social and cultural studies provide evidence for how the da Vinci has reshaped different aspects of the OR. The da Vinci altered training practices for medical students and surgical residents as they were forced into finding ways to train outside the approved means (Beane, 2018). The lack of surgical robotic trainers and time constrictions on using the trainers necessitated students train outside hours when they could be observed and assessed. As Beane (2018) was able to identify, the lack of training kept many from gaining the necessary surgical competence to operate with the da Vinci, but those who did make it relied on specializing their training at the expense of generalized training, using "abstract rehearsal" before and during surgical operations because the orientation of the device and the patient means the resident and surgeon no longer work side-by-side on the patient's body and had to self-teach without much expert supervision (p. 1).

The da Vinci alters work practices by allowing surgeons to "use their hands differently, increasing their procedure capacities for physical manipulation of the organs and tissues," and diminishes the need for assistants since the surgeon essentially has four operable arms instead of two (Sergeeva, et al., 2018, p. 3). But it also reduces performance by attenuating their "abilities to perceive and act in different ways," for instance, by cutting off their ability to feel the body which could make it difficult to stem bleeding or even find the source (p. 3). Shifts are confined to the performance of the surgeon. It alters a number of relationships and raises and reduces the authority of different members of the surgical team, elevating experienced nurses to surgical assistants in some cases, turning residents into students by reducing their ability to assist with the surgery, and committing more of the surgeon's time to specializing on technique rather than supervising the team (p. 4 – 5). Focusing more specifically on how these changes impact physical spacing and touching in the OR and how those changes affect surgical teams, Pelikan, et al. (2018) argue that increases in physical and sensory distance between team members impacts their social awareness, affective states, and the creation of common ground. These shifts have effects "on power distribution, practice, and collaborative experience within the surgical team" (p. 1).

Olson (2009) wrote perhaps the earliest and most comprehensive study on the da Vinci from a cultural perspective. In his dissertation, he applied cultural studies, media studies, and communication lenses to argue that:

> the introduction of robots into surgical practice exacerbates existing tensions within the surgical profession, such as the surgeon's ambivalent relation to the manual aspects of surgical craft, the increasing strictures on the surgeon's professional autonomy in an era of managed care and corporate medicine, and the displacement of the surgeon's expertise, authority and judgement in the face of proliferating loci on medical knowledge production and exchange (p. 8 – 9).

Olson's dissertation offers a deep dive into cultural and technical aspects of the dVSS that I refer to throughout this project. Many of the empirical findings in my project, related to surgeons and the OR, confirm findings in his project, completed ten years prior, suggesting both how salient his research is and how universalized some of the experience of working with the da Vinci seem to be. However, where his project focused on cultural and political issues concerning the way notions of care are altered with the da Vinci, my project focuses on the sociotechnical co-construction of touch, using the da Vinci as a case study. In this way, my project centers touch to understand its co-construction with RSAs, but in better understanding those relationships, this project also adds to a growing body of knowledge about the sociotechnical shaping of the da Vinci and the OR.

In the following sections I focus on the development of touch and technology to consider how shifts in science and technology have given rise to new ways of thinking and making touch. The sections provide a foundation for considering some of the lineage that informs the co-construction of RSAs and touch, from the development of haptics as the science of touch through the conceptions of haptics used in human-computer interaction (HCI).

2.6. Making Touch, Touch

We reach out and touch someone to verify their presence, as if touch is the arbiter of truth. Paraphrasing Gallace and Spence (2014), to touch is to make real. These formulations have largely positioned touch in opposition to *modernity*, in opposition to the ability to be modernized and instrumentalized like vision and hearing. And yet, as the history of haptics suggests, attempts to make touch like vision and hearing push back against the notion that touch resisted modernity's impulses to rationalize and instrumentalize sensory systems for capital gain, conditioning, and control:

> It is as if the tactile does not have its own history, and as such can be treated as a natural rather than a social object. In the nineteenth century, touch (quite like vision) became radically implicated in the trajectory of scientific modernity;

> demystified, quantified and mediated by new empirical techniques for measuring perceptual processes (Parisi, 2009, p. 141).

2.6.1. Haptics: The Science of Touch - On Making Touch Modern

Pushing back against the notion that touch has resisted instrumenalization, Parisi (2018) investigates how haptics emerged from the science of touch to become the doctrine of touch from the mid 1700s to late 1800s and early 1900s. Taking a genealogical approach and investigating discourses produced in different scientific disciplines, he uncovers evidence of the construction of touch as a thoroughly modernist project that sought to instrumentalize touch in similar ways to seeing and hearing.

His work provides an account of the history of haptics as a sociotechnical project that I will not try to summarize in its entirety here. Rather I wish to highlight some of the important findings in his work that are paramount to understanding the historical construction of touch in labs — establishing one foundational thread from which this project builds on. He makes a case about the way the haptic has largely been treated in media theory as "a space outside the purview of optical rationality, a purely phenomenological and ahistorical category of experience not subjected to the same modes of domination, subjugation and most significantly rationalization that have been used to foster at best a mistrust and at worst a demonization of the visual" (2009, p. 79). His approach is a decidedly critical take on the haptic, one that seeks to position touch as a sense already instrumentalized by technologies and techniques of modernity starting as early as the mid-1700s. The argument is germane as it seeks to overturn the taken for granted nature of touch as a sense somehow necessarily resistant to mediation. And while this review of literature reveals that there are certainly aspects of touch that make it differently difficult to mediate than vision and audition, it no less has gone through, and continues to go through its own process of abstraction, a process meant to quantify human touch for the purposes of scientific discovery and commercial efficiency.

Parisi (2008) discusses two models of touch that situate his argument and provide additional nuances to considering how we come to conceptualize touch and what those conceptualizations mean for theorizing touch and media. He describes the notion of passive and active touch as a bifurcation between "touch as something that the subject *does to* an object and touch as something *done to* the subject" (pg. 318). He ascribes the notions of passive and active touch to psychoanalytic models developed by E.H. Weber and David Katz. Whereas Weber used instruments to press against the body and gauge reactions, Katz argued that touch was most acutely felt through an active hand, one that consciously grasped objects. He argues that considering the psychophysical models and other models of touch matter because they influence notions about the boundaries and limits of haptic media and our haptic interactions with media. Tracing the genealogical histories informing the development of modern haptic technologies, locating the rationalization and normalization of touch primarily informed by Weber's theories, Parisi (2011) argues, "one cannot understand the contemporary relation between tactility and technology (and between media technology and the haptic, more specifically) without first confronting the methods and techniques used to render touch during the nineteenth century" (p. 194).

Weber's decision to "isolate touch as a physiological process and differentiate it based on its anatomical structures as they could be observed from the articulates of his subjects in the controlled and simulated conditions of the labs" offered a break from work that "debated extensively about the status of touch in the overall configuration of the human" (Parisi, 2009, p. 131). Weber's work was in contrast to "Johann Gottfried Herder (1744 – 1803), for example, [who] had located touch at the center of the epistemology of the external world. It was also counter to Friedrich Schiller (1759–1805) who "defined touch only as a force that acted upon man, distinguished from the active, distal senses of seeing and hearing" (Parisi, 2009, p. 131).

Parisi (2009) also outlines a brief history of other scientific investigations uncovering the links between the nervous system and touch, produced through experiments by Charles Bell (1774– 842) (p. 132), in sometimes lurid detail, including experiments on puppies that included cutting their posterior nerve roots and stitching them back together and work by Luigi Galvini that "animated the legs of dissected frog by passing electric current through them" (p. 133). He goes on to note that other, what he terms "the next important precondition for the science of touch" emerged from the work of Johannes Peter Müller "rendering the senses as carriers of discrete energies" (p. 134). Importantly, while Müller's work on touch contained notions of pleasure and pain, Weber's exploration to map the human tactile system largely avoided invoking pleasure or pain as it would introduce a source of uncertainty and noise in the data of measuring. This is important to note because, until recently, the science of touch has typically forwarded into haptic technologies constructions that similarly avoid evoking pleasure or pain in the rendering and transmission of data via touch.

By instrumentalizing touch, turning the human haptic system into something that could be measured, quantified, and studied using scientific methods, Weber, building on important work from Herder, Schiller, Bell, Müller, and others laid the early groundwork for experimental psychological and psychophysical approaches to touch. These fields, in turn, have laid much of foundation that informs haptic development in HCI.

2.6.1.1. Entering the Age of Haptic HCI

The history of haptic interfaces in HCI is relatively short compared to the 100-plus year history of image displays, yet the variety of devices and growth of haptic oriented inquiry has started to gain critical traction (Iwata, 2008). We are catching up to the high-tech devices of our future and yet, at the same time, as we get closer, they seem to be continually receding. The promise of haptic HCI (hHCI) is a promise always just around the corner. Regardless of whether we achieve the goals of hHCI, the cultural imaginary of touch and machines provides important clues about the construction of touch in fields of haptics, design, engineering, and HCI.

Despite the hugely successful iPod Touch which arguably ushered in a wave of touchscreen devices designed to take advantage of the "naturalness" of direct touch manipulation, keyboards and other traditional haptic input devices remain dominant ways of interacting with computers. The continued domination of the keyboard could be chalked up to good HCI design; "easy to learn, easy to use." It's debatable how easy it is to learn the keyboard, but for many it has become a naturalized extension of their fingers. The simple mechanical feedback mechanism that keys produce when pushed helps the process become intuitive in a way that typing on a touchscreen may lack. In McLuhanesque terms, the keyboard as an extension of 'man' shifts the sensorium and orients the fingers to desire haptic encounters over the unfeeling flatness of the screen (McLuhan, 1994). This internalized extension may explain why projected keyboards and innovations like skinput (C. Harrison, Tan, & Morris, 2011) never caught on. Even with vibration feedback, there is nothing to indicate the edge of the keys, not to mention issues of spacing on small tablets that make typing a cramped and uncomfortable procedure. Thus, some of the opportunities and challenges for hHCI from a purely psychophysical perspective involve figuring out ways of producing hHCI that produces effective forms of feedback on touchscreen displays, enabling an active form of touch from the device instead of remaining merely passive.

In addition to the haptic challenges of interacting with touchscreens, hHCI has an opportunity to explore novel uses of cheap, existing haptic feedback mechanisms like vibrators in phones or tactile actuators on smart watches. Features like Apple's "taptic engine," which use tiny actuators to communicate contextual information and notifications constitute one example.

Although the haptic signaling technology rests in a longer history of attempts to transmit information through touch devices (Parisi, 2020), its mass diffusion makes it a potentially interesting case study. By being usable in the field, in everyday contexts, and by providing sensory feedback, emerging haptic technologies provide touch scientists "powerful new tools for systematically producing and controlling haptic and multisensory stimuli in innovative ways never previously possible" (Lederman & Klatzky, 2009, p. 1456).

To develop his novel man-machine communication system, which rendered computer memories into three-dimensional tactile experiences (Noll, 1972) required knowledge of the human haptic system developed through the psychophysics of haptics. The psychophysics of haptics has made possible hHCI involving the design of devices that translate haptic qualities of objects and humans into computer code and then into felt interactions via vibration, force feedback, skin-stretch (Luk et al., 2006), and tactile-feedback (Okamura, 2009). As Saddik et al. (2011) suggest, "the journey toward multimedia haptics starts by understanding the human haptic system" (p. 9).

Ultimately, as HCI is about usability from the notion of being "easy to learn, easy to use" (Dix, 2004), the goal of the psychophysical approach to the study of haptics is "to develop effective tactile, haptic, and multisensory interfaces for use in a wide range of application domains involving different teleoperational and virtual environments" (Lederman & Klatzky, 2009, p. 1455). Haptic HCI designers need to have a fundamental understanding of how the human haptic system operates on a psychophysical level in order to achieve the fidelity required to achieve the right "feel" (Paterson, 2007).

Of course, humans perceive and interact with computers through more than skin and muscles. In fact, human-computer interaction accounts for multiple modalities while emphasizing visual and auditory forms of interaction. Using a mouse to move a cursor on a screen requires coordination between the eyes and the hands. Likewise, operating a pen-based force display to mold shapes in a CAD program requires interaction between visual and haptic modalities. Given the fact that we live in a multisensory world and interact with our environment through multiple modalities at once, there has long been interest in intersensory interactions. The question for perception researchers concerned with "interactions between haptic perception and other sensory modalities" according to Lederman & Klatzky (2009) seems to be, "how are inputs from multiple modalities about a common physical event combined" (p. 1451)?

Modalities are treated together in terms of how they overlap to inform each other and assigned to different aspects of HCI for which they are deemed best suited. For instance, studies suggest that, relative to the eye, skin is worse at distinguishing spatial features but better than the ear and has a better capacity for distinguishing temporal stimuli than vision but not better than audition (Lederman & Klatzky, 2009). These capacities of audition, vision, and the haptic suggest certain types of configurations when designing the most efficient forms of HCI. But questions remain about who these efficiencies are designed for and who actually benefits. For instance, "use of the haptic modality has potential for offloading screen communication, and increasing perceptual bandwidth available for interaction with a mobile information appliance" (Luk et., 2006), but that presumes a normative haptic user. In the same way, the auditory modality has the potential for offloading haptic and visual communication involved in navigating a car, which is why the voice on the GPS can be useful – but the usefulness only extends to those with the ability to hear and interpret the voice of the GPS and to those whose voices can be recognized by the listening device.

Despite the fact that modalities are always intersecting, HCI has tended to treat interaction modalities in different ways. The dominance of the graphical user interface in HCI places the visual modality at the center of computer interaction and relegates the hand and body to a supporting, more often than not ancillary role. While haptic technologies engaging three-dimensional computational objects exist, they are still expensive and represent a niche form of HCI. In the hierarchy of HCI modalities, haptics has traditionally come in a distant third place, still receiving more attention than olfaction and taste. However, an emerging wave of technologies may move hHCI to the center[2], challenging the long dominance of vision and audition.

The psychophysics of hHCI could benefit a world increasingly inundated with haptic technologies, from mobile phones to robotic helpers, but to conceptualize haptics from only a cognitivist perspective would be to miss the much bigger role hHCI and hHRI may play in co-constructing our everyday life worlds. As Cranny-Francis (2013) argues, "far from being a simple, muscular action or response, touch locates us in the world, connects us to each other, and enables us to operate effectively as embodied individuals and as social subjects" (p. 35). Touch is social, political, cultural, and inundated with complex meanings. To focus only on the psychophysical aspects of hHCI, regardless of how foundational they may be, is to miss out on understanding the social, political, and cultural significance of touch and technology. Focusing on meaning construction involved in HCI, the third paradigm acknowledges that "meaning derives from information, of course, but is also irreducibly connected to the viewpoints, interactions, histories, and local resources available to those making sense of the interface and therefore to some extent beyond the reach of formalization" (S. Harrison et al., 2011, p. 389).

[2] See Haptx (haptx.com), Lofelt (lofelt.com), and Teslasuit (teslasuit.io) for some examples.

We find ourselves at a moment then, when haptic technologies may play increasingly prominent roles in our interactions with devices and in our media landscapes. It is a period, not unlike prior periods, when media and communication technologies like cinema, radio, telephones and electricity were emerging, that would have indelible impacts on every aspect of human life. It has yet to be seen whether this will be the moment when haptic devices become mainstream, but even if they do not, it is likely they will in some not too distant future – and their current development will echo forward. The importance of surveying the area as it's being built, to understand the cultures currently developing our haptic futures, will not only pay dividends toward helping us theorize haptic media now but provide documentation that can be mined in the future, once haptic conventions have become entrenched. Documenting and analyzing the haptic development, materiality, and imaginary of the dVSS is one way to forward this work.

2.6.1.2. Humans and Machines: Human-Machine Communication

While considering touch aspects of RSAs through HCI offers an important first step, the approach falls short in considering how the machines act as communicative agents in the OR. Human-machine communication offers an orientation that opens ways to consider how the touch aspects of the device provoke shared rituals, functional exchanges, and intimate connections. Human-machine communication (HMC) suggests new avenues for inquiries about communication, technology, and society. Gunkel made the first call for a "reorientation and reconceptualization of communication studies" in 2012, in response to the growing emergence of integrated systems that were more autonomous than prior machines. The move suggested that emerging computing technologies and machines, rather than being mere mediators or mediums ——technologies to channel communication between humans, were increasingly acting as autonomous interlocutors. Jones (2014) made an additional push for HMC:

> The importance of HMC is in large part due to its insertion of the machine as itself an interpellated subject, always-already situated within the learned behaviours of an individual user and also the aggregate bloc of users whose communication has been mined and algorithmically processed to present a seemingly autonomous and coherent interlocutor, one at the user's beck and call, ready to provide information, control and to be controlled (p. 253).

And as McDowell and Gunkel (2016) make clear, "The machine—in the form of a physically embodied robot, an intelligent software algorithm, or a socialbot—now stares us in the face as another communicative subject possessing what Emmanual Levinas called 'face'" (p. 2)[3]. Guzman (2016) expands the HMC orientation by arguing that it should move beyond considerations of ICTs to incorporate industrial machines. As she states, "the interaction between humans and industrial machines have meaning beyond the transmission of information that fuels factories: they are rituals, in Carey's sense of the term, that contribute to an understanding of the self, other technologies, and, ultimately, culture" (Guzman, 2016, p. 6). HMC recognizes that "many emerging technologies no longer readily fit into the role of medium only. They are designed to function as things with which people interact" (Guzman, 2018). Beyond interacting agent, "the machine has become a communicative subject, and it is this subjectivity, rather than interactivity, that marks this technological transition" (Guzman, 2018).

Communication with machines has always involved touch, even the minimal interaction of pressing a button (Plotnick, 2018), but as hHCI and the hapticity of machines becomes more sophisticated, haptic communication with and through machines will become increasingly symbolic, affective, and meaningful. Communication and media studies have often given touch short shift in their historical development with notable exceptions such as interpersonal and

[3] I approach the da Vinci robot as a machine via human-machine communication, which aligns with the idea that "the word robot is now used to describe a huge range of different forms of machine" (Sandry, 2015).

psychological studies of touch and touch theories of media produced by Grusin (2010), Marks (2002), and McLuhan (1994). However, human-machine communication can treat touch and haptics as serious from the start. Focusing on touch communication, including mundane forms that are not intentionally designed to be communicative, constitute important aspects of human-machine communication that should be core to its conceptual, theoretical, and research development – and should not be treated as an appendage easily cut away. Arguably, thinking haptic media with an HMC lens will help develop theories of haptic media while also clearly articulating the social, cultural, and technical construction of human-machine touch as it continues to develop.

In Communication as Culture, Carey (1992) argues that "communication is a symbolic process whereby reality is produced, maintained, repaired, and transformed" (p. 23). So, we might ask, what kind of reality does haptic human-machine communication produce, maintain, repair, and transform? What kind of reality are haptic designers producing by formalizing communication through and with RSAs? And what kind of reality are surgical teams constructing through the use of RSAs? The emergence of haptic media studies provides an orientation that can help frame a study that attempts to answer those questions.

2.6.1.3. The Emergence of Haptic Media Studies

Haptic media are mostly unaccounted for and unexamined in the field of media studies. While other disciplines have marched forward in reclaiming knowledge associated with non-audio-visual modalities, media studies remains largely defined by its communication biases, shaped by seeing and hearing, vision and sound; objects, orientations, and practices that count as media and communication are primarily written and read, spoken and heard, produced and seen. When Peters (1999) makes the argument that touch "defies inscription" and Montagu (1978) conflates a technologized world with the "deprivation of sensory experience" they are forwarding notions that the senses, especially touch, are physiological rather than cultural, and natural rather than mediated. The mistake in their thinking represents a vacuum of knowledge in media studies regarding objects, orientations, and practices that are otherwise — other than visual and other than auditory, that a haptic media studies is beginning to explicate by way of rethinking the media of media studies[4].

While touch in media studies is relatively undertheorized, there are intellectual lineages within media studies that do stake some claim to producing ideations on haptic orientations. Visual theories of haptic media are prevalent today, marked by cinema and art theorists framing of touch as a visual sense. Their conceptualization of touch suggests the first way media studies define touch. By first, I do not mean to suggest that defining touch as a visual sense happened first chronologically, although discovering earlier arguments about touch in art history may suggest its chronological primacy. Rather, I discuss visual touch first because it represents a position that is most salient in media studies of touch.

Marks (2002) characterizes these discussions concerning the tactile dimensions of art and cinema, happening since at least the turn of the 20th century, as concerning "haptic visuality" (pg. xii). She elaborates on Deleuze and Guattari's notion of haptics, arguing that haptic encounters are both smoother and more particular, as opposed to abstract and striated. The point here is that haptic encounters, never haptic alone, but including vision and other senses, bring the body into a close encounter and generate knowledge that is more complete. Focusing on haptic visuality to counter

[4] Fields such as anthropology (Howes, 2003; Classen, 2012), art history (Candlin, 2006), gender studies (Bradac, et. al., 1984; Segal, 2009), and history (Jütte, 2008) provide useful insights for considering the cultural aspects of touch that could help inform perspectives on touch in communication and media studies.

what she sees as an increasing shift toward the dematerialization of objects and disembodiment of individuals through optical visuality, a move especially prominent among early Internet scholars, Marks (2002) intends to "restore a flow between the haptic and the optical that our culture is currently lacking" (pg. xiii). Thus, for Marks, haptics represents an embodied and metaphorical approach bringing critics closer to their objects of criticism; invoking McLuhan's notion of hot and cold media, "as a way to 'warm up' our cultural tendency to take a distance" (pg. xiii).

Taking a turn toward new media devices, Cooley (2004) develops the notion of "tactile vision" to theorize the general interaction with mobile screens, including practices such as holding them. Cooley draws on Benjamin's notion of tactile, which "explains tactile vision as sensual and diffuse and potentially charged with the immediacy and contingency of the everyday" (pg. 133).

Influenced by Cooley's notion of "tactile vision" but pushing it further, Verhoeff (2009) suggests the notion of "haptic vision" stating that:

> the haptic nature of the touch screen technology transforms the practice of screening; it foregrounds the temporal collapse between making and viewing images. Using the screen of the DS is a physical and performative activity. Viewing is no longer a matter of perceptually receiving images (pg. 214*)*.

While Cooley and Verhoeff clearly suggest a subtle shift toward more active forms of touch (literal physical interaction between humans and devices) that intersect with our sense of vision in psychophysical and cultural ways, the focus is still squarely rooted in theorizing the visual regimes of the devices they consider.

Scholars orienting touch as a way of seeing, as extending the sense of sight, or augmenting it using terms "tactile vision," "haptic visuality," or "touch vision" all share similar theoretical commitments rooted in approaches to early cinema theory. In their case, conceptualizations of media, as primarily visual, inform the way they theorize touch. Touch is theorized in the service of vision and visual theories of media. Marking vision as a form of contact positions the visual as having haptic qualities while subverting the notion that touch, touching media, and the hapticity of media are worthy of inquiry in themselves. As Huhtamo (2007) states, "the idea of 'haptic visuality' implies the transportation of qualities of touch to the realm of vision and visuality. It confronts the issue of the physicality of touch indirectly, through a corporeal operation involving the eyes and the brain. The hands are not part of it, except as an imaginary 'projection'" (pg. 73).

Shifting from the cinematic roots of media studies to one focused on broadening the category of media to subsume all types of technologies, Marshall McLuhan is perhaps the most well-known media scholar focused media and the senses. His aphorisms concerning media as extensions of the human sensorium, notions of sensory-ratios established by particular media, and ideas concerning tactility reverberate through much of the sensory anthropology research agenda developed by David Howes. According to Anthony Synnott (1993), "McLuhan became interested in the senses as he realized that poets like Hopkins, Eliot and Yeats each experienced their reality with a different 'sensory mix'" (p. 149). Inspired by the poets but also greatly influenced by Lewis Mumford and Harold Innis, McLuhan (1962) thinks the sensorium in new ways while considering the consequences of media: "if a new technology extends one or more of our senses outside us into the social world, then new ratios among all our senses will occur in that particular culture" (p. 41). By implicating media in the conditioning of the senses McLuhan offers a radically different vision for media studies and challenges notions of a static sensorium. His insights suggest that media are not just about the exchange of messages through empty vessels but that the mediums that are part of media (the television, clothing, money, and a host of other cultural artifacts) are part of a media environment that alters the way the human sensorium works and by extension the way individuals and society experience the world (McLuhan, 1994). Despite his contributions to considering the senses in media studies, McLuhan's conception of touch still shares a common lineage and affinity with Mark's (2002) notion of haptic visuality. For instance, his idea of tactile television argued that the effects of the visual medium were primarily felt in the body (McLuhan, 1994).

Offering a nonvisual-centric tactility, Wanda Strauven (2011), Erkki Huhtamo (2007) and Jussi Parikka (2012) articulate ways that touch has always been part of our media experiences. These encounters posit early cinema in new physical perspectives that are committed to understanding "how our bodies are activated and moulded by media technologies" (Parrika, 2012, pg. 29). In placing touch and haptic materiality in a position of primacy, they begin to conceptualize touch and theorize media beyond the scopic regime.

The key to these works is their argument that human touch is not merely physiological, incapable of being mediated, and resistant to cultural construction. Rather, touch is cultural, meaning it conditions "our experience and understanding of our bodies and the world at a fundamental level" (Classen, 1997, p. 401). Haptic media studies coalesces around this reconceptualization of touch, which attempts to lay a foundation that destabilizes the visual-centric roots of touch in media studies. Expressed by Parisi and Archer (2017):

> This is to suggest that touch—and, more specifically, the poorly-defined experiential category of 'the haptic'—does not exist in a realm unspoiled by and immune to power; instead, we understand touch as having a dynamic cultural life, constantly marked by its encounters with and expressions through a variety of apparatuses (p. 2).

The arguments and evidence presented in my literature review clearly lay out a strong case for the co-construction of touch and technology. The importance of establishing the sociotechnical construction of touch and its ability to be mediated, and in fact have a media and cultural life of its own, is important for establishing a foundation that this project can build on. The fact that touch is constructed and can be mediated means that the development and use of RSAs will likely shape notions and practices of touch associated with humans and machines in medical settings. In the next chapter I discuss the methods I use in this project to explore and analyze how touch is being co-constructed with surgeons, engineers, and RSAs.

3. CONCEPTUAL FRAMEWORK

It is necessary to unpack a few conceptual ideas to provide a shared understanding of key terms as I use them in this research, including haptic realities, the idea of the sensorium in relation to the sociotechnical co-construction of touch, social construction of technology (SCOT), actor-network theory (ANT), and affordances. With the exception of haptic realities, which I introduce in this dissertation, all are broad concepts with distinct intellectual histories. The point of this section is not to trace the development of these concepts in depth. Instead, I provide definitional boundaries for these concepts to make them meaningful and useful for this study.

3.1. Haptic Realities

Haptic realities are socially and materially constructed. If communication is a process that produces certain types of reality (Carey, 1992), then haptic realities are produced through touch communication technologies and communication about touch technologies.[5] Exploring haptic realities means thinking about "the multifaceted complexity of technology as *communication* made durable" (Lievrouw. 2014, p. 50). Unlike other approaches to touch in the field of communication, like proxemics (Hall, 1959; 1966, Kauffman, 1971) and nonverbal communication, which primarily treat touch as aspects of interpersonal communication (Guerrero & Hecht, 2008; Hall, 1996; Harrison, R & Knapp, M., 1972), developing the concept of haptic realities is meant to be an orienting device for communication and media studies scholars that centers touch and touch technologies. It is meant to provide a concept for studying touch and communication that focuses

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[5] I purposely use the plural realities because I am not suggesting that haptics creates a singular reality that has defining features which constitute it as abiding by its own internal logics and boundaries as with the concept of virtual reality.

on sociotechnical and material constructions, not just their linguistic, spatial, interpersonal, or affective qualities.

I use the phrase haptic realities instead of touch realities because it situates the concept in terms of the technoscientific lineage that has approached touch in positivist terms in order to turn it into something usable. The rendering of touch via haptics research reveals one way that touch is constructed. The idea of the human haptic system, which is used by haptic engineers to develop technologies for touch interaction, is based on the abstraction and mapping of touch through a series of experiments performed by different people using different instruments with differing goals. This research agenda, laid bare in part by Parisi (2018), creates a type of map or simulation that engineers rely on to build touch machines. In building them, they feed back into the reification of haptic realities that manifest them – creating a normative version of touch for humans and machines. Focusing on the haptic realities produced by the introduction of new touch technologies is not meant to suggest that they determine realities but that their touch aspects play an important role in shaping realities, perhaps an outsized role. In any lifeworld where touch plays a large part in the cultural norms or epistemological constraints of a space, the introduction of new technologies which alter and mediate touch will play important roles in shaping reality. Haptic realities emerge, then, at the nexus of touch and touch technologies and the shifting practices and ideas that orient around reconfiguring touch for these technologies, and in the contexts of their development and use. For this project, I use the concept of haptic realities to investigate how touch is produced, altered, maintained, and controlled in the process of communication between haptic engineers, surgical teams, and RSAs.

3.2. The Sensorium and the Shaping of Haptic Realities

The importance of excavating the history of the senses and elevating touch as a sense worth studying stems not only from recognizing it as co-constructed with technology but also in understanding how that construction impacts knowledge, practice, and agency in the world. The power of media resides in their potential for rearranging our senses, for altering the sensorium, directing our attention, and thus for playing a role in shaping our reality. While the implications of perceptual shifts wrought by audio and visual technologies have been explored, the impact of touch technologies on altering touch has, until recently, received less attention – at least in communication and media studies.

As Caroline A. Jones points out (2006), although "the human sensorium has always been mediated," due to contemporary technologies and technics that have "amplified, shielded, channeled, prosthetized, simulated, stimulated, irritated—our sensorium is more mediated today than ever before" (p. 5). But what is the sensorium? The medical and psychophysical roots of the term link directly to the body's ability to sense via the brain's ability to register sensation into perception. According to Biology-Online Dictionary, it is "the place where external impressions are localised, and transformed into sensations, prior to being reflected to other parts of the organism." As the term largely faded from use in biology and psychology, thinking about the term socially gained traction in media studies and sensory studies. In a social sense, the human sensorium is mediated and relational, expressed individually and collectively, as technology subjects it "to a complex form of training" (Benjamin, 2006, p. 191). One way this training takes place is through measuring individual sensory responses, aggregating the data, and producing standard protocols that inform the design of devices to interact with a normative notion of a sensing body. For instance, aggregating tactile responsiveness data and creating an average out of subjective responses produces a "'normal' sensorium" that can "be demarcated" (Paterson, 2018, pg. 79). This reorientation of the sensorium sets up the senses to be examined as socially constructed, wresting their grip from biology and psychology. Using a model of the sensorium as social, scholars like Benjamin (1969[1935]), Innis (2007, 2008), McLuhan (1962, 1994), and Ong (1967, 2002) have sought to lend understanding to the historical shifts wrought by changing technological ecosystems.

McLuhan's (2010) famous aphorism, "if a new technology extends one or more of our senses outside us into the social world, then new ratios among all our senses will occur in that particular culture" (p. 41) articulates a media ecologist understanding of the sensorium. James Carey (1981) offers an insightful take on McLuhan's sensorial perspectives toward media, stating that McLuhan "sensed that cultural forms operated not at the level of cognition or information or even effect. The media of communication affect society principally by changing the dominant structures of taste and feeling, by altering the desired forms of experience" (166). Parisi (2008) argues that the significance of media as 'extensions of man' does not lie in the media's ability to extend the sense organs into the external world but rather in the reconfiguration of the sensorium brought about by this technological conditioning of bodily habits" (pg. 309). The important point about Parisi's interpretation is that it establishes the notion that technologies, rather than merely extensions of our senses are really reflections of our senses, which upon engaging reify a notion of how that sense is constituted. By implicating media technologies in the conditioning of the senses, McLuhan offers a radically different vision for the entanglement of technology and society while challenging notions of a static sensorium.

Gallace and Spence (2014) do not use the term sensorium, coming from a neuroscientific perspective, but their arguments about the way touch technologies may shift our perceptions of the world begin meshing the biological, social, and media ecological conceptions of sensorium when they argue:

> A growing number of tactile devices will likely come to be a part of many of our lives that we simply take for granted in the years to come. They will also change the way in which our brain processes and selects information from the outside world that is, sensations that were once considered of little relevance, such as random vibrations, will likely be prioritized and even hallucinated by the neural circuits in our brains (p. 9).

Given the potential for emerging haptic technologies to shift our way of being in the world, I interrogate the ways they are being imagined and designed and the haptic realities they articulate—all of which lead to alterations of the sensorium.

Approaches to communication and technology developed by McLuhan and other media theorists offer useful theory to consider how technologies serve as extensions and reconfigure the sensorium but they tend toward being technologically deterministic. By focusing on the material and the technological, they often fail to adequately attend to the social elements of their development. Social construction of technology (SCOT) offers a theory of technology that serves as a corrective to those impulses, but my use of the framework is meant to be paired with media ecological approaches because they can serve as compliments. Pairing a SCOT approach with theories about the sensorium provides ways to consider how the construction of the senses play roles in shaping the development, design, implementation, and use of haptic technologies. This merged conceptualization closely relates to another STS concept, co-production. The notion of co-production recognizes that technologies are both material and social. As Jasanoff (2004) states, "knowledge and its material embodiments are at once products of social work and constitutive of forms of life" (p. 2).

3.3. SCOT(t)

I title this section social construction of technology (touch) because I make the argument that SCOT serves as a useful model and approach for considering the construction of technology *and* for considering the construction of touch. Touch can be conceptualized as technology but the social construction of touch technologies is also implicated in the construction of touch itself. Put another way, SCOT serves as a useful model and a useful heuristic for interrogating the co-construction of touch and technology.

Several scholars develop and use constructivist models to inform their work regarding the development of technology (Fischer, 1994; Latour, 1987; MacKenzie & Wajcman, 1999; Pinch & Bijker, 2012). The models shift their emphasis between the constitution of users and user groups and nonhuman actors, contextual focuses, and the varying influences of politics, geography, economics, and technology on the social construction of technology. However, they share several commitments, including taking a general stance against technological determinism and questioning social influences on the historical and contemporary development of technologies before and after they become black boxed. The black box metaphor is used to describe what their studies are trying to get at, which is tracing how social meanings and practices result in specific technologies before they become normalized and taken for granted.

The fundamental assumption that "technology and society are entangled together" (Bijker, et al., 2012, p. xxiii) provides the basic theoretical foundation for the approach developed by social construction of technology. To come to terms with what social constructivist models of technology are really getting at, it is worth elucidating the term technology as defined by SCOT scholars. Summarizing the three ways technology is articulated by MacKenzie & Wajcman (1999), (Bijker et al., 2012) states, "First, there is the level of *physical objects* or *artifacts* for example" robotic surgical assistants, joysticks, and haptic body suits. "Second, 'technology' may refer to *activities* or *processes,* such as" mapping the human tactile system or writing code that provides haptic feedback during robotically assisted operations. "Third, 'technology' can refer to what people *know* as well as what they do. An example is the 'know-how' that goes into designing" the haptic RSA or operating the da Vinci (p. xlii). Stating it more succinctly, "many current observers agree that 'technology' includes not only the built devices themselves, but also the practices and knowledge related to them and the social arrangements that form around those devices, practices and knowledge (Dierkes and Hoffmann, 1992; MacKenzie and Wacjman, 1999)" (Lievrouw, 2002, p. 246).

