Issues in Information Systems
Volume 26, Issue 3, pp. 237-254, 2025

DOI: https://doi.org/10.48009/3_iis_2025_2025_119

The effects of human factors on the acceptance of healthcare 4.0 transformation

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Abstract

Healthcare services and healthcare related systems are increasingly adopting technological solutions to digitalize the industry and move towards a comprehensive Healthcare 4.0 infrastructure and services. Their main goals of doing so include reducing costs, improving care and access to it, optimizing operations, and enhancing patient satisfaction. In the meantime, research and development in the field proposed many innovative frameworks, applications, and techniques to fully transform the healthcare industry into Healthcare 4.0. Yet, many remain in the research, design or at most at the trial phases and very few make it mainstream utilization. Adopting and moving to Healthcare 4.0 face various challenges. Some of these are technical, many of which will be resolved over time. Others are financial, which can be addressed, somehow. Yet, there are other obstacles hindering the efforts that are proving to be very hard to address, these are the social and human acceptance challenges. When considering the introduction of smart systems in healthcare, we must keep in mind the invasive nature of smart healthcare 4.0 applications. This means that we need humans to accept their existence and invasive behavior and trust them to keep them safe and protect their information. In addition, the general perception is that smart systems will eventually replace human workers, which leads to two main problems, the fear of job losses among the healthcare workers, and the danger of losing the human touch and connections between the workers and the patients. In this paper, we review the different human factors and challenges of accepting healthcare 4.0 and smart applications in the healthcare sector. We will study some of the current work in the field discussing the adoption and acceptance of such systems. We will also discuss the challenges and possible approaches to address them and increase the acceptance levels of embracing Healthcare 4.0.

Keywords: Healthcare 4.0, smart healthcare applications, digital transformation, digitalization, human factors, technology acceptance

Introduction

Healthcare 4.0 aims to create digitalized, autonomous, and highly adaptive integrated smart healthcare applications. The main objective is to improve healthcare services while reducing their costs (Detwal et al., 2024; Estrela et al., 2018; and Mohamed et al., 2019). Earlier, we discussed the transformation to Healthcare 4.0 and the various challenges involved (Al-Jaroodi et al., 2022). One of the main challenges we identified was the human factors, which we are focusing on in this paper. Research and development gearing towards the transformation is enormous and still growing. In general, there is an agreement that technically, the adoption of a comprehensive Healthcare 4.0

framework will lead to more efficient operations, better management, improved services, increased patients' satisfaction levels and lower costs. There are many applications in place and under consideration that pave the way to larger scale adoption of Healthcare 4.0. Examples include online appointment scheduling, telemedicine, integrated labs and imaging systems, electronic health records, electronic prescription transfer to pharmacies, among many others. In addition, the technology adoption extended beyond healthcare services to their supporting infrastructures like the supply chain operations, suppliers' interactions, inventory controls, and connectivity with insurance systems. Furthermore, technologies advancing medical equipment and providing smart features have evolved and many healthcare facilities now have devices and machines that use software-based smart controls. It has become possible to see robotic components assisting surgeons, automated patient monitoring and medication delivery systems, and many other applications. As for the workers and pat0ients, it has become very common that they own and use one or more smart devices like cell phones, smart watches, tablets, etc. This can help facilitate further integration to include smart systems to help remotely monitor patients, provide public health support, and gather data on patients' environments and behaviors that would be beneficial for medical and public health research.

From the technology perspective, many smart healthcare applications offer varying levels of security and privacy measures, thus affecting how their users (workers and patients) accept them. Many of these applications are designed with reliability, security, privacy, and data ownership management measures as essential requirements. Some users accept such measures, while many are still skeptical. In addition, healthcare service providers may be reluctant to share their data and services with others, which makes it hard to achieve a large scale connected healthcare system under the framework of Healthcare 4.0. Various approaches were devised or proposed to address many of the technical challenges. Unfortunately, the human factors are not entirely connected to technology and some of these factors cannot be resolved with more technology.

In this paper we are trying to investigate the human factors that support or hinder the adoption of Healthcare 4.0 applications and smart healthcare systems and understand the reasons behind them. In addition, we will enumerate the various challenges in this regard and discuss how they could possibly be addressed. As we investigated these aspects, we found that the Technology Acceptance Model (TAM) is a common way to measure user acceptance of technologies and we referenced it as we identify examples of healthcare technologies and systems and their acceptance. We also reviewed some applications and systems that were evaluated for user acceptance using TAM and other similar approaches. The investigation revealed various aspects to consider such as the varying effects and acceptance levels among different groups of healthcare users: patients, the general public, doctors, nurses, managers, support staff, etc. We have come to believe that understanding the human factors and identifying how the different stakeholders perceive them is an important part of finding ways to in-crease the overall acceptance and adoption levels of smart Healthcare 4.0 applications at a large scale. Thus, we are posing several questions we will try to find answers for:

1. Why is the human factor a challenge for the transformation of healthcare systems to Healthcare 4.0 systems?
2. What factors affect the human acceptance of such transformation?
3. Which of the identified factors can be addressed with technological solutions?
4. Which of these factors may not be resolved with technology and why?
5. Are there non-technological conditions that could affect acceptance levels?
6. How far are we from a reasonable acceptance level that will allow the transformation to achieve its goals?

