INVESTIGATING THE EFFECTS OF HUMAN-AUTOMATION INTERACTION IN MEDICINE

A Research Paper submitted to the Department of Engineering and Society
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Biomedical Engineering

By

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March 27, 2020

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Every day new discoveries are made in the medical field and experts gain more insight into the world of diseases, and with these new discoveries come greater expectations and demand for treatments. Advances in medical science over the past two centuries have opened up doors to ways of treatment that were not previously seen as possible. The growing integration of technology and medicine has allowed physicians to treat patients in more depth and to better results. However, as technology is increasingly being implemented within medicine, medical treatment can be seen as augmented medicine. Augmentation adds to automaticity, and with increased automaticity come both great benefits and risks, which will be explored in this research paper. One of the greatest benefits of increasing automation in medicine is bettering medical treatment. Being able to provide better treatment would be advantageous for the health and wellbeing of patients, but the medical professionals who administer these treatments suffer the consequences. Medicine is seeing increasing numbers of health professionals who suffer from stress and burnout. According to Medscape's National Physician Burnout, Depression & Suicide Report in 2019, 4 in 10 physicians report feelings of burnout, and the physician suicide rate is three- to five-fold higher than of the general population (Kane, slide 2; Tawfik et al., 2018). In a survey conducted to study burnout, fatigue, and medical errors, the physicians who reported medical errors had a higher prevalence of burnout than those who did not report errors (77.6% vs 51.5%, respectively) (Tawfik et al., 2018). This research paper will explore the reasons for burnout and fatigue in physicians, study the association between these symptoms and the prevalence of medical errors in a science, technology, and society (STS) context, and model research findings using the Social Construction of Technology and the System in Context conceptual frameworks (Bijker, 2001; Law & Hassard, 1999; Rhodes, 2009).

Tighty coupled with the STS research, the technical project addresses an issue that is prevalent during invasive cardiac procedures to treat atrial fibrillation (AFib): an intracardiac ultrasound catheter's inability to remain in a set position which can result in the loss of valuable time and efficiency within the procedure room and a higher risk of procedural complications. Atrial fibrillation is one of the most common irregular heart rhythms that affect at least 2.7 million Americans and is present in one in four adults over the age of 40 years (American Heart Association, 2016; Lloyd-Jones et al., 2004). In the German Stroke Data Bank, Grau et al. (2001) found that one-fourth of the 5,000 documented strokes resulted from a cardiac source, such as AFib. Not only is AFib a leading cause of stroke, but it can also weaken the muscles of the heart and increase heart failure among many other heart-related complications if left untreated (Mayo Clinic, 2019). As technologies have increasingly evolved, not only has AFib detection improved, but treatments for the disease have also progressed. Catheter-based procedures are regularly performed to treat Afib and eradicate the origin of the arrythmia by ablating, or producing heat to scar, the tissue. As ablation devices underwent technical improvements over the last decade, the need for tools to help guide physicians during ablation procedures and maintain patient safety grew (Keçe, Zeppenfeld, & Trines, 2018).

Using pulse-echo signals to create real-time images of inside the heart, the intracardiac ultrasound catheter is a pertinent tool with numerous advantages for physicians performing cardiac procedures such as ablations for Afib, however an issue regarding the stability of device was identified by the Capstone team for the technical project (Stephens et al., 2008). No efforts have yet been made from a technological standpoint or medical device industry to minimize the risks that already come with cardiac catheterization, such as injury to blood vessels and fluid buildup in the area surrounding the heart (Spragg et al., 2008). Recognizing that these risks could potentially be heightened with catheter instability, the technical project seeks to develop a device that provides stability to the intracardiac ultrasound catheter by augmenting the natural tendencies of the tool. This augmentation increases automaticity in intracardiac ultrasound catheters and will ultimately affect the levels of physician involvement during procedures.

The STS research will analyze the advantages and consequences of automation in medicine and more specifically investigate how varying levels of automation can contribute to physician complacency and promote a lack of oversight in medical procedures. Together, the STS research and technical project is written as a conference-style paper for a biomedical journal which studies automation in medicine and the implications it has on providing medical care.

THE POWER OF AUTOMATION IN MEDICINE

As the demands for medical breakthroughs and better patient outcomes grow, the medical field is evolving increasingly more toward technology. Advances in engineering have played a major role in improving diagnostics, therapeutics, and delivery in medicine, therefore by introducing automation into medicine, technologies have enabled more precision, consistency, and efficiency.