The broad definition of technology offered by SCOT scholars opens up a space for the consideration of touch as both a technology in manifest physical forms, such as the haptic feedback system used in the haptic RSA, as well as meaningful practices that influence the shape and use of those technologies. Focusing on the construction of touch from a SCOT perspective can mean focusing on the co-construction of touch as concept, practice, and material manifestation.

Informed by a SCOT definition of technology, Bijker and Pinch (2012) argue for a shift away from linear and static development of technology to a fluid and dynamic way of approaching them that analyzes the social processes involved in the life of the sciences, technologies, and the ways both develop within social frameworks involving social actors. SCOT and other social shaping of technology (SST) related approaches "share a basic theoretical commitment: that technological determinism is an inadequate description or explanation of technological innovation and development, or of social change more generally" (Lievrouw, 2002, p. 248).

Bijker and Pinch (2012) suggest that technological development is not inevitable, that it only seems that way because we tend to look at technology once it has already become stabilized.

The black boxing of technology happens because we tend to take developments in technology for granted, assuming that the technology we have is the product of better science and increased efficiency – ultimately progressing in a teleological manner. Because we tend to study technologies only after their meaning and societal status have become stabilized, we often miss the debates that brought them into being in the first place, and, in doing so, misunderstand how they are involved in, and are the products of, a process of social construction.

Early SCOT research was mostly concerned with how early stage technologies stabilized. Later studies recognized co-construction of users and technology alike and addressed issues of how users could continually destabilize technologies. The (new) strength of SCOT "is that it focuses on user practices and forums where the input of users can be studied" (Fischer, 1994, 544). Recognizing users as playing germinal and ongoing roles in the construction of technology is vital, but it also fails to fully account for the ways that technologies play a role in the construction process as well. SCOT is charged with being socially deterministic but continues to take a radically constructivist view (Lievrouw, 2014, p. 22) while other related approaches within science and technology studies (STS) have begun to incorporate sociotechnical notions that consider that the "sheer material presence of technological artifacts influence and shape human action just as surely as action shapes artifacts: both directions of the relationship should be accounted for" (Jasanoff, 2004; Wyatt, 2008) (Lievrouw, 2014, p. 23). The co-construction of touch goes beyond social actors, and social determinism, and must also consider the role RSAs play in constructing touch. Actor-network theory (ANT) provides a complimentary approach to SCOT which helps address both social and material actors.

3.4. ANT

> ANT furnishes us with the tools to better attend to the minute displacements, translations, practices, riots, processes, protests, arguments, expeditions, struggles,

> and swap-meets – no matter what the actors involved may look like (Sayes, 2013, pg. 145).

ANT started to take shape in an essay about electric vehicles in France (Callon, 1987). The essay detailed the construction of technological systems that started to account for nonhumans as essential actors in the process. ANT developed further at the Centre De Sociologie de L'Innovation in Paris when Bruno Latour joined a group of young researchers interested in technological development, especially from a science and industry standpoint (Muniesa, 2015). The approach quickly turned from treating the nonhuman as an actor that "merely transports action from elsewhere," to classifying nonhumans as "mediators" (Sayes, 2013, p. 138). As Latour (1996) states, "objects are not means but rather mediators – just as other actors are. They do not transmit our force faithfully, any more than we are faithful messengers of theirs" (p. 240).

From one position of ANT, reality is constructed in a systematic process "as an outcome of an organized, fragile, and laborious process of material articulation" (Muniesa, 2015, p. 80). The focus, possibly stemming from the engineering background of Callon, places an emphasis on how materials, artifacts, and other nonhumans matter in the construction of reality that go beyond the typical ideas of social construction which place outsized weight on the "social conventions, belief systems, mental states, or collective representation" of humans (Muniesa, 2015, p. 80).

ANT is typically thought to articulate ideas of agency that treat humans and nonhumans as part of symmetrical networks that produce agency through interaction (Latour, 2005). Agency thus arises as a relational concept. Action is possible only as interaction and interaction with RSAs involves a web of multiple interacting human and nonhuman actors.

In the actor-network formulation, subject-object distinctions break down resulting in networks of collective action (Callon & Law, 1995). But the symmetrical treatment between humans and nonhumans fails to recognize the way cultural values of designers are materialized in the technologies they create – denying the politics infused in machines. These values shape the allowances of their technologies, which shape their affordances in interaction. The symmetrical approach also omits "the concepts of human intentionality and creativity" (Kaptelinin and Nardi, 2009, p. 241). I purposely use the terms actors instead of actants[6] throughout this dissertation to acknowledge this asymmetry and situate my use of ANT in a social construction of technology context which acknowledges the outsized roles of human actors in "networks of collective action."

Using a more asymmetrical treatment of ANT provides an important corrective to ideas about the construction of reality that premise human actors to the exclusion of nonhuman actors while acknowledging that human and nonhuman agency ought not be treated equally. Pushing against the theory moniker, it also provides more in the way of a methodology than a theory (Sayes, 2013) which can be usefully applied to understand how RSAs are vital players in the co-construction of touch. It does not provide a specific set of methods, but it does lay out a general framework that situates mixed qualitative methods to consider materials as actors in the creation of sociotechnical configurations, which is why I later expand on my use of ANT in my methods section. It serves as a reminder to interrogate the transactions, transitions, and tensions within the network of both social and material actors.

3.5. Affordances

Affordances offer one way to understand how the materiality of the dVSS both manifests values concerning touch and alters touch relationships in the OR. Deriving from James Gibson's anti-representationalist theory of perception, affordances is a concept for dealing with the way technologies shape our use and interaction with them based on social and environmental

[6] The term actant is used in ANT to replace "the term *actor* because *actor* generally has a human connotation" (Davis, 2020, p. 51), and is meant to signify the symmetry in the networked relationships by not privileging humans over nonhumans.

constraints (Gibson, 1977). These affordances define constraints and possibilities within which actions and ideas can take shape. In the field of the design, the concept has been developed to explain the user friendliness of practical objects, suggesting that well-designed objects align with user intentions and goals (Norman, 2013). Coined "perceptible affordances," designers often incorporate features in technologies which make their affordances explicit (Graver, 1991). According to Novak, at al. (2016):

> Instead of the intents informing the allowable actions, the affordances of technologies and environments often guide the intents of humans. The perceptible affordance of the technology prompts the human to adapt their intentions to fit the limitations of the technology. Even though well designed, the human is still operating under the constraints of the technology.

The affordances of technologies co-construct interaction. They are "*how"* objects shape action for socially situated subjects" (Davis, 2020, p. 6). Interrogating how those affordances take shape reveals their socio-material histories, practices, and contexts (Kress, 2010). These include revealing shifts in social relationships (Jewitt, et al., 2019). The concept offers a useful tool to interrogate the ways touch materializes in the da Vinci and investigate shifts in the way surgeons and the surgical team navigate an altered socio-material operating room.

Understanding the co-construction of touch and technology around RSAs means understanding how groups involved in their development, and use, negotiate touch, but it also means understanding how the RSA itself serves as an actor in the construction of touch. The materiality and affordances of the devices, their imaginings, and the chain of social interaction play co-shaping roles with human actors in forming haptic realities.

4. METHODS

My literature review lays out some relationships between touch, technology, and medicine. These relationships are complicated and mutually influential. The introduction of new technologies, like robotic surgical assistants beg new questions about these relationships and serve as case studies for understanding the intersections of touch and technology. The overarching question I ask from a sociotechnical perspective is, *how is touch socially and materially co-constructed between the dVSS, engineers, and surgical teams in the operating room?* With the development of haptic systems to aid the dVSS and the emergence of competitor systems, I ask the secondary question, *how do imaginings about haptics and emerging RSAs co-construct surgical touch?*

In the following sections, I lay out the details of the methods I incorporated to answer the guiding questions posed in this dissertation. I explain why I choose the methods, provide biographical information about key participants to contextualize their relationships and how they were selected, and give explanations about my field site and objects of study. I also present my account of the process because I believe understanding some of the issues I encountered serves a methodological purpose that may help others interested in studying these groups, sites, and materials.

4.1. Methodological Justification

This study provides an empirical account of the relationship between touch, surgical teams, engineers, and RSAs while beginning to build a sociotechnical theory of touch at a specific site. Answering my primary research questions involves focusing on the social and material aspects of the RSAs. I use a case study approach by focusing on the dVSS to interrogate these aspects and relationships. Understanding co-construction means observing practices of touch in the OR and training lab, interviewing surgeons and engineers to learn about their ideas of touch, and attending to the material affordances of the dVSS and the operating room. Incorporating methods and theoretical frames from social construction of technology, actor-network theory, and mixed qualitative methods allows me to consider the social and material relationships between touch, human, and machine actors. These approaches help make sense of their complicated interrelationships. They attest to the idea that touch is emergent and relational rather than static. They help me articulate what touch is in these spaces, to these actors, and how it is enacted and defined in the tension of activity. They also allow me to take account of how imagining haptics and emerging RSAs relates to the co-construction of surgical touch.

My methodological choices are informed by my questions but being reflexive, I am making them for strategic reasons as well. In developing this project, I have considered using historical and discourse analysis methods. The questions I pose are wide enough to invite several potential methods. I originally partnered ethnographic methods with historical methods because contemporary practices do not emerge independent of historical context. While I do not provide a deep historical account of these practices in a systematic way that would require historical approaches, I do offer some historical context to situate my findings. More cultural-historical work will be necessary in future research on this topic; however, for the purposes of this dissertation, providing an empirical account provides a snapshot that can later be put into more meaningful conversation with historical context.

Touch takes shape through everyday practices between multiple human and nonhuman actors, which SCOT and mixed qualitative methods help me explore. The methods provide the tools to account for the way RSAs are implicated in a process of negotiation to construct touch in everyday life, or at least in the case of this project, in the operating room. They are also methods that allow me to triangulate my findings. SCOT focuses on the way that technology is constructed through a process of negotiation between principal actors. In the next section, I argue the model and method can be usefully applied to understanding the construction of touch. I pull from SCOT to provide tools for my inquiry but also to provide a useful heuristic for thinking touch. It is not the only way to inquire about the social and cultural aspects of touch, but it does present a novel approach that I believe can be applied to many other sociotechnical configurations of touch beyond the narrow scope of this study.

I use mixed qualitative methods, including observations, interviews, and document analysis, associated with ethnographic methods because they provide the most appropriate approach to my research as they are positioned to "stress the socially constructed nature of reality," recognize the situatedness of any inquiry, and attest to the position of the researcher as being implicated in the research (Emerson, et al., 1995, pg. 8). I make the distinction between using mixed qualitative methods and doing ethnography because, while the methods I use for this study, and the analysis I employ, are associated with methods used in doing ethnography, I did not spend enough time in the field nor develop deep enough relationships with my participants to consider myself to be part of the community I engaged.

Focused on the intersection of touch, media, and technology, I orient my research to consider touch as embedded in media technologies and as physical interaction between humans and specific touch machines in the context of the operating room and the lab. I associate the methodological approach I take in this dissertation with qualitative studies of workspaces, medical practices, and technological development (Bardini, 2000; Orr, 1996; Suchman 2007; Zuboff, 1988; Zetka, 2003). These works provide generative ideas about applying method, performing analysis, and writing narratively. Like these aspirational models, employing a mixed qualitative methods approach gets me closer to the everyday practices where the co-construction of touch and technology take place, allowing me to reflect on the constructions from discursive and experiential vantage points. Because touch is my object of inquiry, and the da Vinci my primary case study, it is important to trace the negotiation, relationships, and interpretation of touch through the interaction of social and material actors related to the da Vinci.

4.1.1. ANT Inspired SCOT(t)

Doing what I refer to as ANT inspired SCOT(t), consists of first identifying relevant social actors, including nonhuman actors, who play a role in the co-construction of touch and technology. ANT[7] provides the theoretical foundation to consider the agential qualities of the da Vinci and its material affordances in the co-constructive process. Pinch and Bijker's (2012) early model suggested that social groups be defined by those sharing similar meanings, "attached to a specific artifact" (p. 23). In the case of RSAs, those shared meanings revolve around the co-construction of touch in medical settings. Engineers and surgeons play vital and intersecting roles. By identifying groups that debate the meaning of particular artifacts, researchers can identify the discourses that drive certain technologies to success and others to failure. In my study, the point is not necessarily to identify how debates drive technologies to success or not, but instead to identify relevant actors negotiating the sociotechnical conditions of medical touch with RSAs. The success and failure aspect emerge from how ideas and practices of touch are negotiated between the actors; which become more salient and which evoke continued tension?

In addition to identifying relevant groups, "interpretative flexibility of a technology must be shown" meaning, "not only (is) there flexibility in how people think of or interpret artifacts but

[7] As I laid out in my concepts chapter, I employ an asymmetrical version of ANT that allows a "space for critical accountability" (Davis, 2020, p. 113).

also that there is flexibility in how artifacts are *designed*" (p. 34). I apply this idea of interpretative flexibility to the touch aspects of RSAs and to the conceptions about touch that coalesce with the devices. Making haptics for medical devices is currently in a state of great flux, thus open to interpretative flexibility. The RSAs I investigate illustrate the degree of debate happening around these devices, from technical conflicts regarding how to design haptic feedback in RSAs or whether to include it all, to social conflicts about whether surgeons should give touch over to RSAs entirely. In other words, touch and RSAs are in active states of development and negotiation – which makes it a ripe time to trace and understand the co-construction before it becomes black boxed.

The model provides a way to identify how technologies become stabilized and dominant, cutting off the potential for alternative technologies to be developed in their place. Translating to my project, this means considering how touch becomes materialized and standardized and how social conceptions of touch become normative. To do this, Pinch and Bijker (2012) lay out a way of mapping the debate between relevant actors and tracking them until the debates stabilize. They suggest that this typically happens in one of two ways. Through rhetorical closure, where relevant social groups perceive the problems that they were arguing about, to be solved. As they point out, the problems do not need to be solved for rhetorical closure to take place (pg. 37). The other means of closure involves a redefinition of the problem, whereby the artifact under consideration solves the problem based on this redefinition (pp. 38 – 39). I am not able to identify closures because the co-construction of touch and RSAs is currently active and contains multiplicities. Another reason that closures are hard to identify is that RSAs like the da Vinci are "boundary objects," meaning they are interpreted differently by intersecting social actors because those actors reside in their own contexts and may have different aims (Star & Griesemer, 1989). In other words, the context and aims of surgeons likely lead to different interpretations of touch in relation to the da Vinci than engineers, even though the material qualities of the object remain the same. By being in the field, using an ANT inspired SCOT(t) approach, and through triangulation, I account for multiple interpretations while identifying some areas of tension and potential closure that animate the surgical touch being co-constructed with RSAs.

4.1.2. Case Studies and Mixed Qualitative Methods

My research takes a case study approach while using multiple mixed qualitative methods. My use of the dVSS as my primary case and other RSAs as secondary cases falls somewhere between what Stake (2000) identifies as *instrumental* and *intrinsic* case studies (p. 437). Whereas an *instrumental case study* uses a specific case to generate more generalizable theory, an *intrinsic case study* is oriented toward generating a better understanding about the specific case. For the purposes of my study, I focus on the dVSS because it is the most widely used RSA on the market, making it a more representative case to draw generalizations concerning the co-construction of touch and technology. At the same time, my study also focuses on the particulars of the dVSS case, shedding light on the specifics of touch as developed and practiced in relation to the device. As Stake (2000) also points outs, "case study is not a methodological choice but a choice of what is to be studied" (p. 435). So while my study does take a case study approach because it focuses on a "specific, unique, bounded system" to understand touch through investigating a specific set of relationships associated with the da Vinci, I use several qualitative methods to explore the case and argue that my generalized findings are not bounded by the case because through my methods I consider touch and technology beyond the da Vinci.

Exploring touch in multiple contexts, between designers, users, and participants necessitates a flexible methodology that recognizes the co-construction of the touch and technology. Scholars taking sensory orientations have identified the social role of the senses in multiple contexts (Chou, 2008; Howes, 2003; Pink, 2009) and suggested ways for getting at how the senses become constructed in interaction with others and things (Richardson & Hjorth, 2017).[8] There are many reactions and movements away from the purely textual interpretation of cultures including performative turns (Conquergood, 1991), feminist, racial, and post-colonialist turns (Denzin & Lincoln, 2000). Focusing on social and material aspects, mixed qualitative methods help me acknowledge the relational meaning produced through interaction as both socially and materially constructed. In the case of RSAs, that means understanding how conceptions of touch are produced between the experience of touching the device, or feeling it touch back, and ideas of what surgical touch should do, how it should feel, who, or what, can do it, and why it is meaningful.

There are practical limits and epistemological concerns about how touch can be adequately "captured" and "represented" through qualitative approaches. Howes (2003) suggests that the problem with studying the senses through ethnography stems, at least in part, from the inability to capture non-visual and non-auditory senses, stating: "Smells may be disruptive and elusive; touches, interactive and personal; sights and sounds, however, can be mechanically detached from the people who produce them and can be controlled at the will of the observer" (pg. 7). The ability to "capture" the senses for proper observation echoes concerns about objectivism and rationality, regardless of the fact that the ability to record and capture, in a mechanical way, is equally problematic in providing "authentic" representation. In this case, influences from the rationalists still echo through modern scholarship, "take, for example, the quest for disembodied observation,

[8] The work in this dissertation intersects with other sensory work being done by scholars but I do not center their methodological approaches in this research because my study focuses more on the sociotechnical aspects of touch than on the embodied and sensual aspects.

which is the 'best of all possible worlds' (to evoke Voltaire) is transformed into disembodied representation, a bloodless process that saps the body of its sensuousness" (Stoller, 1997, pg. xiii).

What Stoller (1997) identifies is really a problem of representation, a crisis occurring not only in the process of writing sensual experience but also in writing qualitative accounts in general. The crisis of representation has resulted in a number of experimental writing and performance genres meant to circumvent issues of representation or at least to think representation otherwise (Brady, 2004; Van Maanen, 2011). Despite these novel approaches, which are likely to be crafted with some anxiety at the thought of rejection from mainstream academics, the looming question that potentially haunts scholars who would otherwise engage haptics through qualitative methods still remains, "How do we write meaningfully about those everyday embodied experiences of touching and feeling, conjunctions of sensation and emotion that cannot arise without the physicality of the body" (Paterson, 2009, 766)? My study does not propose to answer this question, but it is important to be aware of the fundamental limitations of any method. In the case of studying touch, it is important to recognize that "capturing" and "representing" touch is implicated in the process of the co-construction of touch through making a series of choices about which material and discursive aspects of touch and technology matter and through transforming touch to text.

Using mixed qualitative methods serves a double role as a set of methods used for collecting data and analyzing that data. In my study, I examined documents and materials related to the RSAs, used the da Vinci and other haptic RSAs, observed others using them, and interviewed engineers and practitioners of these devices in an effort to collect data about the construction of touch. Because I took a grounded approach to studying my cases I approached them without a priori categories, beyond the case and the actors identified in my SCOT(t) analysis. In other words, I used the data I collected to construct categories for analysis, which iteratively focused my data collection, and that process resulted in narrower categories and themes. The repetitive process involves a great deal of reflexivity along the way.

Being reflexive began by considering my own positionality in relation to my research. For me that meant considering how I was positioned as a white male graduate student at a research university and thinking through the kinds of opportunity and access that position would provide me in pursing my research. Although I had been a graduate student doing research for several years I did not have contacts and connections with people on the medical campus. I had to consider how I might be able to gain access to surgeons, the operating room, and to engineers who had worked with the da Vinci.

As I made contacts with surgeons through a committee member who worked with them and established connections to engineers through another committee member and then through referrals, I continually had to consider how I would present my research to my informants, how I would negotiate interviewing time with them, and consider how I would deal with domain specific jargon and ideas. As Mikecz (2012) points out:

> The researcher's positionality is central to successful elite interviewing. It is not determined on an 'insider/outsider' dichotomy but is on an 'insider-outsider' continuum that can be positively influenced by the researcher through thorough preparation. Positionality is dynamic; it evolves during the course of data collection and becomes a key determinant of the research's success (p. 492).

Having a background in communication, I did not have the technical knowledge or expertise in the fields of medicine nor in engineering to enter into discourse on a shared plane. In order to bridge the gulf of knowledge, I researched both my informants and their areas of research before engaging in interviews. I also considered how I could present my research in ways that would be meaningful to my informants. This ended up being important in terms of helping strengthen my interpretations and in more deeply considering the ethical implications of interviewing surgeons and engineers, and in pursuing my research. Finally, I continually had to reflect on how my own biases as a researcher with no training in the medical fields nor in engineering influenced my interpretations of the data.

Given the fact that I explore my topic from a variety of angles, and never fully immerse myself in the communities I am engaging, I seek a balance between providing thick description (Geertz, 1973) and thin description (Jackson, 2013; Benjamin, 2019) in this project. Thick description acknowledges and tries to parse apart and reassemble the many layers of signification in any event, thing, or interaction. In using ethnographic methods, I participate in sites where touch takes shape between humans and nonhumans. Following Geertz (1973), I attend to touch in action in the operating room and the lab "because it is through the flow of behavior—or, more precisely, social action—that cultural forms find articulation" (p. 17). At the same time, and with some seeming contradiction, I borrow from thin description because it offers an approach that "allows greater elasticity, engaging fields of thought and action too often disconnected" (Benjamin, 2019, p. 45). Analyzing the co-construction of touch and technology means engaging with disparate fields from communication to science and technology studies to medicine and engineering. At the same time, as a critique of the overreaching claims often made concerning authoritative interpretations of culture by implementors of thick description, I borrow the ethos of thin description. As Benjamin (2019) points out, "thinness, in this way, attempts a humble but no less ambitious approach to knowledge production" (p. 45). While thin description is a critique of thick description, offering an alternative interpretative method for qualitative researchers, my own project walks a line between immersion and surface-level engagement that makes use of both approaches. In the following three sections, I articulate the methods and processes I used to make sense of touch and RSAs.

4.2. Finding Field Sites

The University of Illinois at Chicago (UIC) is home to a premier surgical robotics program. Having access to the da Vinci, to the residents and medical students training on the da Vinci, and the surgical teams using it in practice makes it an ideal site for my study. Being a student at the University gave me access to the medical campus, but gaining access to the OR was not a straightforward or simple task. When I began the project, I sent emails to Dr. Pier Giulianotti because I knew he was the Chief of the Division of General, Minimally Invasive, and Robotic Surgery. I wanted to interview him and I thought that if I contacted him, I would be able to gain access to the OR. I sent several emails but never received a response. If I had read scholarship on observing and interviewing elites earlier in the process, I may have realized it would be more complicated to gain access because "gaining access to elites has to be carefully negotiated" (Mikecz, 2012, p. 483). I was finally able to access the OR after Dr. Luciano put me in contact with Dr. Gangemi. To study emerging RSAs, Dr. Luciano allowed me to come to his lab to try haptic programs he was creating. Focusing on both of these field sites provides a better sense of what is happening to touch with the development and implementation of RSAs. The results of my study are limited to focusing on groups that are working at UIC, but combining observations with interviews and analysis of additional documentation provides important empirical evidence that can be applied to subsequent and larger projects.

4.3. Participant Observation

Participant observation refers to being in the field as both observer and participant, "built on the alignments between engaging in everyday activities, on one hand, and recording and analyzing those activities, on the other" (Boellstorff, et. al., 2012, p. 69). It is a shift from the idea that an observer can ever hold a purely objective point of view as an observer out of context. While there is a continuum of participation from actively engaging in cultural practices and rituals to passively observing them without taking part directly, the mere presence of a researcher in a space creates a mode of participation. In the case of the da Vinci and haptic RSA, I acted as a participant observer in two ways. First, I used the da Vinci training simulator and haptic RSA to get a personal sense of their affordances. Trying the devices gave me an embodied sense of the device so that I could account for my own reactions when considering their development and use. While I did not actively participate in the operating room, as it was unsafe and unethical to do so, my mere presence as an observer made me a kind of participant. However, since UIC is a teaching hospital and the OR is accustomed to frequent outside visitors – from students, researchers, vendors, and other technical staff– there was a kind of de facto acceptance of me being in the space even though I did not spend enough time in the operating room to become part of the community. Despite the acceptance of my presence, I could never really be just an observer because each time I walked into the OR, I altered it through being there, through needing to find a place to stand out of the way, by being asked if I had any questions by the medical technicians, and by being invited to sit at the training console by the surgeon.

In each situation I had to reflexively consider where to stand, how to respond, and what spaces and people to engage, in ways that would not disrupt surgery. I weighed the ethical concerns of engagement as a potential source of distraction. After each observation I gained a better sense of how to interact with others and traverse the space. The first time I entered the operating room, I did not have a keen sense of awareness about the safe distance I needed to maintain from the sterile field. My presence became immediately felt in the OR as I approached the boundary of the sterile field and the medical technician immediately halted me with words before I could break it. After that I developed much keener bodily awareness about my proximity to that field and maneuvered the OR more carefully.

As a supplement to participant observation, I also adapt Hodder's (2000) ideas about interpreting material culture because it gives me tools for more closely considering the work that the RSAs are doing in co-constructing touch in practice. He makes a convincing argument for focusing on cultural artifacts as "material symbols that do not work through rules of representation, using a language-like syntax. Rather, they work through the evocation of sets of practices within individual experience" (p. 707). This is an important point for my project because in focusing on touch and machines that materialize touch in multiple ways, I focus on an object of study that may not conform to typical forms of representation. Using Hodder's formulation, I treat the touch of RSAs as material symbols that "come to have abstract meaning through association and practice" (Hodder, 2000, p. 707).

During my project, I observed one laparoscopic surgery, six surgeries using the da Vinci Xi, and one surgery using the da Vinci SP. I observed four training sessions in the robotic training lab. Training sessions involved both virtual training and live training on sedated pigs. I was also allowed to try the da Vinci Si simulator in virtual training mode. I spent time in Dr. Luciano's lab trying his haptic surgical programs and two surgical fellows also agreed to allow me to observe and interview them while they tried the programs.

In order to enter the operating room, I had to obtain approval based on my research agenda and I was issued a badge listing me as a research assistant. The process of gaining access involved several email exchanges over the course of a few months in order to identify surgeons willing to be interviewed and observed. Once I was able to interview Dr. Antonio Gangemi, he helped me figure out the necessary paperwork to fill out so I could access the OR as a research assistant. He and Dr. Simone Crivellaro were generous enough to allow me to observe several surgeries over the course of a few months. There were instances when a scheduled surgery was canceled, which meant rescheduling my observation time or observing other robotic surgeries performed by surgeons I was unable to interview for this project.

4.4. Qualitative Interviews

Qualitative interviews provide another model that helped me triangulate my findings. As with participant observation, qualitative interviews are designed to aid discovery rather than to impose pre-defined categories. I use unstructured and semi-structured interviewing techniques (Fontana & Frey, 2000), depending on the context of interviews. I engaged in unstructured interviews while doing participant observations with surgical teams and during training sessions but I performed semi-structured interviews with surgeons outside the OR.

Participant observation and unstructured interviews go together because participant observation collects much data through informal conversations (Lofland 1971). I reached out to engineers and practioners with the help of haptic researchers and robotic surgeons I was already in contact with, using snowball sampling (Biernacki & Waldorf, 1981). Snowball sampling is useful in identifying potential interviewees but it also helps reveal connections between participants (Noy, 2008). This is especially important for research involving "elite" subject matter experts who can often be hard to contact independently but also whose work is often connected. The strategy also helps speed up a process that "has to be carefully negotiated, which can take much longer time and higher costs than non-elite studies" (Mikecz, 2012, p. 483). Referrals become the coin of the realm for gaining access.

Before beginning interviews, I researched my interviewees in order to plan my interviews. It was important to have background information on each of my informants because it allowed me to establish a rapport from the beginning and to provide a more flexible framework to probe them on questions about their ideas and relationships to touch and technology. Pre-planning is especially important when interviewing elites because they "are very difficult, if not virtually impossible, to repeat" (Mikecz, 2012, p. 483). This is because elites often protect their time and accessibility. Indeed, while I was lucky to interview informants who were generous with their time, it was difficult to schedule times to perform even one interview in several cases.

I took a semi-structed approach to interviewing surgeons and engineers outside the OR because the case of RSAs and the object of touch provided a loose boundary for developing the questions I wanted to ask. Keeping them semi-structured allowed me to collect a "greater breadth of data" than structured interviewing (Fontana & Fey, 2000, p. 652). It was important for me to use a more open-ended approach to interviewing in order to allow for flexibility of answers and to follow up with questions that were not originally intended. The approach also allowed me to "hear about the interviewees' beliefs, attitudes, and motives" (Mikecz, 2012, p. 485) in their own words. For instance, when I interviewed Dr. Gangemi with the assistance of Dr. Luciano, I ended up asking follow-up questions that were spurred by answers to my more formal questions and Dr. Luciano asked questions that I would not have thought to ask. In my semi-structured interviews I attempted to probe the co-construction of touch "without imposing any a priori categorization" that could reduce the boundaries of my inquiry (Fontana & Fey, 2000, p. 653). At the same time, I kept some consistency regarding the questions I asked informants since my study is concerned with a specific set of practices and relationships that orient around touch and technology.

It is important to use the names of the “elite” interviewees, both the surgeons and the engineers in my study, because it allows me to make connections between them more explicit and helps establish the veracity of the claims I am making in this study. I weighed the ethical concerns about sharing their responses and how open they may be to speak freely with how providing anonymity may have provided more freedom to speak. Given the relatively non-sensitive nature of my inquiry, I argue that the importance of recognizing these public figures outweighs potential harms of sharing and analyzing their responses. Their decisions play outsized roles in shaping the design, implementation, and use of the dVSS and identifying them allows future researchers to trace their connections and influence on shaping touch. On the other hand, it was important to protect the anonymity of the data I collected from non-elite figures because of power differentials that could result in greater impact on them.

As with my other methods, I continued interviews until they reach redundancy. I determined redundancy based on the analysis of data collected through different methods, meaning I did not determine when to end interviews based only on the data collected from interviews. A multiplicity of meanings emerged while investigating the practices and meanings of touch with RSAs, which continually opened threads for further investigation. This is why I made decisions about which aspects to focus on early in the process through coding and reflection. By being reflexive throughout the process, I was able to identify salient themes emerging from my analysis and set aside less salient themes for further analysis at a later time.

Each group I interview requires different approaches to recruiting participants and posing questions, based on their peculiarities. For that reason, I discuss the recruiting, question development, and interview processes in the next sections.

4.5. Participant Process

I have laid out the methodological approaches that I used to recruit participants in the previous sections, but I want to provide more detail on the process, as I think it may be useful for other communication researchers trying to do work in engineering and medical spheres. When I proposed this project, I thought I would have a relatively easy time gaining access to interview surgeons and do observations in the OR because I am a student at the University I had selected as my field site. I thought it would be harder to find engineers working on haptics, especially those who had worked on the da Vinci, because I had no clear connections in the beginning.

After I successfully defended my proposal and received IRB approval, I started sending emails to surgeons and engineers – like cold-calling. I did not hear back from any of the surgeons nor engineers I contacted using that method. I talked to doctor friends to see if they had any connections, but that was a dead end. Dr. Luciano introduced me to Dr. Gangemi and Dr. Crivellaro through an email referral and suggested I send an email to them with details about my project. In crafting emails to them, I tried to translate my project to show how it could be relevant to their work (See Appendix B). After a few email exchanges, and figuring out logistics, we were finally able to meet for interviews. I reached out to other surgeons in the department but was unable to make connections.

The process of identifying engineers to interview for this project included a series of steps. For the da Vinci case study, I first reached out to engineers I had identified as being associated with the da Vinci project at its origins or to engineers who had worked on the device to add haptic feedback. These engineers included Dr. Kenneth Salisbury, Dr. Akhil Madhani, Dr. Katherine Kuckenbecker, Dr. Allison Okamura, and Dr. Günter Niemeyer. I was put in contact with Dr. Salisbury through Dr. Parisi and Dr. Kuckenbecker answered an email I sent to her directly. Dr.

Salisbury tried to put me in contact with Dr. Madhani and Dr. Kuckenbecker tried to put me in contact with Dr. Okamura and Dr. Niemeyer. Through connections made at a workshop I attended at a computer-human interaction (CHI) conference, I was able to interview Dr. Prattichizzo. And Dr. Colgate answered a direct request for an interview. Dr. Okamura responded to an email request that she would not be available to be interviewed for the project while I never heard from Dr. Akhil, despite repeated attempts at contact. I also interviewed Dr. Cristian Luciano about his perspectives on haptics and work in his mixed reality lab. Each participant suggested other potential contacts, although some suggested others I had already interviewed. The expert community around this narrow topic is, unsurprisingly, not very large. But several attempts to contact other engineers before I felt I had reached saturation received no responses.

4.5.1. Surgical Team

I formally interviewed and observed surgeries performed by Dr. Antonio Gangemi and Dr. Simone Crivellaro. Dr. Gangemi is an Assistant Professor of Surgery and Clinical Director of the Surgical Skills Laboratory at UIC. He was trained in general surgery at UIC but also started using the robotic surgical assistant in 2012. As Clinical Director of the Surgical Skills Laboratory, he oversees the training of medical students and residents in the surgical robotics training lab and in the operating room. Dr. Simone Crivellaro has been performing robotic surgery for several years and specializes in robotic procedures to treat urologic conditions. He is also one of the only surgeons worldwide to extensively use the single port da Vinci because UIC was one of the first institutions to offer single-incision robotic urological procedures. Both surgeons were amongst the first wave of surgeons to adapt robotic surgery into their practice using the dVSS.

While the primary focus of this research relies on experiences from robotic surgeons, observations and side conversations reveal intersections with the surgical team, including medical technicians, nurses, surgeons, residents, fellows and da Vinci technical support members. Each robotic team had a medical technician. A medical technician is a nurse trained specifically in keeping the sterile field, preparing instruments, and changing them throughout the surgery with the robot. I spoke to medical technicians informally to get their sense of how the robot has altered the sense of touch in the operating room. I observed residents during surgery and lab training but was unable to interview them outside of brief side conversations due to the busyness of their schedules. I observed Fellows during surgery and informally interviewed three during lab training. While some of the unstructured conversations are included in my analysis, I do not go into greater biographical detail about team members due to concerns about anonymity.

4.5.2. Engineers

I formally interviewed six haptic and robotics engineers. It is worth laying out some of their biography here to provide context but also to establish the connections between each of them, where connections are present.