In this paper, we will discuss technology acceptance models, aspects of healthcare applications acceptance; human factors affecting the acceptance; and a brief review of related work in Section II. In Section III we discuss the significance of the human factor and their effect on advancing towards Healthcare 4.0. are important and in Section IV we attempt to identify which of these factors can be addressed. In Section V we illustrate an example of disastrous events on technology acceptance using the Covid-19 pandemic. In Section VI we investigate some non-technological aspects and explore possible approaches to address them. Finally, Section VII concludes the paper.

Background and Related Work

Work is ongoing to find ways to implement and advance the notion of Healthcare 4.0. Some address its definition and foundations, others propose applications and more discuss the challenges and technological advancements needed. In addition, many discuss future advancements and examples of what can be achieved. Various examples and details can be found in (Al-Jaroodi et al., 2022; Chanchaichujit et al., 2019; Sharma & Jain, 2024; Khalil & Bou Abdo, 2022; Jayaraman et al., 2020; Klinker et al., 2020; Alkhatib et al., 2024; Kumar et al., 2020; and Al-Jaroodi et al., 2020).

Our review starts with a brief discussion of TAM as a reference model used to evaluate acceptance of technology and one that can be (and has been) adapted to address this in healthcare systems. TAM was introduced in 1985 based on psychology methods to provide a formal assessment tool for acceptance in the information technology field (Marangunić & Granić, 2015 and Holden & Karsh, 2010). Some studies highlighted the effectiveness in predicting acceptance levels (Rahimi et al., 2018 and Ammenwerth, 2019). One example of its use is measuring users' willingness to use wearable devices in Industry 4.0 applications (Cheng et al., 2020); how well augmented reality is accepted (Rauschnabel & Ro, 2016); techno-logical solutions used during the COVID-19 pandemic (Geng, & Demuyakor, 2022); and using TAM to under-stand the usability aspects of personal self-assessment applications (Knox et al., 2021). Other work focused on using TAM to evaluate healthcare providers' and administrators' perspective on how easy it is to use technology in their field (Nguyen et al., 2020) and what affects nurses the level of acceptance of health information systems (Baratpour et al., 2017). Some also covered factors that affect how the elderly would accept and use healthcare technologies (Portz et al., 2019; Smarr et al., 2012; Cruz et al., 2022 and Dimitrova & Ketikidis, 2022). Furthermore, TAM was used to identify the barriers to using telemedicine in remote areas an article by Holtz et al., 2022 and Biancone et al., 2021 shows how TAM helps identify critical variables that may affect the acceptance of telemedicine.

Healthcare applications being evaluated using TAM grew in numbers, thus some questioned its adequacy for such applications. TAM's suitability for healthcare applications from the management perspective was addressed in Zhang et al., 2019 and a modified version was proposed to integrate stakeholders' perspectives with the evaluation method used in TAM. Another revised version of TAM was introduced to evaluate healthcare professionals' acceptance of healthcare information systems (Ketikidis et al., 2012). This proposed modification adds categories like ease-of-use relevance to healthcare and social factors as variables to consider in the model. Following, many additional adaptations, updates and modifications were proposed to add criteria like user satisfaction, safety, and privacy to the model (Akritidi et al., 2022), while others suggested to add credibility, irreplaceability, compatibility, perceived trust, and intention to use to the model (Ahmed et al., 2020; Nasir & Yurder, 2015 and van der Ham et al., 2020). Another model, ECM (Expectation Confirmation Model), was used along with TAM to predict the likelihood e-health services will be used long term (Kumar & Natarajan, 2020) and others added usability and social behavior theories (Tao et al., 2020).

Others proposed to integrate TAM with the theory of planned behavior (Seth et al., 2019), while others considered the extension of TAM to help evaluate the intentions to adopt IoT-based healthcare applications (Liu et al., 2022). Several other studies applied TAM to measure the acceptance of healthcare applications such as digital mobile technologies (Geng & Demuyakor, 2022); self-management app, COPD.Pal® (Knox et al., 2021); Health wearable devices (Ahmed et al., 2020; Nasir & Yurder, 2015 and Sun & Rao, 2015); use of smart phones for health applications (Abolfotouh et al., 2019); e-health services (Kumar & Natarajan, 2020), health information and patients portals (Portz et al., 2019 and Tao et al., 2020); Digital Cognitive Rehabilitation (van der Ham et al., 2020); Hospital management technology (Seth et al., 2019); telemedicine (Holtz et al., 2022 and Biancone et al., 2021); hospital information systems (Baratpour et al., 2017), IoT-based health management tool (Liu et al., 2022 and Tamori et al., 2022).

In general, these studies have shown that human factors are prominent in the decision to adopt a technological

solution, while social norms and influences had high impact as well. Many of the studies (described above) and several others like Yang Meier et al., 2020; Hsiao & Chen, 2016; Holden et al., 2016; Sharifian et al., 2014; Sıcakyüz & Yüregir, 2020; Issom et al., 2020; Ziefle & Calero Valdez, 2017; Gücin & Berk, 2015; Choudhury & Urena, 2022; Tu et al., 2022 attempted to pinpoint the human and social factors affecting Healthcare 4.0 and smart healthcare applications' acceptance and usage levels. As a result, several factors were identified. The following list provides examples of such factors.

