A Literature Review on the Current State and Ethical Implications of Robotics in Healthcare

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Abstract

With an increase in average lifespan in the United States comes an increase in pressure on the medical industry. More doctors are needed to treat the ever-growing patient population, and creative solutions are now being required to provide widespread medical assistance. Robotic technology and artificial intelligence (AI) systems provide a viable solution to this rising challenge. These advancements have the potential to revolutionize telehealth and telerehabilitation, providing more comprehensive care for patients who may be unable to meet with doctors in person. Robotics show promise in therapeutic applications, such as supporting patients with social anxiety and other disorders. Additionally, artificial intelligence can automate mundane tasks performed by medical professionals (such as speech-to-text dictation or preliminary diagnosis of medical imagery), further freeing a doctor's time for more patients. However, the adoption of these technologies raises important challenges. Public concerns about maintaining the integrity of the doctor-patient relationship and the evolving nature of AI and robotics remain roadblocks to full integration into the medical field. There are also important ethical concerns involving patient privacy, the encoding of ethical standards into robots, and the future of human-machine interaction. As such, more research is needed to 1) answer those ethical questions, 2) further explore public reception of this technology, and 3) improve the readiness of this technology for medical applications.

Keywords: Robotics, Healthcare, Ethical Technology, Human-Machine Interaction

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As the technological age advances, the boundary between science and science fiction begins to blur. Medical photo-imagery can diagnose conditions before they manifest in the outward sense, organ transplants offer renewed hope for patients, and minimally invasive surgery reduces the risk of extensive medical operations. Consequently, these technological advances have led to an increase in overall health, recovery, and well-being, especially with an increase in the average lifespan (Medina et al., 2020). However, with this increase comes an additional burden on the healthcare industry, which requires more medical professionals than the workforce can produce. As such, finding an alternative or supplemental solution is necessary for sustained growth, and this solution once again crosses the boundary from science fiction into science: robotics.

Robotics and artificial intelligence (AI) systems provide unique advantages to the healthcare system, such as the possibility of automating simpler work like documentation, as well as the ability of long-range telehealth for patients not available for in-person medical visits. Repeated scenarios like the COVID-19 pandemic reveal a need for adaptable mediums through which healthcare can be administered. Robotic and AI technologies are rapidly evolving, especially with the advent of Large-Language Models (LLMs) like ChatGPT, and the apparent readiness of this technology is exciting. However, the implementation of such technology does not rely solely on its readiness; it also depends on social acceptance of it. Social engineering is an important facet of this topic, as the public's acceptance of new technology is what ultimately determines its success and survival. Bordering on the realm of science fiction, important ethical

questions are being raised regarding automation and the role it should have in daily life. As such, this literature review will focus on the following question: "What is the current state and ethical implications of robotics in healthcare?"

This literature review consists of four main sections. The first will discuss the current state of robotic technology in healthcare, citing specific examples in a variety of applications. This section will primarily focus on the technology readiness of these systems. The second will discuss the response to these technologies by both patients and medical professionals, focusing on the social reception of these systems. The third will discuss some of the ethical inquiries into the role of robotics and automation in the future. Lastly, the fourth section will discuss future research that must be done to advance further in the development of robotics in healthcare.

The Current State of Robots in Healthcare

Among doctors' and patients' most valuable resources is their time. Robotics in healthcare offer many advantages for both medical professionals and patients, and this section's purpose is to determine the readiness of current technology for these applications. The applications of interest can be divided into three main categories: telehealth, companionship, and AI automation.

Telehealth

Telehealth encompasses the use of electronic technologies to provide healthcare services remotely (US Department of Health, 2022). Due to increasing healthcare demands, a doctor's time becomes increasingly divided between office visits, consultations, surgeries, and the physical travel required for each of the aforementioned activities. Telehealth would enable a doctor to remotely perform many of these tasks, or even coach a less experienced doctor across the country. This concept was explored by Leoste et al. (2024) in which the researchers tested a telepresence