Dr. Kenneth Salibury and Dr. Günter Niemeyer both worked on the original dVSS project. I provide more details about their connection to the project in chapter 6. Dr. Kenneth Salisbury is a Professor Emeritus at Stanford University in the departments of Computer Science and Surgery. He also held a courtesy appointment in the Department of Mechanical Engineering. He worked on development of the Stanford-JPL Robot Hand, the JPL Force Reflecting Hand Controller, the MIT-WAM arm, and the Black Falcon Surgical Robot. He also worked with his student, Thomas Massie, to develop the first "practical force feedback device," later marketed as the PHANToM haptic interface (Šabanovic, 2010). After accepting a post-doc at the Massachusetts Institute of Technology (MIT) to work in the AI lab, he ended up working at MIT for 17 years before working with Intuitive and moving back into academia via Stanford.

Dr. Günter Niemeyer worked with Dr. Kenneth Salisbury for a short time at MIT as a postdoctoral researcher developing surgical robotics. In 1997, he started working for Intuitive and was a key designer of the da Vinci. He joined the Stanford faculty in 2001, directing the Telerobotics lab. He is currently a Visiting Professor at the California Institute of Technology but he is also a senior research scientist at Disney Research, Los Angeles, specializing in making robots more expressive through haptic interactions.

Dr. Katherine Kuckenbecker worked with Dr. Niemeyer at Stanford as an undergraduate. She earned her Ph.D. in Mechanical Engineering at Stanford in 2006 before doing a postdoctoral fellowship at Johns Hopkins University where she worked with Dr. Allison Okamura. Dr. Kuckenbecker went on to be an Associate Professor of Mechanical Engineering and Applied Mechanics at the University of Pennsylvania. While there, she held the Class of 1940 Bicentennial Endowed Term Chair and worked in GRASP lab, a general robotics, automation, and sensing laboratory at the University of Pennsylvania. At GRASP lab, she developed VerroTouch, a device that could be attached to the arms of an RSA, like the da Vinci, to provide haptic feedback. She became the director of the Haptic Intelligence Department at the Max Planck Institute for Intelligent Systems in 2018.

Dr. Edward Colgate received his Ph.D. from the Department of Mechanical Engineering in 1988. He is currently the Allen K. and Johnnie Cordell Breed Senior Professor in Design at Northwestern University. During his tenure at Northwestern, he was co-director of the Segal Design Institute with Donald A. Norman. He has commercialized several of his robotic and haptic-related research projects, including a surface haptics product developed by a company he co-formed called Tanvas, Inc. From 2007 to 2013, he also served as the founding editor-in-chief of the IEEE Transactions on Haptics.

Dr. Domenico Prattichizzo, an Italian haptics, robotics, and wearable technology scientist served as co-editor in chief of IEEE Transaction on Haptics from 2007 to 2013 with Dr. Colgate. In 2020, he became the editor-in-chief, taking over for Dr. Lynette A. Jones. He is a Professor of Robotics and Automation at University of Siena where he is a faculty member in the Siena Robotics and Systems Lab. He is also co-founder of a wearable haptics and tactile communication company called WEART.

Dr. Cristian Luciano is the director of the Mixed Reality Lab at University of Illinois at Chicago (UIC) and assistant director of the Innovation Medicine program. He is also the director of engineering in a Department of Urology lab called the UR*Lab. He holds a Ph.D. in industrial engineering and operations from UIC and is currently a research assistant professor of bioengineering. His areas of specialization combine engineering and medicine where he has innovated for surgical simulation, training, presurgical planning, and surgical guidance.

These experts' biographies clearly show their strong relationships and influence on both the development of the da Vinci and on the fields of haptics, teleoperation, and robotics more generally. There is a clear lineage that runs between many of the research engineers, especially with many links between the institutions of MIT and Stanford. I argue that understanding their views on touch, haptics, and surgical robotics, while perhaps not entirely representative of the field, provides clear insight into dominant strands of thought. Their combined work on the da Vinci, whether directly working with Intuitive, or indirectly working through Intuitive grants or with da Vinci robotic surgeons, also suggests the large influence they have had on the development of haptics for the da Vinci, and perceptions and practices of touch related to the dVSS. It is important to consider their connections to each other in interpreting their responses and analyzing data because they directly influence each other's perspectives and approaches to haptics and engineering. Their responses become more meaningful when considered as taking part in a larger, interconnected knowledge community. Sketching these connections help make sense of the epistemologies informing their responses.

4.6. Generating Questions

I used my literature review, a review of associated documents, including documents that provided evidence about what surgeons and engineers had said about touch and the da Vinci in prior interviews and public lectures, and the primary inquiry of my study, to guide the generation of open-ended questions at the start of my research process (See Appendix C). There is no clear guide to developing questions that get at the co-construction of touch. There are growing methodological approaches and the development of questions that help engage these areas (Jewitt, et. al., 2020), but given the exploratory nature of this research and the difficulty of "capturing" touch, I developed my initial questions based on prior research and intuition. The questions I initially posed helped me answer my research questions by focusing specifically on aspects of touch as they related to the development of the dVSS, and practices and ideas associated with it. These initial questions were meant as a flexible guide as I began contacting participants and entered the field, but the primary questions listed in Appendix C remained mostly consistent across participants. As I progressed through the research process, I reflexively added or slightly altered my questions to attend to emerging themes and also to adapt to the expert I was interviewing. Because interviews were semi-structured, I also generated questions as new topics or themes emerged. In regard to the engineers I interviewed, I researched their backgrounds, interviews, and talks to tailor my questions to each participant. And as I moved from one participant to the next, I also altered questions in a way that reflected the knowledge I had gained from prior participants.

4.6.1. Interview Process

Before beginning the interviewing process, I had to think about how I would present myself and my study. I discussed my project with Dr. Luciano and tried to gauge how to orient myself and my project based on his interactions with surgeons. As an informant who worked with the surgeons, he was able to provide insights about how I needed to frame my project in order to make it more likely they would talk to me. This was important because as Fontana and Frey (2000) point out, “once the interviewer’s presentation of self is ‘cast,’ it leaves a profound impression on the respondents and has great influence over the success (or lack of it) of the study” (p. 655). Additionally, by sending a carefully worded email and also beginning my interviews with an explanation of my project, I made sure to establish my involvement with the project and it’s motivating goals (Ostrander, 1995, p. 485).

I started my interview process with the surgeons by conducting a semi-structured interview with Dr. Gangemi. Dr. Luciano served as an insider to connect me with surgeons at UIC, acting “as a guide and a translator of cultural mores and, at times, jargon or language” (Fontana & Fey, 2000, p. 655). In the case of interviewing Dr. Gangemi, he accompanied me to the interview, helping me establish a connection and also asking valuable questions that I may not have considered without the insider knowledge that he possessed. After explaining my project to the surgeon, I began the interview with some of the structured questions I had already written. As Dr. Gangemi answered the first couple of questions, I tried to remain flexible and follow up with questions that I had not prewritten when it helped me delve deeper into a particular topic area. At some point, the interview became more of a discussion between Dr. Luciano, Dr. Gangemi, and me. The interview lasted approximately 45 minutes. After completing the interview we debriefed as we headed back to Dr. Luciano’s office and he told me that he had not thought to ask some of the questions I had asked of the surgeon but recognized they were important questions. The exchange offered a bridge that helped overcome some of the discipline specific differences that had made it hard to communicate the purpose and goals of my project.

When I observed Dr. Gangemi in the OR and the training lab, we engaged in unstructured interviews where I followed up on questions that arose out of the semi-structured interview and through observations. Throughout the process, I engaged in an analysis of my interview notes to check assumptions and themes that emerged in my semi-structured and unstructured interviews. I used that analysis to slightly alter some of my initial interview questions before I formally interviewed Dr. Crivellaro for approximately 25 minutes. The process was iterative, moving between semi-structured and unstructured interviews throughout the duration of the study. The iterative process provided some confirmation of my findings while leaving the possibility open to discover other important themes.

I took a slightly different approach to the interview process with the engineers. Because I was not observing the engineers in the lab, with the exception of Dr. Luciano, I used a set of open-ended questions to guide our semi-structured interviews. After each interview, I analyzed the data for general themes and asked additional questions or slightly retailored questions for the next interviewee. Each interview lasted between one to two hours, with Dr. Kuckenbecker and Dr. Luciano granting me follow-up interviews where I expanded on my base set of questions. In the case of Dr. Luciano, I engaged in unstructured and semi-structured interviews over the course of several meetings.

It is important to recognize that "interviewers are increasingly seen as active participants in interactions with respondents, and interviews are seen as negotiated accomplishments of both interviewers and respondents that are shaped by the contexts and situations in which they take place" (Fontana & Fey, 2000, p. 663). This was certainly the case throughout the interviewing process as I started to make connections between different interviews and interviewees that prompted more connected and reflective responses.

4.7. Data Collection and Analysis

My approach to qualitative data collection and analysis is informed by my outline of qualitative approaches, but I adapt general guidelines from Emerson, et al. (1995) and Saldaña (2015) to provide a detailed step-by-step guide for my research. While in the field, I manually took notes in a journal, attempting to capture as much detail about the field as possible. I used my notes to aid my recollection when writing more detailed field notes each time I exited the field. The process of observing, note taking, and writing detailed field notes provided the first step in focusing my data collection as I made initial decisions about which aspects of my observations to include and exclude. This is necessary as it is not possible to include every detail of an observation. In the case of recorded interviews, I tried to manually transcribe the interviews within a week of obtaining them, but this was an arduous process for some of the longer interviews and took me longer in those cases.

I used MaxQDA software to input my notes, transcribe recorded interviews, and to keep them secure/encrypted. Using computer software to aid qualitative analysis has now become commonplace. The software is meant to facilitate the process of coding, identifying thematic threads, developing memos, and performing larger meta-analyses of the raw and coded data. I used MaxQDA software because I generated a great deal of empirical material based on observations, interviews, and analysis and it helped me keep that data organized. MaxQDA helped me more easily identify themes emerging from my data by automating that process to a certain degree –

specifically in representing the salience of themes by showing their redundancy in the corpus and identifying connections between themes.

Following Saldaña's method, I wrote preliminary jottings and attached them as analytic memos. These memos, which were reflections on potential codes on the process of being in the field, performing interviews, and reflecting on the overall trajectory of my project, served as "ideas for analytic consideration" (Saldaña, 2015, p. 17). These analytics memos also helped refine my observations and interviews by focusing my research. I read and coded initial notes using an open-coding approach which helped identify key ideas and themes. The codes I used were evocative words (distraction, comfort, irritation), symbolic phrases (grips come to life, touch anxiety, haptic imaginary), and in-vivo text (robotic kiss, surgeons say they feel with their eyes, true touch), that helped me identify categories for interpretation and analysis. Following this process, I used my "interpretations of data" to "shape" my "emergent codes in grounded theory" (Charmaz, 2000, p. 515). I read through my field notes and codes several times in an iterative process, adding, altering, and cutting codes as the project developed. As I progressed through data collection, I used an intuitive approach, reflecting on my encounters in the field and in my interviews while at the same time writing, reviewing, and coding my field notes in a more systemic way.

Because this study focuses on the sociotechnical co-construction of touch, and not the general culture of the operating room or the lab, I used coding with particular attention to instances when concepts of touch or touch behaviors emerged in my notes. But I also coded my notes for general practices in the OR– from my feelings of entering the OR to rituals of sanitizing and norms of interaction– as these represented aspects of the OR that could be associated with the da Vinci and touch in indirect ways.

After spending time in the field and coding notes, I began making integrative memos to identify and clarify emerging patterns in my data (Emerson, et al., 1995, p. 172). When I started to identify patterns and coding became repetitive, I grouped codes into categories and engaged in closer and more narrowed readings of coded sections of my field notes. The approach is similar to grounded theory in that I derive "analytic categories directly from the data, not from preconceived concepts or hypotheses" (Charmaz, 2001, p. 336 - 37). The process is a fundamentally inductive, iterative, and interpretative one. Finally, I reviewed categories to derive themes and concepts that helped me move toward making more theoretical claims from the data.

4.7.1. Additional Data Sources

Since my research focused on the da Vinci and experts in the field, I also gathered data from textual resources associated with the development and marketing of the da Vinci, patent data, scholarly and popular interviews with robotic surgeons and da Vinci engineers, scholarly sources on the development and implementation of the dVSS, and videos posted to YouTube by Intuitive showing the da Vinci in use. I used Google alerts with the keywords "haptic" and "surgical robotics" to send me emails with potentially related data sources over the course of two years, during the writing of my proposal and my dissertation. I also performed general keyword research using Google and scholarly databases to identify videos, popular press interviews, patents, and scholarly contributions associated with Intuitive, the participants in my study, and for engineers Dr. Akhil Madhani and Dr. Allison Okamura, who I had hoped to interview but was unable to ultimately contact. I collected sources containing interviews with robotic surgeons who reflected specifically on touch and the da Vinci. Collecting additional data sources is not conceptualized as an entirely distinct category from my participants. I followed lines and intersections to documents that are relevant to understanding the historical construction of touch and the da Vinci and to contextualize my participants in relation to the da Vinci. As I identified related documents, I used the same qualitative coding approach I used to code my interviews and observations. I moved reflexively through a process of induction while investigating my documents, observations, and interviews to identify thematic patterns and topics that helped me verify and refine my coding schema. The additional data I collected added supplemental resources to focus my observations and interviews, and to hone the development of my codes, categories, and concepts while also helping to contextualize my findings.

4.7.2. Storage of Data

I collected data via handwritten notes during observations and initial interviews before I requested a modification to my IRB approval allowing me to audio record during interviews. Data was copied into the QDA manager and kept on an encrypted computer. Names were not collected except when working with publicly identified experts in their domains. Informed consent was obtained orally to avoid identifying names with pseudonyms. Audio recordings and transcripts were maintained in electronic copy on an encrypted external hard drive, stored in the Principal Investigator's (PI) locked UIC office. Audio recordings were deleted/destroyed following transcription (i.e., within two weeks of the in-person session).

4.7.3. Data Analysis

I use a multi-method analytic approach to identify salient themes and concepts concerning touch that emerged from interviews with engineers and observations and interviews with users. I analyzed the data qualitatively with the aid of QDA software. The multi-method approach used in this study is guided by the notion that triangulation can help produce more insightful and confirmable results. I used a "'complex' form of triangulation" also called *multiple triangulation* by combining different triangulation techniques including using different data collection and analysis methods (Natow, 2020). Each method produces slightly different data and analysis, but by combining them, I was able to identify salient themes that converged between them. 'Elites' "can demonstrate unique views of reality, from a privileged or powerful standpoint," so using "complex" triangulation also allowed me another way to check their perspectives (Natow, 2020, p. 163). Interviews, observations, and additional data sources produce areas of agreement and identify tensions. Those sites of tension suggest areas where negotiation is taking place and it is in those seams that the construction of touch is also actively rising. I used ANT inspired SCOT(t) to further interrogate these tensions, closures, and active areas of negotiation because they provide tools to pry open blackboxed, sociotechnical configurations of touch.

Each method involves the abstracting of social life from the lived experience of that life. In the case of this project, it means abstracting the touch and haptic aspects of social worlds, turning observations, interviews, and experience into written representations to be combed, coded, and combined. The goal of combining these methods is to create a coherent set of empirical findings that provide foundational knowledge about the touch practices and haptic realities associated with RSAs.

Even though I have described the methods in separate sections, mixed qualitative methods overlap to a great degree. They are driven by the same epistemological assumptions. Because they involve an iterative and reflexive process, I performed these analyses together, using them to build off of and feed back into each other. The data and analysis from each approach informs the development of the other so that, for instance, interview questions are partially informed by document analysis, and coding of mixed sources may be partially informed by participant observation and interviews. Qualitative research involves an iterative, reflexive, and cyclical process, moving between and across various sources of data in order to refine research questions, hone analysis, and to provide more concise insights (Lincoln & Denzin, 2000; Baym & Markham, 2008). Because I needed to go through IRB to do the human subjects aspects of my proposed study, I started by collecting and analyzing documentary data sources and moved on to using other methods as I was granted permission to pursue my research. Once I had permission to pursue all areas of inquiry, I engaged in a reflexive process of data collection, coding, and analysis, as I have laid out in previous sections.

At the same time, I used my ANT-inspired SCOT(t) as a model to identify tensions that emerge in negotiating the construction of touch. This also helped me identify an end point for my field work as I discovered areas of rhetorical closure. The production and stabilization of practices and meanings introduced by any new sociotechnical configuration does not mean to suggest some kind of final state can be reached, but it does help identify a momentary stasis.

One of the most challenging aspects of my study was determining when I should leave the field. It is impossible to follow all of the potential stories and threads that developed throughout my investigation. Using a multi-method approach, I was able to identify tensions and redundancies and reach a point of saturation that indicated an end to this study, but it only represented one of many potential endings. At the same time, as a foundational study, it provides pathways for multiple studies that can build on this work.

4.7.4. Ending Data Collection

It is hard to determine when to leave the field and end data collection. Things are always changing. The scene is never fully set. The concern I have with making claims that have already shifted by the time I defend this dissertation is palpable. But at some point, a researcher has to leave the field and write, to present what they have found, and make an argument in defense of their analysis. The decision is artificial in the sense that the work is never really done, but it is not meaningless or random. I left the field once I started to find recurring themes in my coding — known as saturation. The experiences I started to have in the field, the practices I was identifying, and the ideas I was encountering began to repeat and echoed the experiences of other researchers I talked to anonymously who had done similar field work. This does not mean that the social situation is not dynamic, nor that it will not change, nor that another researcher would not interpret observations and interviews in different ways that could have required more or less time in the field. Research is always radically contextual not only due to the site of investigation but also due to the researcher doing the research. Recognizing these realities should not undercut the findings of a study. Rather it should reinforce them by giving readers a lens to critically reflect on the analytic narrative.

4.8. Ethical Considerations

Doing research with humans in medical settings presents a host of potential ethical issues. From concerns about privacy to maintaining integrity and trust, ethical standards for qualitative research, especially in sensitive areas like medicine, should be high. For my research, there are a host of potential ethical issues which I attempted to account for upfront and others that I dealt with as they emerged. Laying out a framework for both helped me make more ethical decisions when a choice presented itself.

Guillemin and Gillam (2004) suggest there are two basic dimensions of ethics in research, "procedural ethics, which usually involves seeking approval from a relevant ethics committee to undertake research involving humans; and (b) 'ethics in practice' or the everyday ethical issues that arise in the doing of research" (p. 263). Procedural ethics provides a kind of template, or checklist, of known issues which must be dealt with to the satisfaction of an IRB committee. It was necessary to consider a host of potential ethical issues related to maintaining anonymity of participants and securing analog and digital data. It is important to recognize that meeting the bar set by "procedural ethics" is only the first step. The second step, which is ongoing throughout the process, is dealing with ethics in the everyday practice of interacting with participants and doing the research.

A general framework for making ethical decisions includes, nonmaleficence: do no harm to participants; beneficence: do research to provide benefits; autonomy: respect research participants (or co-researchers); and justice: treat people equally (Murphy and Dingwall, 2007, pg. 339). These ethical considerations do not provide a step-by-step guide to determining what is right and wrong in the field, but they are general guiding principles to continually reflect on. Reflexivity provides the bedrock for all qualitative research but can also steer ethical considerations (Guillemin and Gillam, 2004). Being reflexive about the goals of my project not only serves to help me understand the construction of culture and my role in that construction. It also helps me continually question whether the research is meeting the general principles I have laid out. It also acts as a useful guide in everyday interaction, helping make decisions that serve to maintain the "autonomy, dignity, and privacy" of others (Guillemin and Gillam, 2004, pg. 275).

There were several moments when I had to consider "ethics of practice" throughout this project, but two instances serve as representations of the choices I had to make. First, I got the distinct impression from the beginning that requesting time for an interview with a surgeon was a major inconvenience. This feeling probably emerged from the perceived power differential between myself and the surgeons, making me feel like I was asking for a 'favor' (Herod, 1999). The surgeons I interviewed were gracious with their time and answers, but it was clear they were very busy and my concern with interrupting their schedules made me feel like I would be imposing by asking them for another interview. Second, I wanted to interview Dr. Gangemi's residents, but he made it clear that they were too busy to do interviews. When I got a chance to observe them during training sessions, I wanted to request interviews with them directly, but I felt like it would be crossing an ethical line since Dr. Gangemi had already made it clear he thought they were too busy, and it was clear to me he thought he was trying to protect their best interests[9].

4.9. Reflections on the Process

While the open-ended nature of this type of qualitative research makes the task daunting on its own, many researchers have provided insights into the sense of disorientation the work can bring. However, the part of the process I wish to focus on deals with the barriers to entry I faced, which is not unique in ethnographic-style inquiry but worth providing some reflection given the specific context. I think it is worth offering some reflections on these aspects of this project because it may help other researchers coming from non-medical and non-engineering fields who wish to perform qualitative inquiries within these areas. This reflection does provide some analytical insight about the power imbalance at play in researching an area of vital economic interest to the institution, but it is mostly meant to provide some insight about the hurdles and feelings a novice might face in researching the surgical field. I am primarily going to focus this reflection on the process of gaining access to the OR and observing in the OR because these two aspects presented the biggest hurdles to completing this project.

When I started my research, I thought that studying the da Vinci at UIC offered a perfect opportunity since it was home to one of the premier robotic surgical programs in the world. I naively figured I could reach out to the head of the program with a few details about my study and he would welcome me. Instead, I sent many emails only to get a response from an assistant who

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[9] Upon further reflection I probably deferred to the doctor because I did not feel I had power in the situation and I did not want to jeopardize my access to him or the O.R.

never replied to several follow-up emails. While Dr. Luciano put me in contact with Dr. Gangemi, it also took several emails to finally get an affirmative reply. While I waited for that reply, feeling down on the prospects of the project, a former Ph.D. student put me in contact with some of his contacts in the medical department. I thought taking an interview with them would help me gain the access I needed, but that only resulted in them inquiring about my project because they were concerned my research might be focused on being entirely critical of the da Vinci, which they were concerned about because it might bring bad press to UIC. I believe the concern emanated from a protective place since U of I doctors had generated controversy in 2014 for appearing in a national marketing campaign for the da Vinci (King, K. & Cohen, J.S. 2014). Despite assurances that I should follow my research where it took me, I always felt a sense of concern in the back of my mind. Although I knew my research was not focused on specific outcomes or positivistic assessments of the da Vinci, and there was nothing about my research question that suggested I would add details that could cause undo scrutiny, it felt like an extra weight I carried through the process and made me keenly aware of the power differentials at play. It was a relief when Dr. Gangemi agreed to an interview and was open to having me observe in the OR. His enthusiasm helped rekindle my sense that continuing the project was possible.

Once Dr. Gangemi invited me to observe in the OR, the barriers to entry lowered substantially. After filling out some paperwork, I was able to get a photo badge and have it keyed so I could get scrubs and enter the OR when I wanted. Even though I had full access, I never felt comfortable just going to the OR without knowing Dr. Gangemi or Dr. Crivellaro were scheduled to perform a surgery. The first few trips to the OR were the most daunting as I felt like a fish out of water. I watched others to learn where to go and the protocols to follow. I stood outside operating rooms while the surgical team set up, feeling too timid to go in until the doctor arrived. Standing outside, not quite knowing what to do with myself, a nurse asked me if I needed help. I told them why I was there and they whisked me to another room where another surgeon was performing a liver transplant using the da Vinci. The experience felt surreal. I never felt completely comfortable in the operating room because I was concerned that I might somehow interfere with the surgery either through distraction or impacting the material conditions of the space by contaminating something through my own touch. Perhaps if I had continued to go to the operating room, learned more names, and interacted with the community in and out of the OR, I eventually would have felt more at ease, but I always felt like I was an imposition. It marks the difference between ethnographic immersion and a more superficial engagement with the field site.

5. IN THE GUIDING GRIPS OF A ROBOTIC SURGICAL ASSISTANT

The most ubiquitous robotic surgical assistant (RSA) on the market, the da Vinci Surgical System (dVSS) directly modifies what it means for the hands to act as healing agents, not only by removing them from direct contact with the patient but also by anesthetizing the felt epistemologies of operating on a patient. With the heat, resistance, and tackiness of the patient's body removed, what remains for the surgeon to touch are the control side grips of an electronically tethered machine. These grips glide easily, control for tremors, and provide haptic feedback about the position of robotic arms but give little indication of the body being manipulated.

Robotic surgical assistants created for human-robot interaction (HRI) constitute an important focal point for understanding the co-construction of touch and technology. The development of RSAs shapes ideas and practices of human and machine touch in medical settings. The values and meanings associated with these systems orient around their haptic materiality, shifting touch practices, and the associations of touch that arise with their integration into training labs and operating rooms.

In this chapter, I analyze data about the shifting and shaping of touch with the da Vinci through an analysis of observations in the OR and the training lab and interviews with two robotic surgeons. The most profound impacts on notions of surgical touch are shaped through the guiding grips of the robotic surgical assistant, but it is the more mundane practices associated with the device that reveal the scope of its influence. The alteration of surgical touch through the grips and the mundane shifts in touch practices around the robot co-construct surgical touch in affective ways as both controlling and caring, not only through the healing hands of the surgeon, but through the guiding grips of a robotic surgical assistant.

5.1. The da Vinci Dance: Entering the Operating Room

I entered the operating room. The blue tiled walls reflected lights from the ceiling. The gray tiled floors amplified my steps. I slowly ambled to a corner of the room, avoiding metal trays, plastic receptacles, and bundles of multi-colored wires running to various monitors, computers, and screens. A nurse and a medical technician prepared the sterile room.

I had seen pictures of the dVSS throughout my research process, but I was not prepared for how large and imposing the robot would be in person (Figure 1). The patient cart, similar to the picture in figure 1, hovered at around 7 feet, pushed up against the exterior blue wall. Its clearance moves between 174 cm (approx. 5 feet, 8 inches) and 247 cm (approx. 8 feet, 1 inch). Having earlier observed a laparoscopic surgery in a room without a dVSS, I was acutely aware that it stood as an imposing figure, even against the wall. My eyes quickly followed tangled cables on the ground to the vision cart (Figure 2) against an adjacent wall and the surgeon console (Figure 3) in the opposing corner. Taken together, the dVSS added a complicated array of networked robotic elements to the operating room which required bodily coordination unique to this configuration.

Figure 1. Intuitive Surgical® da Vinci Xi arms in operation

Figure 2. dVSS Vision Cart[10]

Figure 3. dVSS Surgeon Console

[10] https://www.intuitive.com/en-us/products-and-services/da-vinci/systems##

A medical technician greeted me as I entered the room. He stood by a large table covered in a blue drape. As I moved closer, he told me it was the sterile field and I needed to maintain at least 3 feet of distance at all times. It was not the last time I would hear about the sterile field or be reminded of how much proprioceptive awareness was involved in navigating the operating room.

The technician asked me why I was observing. I responded with a brief explanation of my project. He looked back at me without skipping a beat[11] and started to explain what he was doing, showing each tool used in this robotic surgery – permanent cautery hook (Figure 4)[12], fenestrated bipolar forceps (Figure 5)[4], large needle driver (Figure 6)[4], and a stapler (Figure 7)[4] as he organized them on the sterile instrument table.

Figure 4. Permanent cautery hook

[11] I suspect the technician was not surprised by my observations since UIC is a teaching and research hospital that receives frequent visitors.
[12] Intuitive Instrument & Accessory Catalog, January 2019

Figure 5. Fenestrated bipolar forceps

Figure 6. Large needle driver

Figure 7. Stapler

The instruments he described, which are comparable to other laparoscopic tools, are created specifically by Intuitive for the da Vinci and adapted to the EndoWrist® – their patented grip interface allowing for 7 degrees of freedom. According to Intuitive, these tiny instruments, many smaller than human fingers with the ability to heat, burn, and cauterize skin, staple, and to poke holes in the human body offer “precision beyond the limits of the human hand,”[13] With this assertion, the company attempts to mark a limitation of human touch which the robot already exceeds – despite the fact that it is human hands which continue to co-operate the robotic instruments. The framing echoes the way medical instruments, like thermometers, have come to undermine the authority of human touch as trustworthy in assessing bodily health (Reiser, 1978).

As he described each instrument, I moved closer to get a better look. Without hesitation, he told me to stop before I entered the sterile field. It was not the last time I had to be reminded, and I was not the only one who had to be reminded to maintain a safe distance. Another person who had come another day to collect a sample for a biopsy crossed the sterile field and was told sternly not to do so again. The invisible, forceless field was maintained by a keen spatial awareness.

After a short time, others started to wander into the room. First the anesthesiologists came in, although, again, I was not sure about the time of their arrival. If there is a theme concerning my own involvement with this project that runs throughout, it is the novelty of the operating room for me and my lack of knowledge about it upon first entering the field. The first few observations were disorienting as I tried to figure out how different forms of dress, placement in the OR, and interaction differentiated nurses from residents and anesthesiologists.

Finally, the patient was wheeled into the operating room. What happened next, in each of the operations I observed, was a kind of carefully choreographed dance. Without speaking about what they were doing, each member of the team worked in seamless unison to prepare the patient for surgery. The tight quarters for sometimes upwards of 8 or more people, and a host of machines,

[13] https://www.intuitive.com/en-us/products-and-services/da-vinci/instruments

made this dance especially impressive. It made me think deeply about the need for proprioceptive awareness in the operating room and about the embodied knowledge — the literal muscle memory — involved in preparing the patient for surgery, in putting on sterile surgical gowns, in handing off, replacing instruments, and navigating the sterile field. While there has been limited ethnographic work focused on the impact on surgical touch of robotic assistance, many of my observations correspond to an ethnographic study focused on "how robots are consequential for work practices" in surgery (Sergeeva, et. al., 2018, p. 1). As the authors argue in their conclusion, "by tracing the amount of repair work needed to reweave the disrupted coordination in surgery, our research suggests that embodied experience is a less visible, but important, explanation of work coordination" (p. 6). The embodied experience goes beyond explaining work coordination. It is intimately tied to altered conceptions of touch and locates not just between members of the surgical team, but also the da Vinci.

The operating room is a space in which surgical touch is both sanitized and flattened, and at the same time, of utmost importance. Preparing the operating room begins with a thorough cleaning to sanitize the space. The medical technician, covered in scrubs, prepares a table to be used for all of the instruments. A careful space known as the sterile field is maintained around the space. In preparing to begin surgery, the medical technician puts an additional set of sanitized scrubs over the surgeon after removing them from a plastic bag. The technician and surgeon are careful not to let the scrubs or new gloves touch other surfaces that could lead to contamination. With two sets of scrubs and two sets of gloves, the surgeon's sense of touch is diminished even before introducing other instruments. The proprioceptive knowledge, always knowing where your body is in space, helps the team navigate an intricate and delicate dance that keeps the patient and the medical team safe and the materials sanitary. A misstep can lead to unwanted touch that leads to breakdowns in preparation and in the surgical process.

The need to maintain sterility necessitates draping the arms of the da Vinci with a sanitized plastic gown. Since the instruments of the da Vinci are sanitized, do not require draping, and are inserted into the body of the patient, the drape is meant to protect the da Vinci as much as it is meant to protect the patient. It provides a transparent barrier between the human bodies and robotic body, and patient blood that might contaminate it. The process of draping the da Vinci is quite similar to putting a sterile gown and gloves onto the surgeon, where the medical technician carefully robes the surgeon in a freshly sanitized gown. A million-plus dollar piece of equipment necessitates its own personal protective equipment (PPE), and, like PPE in the age of Covid-19, it also serves a symbolic role, communicating its position as another sterilized member of the surgical team. These protocols of protection are so strict that even brushing up against the draped da Vinci with a surgical gown requires a process of removing the contaminated cover and replacing it with another – a process that is both wasteful and time-consuming. During one observation, I witnessed intense frustration as a novice in the OR accidently backed into the covered da Vinci. The team let out an audible sigh as it meant interrupting their preparation flow to re-drape the device. The exacerbated response suggested it was not a limited occurrence.

In the OR, touch is as much about what you can touch as what you cannot touch. It is about preferencing some types of touch over others. It is about treating the body of the da Vinci like that of the surgeon, materially and symbolically. While touch is often not explicitly reflected on, it communicates the need for effectively maintaining sterility, comfort, and care in the operating room.

5.2. From Blood and Bone to Stool and Steel

The dVSS reconfigures the touch space and the labor of surgical touch in the OR. Shifting practices of touch at the body and the machine alter ideas about the importance of tactile knowledge. While touch remains important to the surgeons, the way it matters changed with the dVSS. In continuing the trend of visualizing medicine, (Edwards, et al. 2010; Ostherr, 2013; Van Dijek, 2005) surgical touch becomes subsumed through the high definition 3D monitor. Although some aspects of the device reorient surgical touch away from felt encounters to visual stimuli, others reconfigure surgical touch away from the hands to incorporate the whole body. These shifts might be thought of in terms of McLuhan's (2010) notion of technological extensions, when he says that, "mechanical means [...] can act as a sort of twist for the kaleidoscope of the entire sensorium" (p. 55). While robotic surgeons still engage directly with the patients, making incisions on the skin to insert ports and palpating the stomach cavity with their fingers to see if it is properly inflated–and even transitioning to open surgery when necessary–working with the dVSS means robotic surgeons spend less time touching blood and bone and more time touching stool and steel. The touch of their whole bodies becomes reconfigured with a machine whose cold steel arms and interchangeable instruments immerse in the living, beating, breathing flesh of the human patient.

5.2.1. Surgical Touch and the dVSS: Reflections from the Office

In attempting to understand how the surgeons I interviewed, Dr. Antonio Gangemi and Dr. Simone Crivellaro, both specialists in robotic surgery, thought about touch in general, in surgical practice, and with the da Vinci, I asked them a series of questions and observed them in the OR. Their answers, and what I observed, revealed a tension regarding the construction of surgical touch that suggested touch was important in ways that were not always apparent, and that importance was less functional and instrumental than they sometimes made it seem in interviews, taking on other cultural attributes like comfort and care.

Dr. Gangemi told me that, "in a broad sense, there is no difference between touching the patient and touching the grips," despite the fact that operating with the dVSS grips conveys no tactile information regarding the human body, no temperature, no texture, no force. Dr. Crivellaro answered with a firm "no" when I asked him whether operating via the grips has changed his relationship with how he thinks about patients during surgery since he's touching the machine more than the patient. Both reactions suggested that the surgeons made no real differentiation between touching the machine and touching the patient. For them, touching the machine and touching the patient were equivalent. I am a bit skeptical of this claim. There are professional reasons for denying the differentiation, but at the same time, beyond removing them from the body throughout most of the surgery, the conditions of anonymity remain the same. The patient is covered and only the area of operation exposed. They have also been performing robotic surgery for many years and their immersion in the experience probably has eroded any distinctions they may have originally felt.

However, both surgeons expressed the importance of being able to touch during surgery with Dr. Gangemi saying "human beings have the need for feeling things, for feeling touch," and Dr. Crivellaro related this need for feeling in conjunction with open surgery[14]:

> Tactile feedback is very important in open surgery because you can't see very well. It's like when you're in a dark room and you need to use your hands to recognize an object, right? If you have tactile feedback than it's much easier to recognize… stuff. Simply for open surgery, some locations are too much remote, are too much hard to reach. So, you can't see exactly what you're doing but you learn how to use your tactile feedback, to recognize different structure.