1. The perceived level of privacy, confidentiality, anonymity, and trust in these systems.
2. The levels of security, reliability, and availability these applications guarantee.
3. The operational safety and control in addition to ownership and accountability.
4. Usability, accessibility, and amount of effort needed to learn and use the applications in addition to the availability or training and support resources.
5. The perception of benefits, usefulness, and convenience of use. In addition to motivations and incentives for use.
6. Performance and quality expectations versus the cost of adopting and using the applications.
7. The personal characteristics of the user base such as age, literacy levels, beliefs, health consciousness, and the knowledge of and attitude towards technology.
8. The social influences such as influences from others, community connections, culture, social norms, and socioeconomic levels.
9. External impact such as rules and regulations, policies, and legislations, and governance.

Several studies investigated the human and social factors that can affect how successful the adoption of healthcare applications in general and Healthcare 4.0 and smart healthcare applications more recently. However, the majority of these studies focus on one or very few applications of the same type. They discuss specific factors as they impact these select applications. We were not able to find published work specifically addressing these factors in a general form as related to any Healthcare 4.0 and smart healthcare applications. In addition, most of these identify the factors, but do not offer solutions. As a result, we are attempting to collect some of these factors and discuss possible approaches to address them to improve the acceptance levels of Healthcare 4.0 and smart healthcare applications.

Human and Social Factors Significance

When it comes to healthcare, patients' employees and employers contribute heavily in generating a multitude of data that can be used in various healthcare applications. With Healthcare 4.0, the data collection becomes more invasive and frequent, making it hard for many to accept. Many of those impacted view such applications as invasive while also feeling that this data is not being protected nor used appropriately. For example, contact tracing apps used during the COVID-19 pandemic were instrumental in the efforts to track and contain the disease. However, many refused to use them as they viewed them as invasive and a violation of their freedom and privacy. Generally, those opposing the use of such apps cited not wanting to be tracked, not trusting where and how the data will be used, and their fear of security risks that may expose their data as the reasons for their opposition. Similar responses were seen with regard to many other monitoring and tracking applications used to support patients or the elderly in their homes. Moreover, there are many occasions where healthcare data are used in ways that could harm their owners like when data breaches happen in healthcare information systems and personal data is leaked. Recently the Dobbs v. Jackson Women's Health (Dobbs v. JWHO, 2022) raised many questions regarding medical (specifically pregnancies and related information) access and how to protect women from legal persecution due to such access. Many, since are trying to stop the use of ministration, sexual activity and female health tracking apps in fear of legal actions if the data is re-leased to authorities.

Another characteristic of these applications is that they are highly coupled with human life, which makes it hard for users to be convinced of their safety and reliability. Unlike electronic health records (EHRs), which collect data

provided voluntarily by the patients during their doctor visits, Healthcare 4.0 applications rely on smart monitoring devices that always collect this data continuously and at all locations. It literally becomes part of their lives, and they feel they must adapt to them and consequently become reluctant to use them. They would feel like they are being watched all the time, which makes them uncomfortable and disruptive to their lives. Here we can also see the social effects from people within the same neighborhood, for example some opposing the use of such monitoring devices in their public spaces and making those who use them feel unwelcome.

We will start by identifying the different groups of people who interact with and use Healthcare 4.0 and smart healthcare applications so that we can clearly identify the various human factors affecting these different groups. In addition, identifying these groups is necessary as the perceptions and levels of acceptance of Healthcare 4.0 and smart healthcare applications among these groups vary drastically. These groups can be divided as follows:

1. Healthcare administrators and staff who manage the operations; perform day-to-day operational tasks; and ensure the smooth operations of all the facilities and services. This group can also be considered highly educated, yet do not have deep knowledge in medical issues for example. As a result, their views of these applications will be different when considering applications in their operational scope versus those for medical or care facilities and services.
2. Healthcare professionals including surgeons, physicians, therapists, lab specialists, nursing staff, and all others who are directly involved with the patients. Generally, these are well-educated people and have some good understanding of technology and its impact on their responsibilities. However, they may vary in their knowledge and familiarity with technology due to various factors like age and the type of work they do.
3. Healthcare systems partners like insurance companies, suppliers, and service providers. Several Healthcare 4.0 applications involve this group and require their buy-in. However, their views and different types of work experiences will affect their views of using such applications significantly.
4. The patients, who are highly connected to and affected by such applications, come with a multitude of different defining characteristics like age, education, socioeconomic level, and social and personal beliefs. This is a difficult group to characterize as they cover the entire spectrum of human types. Some are highly educated, some are pro-technology, some strongly oppose it, some have difficulties learning how to use it, and some do not want to change. Yet, they all have a common characteristic, they want to get better, and this may help them be more willing to accept technology.
5. The general public who may be patients advocates, relatives, care givers or anyone who may in one way or another be involved with healthcare. Those people vary in characteristics like the patients and will in many ways be using some of these applications too. This is the most difficult group to characterize as, like the patients, they have a multitude of differing properties, and they may not have the motivations the patients have to help them accept these technologies.

A good look at these groups makes it clear how difficult it is to quickly identify the human and social factors and find suitable solutions. One approach that could be acceptable to some groups may strongly be opposed by others. As a result, the successful deployment, acceptance and use of Healthcare 40.0 and smart healthcare applications heavily depends on addressing the various factors affecting the groups that will be using them. Here we extend our summarized list of factors (in Section II) and briefly discuss their significance.