By augmenting medicine to integrate technologies in the field, automation is no longer a term just used for factory robots or self-driving vehicles. The word "automation" refers to "the execution by a machine […] of a function that was previously carried out by a human" (Parasuraman & Riley, 1997, p. 231). Automation also includes that a machine cannot act any different from how it was programmed to operate (Vagia, Transeth, & Fjerdingen, 2016). Besides automation helping to do much of the busy, more administrative-heavy work, technology and automation can also be used to perform more complex tasks, such as neurosurgical procedures in medicine. For example, robot-assisted neurosurgery can perform on smaller scales and with greater accuracy and precision that would benefit both the surgeon and the patient, ultimately demonstrating the capacity automation has to innovate medicine (Haidegger, Kovacs, Fordos, Benyo, & Kazanzides, 2008).

SOCIALLY CONSTRUCTING AUTOMATION IN MEDICINE

Despite the great potential automation has in helping to improve accuracy and precision of patient treatment, research studies show a growing prevalence of medical errors. In a 1999 report by the Institute of Medicine (IOM) published that medical errors are responsible for as many as 98,000 deaths a year in the United States (U.S.) (Institute of Medicine [IOM], 2000). In a more recent study by the Johns Hopkins University School of Medicine in 2016, researchers found that more than 250,000 people die in the U.S. each year as a result of medical errors, exceeding the Center for Disease Control and Prevention's (CDC) third leading cause of death in the U.S.: respiratory disease, right behind heart disease and cancer (Makary & Daniel, 2016). Should this generate concern for the competence of doctors and the foundation of the nation's healthcare system? The answer is yes, and no.

THE SYSTEM THAT BREEDS MEDICAL ERRORS

The way "error" is defined varies depending on the context and the subjects. Most commonly in medical literature and for this research paper, the term is defined as "a failure of a planned action to be completed as intended or the use of a wrong plan to achieve an aim" where errors can include complications "in practice, products, procedures, and systems" (IOM, 2000, p. 33-59). Beyond requiring a certain level of care and compassion for the health and wellbeing of others, healthcare providers also go through years of rigorous education and training. Aron, Dutta, Janakiraman, and Pathak (2011) found that medical errors are generally not caused by incompetency of professionals, but rather the systems in place.

The issues with the current system in the context of medicine can be modeled by the Social Construction of Technology (SCOT) framework, as illustrated in Figure 1 (Bijker, 2001; Lam, 2020a). As depicted in the center of the system, the artifact being described as socially constructed is automated technology, specifically automation in medicine. Intended to alleviate manual labor off of humans, automation was introduced to benefit relevant social groups, including patients, medical professionals, institutions (e.g. hospitals), and medical device companies. For the purpose of focusing on the actual implementation of automation in medicine, other relevant social groups such as the government and insurance companies will be excluded from the framework. The included social groups are relevant particularly to automated technologies because each play a role in the artifact's existence and use and are therefore illustrated in framework within the surrounds of the artifact.

