Investigating the Implementation of Automated Technology into the Healthcare Industry

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On my honor as a University Student, I have neither given nor received unauthorized aid on this

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Introduction

In the United States alone, approximately 150,000 anterior cruciate ligament (ACL) injuries occur every year, translating to over $500 million in healthcare costs (Coleman, 2019). These injuries can be especially detrimental to younger athletes, who have to endure not only a 6-9 month recovery and rehabilitation period, but also encounter an increased risk of reinjuring their ACL once they return to competitive sports. One study reported that athletes who were less than 20 at the time of an initial ACL surgery had a subsequent reinjury rate of 28%, approximately six times higher than that of athletes who have not torn their ACL before (Webster et. al., 2014).

A major determinant of the likelihood of reinjury is the rehabilitation process after the initial surgery following an ACL injury. During rehabilitation, patients work with physicians to gradually advance toward walking, running, and eventually playing high-impact sports again. However, each recovery process is unique to the patient and circumstances of the injury, and an incomplete/improper rehabilitation may lead to greater risk of injury (Nyland et. al., 2010). This capstone project will aim to improve the ACL reconstruction rehabilitation process by using wearable sensors to monitor the recovery of patients in the months following surgery.

With the goal of attempting to utilize mobile sensors and machine learning algorithms to aid in the traditional rehabilitation process, this project serves as one example of the increased integration of new technology and automation into the healthcare industry, which have been two of the main drivers in recent changes in the medical industry (Thimbleby, 2013). Introducing new technology into the existing system of infrastructure and workforce creates many opportunities for increased efficiency and improved care for patients, but also can pose some issues in terms of security, privacy, and disruptions of the current healthcare system (Lustgarten

et. al., 2020). The advancements offered by automation technology must be coupled with a careful analysis of its implications toward social groups, existing technology, and infrastructure before being fully adopted. This capstone project, which involves utilizing remote sensors to collect and analyze metrics indicative of successful ACL reconstruction rehabilitation, provides one specific context for the investigation into how the increased integration of automated technologies in the healthcare industry interacts with the existing standards of practice and roles of physicians. Through a study of survey responses from workers in healthcare facilities, this research aims to analyze the ways in which automation has changed the healthcare industry and subsequent reactions, both positive and negative, to these changes from healthcare workers.

Utilizing Wearable Sensors and Automated Technology for ACL Rehabilitation

Currently, the post-ACL reconstruction rehabilitation process consists of 6-9 months of regular sessions of physical therapy with a rehabilitation physician. These sessions gradually increase in rigor and involvement until the patient is cleared to resume walking, running, and eventually returning to their regular daily routine and sports activities (Myer et. al., 2006). Typically, the final decision from a physician to clear an athlete to return to sports is made based on quadricep muscle strength and performance on jumping exercises (Menzer et al., 2017). However, this decision process usually does not consider the potential risk for ACL reinjury (Losciale et. al., 2019). Additionally, most of the determinants of quadricep strength and jumping ability require high-impact activities, which can only be done in the later stages of rehabilitation. There exists a clear need for precise, constant, and objective analysis of the condition of patients' rehabilitation process in order to ensure a successful recovery and minimize the risk of reinjury.

As a proposed improvement to the ACL rehabilitation process, this technical project focused on using wearable sensors attached to participants' legs (Figure 2) to collect EMG and accelerometer data while they completed standard rehabilitation exercises. Data was collected on both healthy participants and patients who had recently undergone ACL surgery. Following collection, significant features were extracted to develop a predictive model that could distinguish between the two subsets of participants.

Figure 1: Trigno Avanti Sensors on a Participants Lower Limbs. Source: Boukhechba (2020)

The long-term goal of this project is to allow for patients to wear sensors in their day-to-day lives during rehabilitation. With metrics that differentiate ACL patients and healthy participants and a model that can successfully predict whether a patient is progressing properly in the rehabilitation process, patients can be more accurately diagnosed and treatment can be tailored to an optimal process. The goal, however, is not to completely phase out rehabilitation physicians, but to use technology to improve the care that physicians are able to provide.

Throughout this technical project, rehabilitation physicians were in their usual role of guiding

patients through the post-surgery rehabilitation process, but now with the added component of

sensors constantly collecting data. This new technology and its associated designated exercises,

while having the intention to improve the process of rehabilitation, may alter the standard

practices of rehabilitation physicians. If the longer-term effects of the project are successful in

utilizing the sensors to improve the rehabilitation process, some disruptions regarding how the

use of this technology may affect current practices in this industry may be encountered.