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[14] Open surgery is an invasive process that relies on making major incisions to gain access to organs or other interior body parts that require operation. Open surgery often involves cutting a large enough opening that a surgeon can physically reach into the body with their own gloved hands.

The tactile knowledge important to surgeons in open surgery is reconfigured with the dVSS, altering the relationship between the hands, surgical craft, the labor of the body, and the importance of professionalized surgical touch and associated knowledges and practices.

According to Dr. Gangemi, "Visual feedback has fully replaced haptic feedback." But Dr. Gangemi also went on to explain that the knowledge of textures and densities in the body, informed by doing open surgery and laparoscopic, played a role in making sense of how to gauge operating in the body without haptic feedback – an idea that suggests the tactile knowledge of the body still informs the ability to operate visually, even if the surgeons did not think this experience was necessary to perform surgical operations with the system. The idea is echoed by other robotic surgeons, including Dr. Crivellaro, who went into detail about how the tactile knowledge of the body becomes enmeshed with visual information of operating in the body in a way that may best be described as psuedohaptics[15].

The repetition marks an important one, moving from the fingers in the body or holding a laparoscopic instrument, to one where the fingers and the feet work in concert with the dVSS, the medical technician next to the patient, and sometimes a medical resident or fellow, to perform the procedure. The importance of vision in surgical procedures is made more profound by the dVSS while human touch is complicated in the process, involving the surgeon's fingers and feet at the control console while the hands, arms, and bodies, of the medical technician, anesthesiologist, nurses, and residents still maintain proximity to the patient body, along with the hulking arms of the robot. The teamwork aspect is not new with the robot, but it is complicated, shifting the locus

[15] Psuedohaptics are described as visual illusions used to promote feelings of touch. See (Costes, et al., 2019).

of control. Distributing the responsibilities of surgical touch across the team means creating a networked haptic experience.

The alteration of surgical touch is exacerbated by the fact that surgeons increasingly express the ability to almost feel the tactility of operating through the visual display. As Dr. Crivellaro told me, "at some point you, you, the feeling is like you're having the tactile feedback. Your brain is perceiving a feedback that you don't really have." This idea was also expressed by Dr. Gangemi who highlighted the adaptability of the brain in learning how to operate with the dVSS. But because of that adaptation to operating with the eyes, he expressed the discomfort in adding feeling of bodily tactility back into operating – at least through the da Vinci, "every time you give haptic feedback, you get distracted." In responding to a question about adding haptic feedback to the da Vinci, Dr. Crivellaro also said, "for me it would be distracting. At this point in my training." The statements highlight how much alterations of touch are achieved through enculturation and training. In both cases, these surgeons are also teachers, passing on ideas about how students will come to feel with their eyes. As one student told me, they were reassured by their surgical instructor that they could "overcome the lack of feedback because you can see deformation." The surgeon's experience thus has an outsized influence on debates about whether more and different types of haptic feedback should be reincorporated.

When pressed about the kinds of haptic feedback they were imagining, both surgeons indicated that they were thinking about a kind of vibration feedback, although they also expressed confusion on that point. Exacerbating the continued ocularcentric tendencies of medicine and surgical operation, when asked if he missed anything about open surgery, Dr. Crivellaro said:

> Nah. (do you prefer the visual knowledge to the…) I do, by far. (what are the reasons?) It makes me feel much more confident in what I'm doing. And I think that makes sense. Because visual is the most powerful sense. When you can clearly see something it's very hard to go wrong because you see

> in detail what you're doing and it's much easier to dissect a (inaudible) when you see it that well. It's much easier to figure out what's happening. Say you have a bleeding. Typically, in open surgery you have a bleeding and then, all of a sudden, you don't see anything anymore. And with the robot, you can see where the bleeding comes from when it starts. Especially small bleedings. Big bleeding doesn't make a difference. But with the 3D camera, with that kind of magnification, you see better. Whereas in open, it's very hard to see. It's just everything is more difficult. There is nothing that I miss, personally speaking, of open surgery. Absolutely nothing.

The point that he makes about the visual sense being the most powerful one frames sight as superior to touch in a way that is common in many discourses about the arrangement of the senses (Classen, 1993; Crary, 1990; Jay, 1993). The qualities ascribed to vision about the power and the control it offers is overstated since the surgeon's visual field is confined by the narrow window the scope offers within the body, a frame that often excludes the robotic arms inside the body. The materiality of the body remains present even in this visual configuration as I witnessed the scope needing to be removed several times during surgery to clear bodily fluids or humidity generated from the bodies' heat. But the expression that Dr. Crivellaro missed "absolutely nothing" is perhaps best explained by Carey (1981) speaking about McLuhan's sensorial perspective toward media when he says, "the media of communication affect society principally by changing the dominant structures of taste and feeling, by altering the desired forms of experience" (p. 166). As the da Vinci shifts the experience of surgery from the hands to the eyes, it acts as a media of communication, "altering desired forms of experience."

Additionally, the easy glide of grips (Figure 8) contributes to the diminishing of touch as important to the surgical process. While the grips do provide feedback to make themselves felt when they could potentially crash into each other or when the arms could collide outside the body, both issues that happen primarily outside the visual field of the surgeon, they rarely call attention to themselves. In fact, it is somewhat the opposite. The grips are computerized and there is a force applied when operating that made me feel as if I was moving them through water or oil when I tried the training simulator, which uses the same console as the operating room device. "The other is the tactile feedback is applying pressure to mechanical device – it's a force to counteract your force" (Dr. Gangemi).

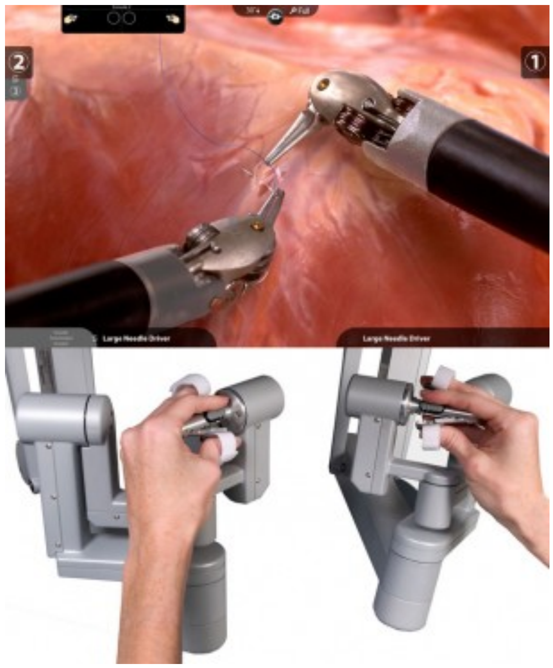

Figure 8. (Top): Simulator image, (Bottom): Fingers in grips

The feeling provides some weight that helps the hands and fingers glide more easily but quickly assimilates into the felt phenomenon of a user's hands – in essence, the grips disappear. Dr. Niemeyer confirms this idea with a story about witnessing a live procedure where the surgeon could not distinguish his own touch from the robot's:

> This was a real live procedure where the surgeon hadn't set it up quite right and felt he couldn't reach the work site he was trying to get to and so he kept going up to the nurse and saying, hey the tools are colliding, I can't move my hand anymore, go fix it. The assistant or nurse was trying to look at these rooms. No, they're all clear you can complete. So, they basically did this for 5 minutes and even kept

> yelling. And it turns out that his physical arm was colliding with the setup. And he was so immersed that he couldn't tell the difference between his physical arm touching a piece of metal and the feedback where the tool stops when it can't go anymore.

The felt presence of the grips paradoxically fades into the background by design. Without the weighted glide feel, the grips would be harder to use because they would provide nothing for the surgeon to rest on or to push against. The computational component of the grips helps them float in position, as the surgeon leaves one arm to operate another. In a sense, this creates the perception of a frictionless encounter, further flattening surgical touch and allowing it to fade further into the background. It is easy to forget about touch or to find it less important than vision in this scenario, even while the work of the surgeon is still firmly located in their ability to make fine, repeated, articulated, and often improvised movements with the grips.

Despite the shifting orientation of touch at the body and at the machine, it still matters, especially at the interface. As Dr. Gangemi remarked during our conversation, "we need friction." While explicit recognition and reflection on surgical touch seems to be diminished by the visual-centeredness of the surgical console, observations and comments made by the surgical team indicated a more complicated co-construction of touch.

5.2.2. Surgical Touch Meets Robotic Touch in the Operating Room

It is important to make a brief distinction between surgical and robotic touch for the purposes of this section, even though I argue later in this study that the two are increasingly not distinguishable. Here, I intentionally use the term surgical touch to signify the touch of humans and robotic touch to signify touch concerning the robot. I make the distinction for the sake of clarity in this section, but I do not operationalize these distinctions in a way that forwards a theory of surgical touch that is distinct from robotic touch. In other words, the distinction here is primarily rhetorical as opposed to conceptual.

I observed the surgeons on several occasions. The first few sessions revealed some surprising issues related to touch that had not come up in our semi-structured interviews. These mundane aspects of touch proved to be salient to the surgeons and to their perceptions of operating the dVSS. In the following vignette, I combine salient aspects from several surgeries I observed.

When I walk into the OR to observe the robotic surgery, I notice two surgical consoles in opposing corners against a blue tiled wall on the far side of the room. The arrangement is specific to only one room and is meant to allow the surgeon and a resident to be at the controls at the same time, so one can take over for the other quickly, if necessary. The other rooms I observe only have one surgical console. Before the patient is wheeled in and the robot docked, the room looks open, with the robot and other carts lining the walls.

I stand against one wall while the surgical team begins to prepare the room, trying to stay out of the way. The medical technician prepares the sterile field while a nurse checks to see that the operating table is ready. Quickly the room fills with other members of the surgical team, including two anesthesiologists, a nurse, the medical technical, an attending surgeon, a medical resident, and a fellow.

Soon after, the patient is wheeled in, still awake, and moved from the gurney to the operating table. The patient is positioned for the surgery while the anesthesiologists, positioned near the head of the patient, sedate the patient before intubating them and applying general anesthesia. As the patient sedates, the resident and student, or sometimes the nurses, drape the patient in blue clothes, leaving only the surgical site exposed. A sheet provides a kind of screen to cordon the patient's head from the rest of the body, leaving the head visible only to the anesthesiologists while the body is visible to the rest of the surgical team. The attending surgeon guides the resident as they swab the skin on the stomach before making incisions for ports to be inserted. While the patient is prepped, I observe another nurse and the medical technician draping the da Vinci arms in a special plastic covering made for the device. The device still leans against the wall, away from the patient who lays in the center of the room.

The surgeon mentions that the patient feels warm on his hands. He asks the anesthesiologist if the patient's temperature is elevated. The anesthesiologist responds that it is normal and the surgeon responds that "temperature is not reliable" which I take to mean that the feeling of touching another person is not a reliable way to measure their temperature. The response manifests the way medical instruments, providing mechanical, chemical, and digital imitation, diminish faith in the human ability to trust our own sense of touch and in the surgeon's ability to trust their own embodied authority.

As the belly of the patient is inflated by the anesthesiologist, the surgeon, or oftentimes, the resident, taps on it. The surgeon and the resident push and feel around the belly with their fingers and mark incision points. The surgeon turns toward me and invites me over to see an instrument they are about to use to puncture the skin. He tells me the tip is sheathed to blunt the sharp tip, but as soon as it comes in contact with the skin, it reveals a sharp tip which the surgeon twists like a screw. The tip is attached to the camera, so I can see it burrow through the layers of skin, fat, and muscle before entering the cavern inside the body. The surgeon narrates the process, explaining that each layer of bodily material has a different feeling, a different texture and resistance that can be felt. Despite the fact that the surgeon can see the camera passing through the layers, he still relies on his tactile knowledge to gauge how hard to press and at what point he should stop in order to avoid puncturing an internal organ as the scope passes through the interior lining of the belly.

Once the camera is inside, the medical student makes another incision on a marked spot where he inserts a port that will be used for one of the robotic arms. I watch him tunnel the port through the layers of skin on the video monitor, glancing at the deformations made on the exterior of the stomach as he presses further. The port eventually pops through the interior layer but the surgeon decides they need to use a larger port, so the medical student takes the smaller port out and guides the larger one in. I notice that the interior skin extends inward as he tries to push the port through the opening. He fishes around for the interior opening, but the port is stuck, making the skin stretch inside the body. The medical student watches the monitor as he searches for the opening – letting, what seems to me, his vision to guide him rather than his hands.

The process is repeated three more times until there are a total of five ports in the patient. Sometimes I observe one more or one less. The robot only has four arms, but occasionally it is necessary to have additional ports for laparoscopic tools to aid in the surgery. In the cases where there are extra ports, the extra instruments or camera, not being used by the robotic surgeon, are handled manually to hold organs or tissue out of the way while the surgeon operates in a specific location.

A nurse walks over to the da Vinci and maneuvers it over to the patient. It seems to operate like a hydraulic lift. With the robot now hovering over the patient, the surgeon docks the robot and positions the arms to the ports. The surgeon is teaching the resident how to target the arms but then the machine says, "Can't reach sterile height for clearance" and "Don't' move operating table while da Vinci is docked." The surgeon tells me there is a problem and starts removing arms and pulling the whole device back. When the surgeon tries to reposition the da Vinci and it repeats the same error code, the surgeon asks a nurse to call a representative from Intuitive because they cannot figure out how to shift the robot to meet the clearance issue. The surgeon tells me he thinks it is an issue with the sensors. We wait while everyone stands around looking at their phones. It seems to me that this issue is not unique to this moment and the reason Dr. Gangemi said, "we are all technicians now" during our interview becomes clearer. The da Vinci does not just require shifts in surgical skill, it requires the surgeon and the surgical team to take on new roles in troubleshooting the device and even introduces a new member to the team. Surgical touch requires skill in healing the patient and treating the device.

For a sterile room, the operating room is surprisingly disorienting to the senses of a novice newbie. The hum of machines resonates below the beeps of monitoring systems. The temperature inside the OR always feels like it drops a few degrees upon entering from the hallway. The footsteps, side conversations, directions for assistance, and emanations from the instrumentation arms, as they move as if by themselves, fill the room. Often, the surgeon starts his favorite classical music station before beginning the surgery.

Once the robot is docked to the patient and the arms are inserted into the ports, the surgeon walks over to the surgical console (Figure 9), takes off his shoes, and sits in the chair. The surgeon calls me over and tells me that he removes his shoes so he can feel the operating pedals better and knows that I am interested in these kinds of details for my study. The practice is common amongst all the surgeons I observed in the OR. The pedals elevate and extend surgical touch, redistributing control to other bodily appendages. In a paradoxical way, while haptic feedback is diminished at the grips, taking off the shoes, another material that mediates foot touch, reveals a desire for a more tactile connection through the feet. Taking off the shoes is a subtle act of resistance against the mediated numbing effect of shoes.

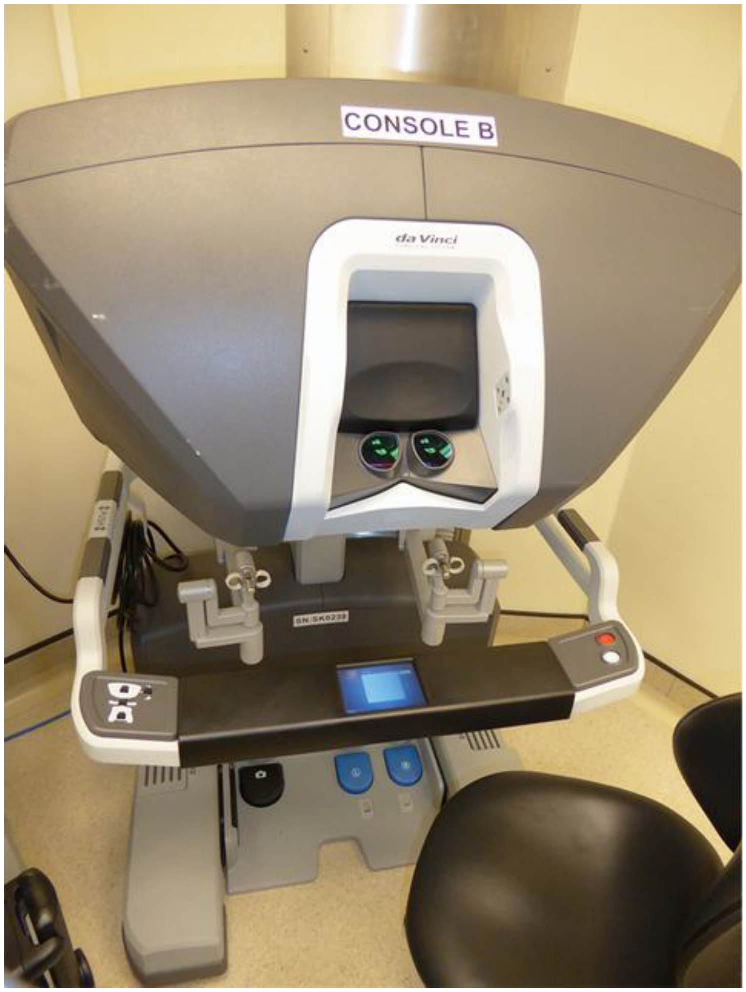

Figure 9. dVSS surgeon console

He shows me the control panel on the surgical console and explains that the device can be set for each operator. The surgeon logs in using their credentials and the console begins to move back to the preset configuration. The surgeon explains how important it is to have the armrest and the headrest at the proper heights and locations to increase his comfort and to reduce fatigue. He points out that it is important to have the proper bodily position. The head should not be bent. The shoulders need to be relaxed. The back needs to be straight without overextending it. Once the console is done adjusting to his preset configuration to conform the proper bodily position, he turns to me and says, “The only problem is the surgeon who operated here before me did not return the chair to my height.”

After adjusting the chair, he leans into the machine and places his fingers on the control grips (Figure 10). He uses his thumb and middle finger to guide the grip. The grip displayed in figure 10 shows the fingers inserted into Velcro loops, but with the exception of a couple medical students training in the lab, I never saw surgeons inserting their fingers into the loops. Instead, they would hold the tips of the grips, just before the loops. Despite the visual invitation to insert their fingers, the affordances offered by the grips oriented the fingers in ways surgeons deemed most comfortable. Different surgeons seemed to have their own techniques for holding and manipulating the grips.

Figure 10. dVSS control grips

I watch the surgeon begin the operation and look up to see the robot arms moving in tandem with the surgeon’s arms and wrists. While the articulation of the instrument is largely located at the wrists of the surgeon, the robotic arms make much larger motions outside the body, even while the articulations inside the body are even smaller than the motions made by the surgeon holding the grips. The surgeon’s hands are both on the grips and seem to be in constant motion, but he shows little arm or body movement, sitting in the ergonomic posture he described to me earlier. As he works, I see he uses both feet on the peddles working in coordination with his hands, to zoom the camera in and out and to change control of the robotic arms.

As I stand next to him watching the movements of his hands and feet, I feel very removed from the rest of the surgical team. With the monitors and robotic arms between myself and the rest of the surgical team, I can barely see them, and their conversations sound like murmurs. The surgeon, meanwhile, is laser focused with a literal tunnel vision enabled by the viewing station. He asks the med tech to change the instrument tool on one of the robotic arms without raising his head. I hear his voice over speakers in the operating room. While his voice is amplified by the microphone on the console, making it easy for the team to understand him, the reverse is not true.

Watching him operate, I notice that he swaps between different instrument arms while using the device. The medical student observing the surgery asks about the ability to control multiple arms and the surgeon tells the student that there is a button on the side of the device you press to change and lock which arms you want to operate. This effectively gives the surgeon extra arms – extensions of both the surgeon's arms and feet. Explaining the procedure for moving between instruments he adds, "I think the next generation will not have to swap with the feet clutch." He goes on to explain that he thinks future iterations will include eye tracking technology which would do the switching. The explanation exposes a desire and imaginary rooted in, and perpetuating, an ocularcentrism dominating the medical field.

The surgeon directs me to sit over at the other control console. One surgical operating room includes two consoles so the surgeon and student can swap controls during the surgery, a bit like a training car that has two sets of controls so the teacher can take over quickly if necessary. He tells me to be careful not to touch the grips but to watch through the viewer. I slowly sit in the chair at the other console, careful not to touch any of the buttons, or the grips, even though I am confident I cannot take control unless I am logged into the device, which I could not do since I do not have credentials. Still, the idea that I could somehow interfere with the surgery promotes a sense of anxiety. I rest my forehead against the viewer. The 3D display is very clear and offers an extraordinary visual of the interiority of the body, but I am struck by the rather limited frame of view, both in the body and to the exterior room. I can only really see the tips of the instruments, and, while the surgeon pulls on the tissue, I even lose view of the instrument tips from time to time. While watching, I hear the surgeon ask the medical student to push on the patient's belly so he can see where to move. Pushing on the exterior part of the belly creates a visual indentation observable in the monitor which spatially orients the surgeon.

At one point, the surgeon begins to try to staple two flaps of skin together, but I look over and see a robotic arm colliding with a laparoscopic instrument being held by one of the fellows. The surgeon does not feel the collision and from his cocoon in the operating console, away from the body, cannot really tell what is happening. To compensate, the team tells the surgeon what is happening outside his field of view and verbally tells him where to move the robotic arms. The interaction implies an amputation that leaves the surgeon dependent on the team to convey both haptic and visual information that would otherwise be seen and felt. While the dVSS extends the range of the surgeon's touch through the machine, the machine also narrows the surgeon's scope of perception.

The surgeon continues to manipulate the robotic instruments from the control console while the team realizes they need to put in a bigger port because the resident, sitting by the patient, could not get the stapler into the right position with the one they had. She pulls the smaller port out, places a knife on the incision and makes it wider. As she struggles to put the new port in, moving it around, pushing hard against the belly, the surgeon continues to operate inside the body without seeming to notice anything is happening outside. Finally, after thirty seconds or so, the surgeon asks if they are doing something and the resident confirms that they are putting a new port in. The surgeon follows up by asking the resident to "hand" a vice to the robotic arms already inside the body for the surgeon to place. The resident accomplishes this maneuver by inserting the vice through a port manually using a laparoscopic tool.

Throughout the surgery, the surgeon repeatedly asks the med tech to clean off the camera. The med tech taps on the robotic arm, which automatically retracts from its position allowing them to disengage the camera instrument. They put the camera in a bottle that looks like a thermos, take it out, and wipe it off with a sterile cloth. Once cleaned, the med tech reattaches the instrument, taps on it, and it automatically returns to its previous position. After the fact, I learn that the camera sometimes becomes clouded by viscera during the surgery, but more often than not, especially at the beginning, the camera lens becomes clouded by the humidity of the interior bodily cavity.

Near the midway point of the surgery, the surgeon asks me to get up so his resident can take over for him on the secondary control console. I stand up and watch the resident take my place. He types in his code and the machine adjusts to his preset preferences. After sitting down, I notice that, unlike the surgeon, he keeps his shoes on. It seemed like an anomaly as I repeatedly witnessed residents take off their shoes in the context of the training lab. Once in position, he begins to complete the stitching the surgeon had started in an attempt to repair skin that had been cut to fix a hernia. The surgeon stands up and walks over to the patient, coaching the resident while watching from the monitors in the room. Everyone is watching the monitors as the resident carefully guides the robotic arm to make a miniscule puncture through the skin, pushing through with one robotic tool while pulling out with the other – fingers replaced by two larger driver needles. The surgeon notices the resident is making a mistake in the stitching, stretching the skin too much, but catches the mistake only after it causes a slight tear. The surgeon returns to his console to take over and comes up with, what he calls a "cleaver solution," sewing a different part of the interior over the flap that has been torn – the one that was meant to cover the original hole. He tells the resident that he's going to make him famous by calling the procedure the (name of the resident) procedure.

After that he allows the resident to finish and the surgery finishes without a hitch. The robotic arms are retracted. The ports are taken out. The five small holes left by the robotic arm ports and an extra port for a laparoscopic arm are sewed up manually by the resident. The patient is cleaned up while the anesthesiologists remove the tubes used to intubate the patient. Finally, the plastic drapes are removed from the robotic assistant by the med tech and nurses and the room is left to be sterilized for the next robotic surgery.

5.3. In the Comforting Arms of the Robotic Surgical Assistant

The da Vinci shifts the locus of comfort, control, and care from the surgeon by sharing the responsibilities of surgical touch and providing a cocoon from which the surgeon operates.
Time and time again, the robotic surgeons I interviewed and observed stated their preference for working with the da Vinci robot. They were quick to point out they did not always recommend it, because it was expensive, and outcomes were often similar to those of laparoscopic surgery. The preferences, sometimes explicitly, and other times implicitly, tended to revolve around ergonomic comfort, a greater sense of control, and an inverted notion of care.

After interviewing Dr. Gangemi in his office, he told me I should observe a laparoscopic surgery so I could see the differences between laparoscopy and robotic surgery. During the surgery, Dr. Gangemi worked side by side with his resident, using all four hands to guide instruments – the resident holding a Nathan retractor to hold the liver back with one hand and guiding the camera with the other while Dr. Gangemi performed the surgical operation. As the surgery unfolded, he pointed out that the camera and visuals can be shaky because the camera is handheld – not so with the robot. He mentioned that he could feel the resistance of things in the body with the laparoscopic tools but did not distinguish his inability to do so with the robot as a limitation. As he moved into a tricky spot of the surgery, he pointed out that the laparoscopic tools could not go around corners like the robot because the ends did not have the Endowrist®. He then mentioned that while laparoscopy has tremors, from the hand holding the instrument, the da Vinci does not because it is controlled by the computer. In a subtle way, this shifts the locus of control from the surgeon to the dVSS, granting more agency to the device while augmenting the agency of the surgeon. The tremor control may actually provide more perceived agency to the surgeon since the surgeon is no longer as concerned about making mistakes which they cannot physiologically control for, but it does not undercut the fact that they are shifting their trust to the device to actually do what it is supposed to do.

As Dr. Gangemi wrapped up, he made one more comment, telling me that laparoscopic surgery was more tiring because of seeing what you were doing on the 2D monitors as opposed to through the 3D viewing hood of the robot. The fact that he felt it was important for me to observe both types of surgeries suggested that there were real differences between the two modes of surgery that could offer some insight into the construction of touch, if compared. The way he detailed these differences indicated to me that the construction of touch for the da Vinci was partially located in comforting and caring for the surgeon as opposed to the patient.

Dr. Crivellaro echoed and elaborated on some of the observational data I collected regarding how the touch of the robot becomes associated with feelings of comfort, care, and control, saying "for me it's more ergonomic, sitting in a chair. It's less tiring. You see better. So that gives you a lot of confidence." Further indicating that doing robotic surgery with the dVSS is geared toward comforting the surgeon, he said:

> There is a lot of discussion about the outcomes (inaudible). You'd better provide better outcomes. And this has been certified only in a couple of procedures, but, for sure, it was my impression from the very beginning, this technology allowed an ok surgeon to perform complex procedure[s]. You know, in a better way. That doesn't always translate to better outcomes. But surgically speaking, makes things easier.

While the surgeon is visually and physically cut off from the team when operating the robot, the team is also cut off from the surgeon. Watching from the control console, it is clear that the team sees the robot, and not the surgeon, and that they see the framed view of the inside of the body through multiple monitors around the operating room. When I asked Dr. Crivellaro about how this shift impacted the way he thought about surgery, from touching the patient directly alongside the team, to touching the patient through the da Vinci grips, he told me that:

> After 10-plus years of using the robot, I feel more comfortable. I mean, having the robot between myself and the patient then to work directly (inaudible). […] If you think about it, when you start doing robotic surgery, the main fear was I'm far away from the patient, the very first time the surgeon was not on the patient, so the main fear is like what if something happened. I don't have control of what I'm doing because the camera is inside the abdomen and I don't know what's happening outside. But in reality, the more you use it and more again your brain adapts. If you've done that procedure a thousand times, you will know perfectly what's going on. Even without looking at it. So, you will tell your assistant exactly what to do. To solve that problem. So, after a while, you feel more confident in performing procedure.

The comforting touch provided by the da Vinci not only leads to a greater sense of control and ease for these surgeons but also leaves an affective mark. When Dr. Gangemi finished one particularly arduous surgery, he stood up from the operating console, walked over to me, and said, "Do you see this red mark on my forehead? It happens when you push your head very hard against the console during hard parts of the surgery." Smiling, he said, "we call it the 'robotic kiss.'" The phrase begets an intimacy that represents the level of comfort felt by the surgeon with the robot. The affection for the robot makes it easier to grant the device increasing agency and allows for a greater diffusion of responsibility.

5.4. Mundane Touch and the Locus of Comfort, Control, and Care

The integration of the dVSS into operating rooms means a shift in the way surgical teams interact, in the way that surgeons train for and perform surgery, and in how the operating room is organized and functions. While other studies have documented some of these changes (Beane, 2018; Sergeeva, et. al, 2018), none have focused solely on the shifting ideas and practices of touch. Focusing on touch not only reveals different aspects of how the dVSS shapes the OR but also provides insights into the way the dVSS shapes ways of thinking about surgical touch. The system reformats surgical touch, alters its relational arrangements, and shifts the locus of touch's power away from the surgeon. The shifts are both profound and mundane.

The system reformats surgical touch by removing the surgeon's hands from the patient's body most of the time. Placed within the comforting cocoon of the operating console, the surgeon can guide the grips of the device from a safe distance – a distance that is produced through the physical separation of bodies, but also from the reformatting of surgical touch away from the felt epistemologies of the tactile body to those of the robotic grips and foot pedals. The process flattens the feeling of doing surgery for the hands and expands it for the feet, but it also reorients the agency of surgical touch away from the human surgeon. Sitting behind the surgical console, the responsibility for a touch that is meant to tear, care, and repair becomes multi-agential – shared between the surgeon and the robotic assistant. With the surgeon's hands on the guiding grips of the robot and the robot's instrumented arms in the patient, the locus of touch control shifts to the robot. The reformatting also includes a shift in surgical practice away from the knowledge produced through touch toward that of vision. Like other areas of medicine, surgery with the robotic assistant is visualized, converting a rich area of medical knowledge concerning the firmness and feltness of the body into something to be seen. This adds an additional layer of comfort and confidence to the surgeon, relying on a sense they deem superior, but it also threatens the professional identity of a surgeon whose craft is built on their tactile understanding of the body. But it is more than that. The use of the device instrumentalizes the surgeon's hands. This instrumentalizing is well-documented in literature about nursing, as Sandelowski (2000) argues:

> The devices nurses used, or, in the case of the thermometer and sphygmomanometer, how they typically used them extended the hands as opposed to the senses or interpretive capacities of the nurse. As depicted on the May 1945 cover of the *Train Nurses and Hospital Review*, the nurse's hand was 'the instrument' by which nurses served their 'fellow man'. The implements nurses used at 'hand's end' were material expressions of what most nurses and physicians viewed as the primary function of the trained nurse, namely, to serve as extensions of 'the physician's hand'. Nursing identity and work were defined by what nurses did, which in turn was increasingly defined by the tools they used (p. 63).

By numbing the hands of the surgeon, the robot extends them and even multiplies them, but it diminishes their ability to engage in sensory and interpretive work. The eyes replace the hands in this capacity, but they are equally reliant on images abstracted and mediated through the 3D viewing hood. Sitting in the robotic cocoon, the surgeon undergoes a kind of physical and sensorial amputation from the surgical team and anything outside the display of the monitor. The robot becomes the arbiter of truth and interpretation, and, I suggest, the alteration of the role of the surgeon and surgical touch is done in the name of developing a "superior touch."

6. A SUPERIOR TOUCH: BEYOND THE LIMITS OF THE HUMAN HAND™

My first reaction to learning that surgeons could not feel what they were doing while using the da Vinci was disbelief. In a general sense, everyone I told who did not have prior knowledge of the device, was both surprised and a bit concerned about the fact that the da Vinci purportedly did not provide surgeons with haptic feedback. This presented another concern for me. I had originally envisioned my dissertation project as studying a device, or set of devices, that were explicitly designed to provide haptic interaction. If the da Vinci was not designed to do so, how would I investigate questions around the development of touch in technological devices? But the lack of feedback also piqued my interest. Was it really true that the device provided no haptic feedback? What did that mean for the practice of surgery and how did it influence the perception of touch for surgeons? How could such a fundamentally defining aspect of surgery, the ability to feel what you are touching – which seemed to be both a defining professional characteristic and fundamentally important aspect of the surgical craft – be missing? And what did that mean for the possibility of surgical touch to be transferred and transformed with the robot? I decided that it was worth pursuing the da Vinci despite the fact that it supposedly lacked haptic feedback in part because the lack of haptic feedback in a profession where touch seems fundamental should be as meaningful to the construction of touch as it would be if the control grips did provide feedback. As I lay out in this chapter, the narrative is not so simple. The interpretive work defining what counts as touch and what does not count in the surgical space provides context for understanding the co-construction of touch, but more than context, it is an active part of that co-construction.

This chapter links to the previous chapter by exploring how engineering the da Vinci both relied on, and advanced, notions of touch that were put at the service of vision and reinforced ocularcentric trajectories of surgery. These decisions ultimately robotized surgical touch in a way that reformatted touch, abstracting human touch for the robot while diminishing the felt touch of surgical operation. The da Vinci incorporates some force feedback, but that feedback both undervalues and constrains the role of touch in surgery while also framing both human and robotic touch as untrustworthy. Engineers reduce surgical touch to action without feeling. The necessity of the surgeon becomes an extension of the robot in that it needs the surgeon to guide and translate force data. Haptic ambiguities reveal strategic choices about what counts as haptics and what does not, which serves surgeons, engineers, and the company – it reveals a great deal of interpretative flexibility, signifying it has not yet become fixed – at least that it is in a moment of rupture, as engineers push back against the idea that haptics is only about force feedback. All of these moves serve to materialize touch in the da Vinci in a way that standardizes and normalizes a version of surgical robotic touch that diminishes the role of felt touch, while maintaining it for reasons of "safety" – which is really an issue of trust, comfort, and a service to the eyes. At the heart of the matter rests a set of contradictions that co-constructs touch as both necessary and unnecessary for surgeons and surgical robots.

Ideas and choices about what constitutes touch and haptics, and what should be added or not, are not neutral, technical positions. They reveal the scope of the co-construction of touch with the da Vinci. And they influence the co-construction of touch and RSAs in the OR. It is my contention that the dVSS actively shapes touch in the OR through sociotechnical transformations that stem from ocularcentrism and haptic ambiguities that reveal a distrust of both human and robotic touch in a way that frames them as both necessary and unnecessary. The haptic ambiguities and distrust in human and machine touch forward ocularcentric notions while simultaneously promoting and undercutting the role of a felt touch in surgery. Ultimately, this push plays toward the idea that tactile mastery of the surgeon is not essential or useful. It can and should be replaced by visually superior methods and by the superior touch of the robot despite the fact that it is the surgeon's expert haptic knowledge, and ability to improvise, that maintains the superiority of their touch in surgical operations.