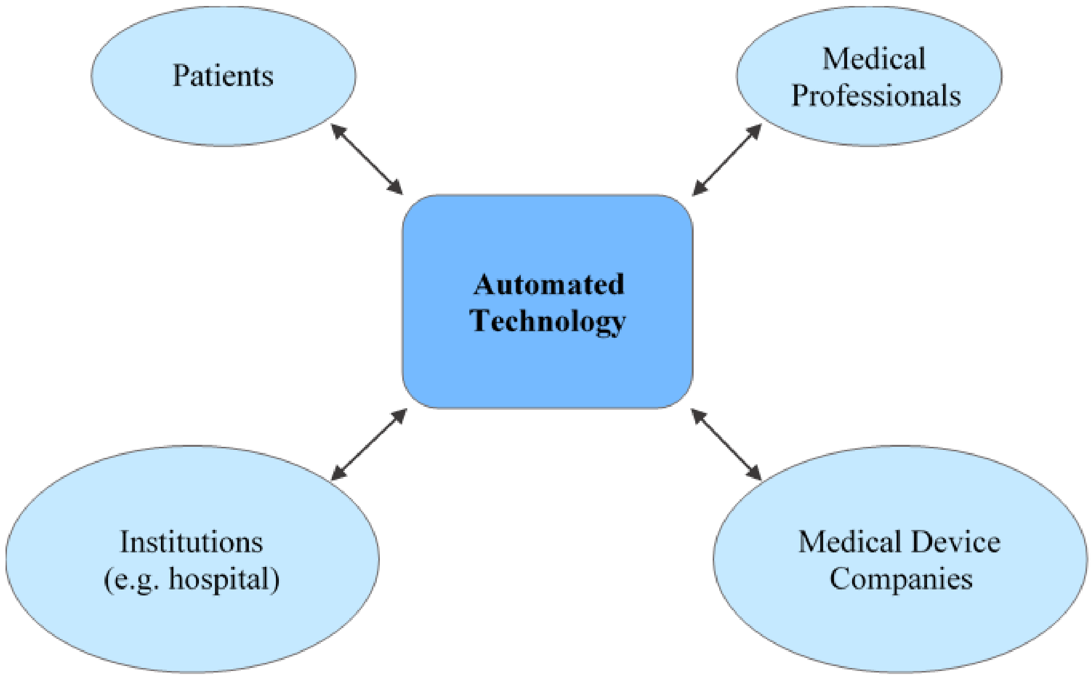

Figure 1. Automated Technology and Social Construction of Technology. The status quo of the system in the context of medicine is modeled by the science, technology, and society (STS) Social Construction of Technology framework. The rectangle in the center depicts the artifact of the system: automated technology. Elements surrounding and connecting to the rectangle represent relevant social groups that play a role in the artifact's existence and use: patients, medical professionals, institutions (e.g. hospitals), and medical device companies. The size of each circular shape illustrates the impact capacity for which each social group has on the implementation of automated technologies. The double-arrows denote the ability for each element to affect and be affected by the technological artifact (Lam, 2020a).

Due to interpretative flexibility, which is the idea that technology can be widely interpreted among social groups, each group can respond drastically different, finding different meaning for the artifact and individually trying to maximize advantages and minimize disadvantages (Johnson, 2005). Despite the potential that automation has to alleviate manual labor off of humans, the lack of structure and balance in the way the social groups interact among each other and with automated technology foster burnout and fatigue in physicians, allow large healthcare organizations to set unrealistic expectations, and exacerbate the business models that value the quantity of patients seen per day over providing quality patient care, all of which prohibit automation from demonstrating its advantages in medicine to the highest degree.

Automated technology in the medical field were introduced for various benefits to patients and medical professionals. Considering the high rates of physician burnout and fatigue, medical professionals could want to use automation as a way to reduce cognitive load and speed up performance, however ultimately fostering complacency and a lack of oversight, partially due to the expectations set forth by institutions who typically prioritize obtaining business over the quality of patient treatment (Kaber, 2017).

Employment under large organizations can create challenges for physicians in terms of flexibility and achieving expectations and thresholds set by the organization. Approximately 75% of physicians in the United States (U.S.) are employed by large healthcare organizations, such as hospitals, academic medical centers, and large practice groups (Shanafelt et al., 2015). The 2015 study by Shanafelt et al. evaluated the impact of organizational leadership on the satisfaction and burnout of physicians working for a large healthcare organization. Burnout refers to the psychological syndrome that characterizes emotionally exhaustion and depersonalization, which leads to decreased effectiveness at work (Maslach, Jackson, & Leiter, 1997). Shanafelt et al. (2015) report that 38% of physicians reported high emotional exhaustion and 15% reported high depersonalization. The study also found that leadership within the organization was strongly associated with the burnout and satisfaction of individual physicians. As illustrated the plots of Figure 2 which were adapted by Lam (2020b), generally, greater dissatisfaction with the organization and higher prevalence of depersonalization and emotional exhaustion were generally associated with lower ratings of supervisor leadership qualities (Shanafelt et al., 2015).