Rehabilitation facility administrators may consider altering standards of practice, physicians may

see their roles as primary decision makers change, patients may experience a new

technologically-driven method of therapy, and manufacturers of sensors may tailor designs for

rehabilitation purposes. Previous research has shown that introducing more automation into the

healthcare industry affects not just the technological aspect of medical facilities, but also broader

organizational aspects within personnel and management of physicians, stressing the importance

of considering the extensive effects of introducing these new technologies (Benzidia et. al.,

2018).

An Interactive Sociotechnical Analysis of Automation in Healthcare

The context of wearable sensors in ACL rehabilitation serves as one of many avenues

that technology and automation are potentially being implemented in the healthcare industry.

Already, remote sensors and predictive models are being utilized for a multitude of uses, such as

in-home rehabilitation and remote care for elderly patients (Ho et. al., 2019). While the increased

use of automation technology may allow for more opportunities in data collection and increase

the accuracy of diagnoses and treatments, careful consideration and analysis is needed before attempting to shift the healthcare industry completely toward automation.

Previous research has delved into some of the potential issues that the increased integration of technology into healthcare presents. Some have focused on privacy-related risks of having a high-technology medical system with the use of specific case studies, such as the WannaCry malware incident, which affected 80 National Health Service (NHS) trusts and more than 600 different NHS organizations in England (Meinert et. al., 2018). While strict laws and regulations exist with the intention of keeping all patient data secure, this specific malware attack provides just one example of a breach in security and privacy. Computer use, patient care, and even medical equipment were all hindered by this breach. Although the adoption of technology presents many opportunities for benefit, it also introduces new forms of security and privacy risks. Beyond privacy and security, integrating technology into the healthcare system also introduces concerns of unsustainability and issues with scalability. Although a technology may be cutting-edge at the time of its introduction, it may already be outdated and replaced with more optimal solutions by the time it would be able to be fully integrated and scaled up into broader systems (Meinert et. al., 2018). Outside of these, the financial implications of increasing the use of technology in healthcare must be considered. With the cost of healthcare, specifically in the United States, already rising to amounts unaffordable to many average citizens (Crowley et al., 2020), adding more high-cost technology may make this problem even worse. Although more advanced technology and automation will increase the abilities of healthcare providers, it will likely correspond with an increase in healthcare costs which may not be fully justified by these advancements (Kumar, 2011).

These are just a few of the non-technical considerations that must be considered when deciding whether to increase the use of technology in the context of the healthcare industry. To properly develop a clearer picture of the specific socio-technical interactions involved in the introduction of automation technology into healthcare, a framework of analysis is needed. In previous research, the Actor-Network Theory (ANT) framework of analysis has been used, considering the interaction of human actors (physicians, patients, hospital administration, etc.) and the non-human actors of new technology (Cresswell et. al., 2010). In this case, the Interactive Sociotechnical Analysis (ISTA) and Unintended Consequences framework of analysis will be used (Harrison et. al., 2007). This combines aspects of ANT along with other frameworks to develop a model that focuses on five main interactions. In the context of healthcare information technology (HIT), those interactions can be seen in the diagram in Figure 2 between social systems, HIT-in-use, new HIT, and technical and physical infrastructures. These same interactions are applicable to the introduction of automation into the healthcare industry. In the first interaction, new automation technologies change the existing social and technical system. In the second, the existing infrastructure of healthcare facilities mediates the use of medical technologies. In the third, social systems (such as the current roles of physicians and patients) mediates healthcare technology uses. In the fourth, existing healthcare technology changes the social systems in place. Finally, in the fifth, these interactions between healthcare technologies and social systems lead to a redesign of new automation technology. These interdependent interactions offer a framework to comprehensively analyze the effects and reactions between new automation technologies and the existing infrastructure and social systems.
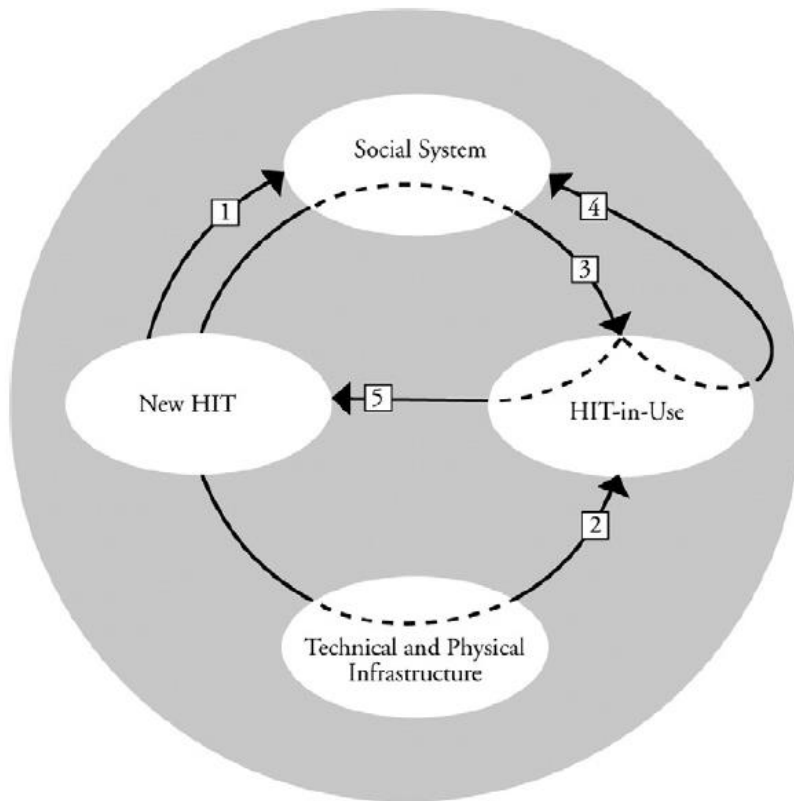
Figure 2. Diagram of ISTA Framework of Analysis. Source: Harrison et al (2007).