1. **The perceived level of privacy, confidentiality, anonymity, and trust in these systems**. This is possibly the most prominent of these factors and has appeared in various studies as important factors that could hinder the adoption of these applications. The invasive nature of the applications raises big concern among the users as to how their privacy is protected and who has access to the data and how the data is to be used. It is necessary to provide the users with the appropriate assurances regarding these aspects. In general, these concerns are common among all groups; however, it seems that groups that are less familiar with technology tend to consider them least (possibly because they do not perceive their significant impact). In addition, healthcare professionals may be less resistant to such applications as they can clearly see their benefits.

2. **The levels of security, reliability, and availability these applications guarantee**. When deploying these applications, it is important to provide and illustrate the measures to ensure the security of these applications to reduce risks of security breaches, data loss or theft, and correct operations. The consequences of successful security attacks in these systems are not limited to loss of property or data, but also to loss of life. Similarly, the reliability and availability of these systems are essential for the same reasons. If users are not convinced of the applications' measures to achieve high security, reliability, and availability, they are less likely to accept using them. Administrators and healthcare professionals may be more aware of these issues and more concerned about them than other groups.

3. **The operational safety and control in addition to ownership and accountability**. People are aware that healthcare services directly affect human wellbeing. Therefore, they need assurances that these services are performed as safely as possible, and that accountability and responsibility are well defined. In addition, they need to have some control over why, who, when, and how their involvement with such applications is exposed. These factors are difficult to measure and just as difficult to satisfy. Here we can see a strong contrast in acceptance levels based on this factor; healthcare professionals may be able to understand the risks and make educated decisions regarding the use of such applications, while patients may be much more reluctant as these applications have a much bigger impact on them.

4. **Usability, accessibility, and amount of effort needed to learn and use the applications in addition to the availability of training and support resources**. People in general resist change due to the perception that it will lead to more work from them. Therefore, accepting and adopting new applications depends highly on how easy it is to use the applications, how accessible they are to everyone who needs them and how much effort users need to exert to use them. In addition, the availability of accessible training and guidance may increase the likelihood of adopting some technologies. Here the impact is somewhat similar across the different groups; however, the variations may arise due to the differentiating characteristics within the groups. For example, older people and people with special needs may have more difficulties learning to use the applications and leads them to feel that it is difficult to change. Some elderly people may also refuse to learn because they feel that it is too late for them.

5. **The perception of benefits, usefulness, and convenience of use. In addition to motivations and incentives for use**. These factors, if present, can help improve acceptance and utilization of these applications among the different groups of users. Doctors, for example, will welcome the use of applications that will make it easier for them to find and use patient's records but are generally not happy to use applications that make their job more like data entry. Patients on the other hand do not care how their records are made available but want to be able to check in for their appointments easily and seamlessly have their prescriptions sent to their pharmacy. Yet, they may be reluctant to use an application that will require them to go through multiple steps and enter a lot of data. Caregivers, however, would welcome applications that will make it easier for them to man-age their patients, but cringe when they find out they need to learn a lot of new things before they can use the applications. Another example is adoption due to certain needs and perceived benefits like telemedicine, which, just 3 years ago, some people viewed as unworthy and ineffective. Yet, when the COVID-19 pandemic hit, many of them realized that telemedicine was necessary to get the medical help they need and avoid getting infected, then when they used it, they were able to see its effectiveness as well.

6. **Performance and quality expectations versus the cost of adopting and using the applications**. People are generally impatient and want to see the results of their activities instantaneously. Performance, thus, becomes a critical factor for accepting these applications. It also has a strong influence when considering costs. Regarding these applications, the different groups' perceptions of performance, quality and value vary depending on who they are and what applications they are considering. Surgeons, for example, value high performing applications that help them simulate surgeries for practice and consider it worth an investment.

However, administrators will be looking at the cost/value factor more intently and may not see the same value of those applications as the surgeons. Patients will appreciate the prompt responses and services of a robot delivering food and medication, but do not care for its cost. Yet, the staff will be unhappy about using such technology because it could reduce the need for them.

7. **The personal characteristics of the user base such as age, literacy levels, beliefs, health consciousness, and the knowledge of and attitude towards technology**. These factors must be studied carefully as they deal with various aspects that technology may not be able to address. Many studies on technology acceptance discussed these factors and a lot of contradicting results were reported. For example, many believe that older people (with less technology literacy) are most likely to refuse to use such applications, yet many studies found the opposite or found that age was not a factor. Personal beliefs are also difficult to identify and may have a strong impact on whether a user will be willing to accept these applications. Regardless of what group the users belong to, these factors will lead to differences within the same groups.

8. **The social influences such as influences from others, community connections, culture, social norms, and socioeconomic levels**. Many studies identified social influence as a strong factor in determining how people may accept such applications. Some potential users cite the lack of empathy of the applications and the potential to limit or even eliminate human connections as deterring factors. Groups like patients and the general public possibly are more susceptible to such impact as they consider applications that were not originally part of their social norm. On the other hand, healthcare professionals, administrators, and partners may see less influence of these factors as they evaluate and use these applications as they generally do not become part of their social lives.

9. **External impact such as rules and regulations, policies and legislation, and governance**. These factors have to do with many external entities and the levels of influence they impose on the applications and the users. Governments may impose some restrictions and regulations governing the deployment and use of this type of applications. Healthcare organizations may also internally impose other policies and rules for these applications. Users will generally have to comply with such regulations when using or considering the use of these applications. In addition, some users accept the idea of their government requiring the use of some applications, while others in others in other countries may consider that a violation of their rights and freedom.