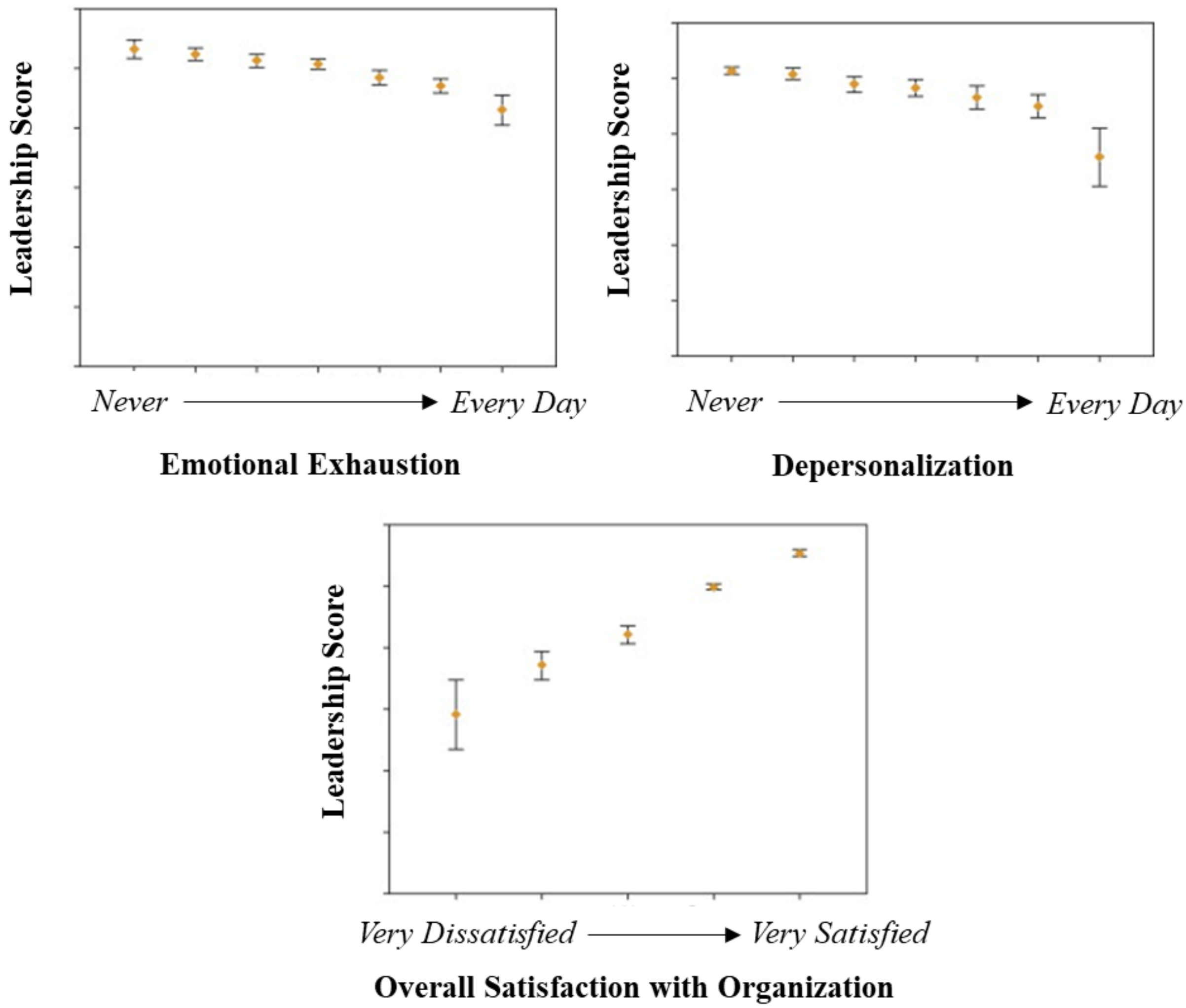

Figure 2. Relationships Between Leadership Score of Supervisor and the Characterizations of Burnout in Physicians. The plots show the negative correlations between how supervisors were scored and physician emotional exhaustion, physican depersonalization, and physician satisfaction. Error bars indicate a convidence interval of 95% (Adapted by A. Lam (2020b) from Shanafelt et al., 2015, *Mayo Clinic Proceedings*).

Findings like these demonstrate that organizational factors largely impact physician well-being, flexibility provided to physicians, and workload expectations. Extensive research shows that "physician burnout … undermines the quality of care physicians provide and contributes to medical errors" (Shanafelt et al., 2010, p. 995). Furthermore, most studies have found an inverse relationship between burnout in healthcare professionals and quality of care provided (Tawfik et al., 2018).

Created by medical device companies, automated technologies are the product of years of hard work by teams of great engineers and leaders. Medical device companies as a social group as well as a business would want to maximize profit, and would therefore continually push for institutions and medical professionals to use their products. Patients would benefit from a reduction in medical errors and more consistent, accurate treatments assisted by automation, but they unfortunately have the least influence on how automated technologies are designed or implemented for medical treatment.