robot to help a doctor collect medical history data and guide a medical intern through basic procedures, as well as virtually monitor a patient at home. Telepresence robots attempt to replicate the physical presence of a doctor through virtual and technological means, and the robot used in the study by Leoste et al. (2024) consisted essentially of a camera and a screen at height level attached to maneuverable wheels. The wheels allowed the robot to maneuver around the environment, simulating a physical presence akin to the presence of the doctor. A similar robot was also explored by Mann et al. (2015), in which a robot with a tablet autonomously coached users to take their own basic medical measurements, such as blood pressure, as well as perform exercises. The research across these two studies found that both robots were indeed effective in gathering information and allowing in-home visits when other concerns (e.g. quarantine) would not allow otherwise. Additionally, Mann et al. (2015) concluded that people reacted more positively when using the robot with a tablet compared to another group that used just a tablet with the same tutorials/instructions. However, these robots were found to be unhelpful in any sort of emergency. If a patient was found to have fallen on the ground, for example, then it would only be able to help indirectly by calling emergency services. While the inability of the robot to physically interact with its environment makes it more docile in case of malfunction, this limited functionality is an overall downside in certain situations.

In contrast, there exist robots capable of interacting with their physical environment. Leoste et al. (2024) tested using a robotic arm to perform virtual rehabilitation visits for upper-limb dysfunction. Some injuries require specialty care, and such care might not be available locally. The idea tested by these researchers was that a doctor could virtually manipulate a robotic arm and coach a patient through important exercises in their rehab process. This setup could be installed once in a person's home and requires little further maintenance. This

technology would once again eliminate the need for in-person visits and provide an advantage over other robots in their ability to interact with their immediate environment.

Companionship

A common need appreciated and anticipated in the healthcare industry is a sense of companionship and care. Some individuals even have companion animals (e.g., dogs) that provide comfort and assist in small tasks. Researchers such as Coghlan et al. (2021) and Šabanović et al. (2013) endeavored to create socially assistive robots (SARs) that would fill that same role. The PARO (a seal-like plush robot) was found effective in increasing social participation in a group setting (Šabanović et al., 2013). In comparing the social interaction of the group members in the final group session of the study vs the initial group session, the researchers in Šabanović et al. (2013) found a 133-586% increase in social interaction depending on depending on the metric used to measure social involvement (visual contact, verbal conversation, etc). In fact, the results were so notable that this study was referenced by most of the other sources used in this literature review. Coghlan et al. (2021) demonstrated the success of three companion-type robots for elderly patients, testing two robot AI assistants similar to an Alexa and a toy robotic dog meant for kids. It's important to note that the report done by Coghlan et al. (2021) only provided a qualitative summary of the survey results given by the study participants. Based on a seemingly large majority opinion, the most well-received was the robotic dog (Coghlan et al., 2021). Interestingly, the robots that proved most successful were those focused solely on providing companionship, rather than assisting with complex tasks. This finding highlights an existing technological gap between the tasks users desire robots to perform and the current limitations of robotic capabilities. It also offers insights into people's preferences for these

robots, a topic that will be further explored later.

Artificial Intelligence

Lastly, AI has been implemented in many repetitive yet necessary tasks. In healthcare, a large hospital in China was used for a case study by Pee et al. (2019) to study the usefulness of AI in tasks related to patient reception, diagnosis, and speech-based medical note-taking. The purpose of these AI systems is not only to speed up each of these processes but also to allow medical professionals to spend more time with patients. When surveyed, most employees in the study spoke positively of the perceived time-saving effects of this technology (Pee et al., 2019). They also said that even though a process like diagnosis is relatively advanced, the AI system could do the bulk of the work, make a suggestion, and then have that suggestion improved and corrected by a medical professional (Pee et al., 2019). A computer-vision program was also developed in Japan to monitor patients in their care room, sensing activities like sleeping, exercising, or most importantly, an emergency (Ravankar et al., 2023). For a large hospital, it would be impossible for a single worker to monitor every room simultaneously. In the case of an emergency such as a fall, a heart attack, or a similar event, this AI system could alert emergency personnel quicker than a human worker, potentially saving the life of the patient. However, not all technologies that claim time-saving benefits meet those expectations. For example, a similar time-saving goal was also attempted in the teaching field by researchers in the UK with a self-learning robot that could then teach a young child how to play a game (Senft et al., 2019). Such teaching technology could be useful in the medical field for assisting little children and/or elderly patients. In contrast to the two previous studies, Senft et al. (2019) found that the robot did not save the teacher any time as they would still need to supervise the robot as it taught a child.

The researchers hypothesized that a better learning algorithm would allow the robot to work more independently. It just so happens that the teaching robot was on the underdeveloped side of that technology readiness curve, while the hospital had greater resources and thus access to better technology. As such, while this study seems counteractive to the previous two, their conclusions were the same: with properly developed technology, AI can save time.