Table 1 represents our view of the impact of these factors on how well users of the different groups may accept the new technology and adopt the Healthcare 4.0 and smart healthcare 4.0 applications. The measures are mere estimates based on the overall perceptions of technology in the various acceptance studies we reviewed. However, they can provide a good insight into what factors are more impactful and thus should be prioritized. For example, privacy is a much stronger concern to the patients because they have a lot of personal and confidential data that they would not want revealed or abused, while operational safety is a big concern to both the pati4ents and their doctors and nurses. We should also recognize other human factors that unfortunately do not frequently appear in this line of research. Two of these are ethics and bias. Both depend heavily on the humans developing, managing, and using these applications and how they choose to do that. However, recently there is a growing interest and discussions about ethics and bias in technology. Whenever there are some interactions and exchange of knowledge about people and their lives, ethics become a serious matter. As healthcare applications gather more and more data and some users gain some advantages because of their knowledge over others, we start wondering how these groups will use that knowledge.

As for bias, the issues arising are becoming serious and making it harder for users to accept new applications for fear of bias (against them). Over the years some studies have shown how some applications may function differently based on the characteristics of the person using them. Applications using artificial intelligence (AI) are an example where bias may be of great consequence as (AI) is only as intelligent as the humans who develop it; thus, they are

also as biased as those people. In addition, many devices designed to use some form of human characteristics can become biased if not all variations of these characteristics are included in the design. One example is the design of a facial tracking system and a soap dispenser both of which function well with light-colored skin but fail to detect darker colored skin (Technomax, 2017).

The studies conducted using TAM and other similar models have shown the different reasons why users may not accept adopting or using a certain technology and using the relevant studies in this area we identified the various human factors that arose from these studies. In addition, various articles proposing or developing Healthcare 4.0 or smart healthcare applications cited several of these factors as challenges for their proposed solutions. As a result, it is necessary to identify what factors may be possible to address so that researchers and developers can include possible solutions along with their proposed or developed applications.

Table 1. Estimated impact of the human factors for the groups of potential users.

#	Human Factors	Administrators	Practitioners	Partners	Patients	Public
1	Privacy, confidentiality, anonymity, and trust	Moderate	Moderate	Moderate	Very High	High
2	Security, reliability, and availability	High	Moderate	High	Moderate	Moderate
3	operational safety, control, ownership, and accountability	Moderate	Very High	Moderate	Very High	High
4	Usability, accessibility, learning curve, training, and support	High	Very High	High	High	High
5	Benefits, usefulness, convenience, motivation, and incentives	Moderate	Very High	High	High	High
6a	Performance, quality	High	Very High	High	Very High	High
6b	Cost	Very High	Moderate	High	Moderate	Moderate
7	Personal characteristics of the user base	Moderate	Moderate	Moderate	Very High	Very High
8	Social influences	Moderate	Moderate	Moderate	High	Very High
9	External impact	High	Moderate	High	Very High	Very High

What Human Factors Are Addressable?

Here we group several of the factors together based on how it may be possible to address them. Overall, we found that some factors may be resolved by applying techniques and technology solutions already available, while some require more advanced approaches that are being considered or may come up in the future. However, there are also some factors that may not be resolved with technology no matter how advanced it gets. These usually require different types of interventions like education, public awareness, and incentives.

1. **Current technology**. Some of the human factors may be addressable by incorporating suitable methods into the applications or integrating these applications with other applications that help resolve them. For example, there are many well developed and tested security measures that can be implemented into applications to protect data at rest and in transit. There are also many methods to detect and mitigate security attacks which can be integrated with the applications. Furthermore, current advances in ICT (Information and Communications Technology) and the resulting Healthcare 4.0 and smart healthcare applications developments have resolved many issues relevant to privacy and confidentiality, security, performance, reliability, access control and usability. The use of smart devices, intuitive interfaces, high performance computing infrastructures, high speed networks and strong security and encryption models ensure high quality and high level of confidence. In addition, the ability to reuse, adapt and incorporate such solutions increased the usefulness and value of the applications and highlighted the conveniences and advantages these applications bring. It is also notable that a lot of hardware and software components used in these applications have become more accessible, cheaper and offer high performance levels. However, software custom

solutions are still very expensive and seem to remain one of the major obstacles for adopting Healthcare 4.0 among smaller organizations.

2. **Future technology**. Despite the vast improvements in current technologies, there are still many proposed Healthcare 4.0 and smart healthcare applications that need more advanced technology solutions than what is currently available. Improvements in various areas like hardware and storage capabilities, network performance and security, software reliability and availability, usability and access controls are necessary to facilitate better applications and lead to higher acceptance and adoption levels. One major issue is privacy protection, which despite all advancements, is still lacking. We anticipate newer tools and methods to manage private data will become available and enhanced solutions will be developed that will assure users of the privacy of their data and lead to higher confidence in using these applications. In the same line, new technologies offer better access controls, improved ownership and control models and more tangible protection methods will further improve the situation. Infrastructure improvements and increased performance and other capabilities will increase the effectiveness and operations of such applications and allow for more features and measures to enhance acceptance. For example, imposing strong encryption requirements on real-time interactive applications will drastically slow them down and if we were to have more powerful processing units to perform the encryption, we can have much faster responses and better user satisfaction. Similarly, many current applications have problems with their user interfaces that make it hard for users to accept them and be comfortable using them. The introduction of new technologies to enhance these interfaces and reduce their visibility to the user will make it a lot easier to accept them. For example, new technologies providing immersive experiences, enhanced voice- and gesture-based interactions and non-biased access could entice more users to use these applications. Another issue that may be resolved with more advanced technologies to help improve some of the interface and operational methods to reduce bias and support equitable use of these applications.