The impact capacity for which each social group has on the implementation of automation is depicted in Figure 1 on page 6 by the size of each social group's circular shape (Lam, 2020a). The institution and medical device company social groups hold the greatest influence because they control how the technology is made and designed to interact with humans and how the technology can and should be employed by users, respectively. As a result of prioritization flaws and the lack of balance and regulations within the system, medical professionals and patients have the least influence although they are the direct users and targets of the automated technology.

Evidently, there are many issues with the current systems in place. The U.S. wants to stimulate “a growing momentum toward creating a national ‘culture of health’” which would eradicate all obstructions in the way of promoting “healthy living among the entire U.S. population” (Bulger, 2015, p. 111). To do this, however, we must tackle burnout rates and moral injuries in the medical profession that are fueled by models in medical care set up to prioritize making money rather than helping people. It is critical to not just embrace the changes that technological advancements will undoubtedly bring about, but to also understand the need for human and automation factors to work together toward common goals.

Rather than promoting a “culture of wealth” that prioritizes business, steps should be taken to promote more of a “culture of health”, eliminating all barriers in the way of promoting “healthy living” in the U.S. (Bulger, 2015). Although each social group has the right to maximize benefits from the artifact, it is not of the best interest of a society in the long run to do so. To refine the collaboration between humans and machines, it is important to observe existing issues within the system in social contexts and identify between which interactions could use improvements. A system to comprehensively optimize the benefits of automated technology is illustrated using the System in Context conceptual framework adapted by W. Bernard Carlson, 2009, originating from John Law’s Actor-Network Theory (Law & Hassard, 1999; Rhodes, 2009). As seen in Figure 3, patient care is prioritized, and therefore in the center, and surrounded by contextual factors and actors within the network that affect the system (Lam, 2020c). The social contexts that give rise to this system include the prioritization of business over quality patient care, the protection of medical professionals and patients, and the various levels of automation (LOA).