Research Design

The main question this thesis seeks to address is: how will the increased integration of automated technologies and processes into the healthcare industry affect existing standards of practice and roles of physicians? As with many industries, the continued implementation of new technologies and automation into healthcare is seemingly inevitable (Angelov et. al., 2019), so it is important to investigate how these new technologies will change and interact with existing groups and systems.

Analysis of this overarching research question was conducted with the use of primary evidence, including surveys sent to physicians as well as a thorough review of prior literature and research articles that have sought to address similar questions. The survey contained questions

related to the ways in which automation technology has been implemented in healthcare facilities and what the reaction has been from administrators and physicians (see Appendix A). In order to answer the broad question of how the increased integration of automated technologies and processes into the healthcare industry affects existing standards of practice and roles of physicians, the survey was designed to first gain a perspective on what each individual healthcare worker's opinion on automation in healthcare was, then investigate what they've seen in regard to the interactions between new automated technology, existing technology, social systems, and current healthcare practices in the context of the ISTA framework. Through responses from physicians to these questions, firsthand knowledge was gained on how automated technology has been introduced and what its potential future implementation may look like based on the reactions of physicians and effect on existing healthcare systems. The analysis of survey responses was compared to previous studies done to establish common conclusions made by individual healthcare workers and industry-wide experts.

Through both primary and secondary research, key commonalities have been drawn on some successes and failures of previously-implemented technologies as well as both hopes and concerns that physicians have for the potential future increase in automated technology in healthcare. This helped in developing a model that was analyzed with the ISTA framework (Harrison et. al., 2007), specifically exploring how these new technologies change the existing social system, while the existing social system and infrastructure mediates the implementation of automated technology.

Results

The survey received responses from 48 members of the healthcare community, ranging

from part-time scribes at hospitals to registered nurses and physicians with decades of work

experience. Overall, many in the healthcare community view the increased implementation of

healthcare as inevitable and welcome the increased efficiency and productivity it may bring.

However, there were concerns from quite a few healthcare workers, specifically in regard to the

need for human decision making and doctor-patient relationships that automated technology may

limit. Analyzing interactions based on the ISTA framework, most respondents agreed that both

their specific social roles and standards of their healthcare facilities as a whole have changed as a

result of automation, but usually did not go as far to say that automation would completely

replace existing healthcare technology in use or lead to a reduction in jobs in the healthcare

industry.

Every single respondent said they either agreed or strongly agreed with the statement "I

think that the amount of automation used in the healthcare industry will increase in the future,"

indicating it appears to be widely accepted that the implementation of automated technology into

the healthcare industry will only continue to increase, see Table 1. One healthcare worker stated

that automation is "the way of the future" and another wrote that its increased introduction into

the industry is "obvious and welcome."

Prompt	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I think that the amount of automation used in the healthcare industry will increase in the future.	0%	0%	0%	58.3%	41.7%
I think that increasing the amount of automation in healthcare is a good thing.	0%	16.7%	41.7%	33.3%	8.3%
My specific role as a healthcare worker has changed as a result of automated technology.	0%	30%	10%	20%	40%
The processes/standards of practice in my healthcare facility as a whole have changed as a result of automated technology.	0%	10%	0%	50%	40%
Most current healthcare technology will become obsolete as a result of automated technology.	8.3%	33.3%	33.3%	25%	0%
In the future, there will be fewer careers in the healthcare industry as a result of automated technology.	8.3%	41.7%	16.7%	33.3%	0%

Table 1. Percentages of Each Response to Selected Survey Questions.