6.1 On the Origins and Early Development of the dVSS

In 2003, Garth H. Ballantyne, MD, and Fred Moll, co-founders of Intuitive Surgical, wrote a brief history regarding the da Vinci surgical system which explained that the dVSS emerged from military and space research[16]. The project was born out of research on telerobotic surgery funded by DARPA. The funding meant to develop and research the possibility of operating on soldiers from remote locations, where the doctor presumably would be under less extraneous pressure to perform. It is interesting to think that perhaps the decision also stemmed from the idea that surgeons, in some way, were worth more than soldiers[17]. While a tele-operated robot could not protect the soldier or support staff during surgery, it would ensure the safety of the surgeon. Better outcomes of the dVSS are still debated, but the device has become widely used, serving the surgeon as much or more than the patient.

6.1.1. Tracing the Roots of the dVSS

A research team led by Phil Green, working for SRI International, formally known as SRI (Stanford Research Institute), out of Palo Alto successfully built a "device that demonstrated, in prototype form, the basic ability to perform remote surgical tele manipulation" (Ballantyne & Moll, 2003, p. 1293). Their original prototype system used two video cameras to project images

[16] For an excellent and comprehensive survey of the origins of tele surgical robotics that led to the dVSS see George, et al. (2018). They also lay out a history between the development of virtual reality and telepresence robotics that should spark another dissertation concerning the co-construction of the senses, medicine, and telepresence technologies.
[17] Although it is beyond the scope of this dissertation, prompted by Annie Jacobsen's (2015) history of DARPA, it is worth investigating how these medicalized technologies have been militarized.

from the battlefield operating table back to a remotely located surgeon[18]. This configuration meant there were two individual units — the "telepresence surgeon's workstation (TSW) and a remote surgical unit (RSU)" (George, et al., 2018). To create the illusion that the surgical handles (as seen in figure 11) were connected to the instrument tips, while viewing the image generated by the remote camera, "the manipulators were located below the mirror" that reflected the images from the video monitor (George, et al., 2018). While the dVSS uses much more sophisticated 3D imagining systems today, this illusion of connection between the grips and the end-effectors is maintained. Dr. Green's system also included haptic feedback. As George, et al. (2018) note, "the Green Telepresence System's manipulators held force-sensing elements on the distal portion of the mechanism that could sense lateral forces and transmit sensations to the surgeon's controllers." While it is tempting to suggest that Dr. Green's system contained haptic feedback no longer present in the dVSS, the claim is ambiguous and primarily relies on defining haptics as force feedback. It is important to point out because haptic ambiguity plays an important role in the co-construction of touch and the da Vinci that I will address in greater detail, later in the chapter. The important distinction to be made now, is that Dr. Green's system contained force-sensing elements at the arm portions of the device, while the dVSS does not, but the ability to display forces was maintained in the da Vinci grips, creating space for its potential activation.

[18] An even earlier concept attempted to pair Jason Lanier's recently developed head-mounted display (HMD) with his DataGlove. According to (George, et al., 2018) the theoretical concept failed in practice due to a lack of "sufficient fidelity in dexterous control for surgical environments" and the inadequate "graphics generated by the helmet".

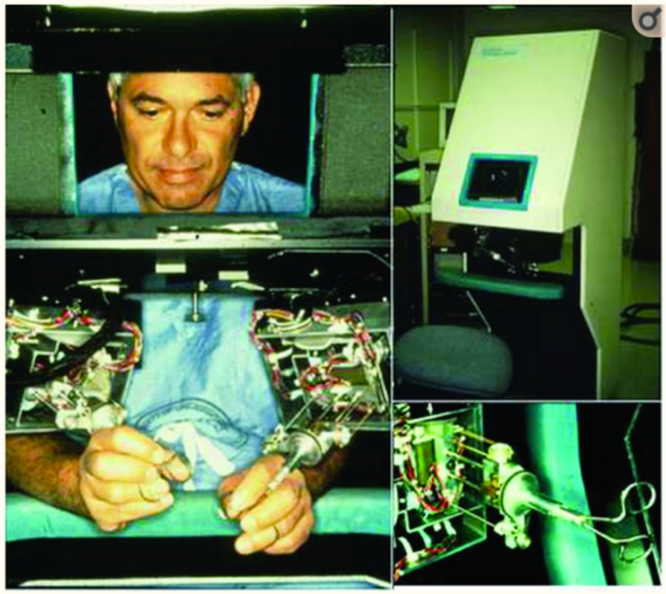

Figure 2.

([bdit]A) COL Anthony LaPorta operating at TSW. ([bdit]B) Early version of the TSW (note the ergonomic design, adjustable stool, and armrest to stabilize and rest the arms). ([bdit]C) TSW master controls, reengineered from a standard surgical instrument.

Figure 11. Telepresence surgeon's workstation (TSW)

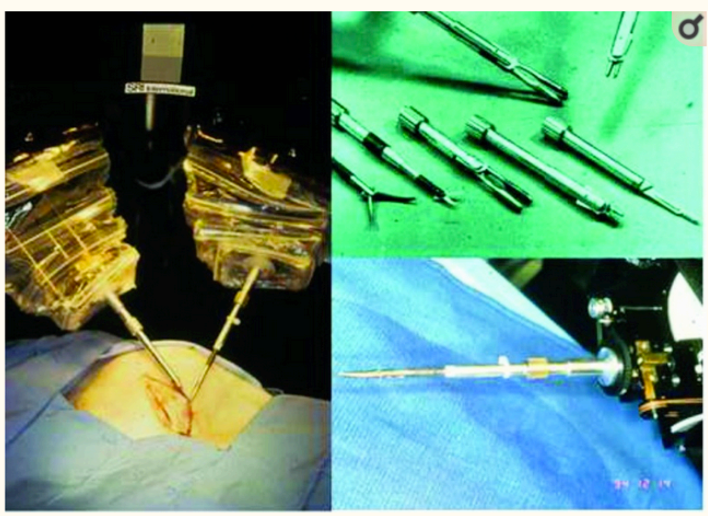

Figure 3.

([bdit]A) Remote surgical unit being used to create an incision. ([bdit]B) Exchangeable end effectors for SRI's RSU. ([bdit]C) RSU end effector with instrument attached.

Figure 12. Remote surgical unit (RSU)

Ballantyne and Moll (2003) pointed out that one of their original colleagues working on the SRI prototype saw the real potential of the robot– not as a teleoperation device– but as one that "represented the first step in a possible technical solution to the fundamental limitations of conventional laparoscopic technique" (p. 1294). The 1980s saw a rapid increase in laparoscopic surgery following innovations of the Hopkins rod lens endoscope and fibre-optic flexible endoscope in the 1950s and 60s (Yang, et.a., 2016). The laparoscopic technique made recovery times much quicker by limiting the need for large incisions, but it also introduced a number of limitations. Laparoscopic tools demanded surgeons learn a set of "nonintuitive motion due to the length of the laparoscopic tools" and was inhibited by a "lack of articulation of the instruments," and "inadequate precision" (p. 1294). They also diminished the surgeon's tactile experience in the body. Ballantyne and Moll (2003) argued that some of these limitations could be overcome "by electronically controlling and articulating the tip of an instrument" to improve "range of motion and dexterity" (p. 1294).

6.1.2. Comforting the Surgical Body

Early on, Ballantyne and Moll emphasized the potential benefits of the device for surgeons. As they tell the story, Intuitive Surgical®, the makers of dVSS, was born out of "the belief that tele-manipulation, if converted into a format compatible with minimally invasive technique, could offer benefits to the surgeon superior to those of conventional endoscopic methods" (p. 2). At its inception, the device was geared more toward benefiting surgeons than necessarily achieving greater outcomes. Claims regarding better outcomes were mostly found wanting and the evidence for better outcomes still remains debated, as studies and the surgeons I interviewed in the previous chapter indicate. Even though it is rarely focused on, the evidence for this claim is evident in Ballantyne and Moll's own words about offering "benefits to the surgeon, in the emphasis put on making robotic assisted minimally invasive surgery (RAMIS) more intuitive than laparoscopic by negating the need to learn "nonintuitive motion" and by focusing on the ergonomic design of the surgical console.

The idea of providing comfort for the surgeon is emphasized by George, et. al (2018) in a note found in figure 10, "note the ergonomic design, adjustable stool, and armrest to stabilize and rest the arms." The notes are specific to Dr. Green's telepresence system, but they are design features incorporated in the dVSS. The surgeons I spoke to also indicated the importance of these ergonomic systems to increase the physical comfort of the surgeon performing surgery. The point here is not to suggest that Intuitive's creators were not interested in building a system that could provide better surgical outcomes. I speculate, lacking evidence for better outcomes, designing the system to support the surgeon, both through material considerations and rhetorical arguments, played– and continues to play – a paramount role in the adaptation of the da Vinci. Without making it explicit, it also exposes the importance of attending to the needs of the surgeon's body. Whether my contention can be empirically verified remains beyond the scope of the current project.

To achieve their goals of providing a "superior" experience for surgeons, Intuitive Surgical® began licensing the patent rights from SRI, IBM, and MIT in 1995, designing a telerobotic system that included "1. A master/slave[19], software-driven system that provided intuitive control of a suite of seven-degree-of-freedom laparoscopic instruments 2. A stereoscopic vision system displayed in an immersive format 3. A system architecture composed of redundant

[19] The use of the master/slave terminology is highly problematic but I maintain it here because it is the terminology used in the documents I examined and by engineers I interviewed. There are insightful critical debates happening that will hopefully shift this terminology in the future, see: https://www.wired.com/story/tech-confronts-use-labels-master-slave/ and Eglash, R. (2007). Broken Metaphor: The Master-Slave Analogy in Technical Literature. *Technology and Culture*, 48(2) pp. 360 – 369.

sensors to provided [sic] maximum safety in operation" (p. 1294)[20]. Some of the primary patents acquired by Intuitive that were associated with the control system, linking the grips and the robotic arms, were developed by Dr. Kenneth Salisbury, Dr. Günter Niemeyer, and Dr. Akhil Madhani.

6.1.2. Getting Grips, Growing Arms

Dr. Salisbury's involvement with Intuitive was serendipitous. He had been working with Dr. Akhil Madhur (his student at the time) and Dr. Günter Niemeyer at MIT (who at the time was a post-doctoral fellow), on his Falcon project. The Falcon project, designed for minimally invasive surgery, and funded by DARPA, involved two iterations— the Silver Falcon and the Black Falcon. The Silver Falcon was a robotic manipulator with 6 degrees of freedom that suffered from "poor structural rigidity, inadequate grip strength for manipulating large needles, and gravitational compensation via counterbalancing" (George, et. al, 2018). The Black Falcon rectified many of these issues and added a 7th degree of freedom. The PHANToM, designed by Thomas Massie and Dr. Salisbury, served as the master controls for the Black Falcon. This is pertinent to mention because the PHANToM was designed as a haptic device using force feedback which is still used in many other applications today. The device was not adopted for clinical applications because there were a number of concerns about the haptic feedback provided, including issues where "the force reflection offered more hindrance than assistance" when "suturing," not being "sensitive enough for operators to discern when the manipulators came in contact with soft tissue," and fatigue caused by attempts to scale up the force (George, et. al., 2018). There were also concerns with Dr. Green's system, but designers believed that "visualization of deflection in soft tissue" and

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[20] Computer Motion actually developed AESOP, the first surgical robot to be approved by the FDA, in 1992 and ZEUS, which incorporated laparoscopic instrumentation. However, due to patent conflicts arising from patents licensed from SRI and those filed by Computer Motion, a legal battle ensued that ended in their merger in 2003.

enhanced “stereoscopic vision” was a sufficient replacement for the ability of feel forces (George, et. al., 2018).

At around that time, Dr. Salisbury got a call from his freshman roommate at Stanford, Robert Younge, who had raised over a 100 million dollars in venture capital to fund the RSA project with Intuitive. Along with Ballantyne and Moll, Robert Younge was a technical co-founder. The Falcon project had been unbeknownst to Younge at the time, and Intuitive was working on a parallel project, so he invited Dr. Salisbury and Dr. Madhur to consult on the da Vinci project, acquiring “all but one of the patents held by MIT” (George, 2018) along the way, which were pertinent to the success of the dVSS (see Figures 13 and 14, for example).

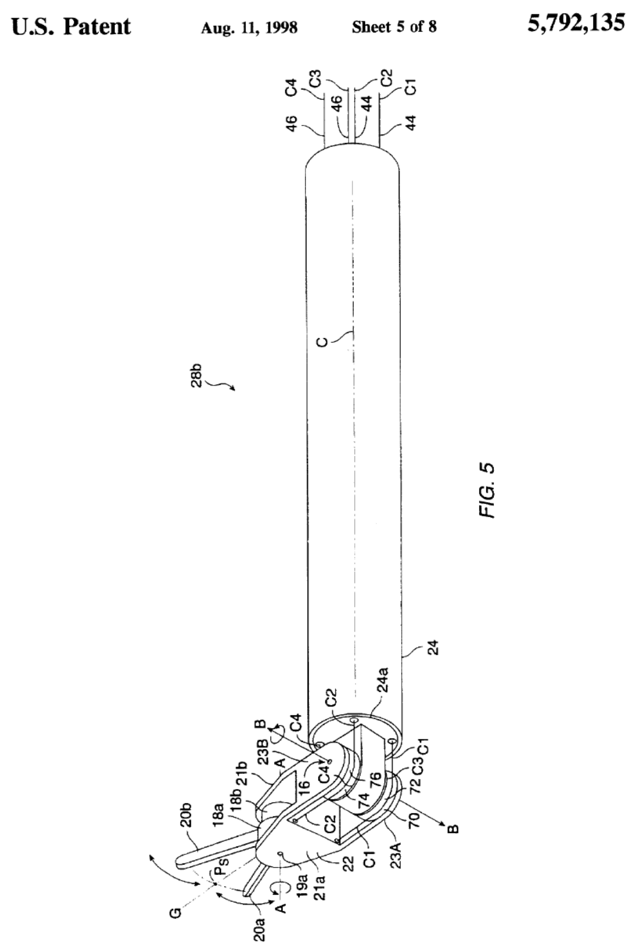

Figure 13. Perspective view of the distal end of the force-reflecting surgical instrument

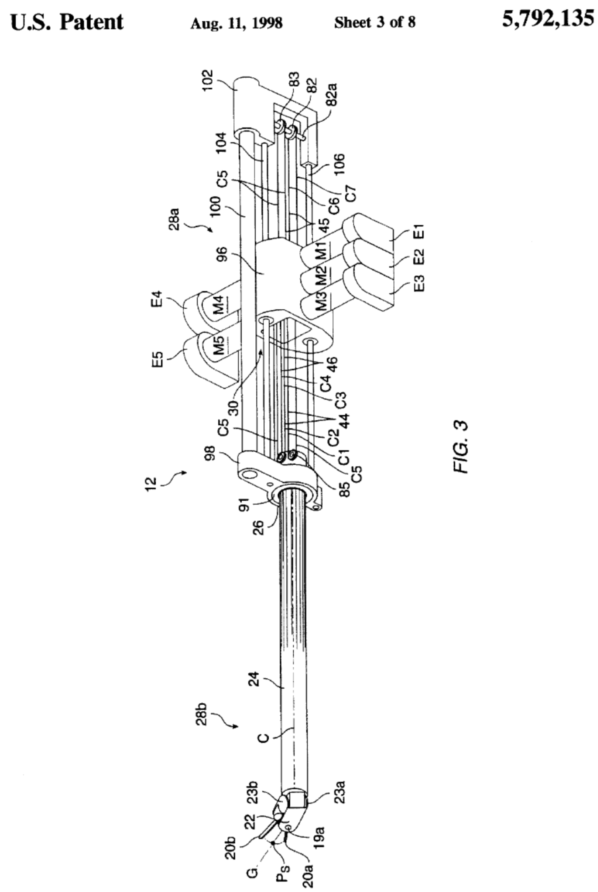

Figure 14. Perspective view of a force-reflecting surgical instrument

Given the importance of orienting the hands in operation and believing that they could develop a more intuitive system, thus the founding name of the company, developers focused first on determining where the surgeon’s hands would be located in virtual space — the space that mapped onto the da Vinci surgical robot. A series of experiments resulted in finding an optimal position. In order to provide the “maximum control and dexterity,” the company decided to connect the “surgeon’s fingers at the master console … to the jaws of the instrument themselves” (p. 1294) to maintain tip-to-tip control. Additionally, “the preference for tip control, combined with the belief that it was critically important to provide seven-degree-of-freedom articulation at the instrument tip, demanded that software algorithms be developed to make tip movement intuitive. These transformations ensure that, when manipulating an articulated tool at the level of the instrument jaws via software, the surgeon's orientation is never lost and the movements are true to the surgeon's intentions" (p. 1294). The language of intuitiveness and staying true to the surgeon's intentions makes it seem as if a surgeon could just sit down and start using the robot. And while the da Vinci certainly aligns with surgical movements in that the instrument mimics the trajectory of surgical movement – unlike the opposing fulcrum effect of laparoscopic tools – the need for extensive training, first in a simulator, suggests how those terms underplay the skill necessary to operate the robot and the extent to which surgical touch is shaped in the encounter.

6.2. Crafting A Superior Touch

The meticulous attention paid to the development of touch– and touch control– in the device points to a recognition that the displacement of the surgeon's hands from traditional human contact, or direct instrument contact, was of vital importance to developing the da Vinci. In a sense, it was first and foremost all about touch. Several copyrighted and trademarked company slogans attest to how Intuitive projected constructing surgical touch including "*The Future of Surgery is Now at Your Fingertips*™ , *Taking Surgical Precision and Technique Beyond the Limits of the Human Hand®*, *Taking Surgery Beyond the Limits of the Human Hand*™ , and "*Beyond the Limits of the Human Hand*™ ." The slogans raise the promise of a robot with superior touch, signifying the unreliability of human touch while also underplaying the work necessary to translate touch between the human and robot and dismissing the role of the human surgeon in the loop. Whether intentional or not, translating surgical touch for the robot standardizes and alters the deep tactile knowledge of the human surgeon. This ultimately constructs felt touch, the ability of the surgeon to physically feel the human body, as desirable but not essential.

6.2.1. Haptic Ambiguities I: Haptics or Not?

In researching touch and the da Vinci, one issue that I kept encountering was whether the system incorporated haptic feedback or not. Early on in the research process, the documentation I read was confusing. There were indications that the system may contain haptic feedback but the accounts were sometimes contradictory. According to Ballantyne and Moll (2003), the master controls do "provide some tensile feedback to the surgeon. When tying a suture, for example, the master indicates through resistance of movement the tension applied to the suture material by two robotic arms. The resistance of the piano wires and pulleys in the robotic arms under some circumstances, however, will obscure this haptic feedback. In particular, bending the most distal articulation of the surgical instruments, their 'wrists,' eliminates the tensile feedback" (p. 1297). They proceed to mention the availability of other haptic sensors that "provide tactile feedback" but point out that, at the time, in 2003 when the article was published, the da Vinci did not incorporate these sensors. In a contrary account, Lenoir (2002) suggested the dVSS incorporated aspects of the PHANToM, imported by Dr. Salisbury, which allowed resistance to be "transmitted back to the console where the surgeon can feel it" by using "three motors" to "generate forces on the thimble that imitate the feel of the object" (p. 32). In his account, the incorporation of the PHANToM haptic interface "greatly facilitates dissecting, cutting, suturing, and other surgical procedures, even those on very small structures, by giving the doctor inches to move in order to cut millimeteres" (p. 33). Acting to inform the engineering community about the developments of the dVSS and showing some boosterism, Guthart and Salisbury (2000) claimed that the masters not only read and transmitted the orientation and grip of surgeons, but they also acted as "haptic displays, transmitting forces and torques to the surgeon in response to various measured and synthetic force cues" (p. 619). Later in the same paper, they suggest that "haptic interfaces and the like will form the technical foundation for the development of the next generation of surgical systems and computer aided procedures" (p. 621). The statement is future oriented but seems to be indicating that the dVSS is the "next generation of surgical systems" that they are referring to even though the system had only just been completed in 1999 and approved for use by the FDA in 2000. These accounts seem to indicate that the da Vinci did have some kind of haptic feedback, even if the accounts offer somewhat different variations about what that means.

Other testimony from surgeons and attempts by other engineers to add haptic feedback offer contradictory evidence. Domenico Savatta, a robotic urologist states, "it always helps to be able to feel what you are doing, to feel the tissue tension and to feel the force when manipulating a suture. Haptics would make it easier to learn robotic surgery, operate on things that are very delicate, and be an overall advantage to have in the system" (Sauser, 2006). And haptic engineer Allison Okamura points out that adding haptic feedback will create "transparency," the idea that surgeons will feel as though "they are directly operating on the patient rather than having a robot mediate the interaction" (Sauser, 2006).

Throughout the development of the dVSS, there has been a concern with haptics, but what counts as haptics and what does not continues to be debated. The ambiguous accounts of haptic feedback in the da Vinci are easy to miss but important for what they seem to point out. The argument that the device provides some kind of haptic feedback, even though it is very limited, and sometimes does not actually provide feedback at all, reflects a recognition of the importance of feeling through touching in surgery. Maintaining the ambiguity creates the potential for "transparency" to be achieved in the future, meaning the surgeon may look forward to one day recovering a fuller sense of touch. It can be read as adding a bit of reassurance to a set of professionals whose craft and profession is so tied to the operation of their hands and the embodied, physical knowledge their touch processes. Perhaps in an attempt to assuage anxieties, Ballantyne and Moll (2003) suggest that, "the surgeon indirectly gains tactile and tensile information through visual cues" (p. 1297). But the expression transforms touch by turning tensile and tactile communication into visual information viewed through the stereoscopic monitor.

I spoke to several haptic engineers who were either directly or indirectly involved in the development of the system in order to understand what accounts for these conflicting stories and what function they play in co-constructing touch and the da Vinci. With the exception of Lenoir's account, which was probably based on prototype versions of the da Vinci that attempted to incorporate haptic feedback from the end-effectors, the ambiguity in the accounts emerges from material and conceptual distinctions. The interviews, along with the documented ambiguities, productively illustrate how haptics is an amorphous idea in the development of the device. It is ambiguous because it eludes easy definition both socially and technically. Political economic ideas of the senses which emerge from the interviews also begin to explain decisions around incorporating certain types of touch-feedback while limiting others. Taken together, definitional ambiguities, the political economy of touch, and the affordances of the OR play intersecting roles in shaping haptics for the dVSS. Determining what counts and what does not count as haptics in the da Vinci shows how touch is co-constructed with the da Vinci and opens a strategic space for imagining its possibilities.

6.2.2. Defining Haptics

In order to understand the ambiguity around haptics and the dVSS, it is useful to consider how the engineers I spoke to conceptualized haptics in general. Their answers reveal a range of possibilities, suggesting that haptics is amorphous even before considering it as a communication tool in human-machine systems. I argue that, as experts in their engineering fields, they do share some general and technical definitions regarding haptics, but in attempting to translate those ideas to me, their answers revealed wider and sometimes conflicting ways of defining the term. It is clear from listening to them attempt to define haptics that there is a process of sociotechnical construction happening. These definitions align with their own work in the field and forward ideas that situate their engineering interventions as the answer to the problem of haptics.

Haptics was defined as a field of study concerned with "studying the ability of humans to perceive a sense of touch and making things that can be perceived as touch" according to Dr. Luciano. Dr. Kuckenbecker said she uses "haptics to define the field — like physics or robotics. It's an interdisciplinary research area that focuses on understanding human and animal and robot touch and finding ways to deliver touch-based cues. There is always an agent and always stuff they are interacting with." Dr. Kuckenbecker's definition points to a much broader conceptualization of the field, but it shares the basic premise that haptics is about studying touch and ways to transmit touch.

Dr. Colgate offers a definition of haptics "as the perceptual system related to touch, hand manipulations of getting information about the world. Through actively touching it, exploring it, manipulating it and sometimes by it actively touching you." And Dr. Prattichizzo defines haptics in terms of touch, stating, it "consists mainly in two parts, one is called kinesthetic perception or kinesthetic interfaces, so the ones that deal with tendons and muscles, and the other one is more tactile, cutaneous interfaces." Both definitions fall within the field of study as defined by Dr. Kuckenbecker. Arguably, all of these definitions are rooted in a functionalist, psychophysical understanding of touch, where touch, including affective aspects, can be reduced to physical inputs and outputs that can be measured, captured, stored, transmitted, and displayed.

Dr. Niemeyer spoke reflectively about the definition, grappling to define it while discussing it in a way that acknowledged haptics as a field historically defined by a narrow concept of touch interfaces:

> Haptics… the sense of touch. […] I think most generically the term gets used in the context in displays to humans. Human in the loop, and whether it is kind of in the virtual reality space where these fictitious forces and touches, or in the teleop where there are real forces being projected back. So, I mean, globally, certainly, I believe haptics is within just a person, within just a robot, but I think the term mostly gets used when a person gets entered into a loop, be it virtual or not. I think there is kind of that split of is it kinesthetic, is it just in some sense motor torque feedback or is it truly touch in a tactile array. So, it's funny when I say truly touch I guess I'm already making, making assumptions and statements in that right there. And then so the field of haptics has certainly gone through its cycles too where I mean, yeah, it started a lot with force feedback because that was easier to do. And I think people kind of, not got tired of it, but realized it was just one aspect and then it pushed pretty hard onto trying to develop other sensory, other displays, tactile arrays […] whole vibration kind of displays and surface displays and certainly with all of the phones and touchpads became kind of a little bit of a hot topic. But yeah, I think, my first image when the word comes up is human in the loop. (ok). For all the right and wrong reasons.

There is a lot going on in Dr. Niemeyer's response that is worth deconstructing further. It incorporates some aspects of the other offered definitions, but also clearly displays a reflexive interrogation of the term and its construction. When he uses the "human in the loop" phrase, he is echoing what the other engineers articulated about haptics being, in a sense, relational between humans and objects, at least in the way the term is used in engineering. He distinguishes from a more global meaning, which seems to align haptics more with the idea of it being an individually located sensory and perceptual system, located within "just a person, within just a robot." He points this out because, as a robotics engineer, he sometimes thinks about touch sensing in relation to "straight robotics by itself." When he returns to this at the end of his response, about it being for "all the right and wrong reasons," I take this to mean that thinking about haptics in terms of human in the loop is useful but also limiting and that it is based more on a path dependency that has formed in the field than it probably should be. A similar lament is found in the Communication field, which tends to premise human communication over machine or animal communication and, at the least, almost always desires a human in the loop as well.

But it is his reflection on the field that most helps in making sense of the haptic ambiguity related to the da Vinci. As the predecessors to the da Vinci were being developed in the late 1980s, and the da Vinci was being developed in the early 1990s, the field of haptics was dominated by force feedback displays according to Dr. Colgate. This notion of what counted as haptics likely influenced decisions about designing a haptic system for the da Vinci, assuming that the important aspects of surgical touch to be captured, transmitted, and displayed, if possible, would be forces. Adding to the sentiment, Dr. Kuckenbecker argues that "people just think haptics is force feedback, but it's difficult, so they give up. Haptics is much broader." Broadening the definition diminishes the role haptics currently plays in the dVSS while opening the possibility of designing novel touch systems to provide surgical feedback.

6.2.3. Haptic Ambiguities II: Forces, Controls, and Latency

There is a desire for haptics to be integrated into the dVSS, as evidenced by social discourses and technical developments like the latent haptic potential built into the grips, but the definition of what counts as haptic feedback is contested and open to different interpretive framings. Interviewing engineers who worked on developing the dVSS, and engineers who attempted to add haptic feedback systems more recently, helps explain how haptics is incorporated in the device, the functions it serves, what its technical limitations are, and to help identify constraints that defined its development. Decisions about what to include and exclude also begin to outline political economies of the senses, where developing communication systems for the eyes is deemed both cheaper and more politically expedient than developing them for the hands or the body. The interviews clear up some haptic ambiguity but evidence why the ambiguity exists in the first place and how maintaining it could serve strategic possibilities for Intuitive and haptic engineers.

Despite the ambiguity in other discourses, the engineers I spoke with clearly noted that the device does provide force feedback but it was not mapped directly to the effector end of the robotic tool, meaning it was not meant to help surgeons feel the texture or density of the patient which could help them make subtle distinctions about their bodily anatomy. As Dr. Kuckenbecker told me, "the feedback is so faint you probably can't differentiate it." When asked if the da Vinci has haptic feedback, Dr. Niemeyer Günter replied:

> it depends a little bit on your definition of haptics. The short answer is the masters are powered. They do move and they do display forces. So, in the strictest, abstract sense, there is haptics. Um, in the practical sense of can I palpate and can I truly detect the things I want to feel, um, I think the answer is negative in that no, it doesn't have the sensitivity and the capability, so in that sense it doesn't. I sometimes I think I try to weasel a little bit on that answer because, I mean, there are, and the system architecture was set up to allow haptics, really force feedback to occur.

His answer is interesting because it shows where some of the ambiguity around haptics in the dVSS arises. Those that contend the device does not have haptics seem to interpret haptics as only existing if it is a system that delivers touch information about the patient. Referring back to Dr. Niemeyer's definition about haptics, those that argue the system does not have haptics are basing that idea on the fact that there is no human in the loop, or at least the patient is not in the loop. The definition excludes the important role that haptics plays for the dVSS as a communication system. Put another way, it is based on human-centric definition of haptic communication.

His answer also illustrates the struggle with defining what counts as haptics, as he feels the need to make the distinction about the device allowing "haptics, really force feedback." It shows how part of the ambiguity of haptics is tied to the fact that it is a term which attempts to encapsulate many aspects of touch. Saying that the device really has force feedback is marking an aspect of haptics that is integrated rather than contesting its integration.

He later elaborated:

> But the masters are basically motorized and the encoders on the motors are observing their motion and become commands to the robot, but any forces you want to display, you can display via those motors and so there is a force display. And so, that's my comment. The system does have haptic feedback. It's a question of, no, it is not palpating, but things like the tool can collide, right, and the tools can run into the limit of range of motion. Those things are actually represented haptically. So, the surgeon will feel the tool won't go any further then, and eventually his hand will stop and he will feel that physical constraint. And so that is haptic feedback of work envelope, of collisions, of things which are easier to detect, to generate synthetically because you know what the work limits are, right, and to detect the collisions and so it's a very course, heavy duty kind of haptics in that it just kind of displays all the big forces and it's just not sensitive enough. The masters are sensitive enough but there is not a sensor sensitive enough to display the direct contact.

The extended explanation points out how important the integration of haptics, represented as force feedback, is to the functioning of the da Vinci and also clearly states its purpose as a communication system between human and machine. At the same time, it constructs incorporated haptics as a crude system. That construction may erode its value to the system as there tends to be a bias in haptics, and perhaps most mediation systems, toward transmitting fine-grained information with high fidelity. But the crude construction is also situated in reference to the forces displayed to the surgeon even through the motion communicated to the robot from the surgeon via the grips is actually highly accurate, recording hand movements 1300 times per second, which "is about a kilohertz, a bit faster than necessary" (Dr. Salisbury). Regardless, the haptic feedback to the surgeon, built into the system, plays an essential function in maintaining control, but that control is mundane and associated with the robot, making it mostly unfelt by the surgeon.

The dVSS reshaped early experiences of one's own body due to the mundane qualities of haptics and the way it immersed the surgeon inside the stereoscopic display. The haptic feedback that the device displays is so subtle it has all but fallen out of the felt perception of robotic surgeons since it is associated with the robot and not the patient. After I told Dr. Niemeyer that surgeons had reported that the da Vinci did have some subtle feedback but nothing they really noticed, he told me a story that indicated even surgeons who helped develop the device had similar experiences:

> One of my favorite stories was I was watching a procedure. This was a real live procedure where the surgeon [...] hadn't set it up quite right and so he couldn't, or felt he couldn't, reach the work site he was trying to get to and so he kept going up to the nurse and saying, "Hey, the tools are colliding, I can't move my hand anymore, go fix it." The nurse was trying to look at these rooms. "No, they're all clear, you can complete." So, they basically did this for 5 minutes and even kept yelling. And it turns out that his physical arm was colliding with the setup. And he was so immersed that he could not tell the difference between his physical arm touching a piece of metal and the feedback where the tool stops when it can't go anymore. Which to me just kind of confirmed that he was so immersed in the system the all the sensations were really dealt with on a very subconscious level. And so, his conscious didn't even really understand what was going on anymore. And so, yeah, it's interesting to hear if they say they have no force feedback yet they do have forces that are displayed to them that they apparently don't even recognize as such.

Speaking to the desire of communicating more fine-grained tactile details from the patient to the surgeon, Dr. Salisbury did admit that it'd be "nice to feel things like calcification" but that they couldn't "get force feedback about it for technical reasons." He explained that the difficulties existed on both the patient side and the side of the surgeon. On the patient side, it would need high fidelity and high servo rates in order to create the necessary force feedback. On the master side, confirming Dr. Niemeyer's comments, he said they "do have some force control in them (motors in them) — to get orientation of the grip right (align the grips with the visuals)." For example, the controls attenuate the surgeon's motion because there are "certain configurations that are very hard to control — to follow certain trajectories it has to make really fast motions through the joint — so the control grips have some force feedback so they can't go through a singularity" Because there are motors in the grips that allow for force feedback, it would be possible to create virtual constraints in training that would allow you to "feel it as force feedback at the master." His point confirms the ability of the grips to display fine-grained forces even while they lack the ability to do so because of limitations in sensor capabilities for the end-effectors. But it also makes clear the latent haptic potential of the grips, waiting to be woken by either better sensors capable of communicating the physical reality of the patient, or virtual constraints which could simulate them. In other words, despite their currently underutilized state, the fact that the grips were built to display in more fine-grained ways affords their potential activation and provides evidence about a desire to integrate additional haptic capabilities. So, what kept Intuitive from turning it on or making haptics about more than forces?

6.2.4. The Political Economy of Touch and the dVSS

There were several constraints the engineers talked about which led to constructing touch, or the lack thereof, for the device in specific directions, including economic, technical, and safety issues. As Dr. Salisbury said, the "economic driver didn't make sense because it was technically difficult." Continuing to forward ocularcentric notions, Intuitive put their money into developing a state-of-the-art visual system instead, believing that focusing on the visual system was perhaps more important because many things a surgeon would need to do would be made "visually apparent." For instance, as Dr. Salisbury told me, "endoscopes were originally monocular, but Intuitive developed a stereo endoscope with high resolution." The surgeons I observed and interviewed in the previous chapter confirmed the value of this trade-off as they suggested that seeing is more important than touching in surgery, and the ability to see with such high-fidelity allows them to make judgments about tissue density based on visual deformations. It is worth considering how the decision to focus on developing the visual system as a trade-off reinforces the notion of vision as dominant, and, perhaps, the preferred mode of surgical engagement. But it is also important to consider how economic explanations that account for the haptic system are also political and mutually influential. The decision to focus on developing visual systems for the dVSS over haptic systems reflects a belief that developing for the eyes is cheaper than developing for the hands, but in doing so, it reinforces the dominance of the eyes in the sensory hierarchy and a demand for technologies that provide better visualizations. Given early concerns about the lack of haptic feedback from surgeons, this seems to indicate an important transition from reliance on the expertise of the human sense of touch to that of the eyes:

> Extremely high-resolution 3D display of how the tissue is deforming can provide a lot of that same information (as touch). It's proven through the years to be very difficult to bring haptic feedback into system that meets all the constraints of actually making something (inaudible), and cheap, and at the same time create an experience that's really valuable for a highly skilled individual. (Dr. Niemeyer).