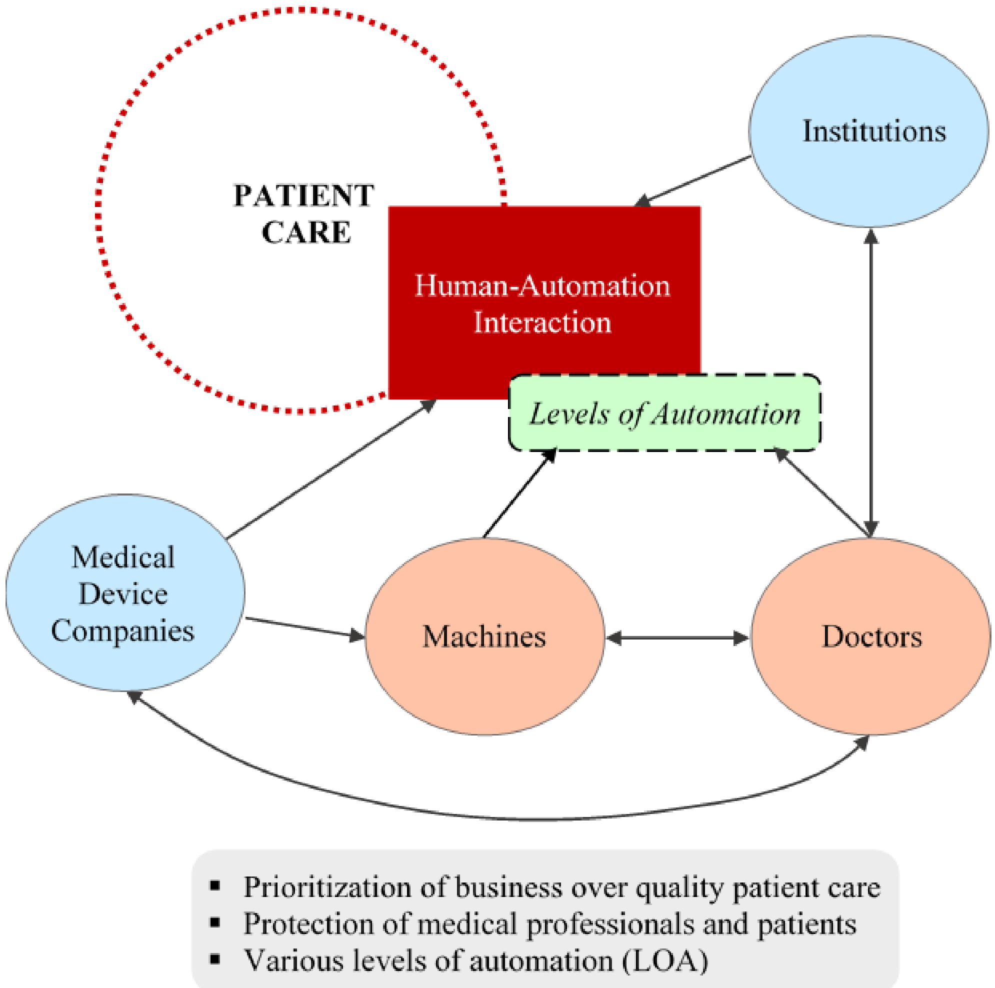

Figure 3. Providing Patient Care Through Human-Automation Interaction as a System in Context. The system in which doctors and patients are consequently harmed by its flaws is refined to through the System in Context conceptual model. The prioritization of providing patient care is depicted by the encompassing shape's position within the model. The three social contexts that give rise to this model are included on the bottom (gray). The barrier, or "gatekeeper," in this system is human-automation interaction, and is shown as a red boundary between patient treatment and the other actors. Actors within the network that affect the system are represented by smaller circles and are classified as primary or second-level actors. Primary actors (orange) that form the basis of human-automation interaction through various levels of automation (green) include doctors and machines. Second-level actors (blue) include institutions (e.g. hospitals) and medical device companies. Double-arrows denote a mutual check, or monitoring, between two actors. The actors operate together to achieve better patient outcomes, reduce burnout in doctors, and promote business operations by achieving greater efficiency and productivity through various flexible levels of human-automation interaction (Lam, 2020c).

Because of business models in place, physicians are often forced to value the quantity of patients seen and bringing in business over providing quality care. Burnout in the medical field is highly contributable to models in medical care that prioritize speed and money over quality patient care, putting doctors in a difficult position where they are unable to offer the care they would want to provide. These models also contribute to "moral injury," a phrase used to describe the inner struggles experienced by medical professionals at work. "Moral injury [is] the emotional, physical and spiritual harm people feel after perpetrating, failing to prevent, or bearing witness to acts that transgress deeply held moral beliefs and expectations" (Bailey, 2020, p. 2, para. 6). Medical professionals are dealing with fatigue and exasperation, driven by "moral injuries" that eventually lead to burnout. Putting exhausted healthcare workers on the front line only exacerbates the likelihood of another medical error occurrence (IOM, 2000). The fragmented and poorly constructed system model impairs the practitioners of medicine, which in turn hurt the people who need help. The wellbeing of patients is in the hands of healthcare professionals; therefore, it is as critical to reduce moral injuries and burnout in the medical field as it is to protect the safety of patients. Exploring the ways humans and machines work together in the context of providing patient treatment can help identify the advantages that the interaction can bring about and the necessary components to establish in the system.

HUMAN-AUTOMATION INTERACTION

The barrier between patient treatment and the other actors is human-automation interaction because it acts as the "gatekeeper," serving as the intermediate factor in how each actor can impact patient treatment. The human factor of human-automation interaction is represented by "doctors", whereas the automation factor is "machines." Thus, the doctor and machine are the primary actors that work together to form the basis of human-automation interaction through various LOA for quality patient care.

When automation and the operating context changes, the human factor must also change and adapt. Often times, we think of things as a binary function: either this, or that. With growing automation in technology, it is easy to fall into binary thinking. Binary thinking is the way we divide a possibility into two categories with no in-between. However, human experiences usually do not "fit into binary categories, and is better described as a continuum with indistinct boundaries" (Bergvall, Bing, & Freed, 2013, p. 1).

The idea is not to choose between machine or human, but to find some balance between the two and feel comfortable moving through the continuum based off of the task goals and how to best achieve them. In some cases, it may be better for a human to perform the task, such as in the diagnosing of a patient. Having automation assume the role of diagnosing patients presenting complications can lead to mistakes due to the inability for the machine to give feedback beyond what was programmed into it, and this can foster dehumanization, or the process of depriving individuals of human qualities which denies their "belonging to a network of caring interpersonal relations" (Haslam & Loughnan, 2014, p. 401). In other cases, it may be more efficient and safer for a machine to perform the task, such as repetitive and dangerous labor on a factory assembly line. It is important to note, however, that efficiency is not equivalent to quality. In medicine, there are many instances where with proper balance in human-automation interaction, greater performance can be achieved. But as with finding balance for anything, seeking balance in human-automation interaction is not a simple nor easy feat. In a study conducted by Endsley and Kaber (1999), human operators benefit the most from automation in the implementation stage of a task under normal operating conditions. In contrast, the absence of a human operator is disadvantageous to “performance recovery if the automated system fails” (p. 1).