3. **Non-technical solutions**. Given the large spectrum of users' characteristics, it is clear that not all acceptance barriers can be resolved with technological solutions. There are various aspects that require approaches that could change the users' understanding, knowledge and perception of Healthcare 4.0 and smart healthcare applications. Among the most important issues requiring non-technological solutions are security and privacy. It is well known that no matter how strong and effective the security and privacy measures are, one human error could negate them all. Some users are aware of this type of problems and simply refuse to use new applications and technologies for fear of these problems, while others are not well versed in this area and would be careless when using the applications and thus leading to security breaches and other relevant problems. As a result, people become more skeptical of these applications and assume they are not secure, or they will not protect their privacy. Similarly, safety can easily be compromised by human errors or lack of appropriate knowledge. For example, an autonomous medication dispenser will work perfectly until someone loads the wrong medication into the machine. Such risks make it hard for users to adopt these applications. Unfortunately, no number of technological advances can eliminate such issues completely. Users' characteristics are another area where technology may not always be able to address. Technology literacy and health consciousness are examples. These may be mitigated through education and coaching but have nothing to do with technology. Disparities in socioeconomic levels also make it hard to convince all users of the feasibility and usefulness of such applications if they do not have the means to access or use them. In addition, the perceived benefits and incentives to use these applications play a role in acceptance and adoption. If users are aware of the benefits, have appropriate motivations and incentives, they would be happy to use the applications, yet, if they do not see the benefits or have no incentives, it becomes harder to do so. A major issue to handle as well is the shortage of qualified and skilled design and development teams to build these applications. Overall, there is a big shortage of qualified computing and technology professionals, and this must be addressed quickly. In addition, the application users need to be properly trained to use these applications. Healthcare professionals and workers will need appropriate training

programs and suitable incentives to use these applications. As for the patients and general public, they need to be educated about the benefits and advantages of these applications and given adequate learning methods to be able to use them.

4. **No solutions**. In this category we face issues and factors that cannot be resolved or changed quickly. Acceptance can be heavily affected by social influences, culture, beliefs, superstitions, and traditions, all of which are very hard to penetrate and change. Many of these factors developed and were nurtured through multiple generations and it is extremely difficult to overcome. Education may help as increased levels of literacy can alleviate some of these influences. This takes time and a lot of organized efforts to affect some improvements. Thus, we must rely on time and long-term planning. Improved educational systems, higher emphasis on technology use and benefits may help improve the situation gradually. Another-er strong influence on acceptance arises from the large disparity in the socioeconomic status of the user base. Once more, some possible approaches to address this may include improved overall education and employment prospects, programs, and funding to make technology more accessible to disadvantaged groups and possibly finding ways to reduce the costs of these technologies to make them more accessible to a wider range of people. Some external factors may also prove to be difficult to tackle as they require strong political will and long-term strategies to work on changing or improving relevant legislation or policies. Furthermore, adopting global solutions is also difficult as different countries have different regulations on software and technology use, especially for applications that are highly involved with humans like Healthcare 4.0 and smart healthcare applications. This also brings us to ethics and ethical misconduct as there are always risks of misuse of applications and data.

The ability to understand and distinguish the types of human factors and how they can be addressed is important to help organize the efforts and ensure the right focus on real problems. When trying to increase the acceptance prospects of Healthcare 4.0 and smart healthcare applications, it is necessary to include adequate consideration of the human factors and identify which can be addressed in each application. In addition, different groups in technology, education, legislation, and other relevant areas will need to work together to create long-term plans to improve education, skills and, subsequently, acceptance of such applications.

The COVID-19 Case Example

The Covid-19 case is an excellent example to illustrate how unexpected or disastrous situations can help make the shift towards acceptance faster despite the social and other external factors hindering it. While many internal and external factors within society influence the adoption of or abstinence from newer healthcare technologies, environmental factors have not been posed as a prominent influencer of mass change. Throughout history, major disasters led to acceptance of methods, tools and technologies that people were hesitant about just before these disasters. Traffic laws enforcing speed limits, penalizing drunk driving, and the use of seatbelts, did not take hold until after numerous fatal accidents occurred due to these factors.

A more recent encounter was the Covid-19 pandemic, which quickly highlighted the necessity of many technologies that existed earlier, including Healthcare systems and technologies, and increased their acceptance. Online education was generally considered as inadequate or of lesser quality than regular in-person education. Over time and with advancements in the technology supporting online education, people started seeing some value to it, but this took a very long time. However, suddenly after the COVID-19 lockdown, it became necessary to rely on online education and many quickly saw its value and more work to make it better and more effective was done in a very short period of time. Now, after the situation improved, many opted to continue to use some forms of online education even though the situation mandating it has been resolved. In the healthcare sector Covid-19 had the same effect on various healthcare systems that were not regarded highly before. Now, more than ever have Healthcare 4.0 and smart

healthcare applications been accepted, funded, and implemented. Evidence for this lies in the contrast between the perception of smart healthcare before and after the height of the 2020 pandemic.