Arguing that the 3D display provides similar information as touch reduces surgical touch and the information important to do touch to the notion of forces and, possibly, textures. If surgical touch is only a matter of forces then there is no political will to push investment in a haptic system that provides the same information. It would be redundant. In fact, if the haptic system is only able to provide force feedback, it may be providing even less tactile information than the 3D display, according to Dr. Niemeyer's formulation, because providing tactile information would involve "an array of sensors" which could "address the mechanoreceptors in the skin" in a "much more fine-grained way." This formulation also clearly suggests that better visualizations are more valuable to surgeons, but I think this is based on, and forwards, ocularcentric biases ingrained in the medical system and in conveying knowledge about the body. Despite focusing on building a superior 3D display, Dr. Niemeyer told me that watching surgeons "touch materials and palpate and try to feel the difference between characteristics of one tissue and another" allures engineers to provide that "very fine level of feedback" but "it's technically very challenging." And "often what is found is that you can get that information into the surgeon's brain in some other way." The idea that you can get the "information into the surgeon's brain in some other way" reduces touch to information which makes its substitution via visual means possible.

> I think the flip of it is the company was well aware of the value of force feedback and touch and clearly there was interest to try and incorporate that. (But) at some point, it's a company and there is cost-benefit analysis. From the fact that sensors are very difficult to deal with, miniaturization, sterility, not to mention having electronics inside the body, and all of those kind of issues associated with it, and flip-side of what does it provide you, how much capability do you get as a result of it, um, the long answer is that it was not an element that was ultimately pursued with large effort. They never abandoned it, or they never stopped kind of thinking about it. But it became clear that the amount of effort it would take to do that was probably not the tallest pole in the tent. There were a lot of other things that they could and did do that were much more effective than pursuing touch or force feedback to the level that it would have actually taken to get it (Dr. Niemeyer).

It is not possible to empirically verify the claim that the company developed aspects of the device that were more effective than "pursuing touch" since a haptic system like he describes was not in fact pursued, but the expression confirms the idea that developing visual systems has more political and economic value than developing haptic systems, which may account for their underdevelopment as compared to audio-visual systems in medicine and other domains. Attempts to incorporate haptics largely gave way to the political economy of touch[21], as Dr. Niemeyer makes clear, but haptic ambiguities, interest in adding different types of haptic feedback, and activating

[21] The claims in this section point toward a political economy of haptics that could be developed further. There are political and economic considerations that played large roles in the development of haptics for the dVSS, and they are interrelated. However, developing a theory of the political economies of haptics and the senses in more depth is beyond the scope of this dissertation. It could certainly be the focus of a future project.

its latent potential, continues. Partially driven by concerns of impending competitors, the political economy of haptics may soon shift.

6.2.4. Haptic Ambiguities III: A Space for Possibilities

Haptic ambiguity primarily orients around whether the feedback from the machine can be considered haptic feedback or whether only feedback about the patient's body, transmitted through the machine, meets the criteria. The ambiguity diminishes the role haptics already plays as a control system, but it also creates a space for adding different types of haptic feedback. In other words, there is a strategic advantage to defining the system as lacking haptic feedback, for haptic engineers and for competitor companies. If the discourse can convincingly claim the system does not have haptic feedback, and argues the absence is a problem, then the problem invites a haptic solution. The point here is not to claim that the da Vinci uses patient-oriented haptic feedback – the evidence that it does not transmit bodily information about the patient to the surgeon via touch sensors and touch displays is established. Nonetheless, the device does contain haptics that allows for comfortable grip motion, compensates for tremors, constrains the robot, and provides limits to the surgeon to keep from damaging the instrument, but these aspects are often erased when making claims about da Vinci's missing touch.

The discourse about the lack of haptic feedback that connects the body of the patient to the body of the surgeon frames the absence in stark terms. As designers of the Alf-X, a competitor to da Vinci state, "Exactly like musicians who use their fingers for producing the desired sound and, in the case of string instruments, feel the vibrations of the strings, it is of utmost importance for a surgeon to be able to feel the consistency of anatomical structures and evaluate the tensility of the suture during knot-tying" (Stark, et. al. 2012). In more technical terms, Bethea, et al. (2004) argue that "the lack of tactile feedback has led to prolonged operative times and difficulty in performing some force-sensitive surgical tasks required in cardiac operations" (p. 193). In an attempt to give surgeons their sense of touch back, at least a pseudohaptic sense of touch, the Bethea et al. (2004) team, with noted haptics engineer Allison Okamura, developed a sensory substitution system which converted force data obtained at the slave end (the robot touching the patient) into a "a visual color bar scale" (p. 195) which was viewed through the same 3D viewing console used to perform the operation[22].

Dr. Okamura points out that adding haptic feedback is important because "we want the surgeon to feel as though they are directly operating on the patient rather than having a robot mediate the interaction […] We call this idea 'transparency,' to make it feel as though the robot isn't even there" (Sauser, 2006). Of course, these concerns, and the idea of "transparency," largely focus on the functional aspects of the da Vinci, treating touch in a functional way rather than showing a concern for the cultural valiance which might be altered by the robot, for example, how it might impact the way surgeons relate to their patients. On the point of adding haptic feedback to the da Vinci, "Okamura's team uses two different techniques to incorporate haptic feedback: a physical force sensor on the robotic tools determines how much force is being applied, while a mathematical computer model estimates the forces between the patient and the robot. All of this information is relayed to the operator as torque applied to the master robot's joystick" (Sauser, 2006). No longer transferred one-to-one in a mechanical way, as Goertz' haptic feedback systems worked[23], these systems bring touch into the digital by transforming it into electronic information

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[22] A version of this system to display forces has been incorporated in Intuitive's most recent da Vinci, the Single Port.

[23] Raymond C. Goertz developed "crude gripers for handling nuclear material" at Argonne National Laboratory in 1947 with spatial awareness but not feedback. By 1948, he'd developed them with "force-feedback", dubbed bi-lateral feedback system (Spencer, 1969).

that can communicate more complicated motions and movements and dynamically scale those actions – a process not possible in a purely mechanical system. In the case of using a program to estimate forces — touch is partially virtualized. By virtualized I mean that the touch forces being calculated are virtual, not actual, because there is no physical sensing mechanism to capture and transmit forces from the arms of the robot to the grips.

Going further, Dr. Okamura suggests that she would like to find a way to get rid of physical force sensors all together because of cost and sterilization concerns – alluding to the political economy of haptics. Turning the work of the hands over to a "complex computer model" that would generate feedback based on estimations of forces radically realigns the physicality of touch, putting it in process of pure "reformatting" as Mika Elo (2012) might put it. Ultimately, the work involved in getting haptics to function properly in these devices from a functionalist perspective is daunting because haptics includes much more than force. Sensing properties like heat, texture, and so forth require additional sensors, additional ways of calculating those properties, additional actuators or devices to convert that information into something which will be received the same from device to human skin and so forth. Several more attempts have been made to add haptic feedback in intervening years, including by haptic engineers Dr. Katherine Kuckenbecker and Dr. Domenico Prattichizzo. And now that many patents on Intuitive's dVSS have lapsed, competitors are starting to emerge that seem intent on filling this void by developing systems that focus on sensing touch information and using haptics to actively assist doctors.

The project Dr. Kuckenbecker developed to address the lack of haptic feedback, VerroTouch, was meant to go around the need for force feedback, which had a number of limitations, by providing vibration feedback instead. She pointed out that there had been this kind of path dependency established regarding what haptics was and should be and it mostly revolved around force feedback. She noticed that there were problems that arose from the lack of haptic feedback because there were times when the instruments were out of the visual field and surgeons had difficulty knowing where the instruments were or whether they may be touching something they should not be touching. She said Dr. Niemeyer told her that in the early iterations of the project, and even after the dVSS was released, there were sometimes issues where surgeons would collide with stuff inside and outside of the body. In order to rectify this problem, her team came up with the novel solution of using vibration to tell the surgeon what was happening. VerroTouch attached sensors to the robotic arms that could pick up vibrations and directly translate them to vibration actuators placed on the grips (McMahan, et. al., 2011). Her project takes advantage of haptic ambiguity by arguing that force feedback alone does not define haptics, and that, in fact, it limits its potential. The political economy of haptics for the dVSS is based on recreating forces, which is expensive and difficult, but Dr. Kuckenbecker offers an alternative that is cheaper and redefines the construction of haptics in the dVSS.

Working more recently in partnership with Intuitive, Dr. Prattichizzo told me they had been working on adding haptic feedback to the da Vinci and had successfully done a proof of concept using a Biotac[24] sensor to measure forces and other tactile elements in high fidelity. As he pointed out, "it's not just a problem of displaying the forces, meaning turning them into force or other types of feedback that could be felt on the master side of the controls. The bigger challenge is measuring the forces, textures, tissue densities and so forth, recording them, and transmitting them to the master controls." He told me that even though the Biotac® sensor worked in theory, its limitation was size. It would never be able to be placed on the end of the robotic arms, but his team

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[24] Biotac, now known as Toccare ®, is a sensor system developed by Syntouch which claims to measure 15 dimensions of touch. https://syntouchinc.com/technology/

was working on a potential solution, “We are putting a lot of attention on how we can measure the forces in a smart way on the slave side. To couple this information with the master.” For disclosure reasons he was unable to go into what this smart way might be.

Haptic ambiguities and the story of attempting to add patient-oriented haptics to the dVSS is interesting for the false starts and failed attempts. It suggests the diminished importance placed on touch in surgery, which seems like a radical shift from the development of the practice over hundreds of years. Yet, engineers, surgeons, and others at Intuitive were well aware of the perceived, if not actual, importance of adding haptics to the dVSS. As Günter told me:

> People were very aware of it (attempts to add haptics). And there was not a procedure that went by that the surgeon didn’t say they would love to feel it, and kind of everyone, everyone wants the capability and everyone within the company understood how difficult it was and what it would mean.

The desire for haptics reveals tensions at the heart of the design of the dVSS and discourses about the importance of touch. Haptic ambiguities allow Intuitive to keep the promise and potential for patient-oriented haptics alive in grips waiting to receive messages from its robotic arms, whether intentional or not. But these ambiguities also undercut the important role haptics already plays in the system and biases the relationship between the surgeon and the patient over the relationship between the surgeon and the robot. This also offers an explanation for why other ergonomic aspects of the device that are important to providing comfort and control for the surgeon are largely hidden in discourses about touch and the dVSS. While the ambiguity opens up the space for potential alternatives and reveals how haptics has largely been constrained by notions that tie it to force feedback, the co-construction of haptics reduces surgical touch to force information that can be communicated visually. The interviews reveal a desire for touch feedback expressed by haptic engineers but an admission of the constraints that keep those possibilities contained and even suggest their nonnecessity. This idea that touch is not essential emerges from reducing haptics to forces that can be translated by a visual system capable of displaying those forces.

6.3. Transformed in Translation

The development of the dVSS involved a myriad of engineering groups developing separate aspects of the system with one group formed to connect the various components together. Engineers like Dr. Niemeyer and select surgeons worked in collaboration to determine the specifications of the device, actively engaging in co-constructing its material properties. This process involved much discussion and testing to determine the standards for the dVSS which ultimately normalized certain functionality, like the control system. Dr. Niemeyer recalled:

> A physician would basically say I want to do this procedure, well great, how big a mechanism do you need? What strengths do you need? And so, there was in some sense a little bit of a role of trying to interpret and connect the engineering world to the clinical world. […] . There was definitely, especially early on, a stage where the questions were how precise do the movements have to be? How much noise can you tolerate in the system? How much compliance can you tolerate in the system? And ultimately we all try to build robots that are as good as we can make them, but in some sense, there's a cost involved and so there was a lot of effort to understand what is truly necessary and what's not and really try to create the specifications that were, that hit the target as close to (inaudible), so we didn't build something that was more capable or less capable than we needed.

Determinations about what was necessary to incorporate to design an "intuitive" surgical robotic system ultimately resulted in a device that transformed surgical touch. These early decisions were suspect of the reliability of surgical and robotic touch, associated them with force feedback, and solidified an ocularcentric approach to developing the da Vinci and surgical practice. Creating a human-machine interface between the surgeon's hands and the robotic arms meant focusing on how to translate forces properly. Proper translation of forces allowed the motion and intention of the surgeon's hands to be communicated to the robotic arms through a series of computational and mechanical transformations. Without the surgeon being able to feel the physical responses of the material they were working with, which could allow their own embodied experiences to make haptic decisions about how hard to push or pull, the da Vinci arms needed to be calibrated. Like all systems of digitalization, determinations about acceptable levels of fidelity to be maintained when translating forces — what is "deemed expendable from or excessive to the movements being reproduced" (Olson, 2009, p. 78) — are determinations made in the design of the system. In the case of the da Vinci, those decisions were made by a team of engineers and surgeons testing and refining da Vinci's touch system on objects, anatomical models, and animals before moving into human trials. These decisions co-construct touch to fit certain standards and norms, based on an abstracted amalgamation of the human body, that become entrenched and perpetuate ideas about what counts and what does not, what is deemed essential and what is determined to be excessive and, therefore, unnecessary. Translating touch for the da Vinci entailed a series of transformations by abstracting it from the human body, focusing it on serving the visual aspects of the device, and by constructing human and machine touch as unreliable and in need of forced correction.

6.3.1. The Human Body as Part Pig, Part Grape

Translating touch for the da Vinci involved a series of abstractions of the human body, including surgical instruments, anatomical models, the da Vinci itself, food, and animals. Calibrating and testing early models of SRI's device involved using anatomical models to test whether forces were properly aligned between the surgeon and the mechanical robot arms. Upon validation, the 4-DOF model moved into trials with cows and pigs, or, to use the clinically correct terminology, bovine and porcine (George, et. al., 2018). Dr. Madhani refined his Silver Falcon using chickens bought from his local grocery store (Davidson, 2000). Dr. Kenneth Salisbury recalled, "Dr. Moll put a laparoscopic tool inside and pulled on it with a force sensor to learn more about range of motion and to quantify it for motor development." He also remembered that it was necessary to do animal trials to find out how much force was needed to do retraction. The process of using pigs to determine these forces also revealed issues regarding sterility. After training on inanimate objects, surgical residents still use anesthetized pigs to refine their skills using the device, relying on visual tissue deformation to guide suturing inside its stomach. In promotional videos, Intuitive shows the refinement of forces as a surgeon operates the robot to suture the skin of a grape back together (Figure 15). In this configuration, robotic touch is constructed as the amalgamation of human, animal, machine, and object. It serves a series of layered abstractions of the human body, envisioning the human body as a kind of hybrid mythological creature – part grape, part pig, part human.

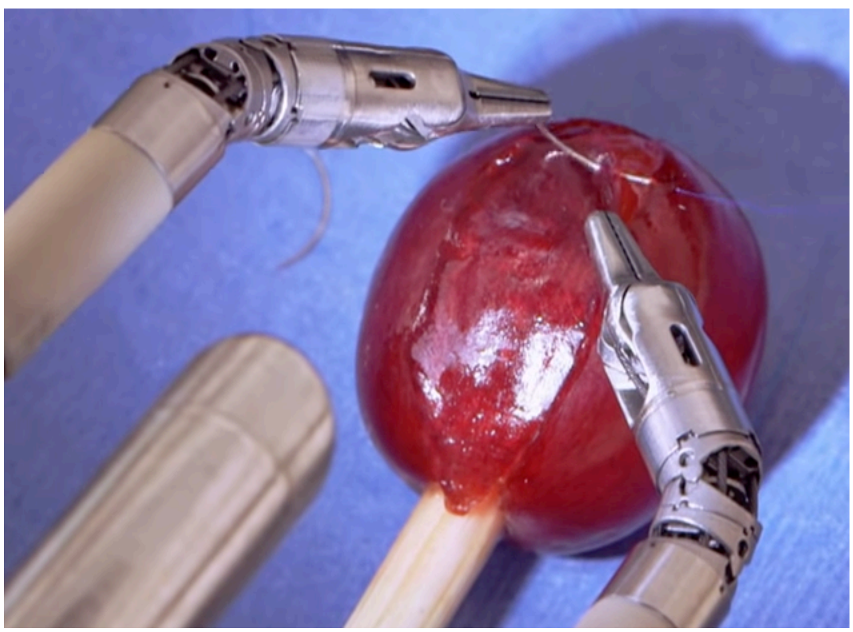

Figure 15. da Vinci robot stitches grape back together (da Vinci Surgery, 2014)

6.3.2. Touch as Information

Translating touch involved complex computational and mechanical engineering that reduced human touch to force information, communicated to the mechanical arms of the robot, that delegated more touch control to the robot (Figure 16). This translation was motivated by a functionalist formulation of touch, one where the ability to cure the internal malady is a matter of translating the forces applied by a surgeon's hands when cutting, pricking, poking, cauterizing, and suturing. The myriad qualities of touch, as a multifaceted sensory system, but also as an affective and relational system, are reduced to computational inputs and outputs that turn surgical motions into robotic ones. In the case of the da Vinci, these translations not only reduce touch to a matter of forces, they also computationally augment those forces. As Olson (2009) succinctly states, "the movement of the hands at the master-controllers does not translate into a one-to-one correspondence of movement at the end-effector in the surgical field. Nor is the system designed to do so. Instead, on a superficial level, it both *scales* the motion reproduced (according to a specified ratio) and filters motion that occurs at the same frequency as human hand tremor" (p. 78). The impact of scaling and filtering means more responsibility for how touch operates in the robot arms, and therefore on the patient, is shifted to the da Vinci. Without being felt, these shifts in the locus of touch control remain largely conceptual for the surgeon, if they are considered at all.

U.S. Patent Aug. 3, 2004 Sheet 18 of 25 US 6,772,053 B2

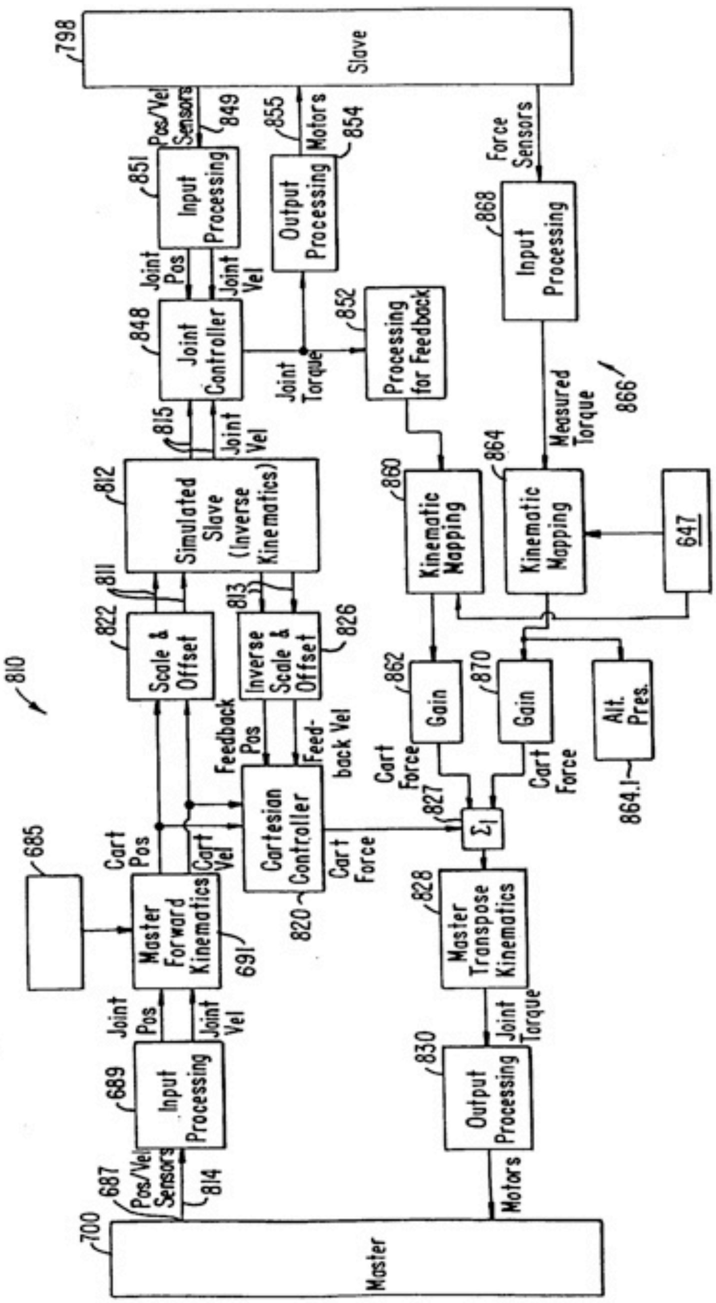

FIG. 14.

Figure 16. Block diagram representing control steps

6.3.3. Trust Issues

The da Vinci does not communicate tactile information from the patient to the surgeon in a meaningful way, but it does display forces back to the surgeon that further shift control over touch to the robot – even though that control remains cooperative. The purpose of these forces is couched in the language of safety but also raises an air of suspicion regarding the reliability of human and machine touch. Both Dr. Salisbury and Dr. Niemeyer relayed that much of the force feedback built into the device had more to do with safety than it did with trying to translate forces from inside the body. In other words, the feedback was more attuned to stopping the surgeon and the machine from making errors like allowing the arms to collide. For instance, the grips only release once the surgeon's forehead is firmly planted on the stereoscopic viewing hood – establishing the "robotic kiss." Or if the operator's hands are removed, the grips will float because of a built-in counter-balance. I felt this and experienced it while I was trying the device on my own in the training lab. In a sense, the device is set up to communicate error to the machine rather than communicating bodily information to the surgeon. While the decisions may have been made with safety in mind, they have the effect of framing human touch as untrustworthy. In doing so, it also strips some autonomy from the surgeon – at least while they are operating with the robot. But the machine is also treated as suspect, unable to move without the touch of the surgeon.

While the force displays in the grips, and computational methods for enacting them were built to both protect against the potential deficiencies of human operators and infrastructural failure, some force sensors were excluded for similar reasons. The decision to not include force sensors on the end-effectors, which could communicate information about the patient's body to the surgeon, was partially based on a general distrust of imbuing the robot with a sense of touch. While the hand-controllers have motors, Dr. Niemeyer told me that there were issues with adding force feedback because it would create loops between the surgeons and the instrument that could make it unstable.

In both cases, the distrust of the surgeon and the robot means translating forces so each has some control over the other. Surgical touch is transformed into a "co-operative" exercise between the surgeon and the robot that attenuates the power of their touch – ceding full control of forces to neither the human operator nor the robot. But because the translation of touch in these cases is geared toward error correction/avoidance and not toward knowledge transfer, these forces are largely taken for granted.

6.3.4. Touching with the Eyes

The socio-technical translation ultimately flattens touch, diminishing the multifaceted and integrated nature of a surgeon's haptic system. It serves to further entrench an ocularcentric logic since touch is reduced to force and the need to feel forces can be effectively severed from the surgeon and the robot. The idea is made evident in a statement from Dr. Salisbury: "Because it's a soft tissue environment, you can get away without force feedback." Providing more technical details about this transformation, Longmore, et. al. (2020) write:

> Imaging and display technology are paramount in RAS systems providing the main method of feedback to the surgeon. Before the introduction of tactile and haptic feedback, the imaging and display technology were the sole interface with which a surgeon obtains feedback from the operating environment. Visual feedback ques such as shadows, motion parallax and binocular cues are used to estimate location in 3D space of the end effectors, while tissue deformation is used to estimate gripping and prodding force being applied (4).

Orienting surgery increasingly toward the eyes diminishes the authority of surgical touch but also creates a kind of path dependency that reifies the desire to resist the re-introduction of felt touch. According to Dr. Niemeyer, "very early on, and maybe because surgeons were still used to having the touch, it was a fairly frequent statement you heard that they missed it and they wanted it back." This runs counter to the sentiment expressed by robotic surgeons in the previous chapter. In response, Dr. Niemeyer also offered a theory that I agree with about the surgeon's response, stating, "They've become experts in what they're doing. They're proficient at it. They don't want to mess with it. They don't want to change it." Surgeons expressed as much when I spoke with them, and even their haptic imaginaries, which I will explore in the next chapter, reveal ocularcentric tendencies.

Translating touch for the robot extracts, transforms, and standardizes surgical touch and its attendant tactile knowledges, based on a series of computational and material abstractions, imbuing the machine with proper forces to perform surgery previously the sole purview of the surgeon. At the same time, this extraction diminishes the role of the tactile knowledge of the surgeon, acting both to constrain and roboticize human surgical touch by aligning the surgeon with the sensory priorities of the robot, rather than the other way around. Paraphrasing Chris Salter[25] (2018), measuring touch for the purpose of translation is for the machine, not for the human. It's about making the machine touch more like the surgeon and making the surgeon touch more like the machine.

6.4. Severing the Surgeon's Hands from the Body of the Patient

The construction of the da Vinci, haptic ambiguities, and transformations of touch reveal social concepts and material conditions that increasingly diminish the role of the surgeon's surgical touch in the OR. The flattening of touch for purposes of making it work for the machine are ultimately rooted in ways of thinking about what touch is, what it can do, and what it should do in

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[25] The paraphrase is taken from a conversation with Chris Salter during the "On haptics, touch, and the internet" roundtable organized by me and David Parisi for the Association of Internet Researchers 2018 conference in Montreal, Canada.

the OR. The structure of the operating room orients around logics of care as cure (Olsen, 2009, p. 3) and those logics make it easier to turn touch into an instrument defined by forces and actions rather than developing notions of touch as affective and relational. Interviewing engineers attempting to broadly define human touch reveals several themes that I argue make it easier to sever surgeon's hands from the body of patients.

> Touch is very broad. […] You can localize other senses to organs… but all organs have a sense of touch. […] the information that lets you know you're there… one of the main ways you're connected to reality (Dr. Kuckenbecker).

> Human touch is a way of getting an idea of the environment that goes beyond vision. [With the] visual modality, I can understand more or less the objects that are in my environment, but if I want to have a better feeling of what is in my parapersonal space then I can go there and touch them, and probably the best thing that I can answer here is that there is the feeling that by touching an object, I can manipulate it. I can move [it], I can deform [it], I can break [it] (Dr. Prattichizzo).

> I can think about [touch] all the way from the receptors in the skin and try to think about what it is that humans are sensitive too. […] I think about it as distributed across surfaces area, across frequencies. […] I think of it as part of, certainly a sensing system, certainly an active sensing system, but also suitable for physical interactions as in compliance and kind of natural reflexes and things like that, so it's a pretty involved, interconnected kind of topic (Dr. Niemeyer).

> When you're thinking about surgical systems, typically we are thinking about kinesthetic force feedback. So, touch is important because we interface with the device. If you grab onto the master of the da Vinci, you're grasping that device with your fingers, through your skin, so touch comes into play. But we tend to think about the feedback we're providing as being a small number of forces and moments. And it being that gross force that's really important. So, we kind of downplay touch, or maybe a better way to put it is that touch, and when I say touch, I mean tactile, that means the mechano-receptors in the skin, they do what they would ordinarily do if you were grabbing a physical tool (Dr. Colgate).

In all of their responses, there is a key idea that touch is a system that allows humans to act and interact in the world. From the broadest philosophical stance, touch serves as a primary way we are "connected to reality." To a narrower, functionalist perspective, "if you grab onto the master of the da Vinci, you're grasping that device with your fingers, through your skin, so touch comes into play." Touch is conceptualized as something that allows us to manipulate the environment and to interact with it.

Within their responses is an idea that touch is something quantifiable, measurable, and manageable. Touch is, in essence, also functional. They do not talk about touch in terms of its affective, relational, or cultural qualities. They do not talk about human touch as caring, compassionate, dangerous, or violating. They talk about touch in abstract terms that divorce it from these other manifestations. It is not to say that they do not ever think of touch in these ways. They almost certainly do. But first and foremost, these responses indicate that they think about touch as something that allows people to interface with the world, to manipulate the world, and to provide a sense of control. All of these ideas are part and parcel to engineering. Engineering is about being able to break down the world into manageable components that can be measured, manipulated, altered, and ultimately controlled.

All of these conceptions of touch are rooted in the context of engineering. They all focus on the psychophysical and functional aspects of touch. That focus is important to designing and developing systems that work, but it also marginalizes other ideas of touch. The construction lends itself to framing touch as something that is nonessential if it is not functionally necessary to produce a given surgical outcome – at least the full richness of touch is nonessential. Being able to grasp the grips is enough. Touch is necessary to act in the world and to manipulate the world, but only a very limited notion of touch, as a set of "forces and moments" as Dr. Colgate puts it, is necessary to achieve these outcomes. With computer vision, a robotic arm, while needing to touch, does not need to have a sense of touch in order to operate within the human body. It does not necessarily need tactile sensors or force sensors or heat sensors that would generate a mechano-physical feeling to complete a task. In other words, constructing touch in functionalist terms allows for it to be more easily marginalized as an important part of surgical operation, of healing, and of caring. It breaks the ties that bind it to surgical practice and relegates it to nonessential status. When a surgeon's touch can be relegated to forces, it is easy to imagine how the surgical robot could be imbued with superior touch.

7. IMAGINING HAPTICS AND ROBOTIC SURGICAL ASSISTANT FUTURES

The co-construction of touch, robotic surgical assistants, engineers, and the surgical team happens in the past and present, but it is also a process of imagining. The imaginary is important because it helps to "produce the shared systems of meaning and belonging that guide how people collectively see and organize the world, in its histories as well as its futures (Jasanoff and Kim, 2015)" (Jewitt et. al., 2019, p. 6). Here I want to emphasize that in invoking the imaginary, I am referring collectively to the way that designing, experimenting, implementing, and marketing haptic interfaces in RSAs involves imagining scenarios for use, use-interface relationships, and possibilities for how touch could be reshaped in the OR. In the process of imagining those potentials, many are made material, even if they never leave the lab. Importantly, the ways engineers, surgeons, marketers, and others imagine haptics in RSAs is influenced by personal experiences but also by cultural and context specific resources (Suchman, 2007, p. 1). As Suchman (2007) points out, "cultural imaginaries are realized in material ways" (p. 1). In many ways, my use of the term imaginary also hews closely with Jewitt, et. al. (2019):

> We use the sociotechnical imaginary to frame our exploration of emerging digital touch communication. The ability of sociotechnical imaginary to generate a discursive space which 'oscillates between imagination and reality' (Kim, 2018: 176) is particularly salient for our purposes given that digital touch communication occupies this space: most digital touch devices are undomesticated, unstable and in labs, rather than 'in the wild' (p. 6).

While I am not exploring "emerging digital touch communication," this project does offer an exploration of touch in relation to RSAs that is rooted both in the "imagination and reality." While the da Vinci is certainly more stable in the OR, ideas about touch and haptics remain unstable in relation to the device, and haptic prototypes developed in the lab and competitor surgical systems have yet to gain the established foothold in the medical establishment. Analyzing the imaginary serves to provide a sense of how material culture reflects and constructs cultural values, everyday practices, and a shared understanding in the world.

The stories that engineers and surgeons told me in interviews revealed imagined affordances and imagined forms of touch present in the dVSS. Sometimes these imaginaries are rooted in the technical facts of the device and sometimes they are more speculative. In both cases, they reveal an interpretive framework being used by different participants in the process to make sense of touch, and touch in relation to the dVSS. These reflections on the past and present suggest some ways touch is being co-constructed. More importantly, the desire to project what might come next, the imaginary of haptics for RSA futures reveals something about the values and orientations that surgeons and engineers have toward touch and robotic surgical assistants now. They tell us about what is possible, and possibly imaginable, but also reveal a level of anxiety about the reshaping of touch in the operating room. There is a disconnect in the imaginaries between surgeons, engineers, and the imaginaries forwarded by advertising these haptic futures. As marketers attempt to reassure patients that robotic surgery still includes a human touch and surgeons envision a future of touchless surgery, odd formulations arise.

In this chapter, I identify common threads in the interviews with surgeons and engineers, along with other documentary evidence about the ways touch is co-constructed with surgeons, engineers, and robotic surgical assistants, as a set of future-oriented imaginaries. These threads identify potential futures and reveal the anxiety around those futures already formulating. These themes are important to identify in terms of the SCOT model, which I have used throughout this project, because like the other data I collected, they suggest the terms of haptics and surgical robotics are in a state of contestation. Different actors with different agendas are setting the terms of what might come next and envisioning the ways haptics and touch will be associated with surgery and surgical assistants in the future. These imaginaries have real social, economic, legal, and political implications for surgeons, the surgical team, engineers, surgical robots, and patients. While notions of touch constructed with the da Vinci are largely locked in by almost two decades of conventions and norms, which the previous two chapters explored, the future of touch and how it may or may not be integrated for surgeons is up for debate. Equally up for debate is what counts as touch. By the end of this chapter, I hope to show that what counts is limited by the imaginaries currently setting forth the agenda, and that, like in previous chapters, those limits serve some over others.

In the case of the haptic imaginary for surgery, the idea follows two concurrent paths. The first imagines a touch future without touch. In a future that is more *Minority Report* (2002) than *Surrogate* (2009), hands wave in the air at nothing but visual representations while surgical robots do the dirty work. The surgeon becomes a facilitator or a director. The other imagines a future where haptics guide surgeons to better operative outcomes, essentially augmenting their abilities and truly enhancing them. The haptic future imagines the surgical robot guiding the surgeon to the proper biopsy instead of the surgeon guiding the robot. In this case, the training data from countless hours of operation becomes the grist for the mechanical mill, endowing robots, through surgical machine learning, with the surgical touch that had been controlled by surgeons up to that point. In other words, in some ways, the haptic future lies less in providing feedback for the surgeon and more in providing feedback for the machine — where the machine and the company become proprietary agents in the administration of surgical touch. This final turn intersects with Rhee's (2018) robotic imaginary, whose "inscriptions of 'the human' erases and dehumanizes those, mostly the marginalized, who are characterized as 'unfamiliar' and 'nonnormative'" (p. 2). While her work focuses on humans who are displaced by this imaginary, imagining haptics for RSAs means marginalizing essential aspects of human touch – from its physiological richness to its affective relational qualities — that allow it to be cast aside as inessential to surgical practice.