LEVELS OF AUTOMATION

From the time automation made an entry into world of manual labor and brought about an increase of productivity, more consistent quality, and greater accuracy and precision, the role that the human operator possesses has changed (Vagia, Transeth, & Fjerdingen, 2016). The assimilation of automation into manual labor introduced different levels of involvement possible for the human operator and machine. This human-automation interaction can be expressed by a taxonomy for varying levels of automation (Vagia, Transeth, & Fjerdingen, 2016). Different LOA have been proposed by many researchers to describe their interpretations of the various combinations of human-automation interaction. Similar to the LOA established in the autonomous vehicle world that most people are familiar with, a taxonomy can be established within the context of a medical system. The five LOA taxonomy presented by Endsley and Kaber (1987) can compactly yet descriptively characterize the human-automation interaction in medicine. Adapted for this research paper, these five LOA are illustrated in Table 1 on page 15 and are listed from least to most assistance via automation (Adapted by Lam from Endsley & Kaber, 1987).

Considering the benefits of having a machine-human effort, and the practicality of completely removing automation from current medical practice, maintaining the first LOA is not optimal. Conversely, because completely removing the human factor from an operation can be detrimental, aiming for a level 5 LOA is also sub-optimal. To maximize the benefits and minimize the possible adverse effects of a human-automation interaction, a given task should be accomplished while maintaining between levels 2 and 4 of the taxonomy.

Table 1.

Levels of Automation in a Medical Context.

Levels of Automation (LOA)	Definition
(1) Manual Support	Manual support with no assistance from the system
(2) Decision Support	Decision support by the operator with input in the form of recommendations provided by the system
(3) Consensual Artificial Intelligence (AI)	Consensual artificial intelligence (AI) by the system with the consent of the operator required to carry out actions
(4) Monitored AI	Monitored AI by the system to be automatically implemented unless vetoed by the operator
(5) Full Automation	Full automation with no operator interaction

A taxonomy by Endsley (1987) interpreting the possible levels of human-automation interaction is depicted. Five levels of automation (LOA) are presented from least (1) to most (5) system assistance, or automation. The degrees of human operator involvement and assistance from the system are described in the right column (Adapted by A. Lam (2020) from M.R. Endsley and D.B. Kaber, 1987, *Ergonomics*).

As illustrated in Figure 4, it is within the continuum between complete manual labor and full automation where the role of the human operator shifts from manual to supervisory, performing less standard, physical tasks and more "intellectual and cognitive tasks of diagnosis, planning, and problem solving" while also maintaining oversight and preventing complacency (Vagia, Transeth, & Fjerdingen, 2016; Liu & Hwang, 2000, p. 235).

Figure 4. Human-Automation Interaction Continuum. The continuous space between manual support (far left) and full automation (far right), including decision support, consensual artificial intelligence, and monitored aritificial intelligence, is ideally where human-automation interactions should strive to maintain within (Lam, 2020d).

DEMONSTRATING THE VALUE OF THE HUMAN-AUTOMATION CONTINUUM: A DIAGONOSTIC LAB

The value of maintaining human-automation interaction within the continuum of the LOA can be illustrated by a scenario presented by Aron et al. (2011). This example will demonstrate the automation of processes within a medical context, the significance of a human operator, and the benefits of a human-automation system. Consider a hospital diagnostic lab where a lab technician's job is to test patients' fluid samples. These fluid samples need to be maintained at a certain temperature in order to prevent decomposition and are therefore stored in a thermostatic storage. When accessing a sample, the lab technician is to manually record in a logbook the time the sample was removed and put back. As the time approaches to return the sample, another employee alerts the technician. If there is any delay in returning the sample, the delay will also be manually noted. These notes are then regularly reviewed by a supervisor for compliance. Each step in this scenario was performed through manual means, decreasing productivity and efficiency and opening up the possibility for greater error.

In the following situation, the same scenario is repeated except some of in-between steps are automated. To remove or replace a sample from the thermostatic storage, the technician must digitally scan an identification card which will automatically log the time and specific sample being tested. As the time approaches to return the sample, the system will alert the technician via an auditory signal. If the technician overrides the alert and there is a delay in returning the sample, the overdue time will be digitally with a flag noting an at-risk sample. Upon a supervisor reviewing the automated logbook and notes, it becomes much easier to identify compliance issues to investigate. Additionally, the automated steps in this process would help diminish errors and better work efficiency.