A study in 2014 was conducted to gauge the perception of wearable, smart health devices to the independent elderly. The elderly participants were given the devices and trained on how to use them. Despite the overall positive reception, many issues were raised. Participants cited privacy, unreliability, and utility as major problems with the product (Steele et al., 2009). Some felt that the monitoring device was of no real threat to their privacy, while others mistook monitoring for surveillance, and did not like the perception of being watched. Many questioned the necessity of the device when other non-invasive devices existed. Since then, similar technologies have been developed and refined and acceptance slowly increased. However, it still took a long time. Suddenly, when the pandemic hit, similar devices and technologies quickly became widely used and many saw great benefits using them.

The restrictions that the pandemic brought about left many without physical aid from healthcare practitioners due to lockdowns. As a result, remote monitoring systems became appealing. Devices that collect medical information and send it to medical personnel have become acceptable. This did not only impact quarantined individuals, but the elderly and those suffering from chronic conditions too, thus allowing patients to receive medical care at home and ease the strain on medical personnel (Taiwo & Ezugwu, 2020). This led to higher acceptance levels even when the cause, the pandemic, was gone. Another example of this research is the potential that AI has on the daily functions of the physician. The research predicts high benefits of using AI, yet also acknowledges it is disruptive and is rumored to replace employees, although the research claims the goal is for AI to assist physicians, not replace them (Ahuja, 2019). Furthermore, due to the pandemic, AI was proposed as a promising method of creating predictive models for pulmonary disease, including Covid-19. (Khemasuwan et al., 2020). With the advantages it brought and the assurance that the technology is beneficial, acceptance came.

The reason for the change in acceptance in these cases is due to the uprooting of some pre-pandemic social norms. Lockdown alone led many to adapt to their lifestyles. Coupled with the influx of patients in hospitals, insufficient medical personnel, and inadequate planning, the importance of healthcare's digital transformation was made clear. All the while, support for the advances in healthcare grew, as the populous and governing bodies wanted to prevent the spread of Covid-19. Virtualized healthcare systems (telemedicine, virtual doctors' visits) were accepted and used as their funding by institutions grew (Dwivedi et al., 2022). Research into technology also increased as proposals for ideas to help mitigate the effects of the pandemic arose.

The Covid-19 pandemic highlighted the utility of Healthcare 4.0 and smart healthcare applications in the modern era. It and the societal shift that followed paved the way towards larger technological acceptance and utility. The reason for the change in acceptance in these cases is due to the uprooting of some pre-pandemic social norms. The lockdown alone led many to adapt to their lifestyles. Coupled with the influx of patients in hospitals, insufficient medical personnel, and inadequate planning, the importance of healthcare's digital transformation was made clear. All the while, support for the advances in healthcare grew, as the populous and governing bodies wanted to prevent the spread of Covid-19. Virtualized healthcare systems (telemedicine, virtual doctors' visits) were accepted and used as their funding by institutions grew (Dwivedi et al., 2022). Research into technology also increased as proposals for ideas to help mitigate the effects of the pandemic arose. The Covid-19 pandemic highlighted the utility of Healthcare 4.0 and smart healthcare applications in the modern era. It and the societal shift that followed paved the way towards larger technological acceptance and utility.

Approaches to Consider

In earlier work we provided a list of challenges Healthcare 4.0 and smart healthcare applications need to address (Al-Jaroodi et al., 2022). Some of these were technical challenges, while others were non-technical. The non-technical challenges included human factors. Yet, when we examine various technical factors, such as privacy, security, access

control, ownership and responsibility, and intellectual property and protected content, we can see that they have a strong influence from the human perspective. As a result, ad-dressing human factors will at the same time have to address various technical aspects of these applications.

Accelerating the transformation to Healthcare 4.0 and smart healthcare applications on an organizational level is underway and slowly resolving many of the technical challenges and some of the non-technical challenges as well. Making the transformation at a national and eventually on a global level is harder and more challenging, but still doable. With the appropriate preparations, long-term strategic planning, and collaboration across all stakeholders (healthcare professionals and administrators, healthcare partners, the supply chains, governments and people), the implementation and deployment of Healthcare 4.0 and smart healthcare applications will progress steadily and applying the necessary measures to increase adoption and acceptance of all will lead to great success. We need to work on finding and creating ways to increase acceptance and adoption levels by stakeholders. Examples of such efforts include:

1. Cultivating and growing the necessary skilled workforce that can help make the transformation happen. In addition to the software developers and technology professionals, we need to prepare the liaisons between the healthcare sector and these professionals. People in the healthcare sector who are capable of communicating their specific needs with the technology professionals are crucial. At the same time some of the technology professionals need to have a good knowledge of the healthcare sector's operations and requirements.
2. Educating and training healthcare professionals and administrators to increase buy-in and gain more support for the transformation. This is extremely important to create the necessary use base that will start using these applications and transfer knowledge to others in their field.
3. Securing the necessary resources to support the transformation. This includes the people doing the work, management, technology, time, and money. The transformation is an expensive venture, and management should understand the benefits and see the positive return on investment to commit to such projects and ensure the availability of the necessary resources.
4. Ensuring users acceptance of the transformation. Involving the healthcare professionals in the process will help increase the chances of their acceptance. In addition, it will be necessary to prepare other users such as patients and the general public to accept the transformation. This can be done through appropriate education programs, early exposure, adequate motivations and incentives, and clear identification of benefits and implications.