The Reception by Patients and Medical Professionals

As mentioned earlier, a critical aspect of technological development is its reception by the public. The technology discussed was received with mixed results across studies, and as such, a summary of the positives and then the negatives is provided below. By addressing these elements of public reception, the continual development of technology can be morphed to provide what is truly needed in the medical field.

Positive Reception

One general trend in positive reception was the perceived cost-saving effects of this technology. The reduced travel time and travel cost demonstrated by Khan et al. (2023) and Leoste et al. (2024) was appreciated by the studies' participants. Patients enjoyed the ability to have an at-home visit when travel elsewhere would have been cumbersome. Additionally, doctors felt that they could visit more patients/mentor more interns with the extra time available to them. Additionally, the employees surveyed in Pee et al. (2019) were satisfied with the time saved by AI automating some of the more repetitive processes. Several healthcare professionals expressed similar sentiments, from chaplains to social workers to medical professionals (Soljacic et al., 2024). In terms of the time-saving ability of medical robots, most patients and medical professionals are excited about their current technological readiness and future potential.

Another general positive trend across the reviewed literature was the effectiveness of robots in therapy settings. The PARO robot (Šabanović et al., 2013) and the Biscuit robot (Coghlan et al., 2021) were both effective in eliciting emotional responses from their users. In particular, the PARO was passed around in a support group of people with social anxiety. The effect was a statistically significant increase in participation by the current holder of PARO, as well as a greater willingness by others to address questions and comments towards the hold of PARO compared to others (Šabanović et al., 2013). A panel of medical professionals also suggested that robots could be used in behavioral therapy to help "practice" social interaction, but more research would need to be done in this area to assess its effectiveness (Soljacic et al., 2024). The potential benefits of robotics in therapy applications show promise among medical professionals, and the participants appeared willing to interact with these robots. Overall, these findings highlight the growing potential of robots as valuable tools in therapeutic settings, offering both emotional support and opportunities for improving social interactions, though continued research is essential to fully understand their long-term impact and effectiveness.

Negative Reception

However, general negative trends were also seen in the reviewed literature. The most prevalent concern was the risk of sacrificing human interaction in the pursuit of efficiency. As surveyed by Leoste et al. (2024), many of the patients looked forward to seeing their doctor in person. They felt that even just a doctor's physical presence showed his or her care for the patient. Additionally, for the elderly demographic especially, their medical visits represent one of the only remaining social conduits left for them (Pee et al., 2019; Leoste et al., 2024; Soljacic et al., 2024). Many patients also consider some robots to be annoying or intrusive. For instance, the Vector

robot tested by Coghlan et al. (2021) seemed too child-like and thus condescending for an adult to use. Additionally, the ElliQ robot in the same study (an AI assistant) was perceived as rude and prone to pestering its users rather than assisting them. There was a notable trend that an individual's social reception of robots is heavily dependent on their reception towards human interaction as well. If a user/patient enjoys constant human presence, a robot companion was similarly well-received; if a user/patient enjoys solitude, a robot companion was similarly poorly received (Coghlan et al., 2021). As such, the reception of assistive robots is also closely tied to general social preferences as well. With this realization in mind, robots can be uniquely programmed for each individual's presence.

One of the main reasons these studies highlighted negative perceptions of the technology was the functional limitations of the technology available to the researchers. In many of the studies, the robot was just unable to perform all the tasks the researchers hoped it to accomplish. For example, the robot tested by Leoste et al. (2024) was initially hoped to be an at-home robot that could monitor and assist a patient in need. Although it performed its monitoring task well, this robot was unable to physically help a patient in the event of an emergency (such as a fall). Robots with this advanced functionality do exist but are not financially available to the general public. A reverse consideration is also that, as the robot becomes more complex, the greater the damage a malfunctioning robot can pose to its patient (such as an arm accidentally swinging in the wrong direction). Until these robots become readily available, patient and doctor reception of these robots will be constrained by the discrepancy between the supposed limitless possibilities of robots and their current technological readiness.

Ethical Implications of This Technology

As robotic technology advances, many important ethical questions must be asked. Gerdes (2014) states that these questions represent a balance between science fiction and science fact since current-day research is typically funded with future-looking ideas. As such, questions about privacy, ethical encoding, and social interaction must be addressed based on both the current and near-future state of robotic technology. Most of these questions revolve around the idea of trust: trusting in companies, trusting in robots, trusting in doctors, etc. Many of the questions discussed in the remainder of this section remain unanswered as there does not exist a uniquely right answer. As such, these ethical concerns are presented here as important considerations to remember as technological advances increase.