Although there was a consensus that the presence of automation would continue to grow in the healthcare industry, responses were mixed on whether or not this would in fact be beneficial to the community as a whole. The next survey prompt was "I think that increasing the amount of automation in healthcare is a good thing." While 41.6% of respondents agreed or strongly agreed with this statement, over half either felt neutral or disagreed. Some workers were quick to point out benefits, specifically calling out automated technology's ability to "increase

productivity and efficiency" while "making our lives easier and saving time." However, others were hesitant to praise the presence of automation. One specific healthcare worker, an acute care nurse of 27 years, said "I have seen firsthand the negative impact automated technology has had on patient care. New clinicians especially often lack even the most basic assessment skills. Much of their training focuses on data entry and while they are very adept at documenting assessments, many simply click the boxes with no actual knowledge of what they are even clicking on." Another nurse responded that "we spend more time looking at screens and on computers rather than with patients." Through responses to the prompt and free response quotes, the major issues many healthcare workers have with automation appear to revolve around its disruptions to the social aspect of healthcare. Whereas automation may improve productivity in some senses, many healthcare workers believe that doctor-patient interactions are a crucial aspect of medical care that are decreasing as a result of new technology.

Branching off the social changes that new automated technology creates, 60% of respondents either agreed or strongly agreed with the statement "My specific role as a healthcare worker has changed as a result of automated technology." Even though some healthcare workers are resistant to the changes to their day-to-day jobs caused by new technology, particularly those who have been working in the industry for a long time, most are being put into new roles centered around working in tandem with automation to improve patient care. There was an even stronger response to the prompt "The processes/standards of practice in my healthcare facility as a whole have changed as a result of automated technology," which ties more into the technical infrastructure aspect of the ISTA framework. Here, 90% of healthcare workers either agreed or strongly agreed with the statement. In most cases, automation appears to be changing how individual healthcare facilities operate as a whole.

While most respondents stated that automation had changed their specific roles and processes in their facilities, most still believe that the existing technology and number of jobs in the healthcare industry would not decrease as a result of new automated technology. Only 25% agreed with the statement "Most current healthcare technology will become obsolete as a result of automated technology." This is representative of the interaction between technology-in-use and new technology in the ISTA model, where existing technology mediates the use and implementation of new forms of technology (in this case, automation). Regardless of the benefits that new automated technology introduces, it seems unlikely to healthcare workers that it will completely replace current technology used in the industry. In addition to this, only one-third of respondents agreed with the statement "In the future, there will be fewer careers in the healthcare industry as a result of automated technology." In fact, one healthcare worker believes that automation will "lead to the need for other workers to run and keep up systems," indicating that these new technologies may actually create new, more technically-focused jobs in the healthcare industry to develop and maintain automated systems.

Discussion

When considering these survey results through the lens of Harrison's ISTA framework, responses from healthcare workers bring to light the model's interactions in the context of automation in healthcare. The prompts regarding if workers' individual roles or standards of practice have changed relate to the interaction of new automation technologies changing the existing social and technical system. Based on the responses of healthcare workers, new automation is having a significant effect on both their own role and even more so on the standards of practice of their healthcare systems. Some of the mediating effects of current

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technology and social systems are also seen, however, through the responses to prompts "Most current healthcare technology will become obsolete as a result of automated technology" and "In the future, there will be fewer careers in the healthcare industry as a result of automated technology" as respondents generally tended to disagree, suggesting an effect on the implementation of automation by existing technology and roles of workers. However, it appears that the effects of automation on the existing healthcare community are overwhelming any mediating effects that current social systems may have on the new forms of technology. Despite any negative opinions that individual workers may have towards automated technology, healthcare facilities will continue to adapt their standards of practice to fit in with the new form of medical care that automation provides.

Although this sample size of 48 healthcare workers is limited, the results can be compared to surveys with larger sample sizes to determine if the findings are consistent across different demographics. A 2019 survey of over 400 employees across the largest hospitals in Saudi Arabia received responses that were more heavily opposed to the introduction of automation into healthcare, with 78% saying they feared that automated technology would replace human healthcare workers (Abdullah & Fakieh, 2019), compared to just 33% agreeing with a similar statement in this research's survey. This suggests there may be some differences in the general opinions towards automated technology between different cultures and regions. However, a survey of 89 United States-based hospital executives found that two-thirds were planning on implementing automation in their workplace (Olive, 2020), consistent with the overwhelming majority that agreed with the survey prompt that automation would continue to increase in the healthcare industry. Despite whatever negative beliefs individual workers may

have towards new technologies, it seems that investments into automation by healthcare facilities will only continue to increase.