We believe that to improve human acceptance and adoption of Healthcare 4.0 and smart healthcare applications a holistic long-term strategic plan for development and deployment is a must. This plan must take into consideration all the human factors and incorporate, with the technical objectives, the necessary objectives to address the non-technical aspects of the human factors. Unfortunately, not many adopted this approach, and it is becoming difficult to incorporate solutions that will address the hu-man factors adequately in existing applications. In addition, the non-technical nature of some of these factors and their solutions make it harder for the technology professionals/researchers to consider them as part of their technological solutions. This also emphasizes the idea of a collaborative approach to the transformation that will include representatives from all stakeholders to include and accommodate for all their different needs.

A holistic approach, which keeps in mind the human factors and the non-technical nature of many of them, should examine the current solutions in use; solutions under investigation and/or development; and future solutions, while keeping the human factors in that light. Any proposed solutions involving any of these must incorporate components addressing human factors. The successful transformation to Healthcare 4.0 and smart healthcare applications, we believe, requires collaborative work of not only the technology and healthcare professionals, but also all the other relevant sectors that may help improve human acceptance of this transformation. Education systems, the legislative bodies, and organizational leadership in all relevant fields must be involved. Long-term changes in various systems

need to be adopted slowly, but surely, pave the way to higher acceptance levels and improved effectiveness of Healthcare 4.0 and smart healthcare applications.

1. The education systems need to address the literacy aspects among the public starting from the early stages of schooling, to help increase interest in technology and technology development among students and increase the number of skilled computing and technology professionals that can support the transformation.

2. General education and public access to information regarding such systems and the transformation efforts will also help enhance the public's knowledge and eventually acceptance of the technology. In addition, proper representations of these technologies, their benefits, their problems and their objectives should be made public so people can understand them. One important factor here is creating some form of trusted entities that can provide such information without ulterior objectives or hidden agendas as people are bombarded with information and misinformation from all directions.

3. Legislative bodies need to recognize the value of this transformation and the intricate connections between technology and the law. We believe that legislators need to be knowledgeable, to a certain degree, of the issues and implications of adopting technology in critical sectors like healthcare at such a large scale and appreciate the need for more relatable legislation and policies.

4. Healthcare administration and leadership need to see the long-term return on investment of the transformation. They need to understand and accept that this project is huge, never-ending, and expensive. However, the benefits in the long run are also huge, numerous and extremely beneficial for all.

5. Healthcare professionals need to be aware of the benefits of the transformation and its impact on their jobs. The positive impact will easily be observed and accepted. However, the negative impact needs to be addressed and met with measures to match them with other benefits. For example, using autonomous patient monitoring systems will reduce the need for nurses to do this task, making them fearful of losing their jobs. However, it is important to note that nurses will be freed to do more important work that they had to delegate to others or ignore and they could work on much more comfortable schedules.

6. Patients will need to overcome their fears and skepticism of technology. There are many ways to help with that such as communicating and demonstrating the benefits; educating them about new services and tools that they can use; demon-starting the positive impact of using the technology are some examples. Yet, we also see that it is important to highlight the issues and problems that may affect them and provide the necessary assurances and education to help them understand and use technology appropriately to avoid these problems.

7. The general public should also be educated on technology, technology use and the benefits of technology and smart healthcare services. It is important to address issues of concern among the people regarding security, privacy, control, and reliability for example. It is also necessary to provide trusted sources they can turn to learn more and get accurate information about the benefits and issues of such technologies.

8. Emphasize the importance of ethics and ethical conduct when using and dealing with any type of application that can affect others. In healthcare systems, many stakeholders have varying levels of access to a lot of public and private data, and it is important that everyone understands the limits of their access and authority when using these systems. Education is one way to do this; however, we believe this is an issue that may never be fully resolved.

A comprehensive digital transformation of the healthcare sector to Healthcare 4.0 and smart healthcare applications

is a long and winding journey. There are many obstacles to overcome, various issues to address, and many benefits to reap. It is important to go through the transformation process with the appropriate knowledge, the right intentions, and proper preparations to achieve success. It is imperative that long-term strategic plans are put in place and that everyone is willing and ready to take that journey.

Conclusion

Achieving a successful digital transformation to Healthcare 4.0 is like tracking a moving target. It is also an ambitious undertaking if we consider all that goes into it. This includes the technologies used, the software needed, the human resources and of course, the users of all types. As this paper illustrated, one of the major obstacles to this transformation is the human factors and how they affect the levels of acceptance and adoption of these technologies.

Examples of these factors include security, privacy, reliability, and usability, which could possibly be addressed with technological solutions. Yet we also have factors that cannot be addressed with technology but require other interventions and methods. Some examples include the users' personal characteristics, social and external impact and ethics and bias. To tackle these, we need collaborative efforts among many entities beyond the technology and healthcare teams. Education systems, legislative systems, and political power are some examples.

The journey is long and demanding and we have a lot of work ahead of us. With this work we hope to bring the human factors to the forefront and ensure that new technologies, solutions and transformation efforts will consider them as major requirements. We offered a quick view of human challenges and hope that it will help others build better solutions and include these factors as they embark on their transformation projects. We believe that any projects contributing to the Healthcare 4.0 vision should account for the human factor and find ways to incorporate solutions that will increase acceptance and adoption among all prospective users of the Healthcare 4.0 and smart healthcare applications.

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