7.1. Touchless Projections

On July 1st, 2020, Intuitive posted an advertisement to YouTube, *The Future is Intuitive* (https://www.youtube.com/watch?v=6KeYgoga9MA). The advertisement imagines a scenario where a patient biopsy reveals a malignant nodule in the lungs. A series of images depict a surgeon interacting with what appears to be a transparent, touchless display, the da Vinci being sterilized in an operating room, replacing the need for plastic drapes, the surgeon speaking with a robotic voice from nowhere to prep for surgery, an array of visual projections both inside and outside the OR having replaced other mechanical and physical interfaces, and a brief shot of humans' hands interacting with surgical grips. The advertisement's focus is primarily on the da Vinci until the end when the surgeon is presented with an award. The advertisement seems to be aimed at both patients and surgeons, depicting a hyper-technologized version of the OR while reassuring both the patient and the surgeon that the surgeon is in control. I do not offer a deep analysis of the advertisement because it goes beyond the scope of this project, but I present it both because it forwards its imaginary future of robotic assisted surgery and because that future orients around the ocularcentric trends that seem to permeate the material and social constructions of the surgical space. It may be these kinds of visual narratives, and other ocularcentric visions of future technologies that dominate media depictions, that influenced Dr. Gangemi to believe that the future of the operating room would not just mean the diminishment of touch but the loss of touch, "from the touch screen to the touch reality, the CT scan projected in the air and you're moving the image around in the air. That would be a touchless interface." Despite these ocularcentric projections, continued concerns about the lack of haptic feedback—and attempts to fill the void—indicate an important imaginary of haptic and RSA futures.

Figure 16. Transparent touchscreen

Figure 17. Wall screen

Figure 18. Hands on dVSS grips

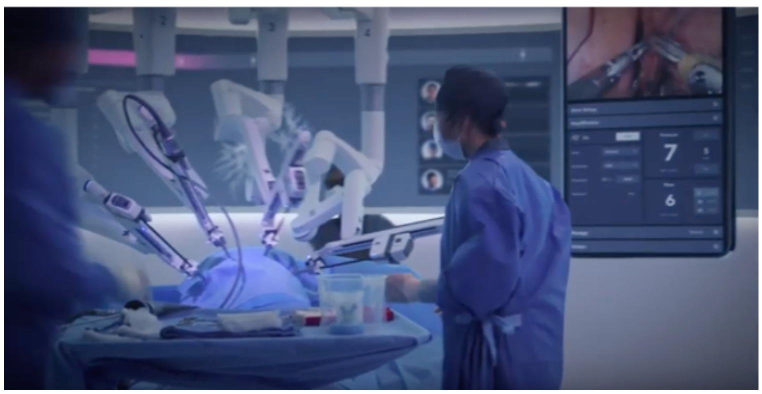

Figure 19. dVSS in imagined operation

7.2. The Rise of Haptics Competitors

Early teleoperation included haptic feedback, which were force feedback systems. While the da Vinci used force feedback as a source of error correction and kept the potential for displaying forces alive in the grips, it never implemented force feedback from the end-effectors or robotic arms, which would have communicated tactile information from the patient to the robot to the surgeon. As a consequence, many of the stories lauding the success of the dVSS continue to point out the absence of haptic feedback as a major gap that Intuitive (Lu, 2017), along with some haptic engineers, attempted to address through experimenting with vibration, Biotec® sensors, and virtual constraints. Competitors use the lack of force feedback as an argument for the benefits their systems could provide, once developed. As researchers associated with the development of SOFAR's Alf-x, which has since become Senhence, pointed out in 2012:

> The most important disadvantage in all existing systems is the lack of haptic feedback. Exactly like musicians who use their fingers for producing the desired sound and, in case of string instruments, feel the vibrations of the strings, it is of utmost importance for a surgeon to be able to feel the consistency and anatomical structures and evaluate the tensility of the suture during knot-tying (Stark, et. al 2012).

It is important to note that even after using a musical analogy to argue for the importance of haptic feedback in surgery, the authors of the review go on to state that the experimental evidence for adding haptic sensation to telesurgical remain in doubt. It shows the rhetorical work done to make the case for haptics and puts it in the imagined terms of playing an instrument – as if operating via surgical robot is akin to playing a part in the symphony. I find the analogy interesting as well because the surgeons I observed, in almost stereotypical fashion, often played classical music in the background while performing their operations.

Since the da Vinci was approved by the FDA in 1999, it has dominated the surgical robotics market – largely due to owning important patents related to teleoperating laparoscopic methods (Tindera, 2019). Many of those patents have recently expired and competitors are entering the surgical robotic space. Many of these systems, including "Avatera, MiroSurge, Revo-I, Versius and SPRINT" and Senhence all promise to fill the haptic void left by the da Vinci, although with the exception of Senhence, information is lacking about how haptic feedback is implemented in these systems (Longmore, et. al., 2020, p. 7). In the case of Senhence, the haptic system can "provide the surgeon with the feeling of force applied by the instruments against tissue. Additionally, the Senhence haptic feedback system can transmit information about the force with which the graspers are grasping tissue and the traction the graspers have on the tissue with 35 grams of sensitivity. The Senhence system can also amplify forced sensed by the surgeon, for example during suturing" (Longmore, et. al., 2020, p. 7).

I point out the emergence of these competitors and their focus on integrating haptic feedback, which again, is primarily defined as force feedback, not to offer up an analysis of the different directions that surgical robotics seem to be going, but instead as a way of pointing out how both the real and imagined haptics of the dVSS prompt material and rhetorical responses from other companies. In turn, those responses will likely prompt a response from Intuitive. The latent haptics in the system and repeated experimental attempts at re-connecting the end-effectors to the grips in various ways suggest as much. If they are not prompted to increase haptic feedback to augment user control by competitors entering the market, the threat of legal issues may serve as the catalyst[26]. Interviews with haptic engineers, and an exploration of haptic programs being developed in the mixed reality lab at UIC, reveal some of the imaginaries likely to shape future directions for the da Vinci and other RSAs.

7.3. From Haptics for Realism to Haptics for Superpowers

Imagining haptics for surgery can be observed in discursive formations and material manifestations. These imaginings reveal a tension between communicating realistic haptic

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[26] Shook, Hardy & Bacon L.L.P. (2019) make the case that future RSAs will be subject to product liability laws if they do not incorporate surgeons' haptic feedback using "vibrations, forces and buzzes" because doing so offers "numerous obvious benefits" to the surgeon. The argument is based on assumed benefits since the evidence is not clear that providing haptic feedback actually does provide clear benefits. Nevertheless, their argument serves as a discourse informing the imaginary around haptics and robotic futures, and they cite Florida Statute Section 768.1257 to make the case that if robotic companies fail to incorporate, they are failing to incorporate technology that is "state-of-the-art at the time of its manufacture," which means they would be held liable if a "state-of-the-art defense was brought against them" (Vrasmasu, 2019).

information and haptic communication that augments the capabilities of surgeons but also imagines how these developments lead to a future without human touch in the OR. The tension between a future designed to convey realistic information or to provide augmentive powers is reflected well in Dr. Prattichizzo's imagining when he says:

> I imagine haptics for surgery will probably be more the direction adding some augmented power to the surgeon. There are two options. One is to be dramatically realistic, this means you have to have a lot of measurements on one side a realistic feedback on the other side to find really small […]. I don't think that will be the future of haptics because at the very end some imaging technique that goes beyond the visual camera can give the real information about the place where to go with the surgery. […] . Of course, they need to have some tactile feedback to understand where this tumor is, but maybe in the future we need to have tools and techniques that goes beyond perception of humans. So in that case, if you want to go beyond the perception of the surgeon, we need to augment the feedback of the surgeon. […] To augment the power of the surgeon, they can use for guidance, they can use it to perceive something that is not perceivable by humans. So this is the way I think the future will be.

Dr. Prattichizzo's imaginary of haptics is driven by technological and social concerns. On one side, what is the point of developing realistic touch if visual technologies are so good? This would indicate that visualizations have cemented themselves as the de facto mode for providing the truth about what is happening in the body. In other words, in this formulation, there is no data that touch could supply that visuals already do not. He suggests that the surgeons may need some tactile feedback, but the way he frames that feedback is that it only needs to confirm the visual data, so it would only need to provide some limited force feedback. The move toward augmentation instead of realism overcomes technological limitations of placing a myriad of sensors on the end-effectors that would be sensitive enough to record the haptic data necessary to communicate realistic representations to the surgeon. His imagining is also informed by his own research, which entailed providing realistic haptic feedback that emulated palpation. Surgeons told him that it was fine, but it was not something that seemed necessary. That experience led him to believe that "if you propose something like augmentation to let you feel something otherwise unperceivable, then they would accept."

Pushing back against the notion that haptics would only be useful as augmentive, Dr. Colgate said that, with recent developments in sensor technology, it could be possible to outfit the da Vinci with "tactile sensors" that "can collect not just the forces and moments but pressure distribution, for instance, or vibrations that occur." In fact, Dr. Kuckenbecker's VerroTouch project, discussed in the previous chapter, already showed the potential that vibration feedback can provide in communicating tactile and grasp information to the surgeon, even with the sensors only being attached to the robotic arms and not the end-effectors. Likewise, Dr. Prattichizzo's own work using Biotec® sensors to collect tactile information and communicate it to the surgeon is also developed to convey realism. And the many competitors coming onto the market also seem to have developed haptics for realism.

7.3.1. Haptics to Augment

The desire to augment human abilities is one of the dreams currently driving the development of visual, auditory, and touch-based technologies. Initiative's own slogans express this desire when they talk about the da Vinci providing capabilities beyond the human hand. And while they have certainly enhanced the visual abilities of surgeons by providing unprecedented views inside the body, the only real alteration they have provided to the hands is the ability to amplify movements, so that when the surgeon moves the grips, the end-effectors can move at a 2:1 ratio (producing half the movement of the surgeon, for instance). This matters in that it allows the surgeon to operate in increasingly small spaces that would not be possible with laparoscopic tools in the hands of surgeons, which can only produce 1:1 ratios of motion. But developments in the lab and imaginaries about surgical haptics certainly express the desire for haptics to enhance surgical capabilities to a much greater extent.

Dr. Luciano and his mixed reality lab are developing haptic programs to augment surgeons' ability to perform in the OR. These technologies are materialized forms of the haptic imaginary, so analyzing them, along with interview data, helps show how touch is being imagined and co-constructed in these spaces. It is worth noting that while other companies and labs are experimenting with emerging haptic interfaces to convey a variety of haptic sensations,[27] Dr. Luciano and his lab primarily use a version of the PHANToM to develop and test surgical programs. The PHANToM and the da Vinci grips are not identical, but they share some similarities, and aspects of the PHANToM were ported to the grips making it a good analogical system for the moment. Dr. Luciano also said he used it because gloves often had a hard time conveying necessary forces due to the energy required to render forces by the servomotors. These technological considerations also show how, even in imagining haptics as augmentive, imaginaries are constrained by technological predecessors that focused on conveying forces over other haptic information.

I spoke to Dr. Luciano about three programs being developed in collaboration with surgeons at UIC to get a sense of how they are constructed, how they work, and what it feels like to use them. Two of the programs are designed as training platforms. And the other is designed to be a guidance system that would help surgeons navigate needles during biopsies to avoid the need for multiple insertions. He said surgeons typically request assistance in developing technology that can help train residents to do complicated procedures and assist directly with the surgery. After analyzing the requests, Dr. Luciano determines if there are any available solutions. If not, he starts

[27] https://www.healthysimulation.com/18394/fundamental-surgery-haptx/

working on what the requirements are from the surgeon's perspective, trying to determine the ideal solution to solve the problem the surgeon presents. He asks questions to identify the exact problem. And then he and his lab come up with potential solutions that surgeons try. They give him feedback and he alters the program through an iterative process. He said that the trained surgeon may know how a procedure feels, but that feeling is subjective. In order to determine what works for the machine, it is necessary to measure and quantify the sensation the surgeons feel. One way to do that is by using a pig and physical instruments with sensors. Sensors attached to the instrument record forces as they pass through layers of skin, subdermal tissue, and fat, and Dr. Luciano's group uses that information to replicate forces for the programs they create.

There is a recognition that this process involves several layers of abstraction that fundamentally shift what is felt and how it is felt. The reflection is apparent when he and his group grapple with questions about what is necessary to reproduce in order to be useful, inquiring about how much information they can get from real nonhuman tissue and how relevant it is to human tissue. These questions and interactions with surgeons illustrate one way that touch is co-constructed in the design process. As the researchers answers these questions, they are making determinations about what counts as "good enough" touch and what is unnecessary. As Dr. Luciano told me, "the information you provide for training may or may not be realistic, but it may still be useful." The purpose of instrumentalizing touch for surgeons is a process that is necessarily exclusionary. The process of exclusion produces usable instruments, but it comes at the cost of diminishing the full spectrum of human touch in the process. It normalizes touch by rejecting the vast variety of subjectively embodied experiences of surgeons and cannot imagine surgical touch beyond its instrumental value — value that is developed both for training and augmentive purposes.

7.3.2. Haptics for Training

Haptic training simulators represent an area of increasing development where the haptic imaginary manifests. Training programs developed in the mixed reality lab offer one example while programs developed by Dr. Seifi, a haptics researcher working with Dr. Kuckenbecker, offer a second. The first example, developed by Dr. Luciano, is designed to emulate the "real" force of inserting a needle into a kidney. The idea behind this program is to give students a tactile sense of what a kidney feels like without having to do training on an anatomically inanimate object, a live animal, or on a person. These processes involve abstracting data about both patients and surgeons, virtualizing them to make them useful in training. While these programs are specifically designed with surgical robots in mind, they emulate earlier work that sought to create virtual training programs that could train students by simulating open and laparoscopic operations without needing a cadaver.

Prentice (2005) articulates how bodies become disembodied and re-embodied in the simulation process. To simulate surgical operations, operators must be able to feel the object they are interacting with. They must feel the resistance of the flesh, tendons, and bones to hone a finely tuned craft. The process of creating haptic simulations involves translating tactile and phenomenal experience from trained surgeons and patients. As Prentice (2005) states:

> To build virtual reality simulators, researchers have had to break down and reformulate knowledge about patients' bodies and surgeons' actions in ways that are technologically compatible with digital computers (p. 838).

The body of the patient and the hand of the surgeon and the knowledge of the computer designer thus intersect to articulate touch in new ways for each other. The process ultimately results in a normalization of the body and surgical practice where mediated standards come to represent multiple bodies and the hands of surgeons come to expect bodies to feel always the same.

A second approach for training uses haptics and virtual fixtures to communicate to the surgical trainee and to help them develop the muscle memory necessary to control an RSA in the proper way. Virtual fixtures are computational limits that create simulated boundaries, or controlled paths, in a virtual space (Abbott, et. al., 2003). They are not meant to emulate "real life" – instead they only exist in virtual space. The idea of using haptics and virtual fixtures in training is that surgeons have to learn to manipulate the da Vinci in counterintuitive ways because the controls are not one-to-one. Using the current surgical trainer, students use a training version of the da Vinci to learn how to operate with it. This training starts with having students perform tasks like moving a virtual ring around a string without letting the ring touch the cords – all done using visual cues (Fig. 20) before advancing to more advanced tasks like suturing a photorealistic intestinal tube (Fig. 21).

Figure 20. Mimic® training simulator image

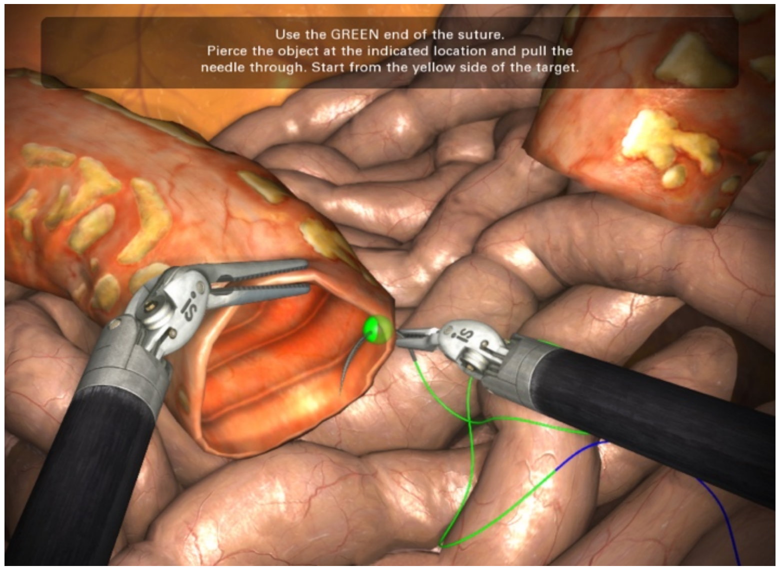

Figure 21. Mimic® training simulator image

Dr. Luciano's program works under the assumption that surgeons might be able to train more efficiently using haptic feedback to stimulate the sensory-motor system instead of just the visual system. To do so, the program involves tracing lines, like performing the ring task. He is testing a few iterations to see which seems to be more effective. The iterations involve different variations on pushing and pulling the operator's hand away from the line, forcing the operator to counteract forces with their own embodied forces. He described the program as being like "training wheels for a bike. You incorporate them to earn how to ride and then you take them off once you develop the necessary psychomotor skills." The program made sense to me when I tried it since I understood the point of the push and pull, but the feeling frustrated me because it felt like the PHANToM pen had a mind of its own. Instead of providing a sense of stability as the training wheel metaphor would suggest, I felt like it actively worked against my sense of agency, like I was fighting the device instead of learning from it.

Designed with a similar intention in mind, Dr. Seifi's project on "personalized training feedback in laparoscopic surgery" uses "haptic sensor data attached to their surgical tools" to "develop personalized haptic and multimodal feedback to correct a trainee's hand movements" (Seifi). In both instances, the use of haptic feedback is defined as error correction – as a way to train the untrained hands of a student in training. In fact, many of the haptic devices created for surgical training rely on haptics to guide surgeons to make the "right" decisions. This makes sense from the point of view that performing surgical operations demands a high degree of skill and training to ensure the safety of the patient, but in homogenizing the feeling of virtualized bodies and standardizing procedures, the training limits the ability of the surgeon to improvise. Seen this way, the haptic imaginary for training is less about providing feedback for the surgeon to make their own decisions and more about guiding the surgeon to make standardized decisions – placing increasing agency in the device. The haptic imaginary continues the work of shifting more control to the device because the epistemologies of surgery are constituted and translated through programming software and interface hardware to the surgeon. The process mediates the experience of the surgeon, but more than that, it situates the grips of the robotic assistant as the teacher.

7.3.3. Haptics for Navigation

Beyond using haptics for training, engineers like Dr. Luciano are also developing haptic programs to augment surgical abilities to provide guidance for surgeons as they are performing surgical procedures. The program, in this example, is designed specifically to help surgeons take biopsies of tumors in the prostate. The differences in density between the tumor and surrounding tissue are not distinguishable for surgeons when inserting needles. This means the surgeon has to collect several samples to make sure they are getting a sample of the tumor and not just the surrounding material. The program is meant to rectify this by providing haptic feedback that helps the surgeon navigate directly to the tumor so they only need to take a single sample. The process involves using magnetic resonance imaging (MRI) and magnetic resonance elastography (MRE) to visualize the prostate, and areas where possible tumors are located, and to approximate the stiffness of the tissues. MREs combine the imaging techniques of MRI with "low frequency vibrations to create a visual map that shows stiffness of body tissues" (Mayo Clinic, 2020). The image is rendered to produce haptic feedback with the PHANToM. As Cristian explained, the platform produces enhanced emulations of touch that would not be noticeable without the device. The differences are minute enough that a surgeon probably could not feel the difference between normal tissue and tumor tissue in the prostate. In this case, the platform is amplifying the difference in a way that renders the difference so that it can be felt through the PHANToM.

The example of using haptics for navigation, by producing a difference that could not be otherwise felt, expresses the imagined potential of haptics for giving surgeons powers beyond their own bodily powers. Instead of trying to simulate realistic versions of the body or tissues, these programs exploit the notion that surgeons only need to feel the relative difference between materials, not their absolute difference, in order to successfully take the biopsy. As with other aspects of surgical robotics, the program amplifies the difference, not by using touch-based sensors, but by using vision-based sensors. In a way, the touch felt through these programs is vision made material. In other words, while the PHANToM produces a felt-force for the surgeon, that force is determined by visual differences, not tangible ones. Even though MREs send physical vibrations through the tissue that make it move, movement is captured and analyzed visually. In that way, the MRE is reproducing a similar logic of surgeons sitting behind the dVSS console, when they say they "feel" through seeing skin deformations. What the surgeons are feeling through the PHANToM are computer visions.

Haptics designed to convey realism, and haptics designed to provide superpowers, both grant increasing autonomy to the robot. Both rely on quantifying and homogenizing human touch to achieve their goals. Without explicitly stating it, these haptic imaginaries forward notions of shared autonomy.

7.4 Shared Autonomy: The Human-Robot Haptic Exchange

The idea of shared autonomy has recently gained cache in engineering and human-robot interaction circles forwarding the idea that future robotic development will be based on utilizing what humans and robots do best in a co-operative fashion. But it goes beyond co-operating to attempting to "determine the operator's goal" so "it can autonomously work toward completing it" (Brooks and Szafi, 2019). The discourse attempts to keep humans in the loop by arguing that the technologies are meant to augment users' abilities – extending their capabilities beyond what a human could do alone. It is a discourse that echoes the aims of human augmentics (Novak, et. al., 2016). But this framing also underplays how training robots to intuit operator goals also means training the device to eventually work autonomously. According to electrical engineer Michael Yip:

> The goal is not to replace human surgeons, but to better assist and enable them to do much more. Human surgeons are still needed to make decisions that can't be left to a robot, such as what treatment is best for the patient, or how a surgical procedure should be performed (Labios, 2017).

Yip's ARCLab is, in fact, focused on how to allow aspects of the da Vinci to operate autonomously to assist the surgeon by using hardware and software to allow two of the robotic arms to complete "routine surgical tasks (suction, irrigation or pulling tissue back)" (Labios, 2017). These tasks are currently performed by residents, fellows, and nurses. Apparently, in this formulation, their touch becomes expendable. But it is reasonable to infer from Yip's statement that the imagined goal is to replace the need for the surgeon to operate the grips as well. The surgeon plans, the robot performs. Much of this work and vision essentially attempts to make the robot more human – and in the case of surgery, that means designing it and training it to touch like a surgeon.

Dr. Crivellaro imagines a similar future for surgical robots arguing that "robotic surgery specifically is moving toward semi-automated surgery. In the beginning it's going to be the robot suggesting, giving you advice on where to cut, on where to dissect, and where to put the stitch, based on video analysis." This idea echoes the marketing video from Intuitive, and I have to wonder how many of these ideas come from their marketing material. He goes on to say:

> And what Cristian is doing with the haptic feedback, I think it goes in that direction as well. Let's say biopsy for example. If you have robotic arm that can perform biopsy by itself. You just plan the treatment, tell the robot where to go with the needle and it goes in there. Tactile feedback can help the algorithm to recognize the structure the needle is going through and it's much more helpful for [the] algorithm, I think, than for [the] surgeon. […] Because all I need is a visual, as a human being. I rely on the visual, ultra-scan data, CT scan data, whatever you're using. You give me a target and I'm going to stick a needle as long as I can see […] I can stick a needle wherever you want and then as a consequence I stick the needle, I feel feedback, and I can know I'm going through fascia, I'm going through kidney, I'm going through this but that's not what is guiding my needle.

The haptic imaginary reflected in Dr. Crivellaro's statement does not discount the importance of haptic communication for the human but situates current developments in haptics as primarily benefitting robotics. This is an interesting point because, just as a lack of haptic feedback constitutes a potential limitation for surgeons using the da Vinci, it is also a limitation for making the system autonomous. Without information about how hard surgeons press the grips when suturing or how tightly they grasp them with stitching, the machine is limited in its ability to act autonomously. The visual acuity of the surgeon combined with their tactile knowledge, even when not directly felt, still has the advantage.

Measuring and quantifying touch for haptic feedback systems, as discussed in Dr. Luciano and Dr. Seifi's projects, are both framed as providing assistance to surgeons either by augmenting their abilities during surgery or through providing standardized training. However, the same data can be used to train the surgical robot. A paper titled, "A Robotic Recording and Playback Platform for Training Surgeons and Learning Autonomous Behaviors Using the da Vinci Surgical System" lays out such a vision (Pandya, et al. 2019). The system Pandya, et al. (2019) develop using the dVSS research kit records video but also movement of the grips and robotic arms, which can be played back. Using this data for training would allow residents to learn from experienced surgeons by literally letting them experience the motion of their hands as they performed the surgery. But in this case, just like the others, that information, along with machine learning, is just as useful for training the robot to do the surgery without a human operator. Beyond that, critical questions emerge about whose touch is being captured for the purposes of training and how might those decisions normalize touch in a way that could be exclusionary? It is probable that the end goal for a company like Intuitive would be to use the millions of hours of data collected from expert surgeons and machine learning algorithms to transfer the surgical touch of humans to the robot. The inability to imagine touch as something more than inputs and outputs, more than visual deformations, more than forces, more than instrumental, makes it easier to relegate human touch to an administrative role as the robot gains increasing autonomy to operate. As a paradox, robotic touch becomes both more and less than human touch. It is the abstraction and assemblage of millions of surgeons' touches, stitched together by machine algorithms, and engineered hardware, but even with all of those networked data points its touch is limited to "forces and moments."

7.5. Imagining a "Superior" Touch

Despite the various ways of imagining haptics and surgical robotic futures, all arrows point in the same direction – toward increasing autonomy for surgical robots. These imaginaries are rooted in the conception that robotic touch can ultimately provide a "superior" touch. With the right plan, it can perform without error, without tiring, without assistance. It is, of course, an imaginary. Technological limitations and social barriers provide resistance to these imaginaries becoming entirely materialized for now. Haptics is hard, and it's even harder in life and death environments. Some surgeons may already be planning to turn over the skill and labor of their bodies to the robot based on marketing visions but others seem to relish the ability to improvise and could prove more resistant. And the work to convince patients to put themselves at the mercy of the end-effectors of the robot could be a challenge. But materials that already exist evince imaginaries that quantify and instrumentalize touch in the service of robotics, and they paint visions of a touchless future that already has some surgeons dreaming of conducting surgery as if conducting an orchestra– hands suturing in midair while the symphony plays over speakers in the background. Imaginaries lay the eventual groundwork for the eradication of barriers while forming path-dependencies that resist alternative ways of imagining. A "superior" touch is one that instrumentalizes human touch and robotic touch, turning them into something that can be maintained and controlled, to produce better surgical outcomes and reduce risk. But it is not without risk. The imaginary of a "superior" touch diminishes the potential for improvisation, shifts the haptic labor of nurses, residents, and even surgeons, and eradicates the full spectrum of touch as a source of care, compassion, and connection, not just cure.

7.6. Afterword

> There is a host of contemporary cultural evidence suggesting that we have extended this nineteenth-century impulse to find new ways to emphasize the importance of the manual in an increasingly industrialized digital world. The exponential growth of farmer's markets, farm-to-table movements, and the elevation of artisanal craftwork of all kinds in the last fifteen years reveal as much (Capuano, 2015, p. 243).

The shift to fully automating surgical touch may or may not come, but what my research suggests is that, if it does, it will not arrive because technology moves in a linear direction but because a social negotiation has allowed it to take place. Surgeons should beware of embracing the role of facilitators because, while they may think they remain superior in this domain, it is not a stretch to imagine that their knowledge could be rendered redundant too. Much like the manual deskilling of laborers in other industries with the increase of automation, the same could happen to surgeons. Perhaps in the future, there will be artesian surgeons who perform with their own caring hands rather than the robotic surgeon offering a standardized and endlessly repeatable "cure."

8. CONCLUSION

In this dissertation, I used mixed qualitative methods to investigate the co-construction of touch and technology as it manifests between robotic surgical assistants, surgical teams, and engineers. I layered theoretical ideas about the relationship between media technologies and the sensorium, social construction of technology, actor-network theory, and affordances to inform my methodological orientations. Based on my theoretical frame, I took a constructivist grounded theory approach to exploring the co-construction of touch and technology because it "celebrates firsthand knowledge of empirical worlds, takes a middle ground between postmodernism and positivism, and offers accessible methods for taking qualitative research into the 21^{st} century" (Charmaz, 2000, p. 510). I applied a "complex" form of triangulation including the use of multiple qualitative methods (interviews, observations, and document analysis) and multiple data sources (engineers, surgical teams, surgical robotic assistants) to a primary case study, Intuitive's da Vinci surgical system (dVSS), in order to account for the complex relationships, ideas, and tensions that co-construct touch and technology. Using the da Vinci as a case study was meant as a way to bound the study, but my methodological approach and theoretical findings are applicable beyond the case. My layered theory and multiple methods helped answer the primary questions driving my research. How is touch socially and materially co-constructed between the dVSS, engineers, and surgical teams in the operating room? And how do imaginings about haptics and emerging RSAs co-construct surgical touch? In this final chapter, I summarize the findings, suggest how they further theory, discuss implications for the fields with which my research intersects, address the limitations of this research, and point toward future directions I hope this research might inspire.

Touch is socially and materially co-constructed between the dVSS, engineers, and the surgical team in the operating room in a way that reveals a number of important tensions and themes. The relationship between power and touch shifts as the robot becomes the point of contact with the patient and various members of the surgical team take over important roles as assistants along with the robot, changing instrument arms, wiping viscera from its camera extension, and robing the robot as they robe the surgeon, in sterile gowns. The tactile embrace of the da Vinci associates touch with comfort, control, and care for the surgeon, suggesting the touch of the da Vinci is oriented toward the surgeon more than the patient. The functionalist perspective of both surgeons and engineers reduces touch to instrumental forces, movements, and moments that often evade the awareness of surgeons using the da Vinci. In tension with this flattening, haptics plays an essential role in the material operation of the da Vinci, allowing both the robot and the surgeon to act in a coordinated fashion to perform surgery. Touch is also transformed through a series of material translations that construct human and machine touch as chimera, digital information, and sources of potential error. These sources of error can be corrected by haptic control systems that reduce tremors and provide virtual constraints, but their value is underplayed by the production of haptic ambiguities which simultaneously hide touch controls and also leave open their potential activation. Touch is constructed as meaningful when felt, when providing patient-oriented tactile feedback but because the da Vinci does not provide that feedback, the importance of the touch controls present in the device and the grips are discounted.

Imaginings about haptics and emerging RSAs co-construct surgical touch through a series of possibilities that ultimately reinforce the potential nonnecessity of human touch in surgery. Imagining haptic feedback for robotic surgical assistants co-constructs surgical touch as both human and machine, moving from providing feedback to human surgeons to attenuate surgery and provide training, to capturing human surgical touch for machine use. By leaning on the current collaboration between surgeons and RSAs and imagining a greater degree of shared autonomy in the future through the incorporation of haptics, surgical touch becomes increasingly standardized and homogenized, leaving it open to become the domain of the robotic surgical assistant.

8.1 Beyond the Limits of the Human Hand II

Getting "beyond the limits of the human hand" is about crafting and projecting a "superior" touch. The trademarked slogan, the work of making touch for the dVSS, and the use of the system reveals the myriad ways touch is co-constructed with technology. It involves a series of sociotechnical and material transformations. I return to "Taking Surgery Beyond the Limits of the Human Hand™" in my conclusion because it offers a useful heuristic to think with, not because my study is focused on a rhetorical analysis of Intuitive's marketing – although that certainly could be a future project. The point here is that in trying to understand the co-construction of touch and technology via case studies involving the dVSS and haptic RSAs, I produced a critical analysis that I did not realize would emerge from the research when I started this project. In some respects, my dissertation has answered the question of what it means to get beyond the limits of the human hand, even while that was not the primary research question driving my project.

The slogan can be read in many ways and each encapsulates the values and orientations articulated in the sociotechnical and material co-construction of touch with the da Vinci. Getting beyond the limits of the human hand involves a series of transitions, tensions, and strategic choices that shape the power of surgical touch, shift agency, and reorient touch that matter. It shapes the haptic realities of the OR, changing how surgeons learn to touch, practice touch and feel touch, altering who is allowed to touch the patient and the robot, and directing how they are allowed to touch. It is about "confirming or challenging certain social orders and roles" (Classen, 2005, p.

349). It goes beyond the limits of the human hand by limiting the human hand, treating it as inessential, and redistributing control through a series of interconnected agents, to other parts of the body, and to the machine.

8.2. Contributions and Connections

Touch is fundamental to human existence, experience, and communication (Classen, 2012; Field, 2003; Hall, 1969; Lafrance, 2009; Reite, 1990) but the emergence, diffusion, and use of haptics and other touch-oriented technologies challenge what counts as touch, how it is shaped and how it shapes, who or what can touch, how they can touch, when they can touch, and how touch is meaningful to existence, experience, and communication in relation to those technologies. From touch screens to taptic engines, from rumble controls to robots that caress, and from tele-tactile dildonics to internet connected tele-touch bracelets, a flood of technologies is entering the stream of daily use and is shaping our tactile imaginaries in ways that could have profound influences on relationships, socialization, economics, politics, organizations, medicine, and society. This moment offers an exciting opportunity to take up these novel formations as they are in progress and to connect these co-constructions of touch and technology to historical antecedents. Several projects completed recently, and currently underway, help provide better theoretical models, richer languages, and more concise methodological approaches to explore touch and technology (Jewitt, et. al., 2020; Paterson, 2007; Parisi, et., al., 2017; Parisi, 2018; Plotnick, 2018). My project aligns with these projects but also creates new space to consider what counts as touch technologies, how we might approach touch and technology, and how those approaches connect to media studies and communication.

Until recently, communication scholars have generally approached touch as a form of nonverbal communication (Finnegan, 2014). As an aspect of nonverbal communication, touch is typically studied to understand how it acts symbolically or how it aids other forms of verbal communication, “just as we ‘do things with words’ so, too, we act through touches” (Finnegan, 2014, p. 208). Within the nonverbal communication literature touch is sometimes used synonymously with the term haptics (Guerrero & Hecht, 2008, p. 183). These orientations typically treat touch in a very narrow sense as observable actions of contact that aid persuasion, communicate affection, or transmit some affective qualities, but they also tend to approach touch without considering its critical and cultural dimensions. They forward tropes about “touch deprivation” without offering ways to critically examine the foundations the claims are built on (Guerrero & Hecht, 2008, p. 183). And using the term haptics synonymously with touch illustrates one instance where the terminology is forwarded without consideration for its historical and cultural dimensions. This ahistorical and uncritical appropriation of haptics devalues the long history of scientific interventions to transform touch into something measurable and marketable (Parisi, 2018).

Proxemics offers another important engagement with touch in communication. It uses observations about tactile distance to understand cultural constructions of space and how they align with various communication contexts (Hall, 1966). When considering touch and technology there is room to apply a range of nonverbal theories of communication, but these approaches are not adequate. Porting old theories and approaches into novel spaces and new interactions tend to keep our perspectives aligned with those theories instead of providing other ways to describe what is happening in these emerging intersections.