Many of the other responses in the survey research connect to findings made in previous studies. As noted above, the primary concern of most healthcare workers was the reduction in doctor-patient interactions. One study investigating the potential effect of this followed the rehabilitation process of patients who recently underwent ACL surgery. The patients were split into two groups, one that received standard supervision from a physician and another that received the same set of instructions but were only monitored by an automated system. In nearly every case, the patients in the group that received doctor supervision had a more successful recovery, providing one example of the importance of doctor-patient human interactions (Saxana et. al., 2020). Studies have also been done on the positive impacts of social support systems in patient care, something that might be limited by automation (Peng et. al., 2013). Some research has been done into the benefits of automation as well, which yielded similar conclusions. One study focused on using an automated system to monitor elderly patients in-home (Ho et. al., 2019). Without any sort of automated technology, these patients would either be forced to stay in healthcare facilities or risk being at home without any sort of monitoring. This highlights the advantages of efficiency, productivity, and similar key benefits to patient care that automation may bring in some contexts.

There were a couple limitations to the scope of this study, namely in the size and makeup of the respondents. First, as mentioned above, a sample size of 48 healthcare workers is not enough to be considered representative of the entire population of this whole group, especially considering that most of the workers worked in middle- to upper-class regions of the United States. Due to the setting and socioeconomic status of the facilities that the respondents worked

in, some factors may not have even been considered, such as the increased cost that automation could lead to for both hospitals and patients (Kumar, 2011). Additionally, nearly all the respondents were either nurses or scribes who mainly dealt with hands-on patient interactions, rather than administrative staff who may have pointed out the more logistically-related issues with new automation in the industry (Benzidia et. al., 2018). Considering these, given the opportunity to conduct this research again, I would have made a more active effort to send the survey out to a more diverse group of healthcare professionals in order to hear from different perspectives, which may have led to opinions on automation in healthcare not addressed by this research.

As I move to a professional engineering career, the findings of this survey and process of data collection and analysis will be of great benefit. While I likely will not personally be working in the healthcare industry, this same analysis of the social and technical considerations from individuals working in a given field when introducing new technologies can be applied in a number of different contexts, and will be something I am more cognizant of as I encounter these situations.

Conclusion

Even if a piece of technology such as a new automated system may theoretically lead to benefits for patients, healthcare workers should be the primary source consulted on the potential advantages and drawbacks of introducing new technologies. As much upside as there may be, a technology might need to be altered or implemented in specific ways in order to not cause negative disruptions to both healthcare workers and patients.

The changes to existing social systems and technologies are just one piece of all the different aspects to consider when introducing automation into healthcare. Future studies may focus on other considerations of implementing new technologies into healthcare, such as security and privacy (Meinert et. al., 2018). In any industry, the decision to increase the technological presence in tasks traditionally conducted by humans will lead to concerns of cybersecurity. This is especially true in healthcare, where an attack on centralized networks could threaten the privacy of patients' sensitive medical and financial records.

Broadly, it appears that the increased implementation of automation in healthcare is accepted amongst many healthcare workers, and it has benefits in the increased productivity and efficiency it may bring, but real concerns exist across the medical community that social interactions, one of the most important aspects of the roles of nurses and physicians, will suffer as a result. In implementing new technology such as automation into an industry as complex and important as healthcare, it is crucial to consider its effects on existing social systems, infrastructure, and current technology-in-use to ensure that its implementation ultimately yields positive outcomes for the community as a whole.

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Appendix

Appendix A - List of Survey Questions for Physicians

Yes/No Question

- I have seen automated technology/automation implemented in my workplace.

Strongly Disagree/Disagree/Neutral/Agree/Strongly Agree Questions

- The amount of automated technology used in my healthcare facility has increased from when I began working.
- My healthcare facility should increase investments into automation and automated technology.
- My specific role as a healthcare worker has changed as a result of automated technology.
- The processes/standards of practice in my healthcare facility as a whole have changed as a result of automated technology.
- I think that the amount of automation used in the healthcare industry will increase in the future.
- Most current healthcare technology will become obsolete as a result of automated technology.
- I think that increasing the amount of automation in healthcare is a good thing.
- In general, my colleagues and administrative staff think that automation in healthcare is a good thing.
- In the future, there will be fewer careers in the healthcare industry as a result of automated technology.

Free Response Question

- Please use this space to write any additional thoughts you have about automated technology in the healthcare industry.