Privacy

Multiple studies showcase the ability of robots and AI to remotely monitor their patients (Coghlan et al., 2021; Leoste et al., 2024; Ravankar et al., 2023). In a high-risk emergency situation, the speed of emergency response is vital. However, with increased automated supervision comes a decrease in personal privacy. Additionally, this sensory data is stored by a third-party company and a certain level of trust must be maintained between this company and its clients. How does a patient know that their personal data is safely guarded?

Ethical Encoding

Furthermore, questions arise regarding ethical encoding in robots. How can a human trust a robot to make an ethical decision? Who decides the delineation of proper ethics? With the rise of self-learning robots, safeguards must be put in place to ensure that a robot will not learn or implement something contrary to basic human ethics. Completely disabling a robot's

self-learning ability would handicap the versatility and overall utility of the robot. As such, safeguards against improper learning are discussed by Gerdes (2014) in the context of the defense industry, but their suggestions are still valid. Gerdes (2014) recommends a low-level experience-based learning system structured with high-level basic rules that must be followed. These rules can act as guide rails that must never be broken, as the robot functions and gathers "experience". The implementation of this ethical structure is must easier said than done, and efforts are ongoing to accomplish this. Additionally, Gerdes (2014) also poses questions about robot accountability. In the situation that a robot fails to accomplish a task, who is the responsible party? Can the robot be punished? Is it fair to punish the manufacturer, and if so, which department? These are important questions as the reality of daily robots becomes more concrete.

Human-Machine Interaction

There are also many ethical questions about human interaction in the future. Many researchers found that a common concern among patients and medical professionals is the degradation of the doctor-patient relationship as medical telehealth technology advances (Leoste et al., 2024; Pee et al., 2019; Soljacic et al., 2024). Soljacic et al. (2024)'s panel of medical professionals expressed worry that a virtual patient might feel underappreciated by a doctor too busy to physically meet with him or her. For the elderly, these medical appointments might represent one of the few remaining conduits of human interaction left available to them. Coghlan et al. (2021) also expressed concern that becoming too reliant on AI for simple tasks like appointment reminders would lead to a quicker degradation of cognitive function in older demographics.

In total, there are many unanswered questions regarding ethics and robotics. The irony is

that many of these questions cannot be fully answered until the state of technology has advanced enough for them to be addressed. In the meantime, such ethical inquiries are still important to discuss as they shape the direction in which money is invested.

Future Research

Despite the many technological advances in robotics and artificial intelligence, significant research remains to be done before these innovations can be fully implemented in the medical field. Further investigation is needed into how to customize robots for individual needs and preferences while maintaining cost-effectiveness and manufacturability (Coghlan et al., 2021; Senft et al., 2019). Additionally, improving robot autonomy is essential to enhance their ability to interact with the physical environment and reduce the need for constant human oversight (Gerdes, 2014; Khan et al., 2023; Leoste et al., 2024; Pee et al., 2019; Senft et al., 2019). Ethical concerns, as well as public perception of robots, must be more thoroughly explored (Gerdes, 2014; Soljacic et al., 2024). Furthermore, there is a need for greater diversity in study participants. Many studies have noted that small sample sizes or limited demographic groups may not fully capture the broader effects of robotic interventions and that different age groups may influence the outcomes (Šabanović et al., 2013; Mann et al., 2015). By addressing these research gaps, the full potential of robotics and AI in healthcare can be realized in a way that is both socially acceptable and ethically sound, ultimately improving access to medical care.

Conclusion

Robotics in healthcare provides many unique advantages to medical personnel, such as decreased travel time, the ability to virtually interact with patients, and the ability to automate certain important tasks. However, this technology is still maturing and its limitations are obvious

as well: cost, its physical dexterity, and its usefulness in various applications. Additionally, there remains a need to maintain the doctor-patient relationship for the establishment of trust, and a robotic medium could harm this relationship. There are important ethical considerations regarding the development of this technology and how it would interact with humans. These issues span from privacy concerns to the ethical trustworthiness of the robot to robot-human interactions. As such, further research is needed in order to address those questions, as well as the public reception of inserting robots into medical appointments. Lastly, more research must be done to advance the readiness of robotic technology.

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