Research into haptic human-robotic interaction (hHRI) tends to treat human-robotic touch as a psychophysical and mechanical problem (Karniel, et. al., 2012) but some research also considers affective and social dimensions of interaction (Yohana, 2011; Okamura, 2018). These studies begin to take approaches adjacent to interpersonal and nonverbal communication but both hHRI and interpersonal and nonverbal communication research could benefit from more direct collaboration. However, while these perspectives are certainly warranted, they risk forwarding tropes about what counts as worthwhile to study and what counts as meaningful interactions. They also fail to apply any critical or sociotechnical perspectives that may challenge some of the basic assumptions their research rests on.

My project provides another perspective to think about touch and communication by offering a way to engage the sociotechnical constructions of touch and to explore the ways the material and social co-construct touch and communication technology. The orientation I offer provides communication scholars with a more critical engagement with touch. The approaches I take in this dissertation and the theory I build are timely because of emerging touch technologies, but they also offer useful tools for re-exploring “old” communication and media technologies.

What I suggest through my research is that communication and media scholars need to focus on touch more consciously, but not just by focusing on overt, often visually apparent, forms of touch. It is equally important to focus on the intersections and below the surfaces. Taking inspiration from Hall’s proxemics, scholars should center touch because it reveals a hidden world that profoundly shifts, shapes, and reconfigures our everyday communication. In this dissertation, I develop a model to access that hidden world by attending to touch in myriad forms, from the design of haptics for robotic surgical assistants and attending to material affordances, to observations in the OR and interviews about touch interactions that often reveal important tensions.

Where prior studies have identified shifting practices in the OR with the introduction of the da Vinci (Beane, 2018, Sergeeva, 2018), my dissertation adds an important perspective to these empirical findings by showing how ideas and practices of touch are changing in the OR not just because of the physical affordances and sociotechnical arrangements, but also because of decisions made about what kinds of haptics to incorporate in the grips. My research makes the case that in order to really understand sociotechnical rearrangements, it is necessary to attend to the social and material aspects of medical technologies because decisions about how to engineer these systems, specifically their touch aspects, influence other social and technical arrangements in the OR.

My project has pushed back against framing touch as innate, natural, and resistant to mediation. Touch and technology are intimately linked together. Understanding one helps make sense of the other. The co-construction of touch and technology, as understood via robotic surgical assistants in this study, points toward the profound, the mundane, and the relational nature of touch in the OR and in the co-construction of touch with the da Vinci. While touch practices in the OR take shape around both profound and mundane moments of reshaping, the affordances of the da Vinci and the way touch is constructed in and through the device are shaped at the intersections of its engagement and design. It is important to keep in mind that the point of getting at the co-construction of touch is not to reveal some ontological state about touch but instead to understand touch as deeply embedded in the social and technical fabric of our everyday lives.

Throughout my fieldwork I focused on how engineers, surgeons, and surgical teams make sense of touch as part of their practices—and with the da Vinci surgical assistant. Touch has been conceptualized in myriad ways throughout history. Those ideas about touch have often intersected with practices of touch, and identities forming around touch, that have corresponded to notions of agency, trust, healing, comfort, connection, control, skill, and so more. What I learned from my fieldwork was the degree to which ideas about touch are shaped in the context of a disciplinary scope and by the context of their construction. The co-construction of touch is deeply technical and deeply social. But while the empirical findings of my study are context dependent, there are general methodological and theoretical contributions that can be applied beyond the scope of haptic RSAs, the da Vinci, and the OR.

8.3. Haptic Realities and the da Vinci

As I articulated in the beginning of this dissertation, haptic realities is a concept meant to orient scholars toward considering the ways that touch communication and communication about touch shape reality. The importance of the concept is in turning attention toward the touch aspects of communication and media technologies. It is not meant to signify the possibility of detaching touch from other aspects of communication, but it is meant to single out touch, and the construction of touch, as aspects of communication which have important implications for our everyday lives. Focusing on haptic realities reveals critical insights about the co-construction of touch and can help scholars understand the relationship between touch, our technological and media landscapes, and the ways we communicate. In the case of the da Vinci those realities are "produced, maintained, repaired, and transformed" (Carey, 1992, p. 23) through material and symbolic moments of communication.

This project focused on the communication between engineers, surgical teams, and RSAs. The sociotechnical development of the da Vinci, from decisions about the ergonomics of the console, to incorporating specific types of haptics in the grips, reveal what kinds of touch are valued and devalued. Providing comfort for the surgical body is elevated in the material affordances of the dVSS while translating tactile information about the patient back to the surgeon is largely excluded. Haptic systems are designed to control rather than communicate.

Focusing on functional forces excludes the full spectrum of human touch, reducing it to an automatable instrument. Instrumentalizing human touch for the da Vinci continues a long project in medical instruments shifting the perception of the senses, alienating human senses, and treating them with suspicion (Reiser, 1978), but it does not operate in exactly the same way. This shift seen in other medical technologies erodes some authority of the surgeon's touch. But where thermometers displaced the authority of the physician's touch to diagnose a fever, the da Vinci re-allocates the authority of the surgeon's touch to make incisions and to sew wounds, placing it in a multi-agential tactile web. These material developments co-construct haptic realities with surgical teams. The affordances of the da Vinci elevate vision over touch and visual epistemologies over felt ones but they also reconfigure the way touch operates in the OR.

Elevating vision over touch continues a long shift in medical and surgical practice as discussed in the literature review. The da Vinci both materializes the values that mark this shift and reinforces them, but if I had approached the da Vinci from a visualist perspective, my application of an ocularcentric worldview would have obfuscated the vital role touch plays with the da Vinci in its material development and its social arrangements. From a distance, these shifts may seem the inevitable trajectory of technological progress, but as my evidence reveals, there is nothing inevitable about the shift toward the eyes. The decision to extend the eyes of surgeons while effectively anesthetizing their hands only reinforces the idea that vision is more important than the other senses in acquiring knowledge about doing surgery and the act of performing surgery. Revealing the extent to which ocularcentrism runs through the design of the dVSS reinforces McLuhan's (1962) idea that "when technology extends one of our senses, a new translation of culture occurs as swiftly as a new technology is interiorized" (p. 40). My argument here is that the shifts in the sensorium are materialized in and reinforced by the haptic realities produced with the da Vinci. Even though discourses actively lament the loss of feeling, and companies try to shift haptic realities by recreating mediatized tactile epistemologies, the current sensorium and haptic realities make it more likely that surgeons will increasingly cede touch control to the machine rather than demand a return to felt epistemologies.

8.2.1. Multi-agential Touch

One of the theoretical contributions my study makes toward understanding touch is by analyzing it as part of an actor-network. This approach reveals that touch is not just constructed in experiences isolated from each other and then shared, it is socially and materially connected. It is made, shared, and experienced by multiple interconnected agents. That is not to say that it is made, shared, and experienced in the same way. It involves a process of social and material negotiation which I explore through analyzing observations, interviews, and affordances. I develop the concept of multi-agential touch to encapsulate the networked co-construction of touch with the da Vinci – although I argue the concept can be extended to any technology that mediates touch.

In the operating room, where the skilled touch of surgeons accords a degree of power and prestige, the multi-agential touch introduced with the integration of RSAs has social, professional, economic, political, and legal ramifications. On the social level, multi-agential touch organizes the roles of the surgical team around the da Vinci. The act of operating was always social to some degree, with medical technicians or nurses handing instruments to surgeons upon request, but in the case of the da Vinci, the surgical instruments that perform the operation are positioned, changed, and cleaned by medical technicians, residents, nurses, and other surgical staff while the surgeon directs the instrument tips from the control grips, mediated through a complicated computational and mechanical system. In a professional sense, multi-agential touch alters professionalized identities by shifting who gets to touch what, and when. Surgical touch becomes technical touch as the surgeon navigates readjusting the device to resume operation after an error and the resident spends less time operating on the patient and more time wiping viscera from an insertable camera. In the economic sense, multi-agential touch alters the cost of surgical touch as the da Vinci introduces new members to the support staff, some trained in maintaining the robot's devices so it can continue to touch properly. Political implications correspond to the social and professional implications, redistributing power between the surgeon, the surgical team, the robot, technical support, and even administrators. It also reallocates the authority of surgical touch among multiple actors. And finally, by redistributing power and agency between the team, engineers, and the machine, multi-agential touch raises legal issues about who is responsible, for instance, in the case of an accident during surgery.

When touch is networked and multi-agential, operating between humans, machines, and their designers, it complicates attempts to pin responsibility for errant touch on any one actor in the network. Studying the da Vinci helped me identify multi-agential touch, but it is not limited to the case study. The implications of it extend to other robotics technologies in industry but also in other human-machine contexts.

8.2.2. Touch and Agency

Touch technologies shift the relationship between touch and agency. The tactile epistemology of the anatomy is augmented by the tactile epistemology of the machine, guided by the eyes. Deep, interior knowledge of the human body is thus replaced by the surface optics of a 3D representation. The grips become a point of power and control for the surgeon, as their touch is transformed and transferred within the robotic surgical assistant. But instead of the patient being in the healing hands of the surgeon, the surgeon is increasingly in the guiding grips of the robot – a robot repaired and maintained by the surgical team and Intuitive specialists. As a consequence of ocularcentric shifts and the emergence of multi-agential touch, agency and responsibility are spread amongst a group of humans and machines interacting to direct action via touch. The communication between the surgeon and the da Vinci creates the perception of an increased sense of agency for the surgeon both through generating a greater sense of control and a greater sense of comfort, but a sense of agency is not necessarily agency itself. In other words, the feeling of being in more control does not mean that you actually have more control. In contrast, the surgeon cedes control to the da Vinci, the team, and even to the company.

8.2.3. Mundane Touch Matters

When I started this project, I thought I would primarily focus on haptics as it was developed and experienced with the da Vinci. I thought my analysis would be driven by attention to the obvious moments that human touch met robotic touch. But to my surprise, an equal amount of my attention was pulled to more mundane forms of touch. I remember the first day I walked into the OR. There was a hand sensor to get to the room with the surgical scrubs but a manually gripped handle on the door to the changing room. It seemed entirely mundane but the purpose of the sensor door was to maintain sterility so it did not make much sense that the door to the changing room did not have one. I tell this story because it started to direct my attention to more mundane moments of touch in the OR, not because I was able to make sense of why there was a sensor on one door and not the other. The affordances offered by the sensor door and the manual door also alerted me to pay attention to moments where touch was unwanted or actively restricted. Just as the sensor door directed me not to touch, the medical technician acting as a verbal sensor, reminded me not to touch the sterile field, even in the proximal sense.

Mundane touch are forms that are not obvious, like slipping off shoes to feel the da Vinci pedals and restricted touch. In the first instance, the nonobvious forms of touch practices do not actively draw attention because they tend to be everyday activities and because they may not be the focal point of investigation. My initial focus in researching the da Vinci oriented around the grips because I thought that is where the co-construction of touch and technology would be the most important, but if I had not considered these nonobvious forms of touch I would have missed vital aspects of touch co-constructed with the da Vinci.

The second instance, restricted forms of touch, serves an equally vital purpose in understanding the co-construction of touch and technology. Relating to Classen's (2012) observations about how museum's reoriented touch toward the eyes through dictates like "touch with your eyes, not with your hands," the OR and the da Vinci restrict certain forms of touch that would violate the sterility of the space and redirect surgeon's to touch the interior of the human body with their eyes, not with their hands. Attending to restricted forms of touch helps reveal power dynamics concerning who or what is allowed to touch and what types of touch are allowable. These restricted forms of touch are also not always obvious because the lack of touch or the restriction of touch is often treated through an ocularcentric lens– the restriction is treated as evidence of the rise of visual culture and visual logics rather than as evidence of the power dynamics of touch.

Restricted forms of touch have a way of fading into the background and becoming nonobvious. This reenforces certain power dynamics around touch by normalizing the restrictions through ritual. Signs directing patrons not to touch rarely adorn museum walls anymore, yet when children enter and attempt to touch the art or even the walls, they are warned not to. Restricted touch only typically becomes apparent when it is violated. In the OR the act of touching the sterile field or the robotic drapes is treated like an act of tactile violence.

It is also the case that some restricted forms are hidden by the materiality of devices. In the case of the da Vinci, virtual constraints and tremor reduction act to restrict touch without raising awareness, operating below felt or observable awareness. Their very hiddenness negates the fundamental work they do to transfer more agency to the machine. In other words, these acts are not only about vision, they are about treating human and machine touch with suspicion, cautious of its potential to violate bodies, parts, and spaces. In the time of Covid-19, devices and conventions that restrict human touch have proliferated, acting as material reminders that human touch is not to be trusted. At the same time, it seems less barriers are being raised to machine touch, marking it as more trustworthy and worthy of inviting into our personal touch spaces as mediator, caretaker, and companion.

While I make arguments about the way the OR forwards the rise of an ocularcentrism spreading through the medical field, the notion of mundane touch should temper those claims. Taking a touch-oriented approach in this project shows a way of acknowledging ocularcentrism while also recognizing that touch is not somehow eradicated in the process.

I use the term mundane touch to turn attention toward often hidden, restricted, or under-appreciated aspects of our touch worlds, not because there is anything mundane about these forms of touch but because their everydayness often keep them out of our awareness. In fact, what I call mundane touch has profound implications for the study of touch, technology, and communication. It reveals a hidden world that orients spaces, time, and relationships in ways that would be inaccessible if researchers only examine on the most obvious forms of touch or on the aspects of touch that are reported as important in interviews. And it prompts us to ask more critical questions about why certain types of touch tend to be hidden, restricted, or otherwise obfuscated.

Focusing on mundane touch in the OR allowed me to analyze why surgeons took their shoes off, how they changed their grip, and the implications of touching a draped da Vinci amongst other mundane moments of touch. At first, I did not really know what these forms of touch meant for my project. I wrestled with whether they mattered and how they mattered. But in understanding the co-construction of touch and technology, incorporating mundane touch serves profound purposes. These small, sometimes seemingly insignificant moments revealed some of the most important ways the da Vinci reshapes touch in the OR.

Mundane touch matters beyond the OR and beyond the case study of this project because it often reveals seams, tensions, and contradictions that may not be apparent otherwise. Despite mostly disregarding the shift that operating with the da Vinci brought to the practice of doing surgery, the mundane moments reveal how much touch still mattered to the surgeons, but it was not their ability to feel the patient that mattered as much as their ability to feel comforted and in control.

8.2.4. Exclusion by Extension

Crafting a superior touch "beyond the limits of the human hand" excludes certain types of touch by way of normalizing touch and standardizing it, in the name of extending it. In the case of this study, extending touch via the da Vinci has meant reducing it to instrumental forces. Those forces have been normalized using an amalgamation of humans, animals, and things. In investigating touch technologies, it is important to ask whose touch is being included and whose is being excluded, how it's being included and excluded, why those inclusions and exclusions are being made and why they matter. Because it is sociotechnically co-constructed, touch is not a natural category immune from power; it is fully political. I account for aspects of touch that are included and excluded in the design and implementation of the da Vinci and derive critical insights regarding the implications of those exclusions – specifically concerning the ways that surgical touch has largely been reduced to a set of instrumental forces in the development of robotic surgical assistants and the way those decisions are based on, and perpetuate, a set of path dependencies that will likely influence future iterations of RSAs.

Providing a full accounting for whose touch is used to create the standards for the da Vinci, whose touch those standards were designed for, and who determines the touch practices oriented around the da Vinci are all areas where I fell short in this project. Engineering and Surgery are two areas that are dominated by white men, and the people I interviewed for this project largely bear out that discrepancy. Professional organizations in both fields are trying to usher in better gender and racial representation. Given that context, it is worth asking more probative and critical questions about the ways that gender, race, and ability intersect with the design, standardization, and normalization of touch in the da Vinci. How may those decisions exclude certain types of bodies and ways of feeling? Framed as getting beyond the human hand, how might those decisions actually disable surgeons instead?

8.3. Implications, Limitations, and Future Directions

In order to answer my research questions, I engaged several disciplines, including communication, media studies, science and technology studies, medical humanities, human-computer interaction, and haptic engineering. I tried to straddle disparate fields and perspectives throughout this dissertation, sometimes with more success than others. I suspect that scholars from any one of these disciplines could point to literature I have missed and perspectives not taken incorporated. The danger in engaging many fields at once is potentially overlooking important threads of research or synthesizing ideas that may be incongruent. I hope others identify these missing pieces and use them as opportunities to build. However fraught the project of traversing many fields, it is a necessary endeavor in order to understand the co-construction of touch and technology. Other case studies would necessitate bridging other disciplinary perspectives. In any case, my research raises theoretical and practical implications for the fields I engage.

This research, along with others (Jewitt, et., al., 2020; Parisi, 2018; Paterson, 2007; Plotnick, 2017) make it clear that communication and media studies need to incorporate touch in ways that get beyond traditional nonverbal approaches because touch technologies and haptic media have long played significant roles in shaping our interactions, our perspectives, and our everyday experiences. Touch should no longer be treated as auxiliary to other forms of communication and media because touch has a historical, cultural, social, economic, political, and technical life of its own.

Exploring touch from this sociotechnical and critical point of view helps make sense of communication in different contexts, recognizes the power dimensions of touch, and adds nuance to ocularcentric claims in many studies of media and technology. My research notes ocularcentric trends with the incorporation of RSAs and I make arguments about the displacement of tactile epistemologies for visual ones, but the theoretical concept of mundane touch helps relocate touch in communication technologies and media. It recognizes that to find how touch is reconfigured in these spaces, how it impacts agency, and how it alters relationships, it is necessary to focus on the intersections, restricted spaces, and hidden places.

Media representations of haptics and surgical touch imagine touch in ways that are fantastical compared to their material realities – often obscuring the way haptics are already implemented and altering agency. While I begin to explore those tensions in my dissertation, the implications from my final analysis chapter are especially germane to media studies. The entire project could be revisited through the lens of imaginaries, providing an even more critical accounting of touch and RSAs. This orientation should help direct future research in media studies that explore representations and materializations of touch in other mediatic spaces as well.

My research findings offer implications for future research in science and technology studies, workplace studies, and human-computer/robot interaction (HCI/HRI) and human-machine communication (HMC) because they expose how touch is deeply embedded in the social, material, and technical formations of various spaces and relationships. Touch is always implicated in science and technology in one way or another. Haptics should be explored as a scientific discipline to provide critical insights about the sociotechnical formation of touch and to examine its structural influence but haptics technologies should also be explored within these larger sociotechnical spheres to understand their implications on society. The touch of nonhumans should also always be considered in these studies as they are vital agents in the formation of multi-agential touch.

Touch intersects with relationships, power dynamics, and spaces, and is made meaningful in different ways when situated within different workplaces. Going forward, my research suggests workplace studies should focus on labs where haptics research and touch research are happening but that workplace studies should also orient their approaches around touch. As my study has shown, focusing on touch reveals various social dynamics, ideas, and practices of the OR that would not be accessible otherwise. Focusing on touch helps make sense of relationships, social arrangements, and organizational practices that may otherwise be overlooked or undervalued[28].

The theoretical contributions I offer regarding touch provide useful tools to incorporate and critically examine touch in all of the fields my research intersects, but for hHCI, hHRI, and haptic engineering, some of the theoretical contributions also have practical applications. The concept of haptic realities offers an orientation for thinking about how people engage with technologies through touch and making touch meaningful. It intersects with the third paradigm of

[28] Ned Barker, et. al. (2020) offer another example of a workplace study focuses on touch interactions between humans and robots in industrial settings.

HCI which argues that "making sense of the interface" is "to some extend beyond the reach of formalization" (Harrison, et al., 2011, p. 389). This challenges scholars and designers to think beyond instrumentalized notions of haptics, allowing room for greater exploration, play, and imagination. It makes it apparent that there is no one size fits all when it comes to designing and implementing touch technologies. The concept of mundane touch directs scholars and engineers to consider all aspects of haptic interfaces and their attendant material structures. The concern with the stool not being attached to the da Vinci offers one practical example of why considering mundane touch in the design process matters. And the concept of exclusion by extension provides a way for hHCI/hHRI designers and haptic engineers to reflect on how their designs may exclude raced, gendered, and differently abled touch, and to address those biases before they become normalized.

My research provides important empirical evidence for the co-construction of touch and technology. However, those findings are limited by the sites and objects I studied, the time I spent in the field, and the people I interviewed. I believe many of my findings can be extended beyond the limits of this study, but recognizing its limitations contextualizes the findings and opens avenues for future research.

I chose to research the RSAs at the University of Illinois at Chicago because it is home to a premier surgical robotics department and some of the most notable robotics surgeons in the world. However, the site-specific context of this study limits the findings to this site and others like it. Teaching hospitals like UIC do not represent the majority of hospitals that use the da Vinci in the U.S. nor in the world. My ability to easily move around the OR once I had access was likely based on the fact that so many people are in the OR for educational and research reasons. In another context, with smaller surgical teams and fewer students, I may have witnessed a different set of shifts to touch based practices in the OR, but that is merely speculative at this point. Future work could rectify this limitation by focusing on more hospitals and a greater variety of hospital settings.

I chose to focus my research on the da Vinci because of its widespread adoption and the influence of Intuitive on the development of surgical robotics. But in focusing on the da Vinci, some of my claims are limited to this specific device at a time when more and more competitors are starting to enter the market – many claiming to incorporate haptic feedback that allows surgeons to feel the patient as they operate. Future research should focus on a wider spectrum of robotic surgical assistants, including training simulators, especially those that incorporate haptic feedback. While some of the findings from this study may apply in those contexts, operating with an RSA that incorporated some kind of patient-based haptic feedback could challenge both the practice and perspective of doing surgery with robotic assistants as presented in this study. However, even in those cases, theoretical insights about haptic realities, multi-agential touch, shifts in agency, and the importance of considering mundane touch would still be significant.

One of the major limitations of this study emerges from the surgeons and surgical teams I interviewed. My interviews were primarily limited to two robotic surgeons. Even though I feel confident in my findings regarding their responses because they echoed each other and other interviews I found in other documents, it is likely that interviewing a wider breadth of surgeons would potentially reveal wider and countervailing themes. To get a fuller sense of how surgeons think about and practice touch with the dVSS and other RSAs, I suggest trying to interview surgeons with varying backgrounds in robotic surgery and at various stages of their robotic careers, as well as focusing on issues of gender, race, and ability when identifying surgeons to interview.

While my study does triangulate findings among several groups, there are other groups that are noticeably absent but surely play roles in the co-construction of touch and technology via

RSAs. In the final analysis chapter, I provide some analysis of the marketing material developed by Intuitive. This analysis suggests a possible influence on surgeons' perceptions of touch that should be followed up on. But in a more macro sense, it means developing methods and analyses that account for companies that make and market RSAs, hospital administrators, and perhaps most importantly, patients. Questions about how patients understand and relate to RSAs and how they may reshape notions of surgical touch remain a key part of the puzzle.

In an ideal world, I would have stayed in the field longer, done more interviews and follow-up interviews, and interviewed a wider set of participants. While I reached redundancy in many of my interviews and observations, the short duration of my project did not allow me to embed myself in the culture of the OR or engineering labs in a way that could grant me a deeper understanding of the wide variety of nuances and contradictions involved in shaping touch with the da Vinci. There were seams that started to emerge regarding institutional values present in haptic engineering, for instance, that could have been relevant but which I could not follow given the duration of my study. But the methods I use in this study and the theoretical contributions I make could help focus a future ethnographic inquiry that focused on the OR, engineering labs, or both.

8.4. An Emergent Research Orientation

In the preface of his book, *The Long Revolution*, Raymond Williams (1961) begins to trace the evolution of modern civilization by considering three distinct revolutions – a cultural revolution being the most complicated (p. xi). The difficulty of articulating our contemporary cultural revolution is that we are in the thick of it. We are in the dark wood of technological, economic, geographical, sensorial, and cultural change. Williams offers a summary of this bewildering state:

> I find increasingly that the values and meanings I need are all in this process of change. If it is pointed out, in traditional terms, that democracy, industry, and extended

> communication are all means rather than ends, I reply that this, precisely, is their revolutionary character, and that to realize and accept this requires new ways of thinking and feeling (Williams, 1961, p. xiii).

It is my hope that this dissertation offers some "new ways of thinking and feeling" the relationships between touch and technology, ways that both provide insights on current sociotechnical configurations of touch and possibilities for future exploration. Technologies of touch are being developed daily. Our touch landscape is changing. Touch technologies promise to further complicate culture as our awareness of the haptic increases and the meaning of touch is exploded. The way we encounter touch, interact with touch, design touch, express touch, and feel touch is shifting and being shaped in these everyday encounters. Just like medical imaging technologies have shifted how we see and interact in medicine, and just as shifts in visual technologies, from X-rays to drone imagery have shaped our understanding of and relationship to the world, I also believe a similar shift has been happening and will continue to happen as touch technologies continue to develop – even if the analogy proves not to hold up completely. For me, these technologies run the gamut, from fabrics, increasingly synthesized to create new textural sensations to digital haptic devices which mediate our touch interactions across space and time or which elicit social reactions to our digital and robotic tactile partners. Projects oriented under the banner of haptic media studies, whether consciously identifying as such or not, represent some of the work in this area, and I believe my work makes a contribution to better understanding touch as having a media and cultural life of its own[29].

In many ways, this dissertation provides an early step toward a much larger project. The da Vinci represents just one case study in a larger constellation of RSAs that could lead to

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[29] I also situate my research alongside work on digital touch communication as represented in projects being done by in-Touch. in-touch-digital.com.

comparative work in the future, but the study of haptic reality ought not be constrained to a limited focus on robotic surgeons, surgical touch or other medical devices. The medical space is only one context where touch is shaped with technology. The theoretical findings of this study should extend to areas in other contexts and to other workplace studies including industrial sites but also to office spaces, labs, domestic spaces, and even to outer space. The broad theoretical commitments of this project and the contributions it makes concerning treating touch as co-constructed, multi-agential, mundane, and exclusionary, are all ways that can reorient studies in the field of communication and media studies to reconsider objects, spaces, and relationships through a touch-oriented approach.

8.5. Future Touch

What does the future of surgical touch feel like? And what can speculating about it tell us about the more generalizable relationship between touch and technology? If touch can be analogized to hearing and sight, then our touch futures are likely entering a stage not unlike that of early cinema and radio. The standards are being set, but are still in contention, and we are only starting to feel the distribution of black and white haptics via rumble controls, mobile vibrations, and surgical force feedback. How will these articulations of touch influence perceptions? Will this be remembered by surgeons as the age of force haptics, denoting a time period and a set of sociotechnical relations, rather than merely a set of sensations? How much can the analogy hold? Will it manifest in different ways since touch contains different psychophysical and social configurations?

The questions are merely speculative, meant to provoke inquiry. But if the past is prologue, then the future of surgical touch, and touch in general, is surely a future that will be increasingly commodified, designed by a few for the many, and normalized in ways that empower some while disenfranchising others. Scholars can begin to rewrite the past and create a new prologue by treating the co-construction of touch and technology in ways modeled in this dissertation, in haptic media studies, and in ways yet demonstrated. Our work cannot only be about interrogating structures already in place. It must also imagine beneficial structures that could replace them.

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APPENDICES

APPENDIX A

Exemption Granted

November 1, 2018

Jason Archer, MA
Communication
Phone: (312) 996-3187 / Fax: (312) 413-2125

RE: Research Protocol # 2018-1304
"Dr. Robot: A Cultural Study of Humans, Robotic Surgical Assistants, and Touch"

Sponsors: None

Dear Jason Archer:

Your Claim of Exemption was reviewed on November 1, 2018 and it was determined that your research protocol meets the criteria for exemption as defined in the U. S. Department of Health and Human Services Regulations for the Protection of Human Subjects [(45 CFR 46.101(b)]. You may now begin your research

The specific exemption category under 45 CFR 46.101(b) is: 2

Exemption Period:	**November 1, 2018 – October 31, 2021**
Performance Site:	UIC
Subject Population:	Adult (18+ years) subjects only
Number of Subjects:	150

You are reminded that investigators whose research involving human subjects is determined to be exempt from the federal regulations for the protection of human subjects still have responsibilities for the ethical conduct of the research under state law and UIC policy. Please be aware of the following UIC policies and responsibilities for investigators:

1. Amendments You are responsible for reporting any amendments to your research protocol that may affect the determination of the exemption and may result in your research no longer being eligible for the exemption that has been granted.

2. Record Keeping You are responsible for maintaining a copy all research related records in a secure location in the event future verification is necessary, at a minimum these documents include: the research protocol, the claim of exemption application, all questionnaires, survey instruments, interview questions and/or data collection instruments associated with this research protocol, recruiting or advertising materials, any consent forms or information sheets given to subjects, or any other pertinent documents.

3. Final Report When you have completed work on your research protocol, you should submit a final report to the Office for Protection of Research Subjects (OPRS).

APPENDIX A (continued)

Exemption Determination
Amendment to Research Protocol – Exempt Review
UIC Amendment #1

March 7, 2019

Jason Archer, MA
Communication
Phone: (312) 996-3187 / Fax: (312) 413-2125

RE: **Protocol # 2018-1304**
Dr. Robot: A Cultural Study of Humans, Robotic Surgical Assistants, and Touch

Dear Jason Archer:

The amendment to your research has been reviewed. Your research continues to meet the criteria for exemption as defined in the U. S. Department of Health and Human Services Regulations for the Protection of Human Subjects [(45 CFR 46.104(d)].

The specific exemption category under 45 CFR 46.104(d) is: 2

You may now implement the amendment in your research.

Please note the following information about your approved amendment:

Amendment Approval Date: March 7, 2019
Amendment:
Summary: UIC Amendment #1: Interviews will be audio-recorded with consent of the participants.

You are reminded that investigators whose research involving human subjects is determined to be exempt from the federal regulations for the protection of human subjects still have responsibilities for the ethical conduct of the research under state law and UIC policy.

Please remember to:

→ Use your research protocol number (2018-1304) on any documents or correspondence with the IRB concerning your research protocol.
→ Review and comply with the policies of the UIC Human Subjects Protection Program (HSPP) and the guidance ***Investigator Responsibilities***.

UNIVERSITY OF ILLINOIS AT CHICAGO
Office for the Protection of Research Subjects
201 AOB (MC 672)
1737 West Polk Street
Chicago, Illinois 60612
Phone (312) 996-1711

APPENDIX B

Recruitment email sent to surgeons:

New technologies are beginning to replace human touch with machine touch. These devices demand new skills, alter training programs, and reconfigure the surgical team. This research project explores ideas and practices of touch in relation to robotic surgical assistants (RSA) to identify the role of human and machine touch in the operating room, to explore challenges that may arise at their intersection, and to theorize about their social implications. To do so requires observations during surgery and informal interviews. The results of this study will assist surgeons and surgical staff as they plan for introduction of robotic surgical processes.

APPENDIX C

Example question template for surgeons:

1. Describe your overall impressions of doing surgery with the da Vinci?
2. What is touch?
3. How would you describe the touch-aspects of the da Vinci?
4. How did you learn to use the da Vinci?
5. Do you think the da Vinci shapes your relationship with the patient and the rest of the surgical team? How?

Example question template for engineers:

1. In a general sense, what do you think about when you think about human touch?
2. How do you define haptics?
3. How did you get involved with designing the da Vinci?
4. How did you conceptualize haptic feedback for the da Vinci?
5. What were the social and technical challenges of incorporating haptic feedback into the da Vinci?

VITA

NAME:	Jason Edward Archer
EDUCATION:	B.A. Communication Studies, University of Iowa, Iowa City, Iowa, 2005
	M.A. Communication, Wake Forest University, Winston-Salem, NC, 2010
	Ph.D. Communication, University of Illinois at Chicago, Illinois, 2021
TEACHING:	Department of Communication, University of Illinois at Chicago, 2011 – 2021
	Department of Communication, DePaul University, Fall 2015
	Department of Communication, Central Piedmont Community College, 2010 – 2011
	Department of Communication, Wake Forest University, 2009 – 2010
EDITORIAL:	Editorial Assistant, *New Media and Society*, University of Illinois at Chicago, 2018 – 2019
HONORS:	National Science Foundation Integrated Graduate Education Research Traineeship (IGERT) Fellowship, University of Chicago at Illinois, 2016 – 2017
	IGERT Mini Grant for Research Materials, University of Illinois at Chicago, 2016
	IGERT Travel Award, University of Illinois at Chicago, 2016
	Graduate Student Council Travel Award, University of Illinois at Chicago, 2012, 2013, 2015, 2017, 2018
	Graduate Student Presenter Award, University of Illinois at Chicago, 2013, 2017, 2018
	LAS PhD Student Travel Award, University of Illinois at Chicago, 2012, 2013, 2015, 2016
	NCA Graduate Student Teaching Award, Department of Communication, University of Illinois at Chicago, 2011, 2012

Graduate Admissions Committee, Graduate Student Representative, Department of Communication, University of Illinois at Chicago, 2014

Department Liaison for University of Illinois Communication Collaboration Conference, 2013

Elected Graduate Student Representative, Wake Forest University, 2009

PROFESSIONAL MEMBERSHIPS:

Association of Internet Researchers
Society of Social Study of Sciences
International Communication Association
Society of Literature, Science and the Arts

PUBLICATIONS:

Journal Articles

2017 Editor's Introduction: Haptic Media Studies, with David Parisi and Mark Paterson, *New Media and Society* special issue 'Haptic Media Studies': Available online at http://journals.sagepub.com/doi/full/10.1177/1461444817717518

2017 "Enjoy your feeling:" a media archeology of material publics, with Nathanael Bassett, *Communication and the Public*: Available online at http://journals.sagepub.com/doi/full/10.1177/2057047317722571

2016 Communication, Machines & Human Augmentics, with John Novak, Victor Mateevitsi, and Steve Jones, *communication +1*: Vol. 5, Article 8. Available online at http://scholarworks.umass.edu/cpo/vol5/iss1/8

2015 Audio dilation in real time speech communication, with John Novak, Valeriy Shafiro, and Robert Kenyon, *The Journal of the Acoustical Society of America*, *137*(4), 2303-2303.

Co-Editor

2017 Haptic Media Studies special issue of *New Media and Society,* co-edited with David Parisi and Mark Paterson.

Published Proceedings

2018 Doctor da Vinci: The Reshaping of Surgical Touch, Workshop CHI 2018, Reshaping Touch Communication: An Interdisciplinary Research Agenda: https://intouchchi.wordpress.com/

2013 Technologizing Touch: Magic, Education, and Domestication in Apple iPad Advertisements, AoIR, Denver, CO.

2013 On-line audio dilation for human interaction," with John Novak, Valeriy Shafiro, Robert Kenyon, and Jason Leigh, INTERSPEECH (pp. 1869-1871).

Chapters in Edited Volumes

2021 "Touching Machines" in *The SAGE Handbook of Human-Machine Communication*. Guzman, Andrea L., McEwen, Rhonda, & Jones, Steve (Eds.) (forthcoming).

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