LOSING OVERSIGHT AND GAINING COMPLACENCY

The term “oversight” refers to as the act of supervising a process or procedure. More specifically, medical oversight refers to the responsibility physicians have for supervising, or overseeing, a medical procedure from beginning to end. Although burnout rates are attributable to the impractical expectations for physicians to achieve high success rates and save lives while also bringing in business for the institution by performing high quantities of procedures, active physician involvement cannot simply be replaced by an automated system. The lack of medical oversight can arguably be resolved by assigning a doctor to watch over the procedure being operated by an automated system. Though this would metaphorically check the box for having an expert present to monitor the procedure, this does not, however, address the issues of complacency.

In an ideal world, technological advances would come in and fix all of the flaws in the system, however it is important to study the reality of how humans actually respond when using automation. If an individual were presented with a technology that can supposedly perform his job, yet he was tasked with the responsibility to be present and watch in case of an adverse event, it is only natural human instinct to feel complacent or even apathetic. Complacency is the “lack of suspicion of a system” as well as the “lack [of] awareness of other potentially better options” and therefore be satisfied with the performance instead (Kaber, 2017, p. 17). Kaber (2017) discusses that when automation is used to achieve task goals, even experts are not immune to complacency and behaviors of accepting of an accessible solution that meets the minimum level of performance. This emphasizes how individuals not as experienced can be even more susceptible to complacency. These behaviors are due to the tendency of humans, particularly those put under high loads of stress, such as physicians, to find ways of reducing cognitive load and speeding up performance (Kaber, 2017).

MAINTAINING CHECKS AND BALANCES

To minimize exploitation of the system by any of the actors and to mitigate the human's suspectibilty to complacency, it is crucial to have institutions and medical device companies as second-level actors to monitor that a proper balance is maintained between the primary actors. Institutions, such as hospitals, should always aim to uphold their medical experts to the highest integrity with the appropriate use of automation and its different LOA to treating patients effectively and efficiently. On the other hand, doctors should righteously ensure they can practice medicine without "moral injury" (Bailey, 2020, p. 2, para. 6). Thus, between institutions and doctors, there exists a mutual check on each other to conduct proper and moral medical practice, as denoted by a double arrow Figure 3 on page 11 (Lam, 2020c). Likewise, medical device companies have the responsibility to design technology with "sufficient flexibility" for human operators to learn and adapt in "near real time" (Kaber, 2017, p. 10). Encompassed within designing flexible technology is including sufficient and effective LOA for human-automation interaction such that doctors will not feel limited by the assistance of, or lack of, technology. Because machines are inanimate objects unable to provide feedback unbiased by their creators, rather than machines keeping medical device companies in check, doctors have the power to express any lack of flexibility or inappropriate features of their machines. Taking social contexts into account and establishing pertinent interactions between relevant actors, the system can yield better patient outcomes, reduce burnout in medical professionals, and promote business operations by achieving greater efficiency and productivity through various levels of human-automation interaction.

HEALTHIER PHYSICIANS AND PATIENTS

The STS research paper addresses medical burnout, moral injury, and medical errors which consequently largely impacts patient care in the United States. Following the investigation of the flawed system that confines medical practice and inhibits quality patient care, the system is illustrated with the Social Construction of Technology model to depict the imbalance in powers between social groups in association with automated technology in medicine (Bijker, 2001). The system is further refined and conceptualized with the System in Context framework of the Actor-Network Theory where the contexts in which automation exist and fit in social, cultural, and technical contexts are depicted (Law & Hassard, 1999; Rhodes, 2009). Human-automation interaction is valuable in furthering medicine, medical care, and the wellness of the nation's people, but only with sufficient flexibility between human operators and machines and proper oversight by institutions and medical device companies. Although human-automation interaction and the levels of automation have been studied in many engineering disciplines, these fields need to be further investigated in the context of medical practice to better understand how to best produce effective cooperation between medical professionals and machines. This can be studied through observing human-automation interactions as well as researching the psychological implications surrounding human-automation interaction, especially as the world is increasingly revolving around technological advancements and evolving toward automation. Lastly, it is crucial to understand existing issues within the system in a science, technology, and society context in order to improve the collaboration between humans and machines and effectively design human-automation interactions in the future.

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