



Critical review of mixed reality integration with medical devices for patient care

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Abstract: *This critical review evaluates the integration of mixed reality on medical devices for patient care. Over the years, scientists, researchers, and engineers have developed more efficient and sustainable technology to provide better patient care. Mixed reality provides an emerging research area towards understanding how they may overcome the current obstacles facing increased adoption of mixed reality and related technologies on medical devices for patient care. Thus, the main objectives to undertake this study is to understand the current state of adoption of mixed reality tools and technologies within the healthcare domain, strive to determine factors limiting the adoption of mixed reality inpatient care, and understand potential new opportunities to adopt mixed reality inpatient care. Furthermore, this research relied on secondary data sources from more than thirty publications that included online journals and materials. Based on the materials, it is clear that most of them focused on evaluating the potential application of mixed reality in healthcare. However, to overcome challenges related to adopting mixed reality in the field, there is a need to have better network bandwidth capabilities, better middleware services and technologies that are more HIPAA compliant for easier integration of mixed reality to medical devices.*

Key Words: *Mixed reality, Augmented Reality, Mixed Reality for Healthcare, Mixed Reality for Patience Care, Mixed reality for paramedics, Mixed reality in medicine, Healthcare Augmented Reality, Smart Healthcare.*

1. BACKGROUND :

The emergence of mixed reality and alternative forms of imaging and visualization techniques such as augmented reality and virtual reality has provided researchers within the healthcare field with an opportunity to evaluate how such technologies may be applied for better patient care. Mixed reality is a technology that blends the real and virtual worlds to produce new interactable visualizations. Such visualizations help unlock new opportunities to visualize and interact with various computing processes. Thus, mixed reality may be used in the healthcare field to unlock new potential through medical devices that integrate with mixed reality towards better care. As developed nations continue to face the challenge of increasing the aging population, there is a need to ensure that such populations are provided with better patient care through medical devices integrated with mixed reality. Unlike previous perceptions that mixed reality would have been predominantly used in other industries such as the gaming, entertainment, and media industries, it has also proven to provide viable opportunities in the medical field by integrating mixed reality with medical equipment and tools towards better medical processes. Thus, patients are able to get better healthcare services whereas healthcare professionals are able to issue high quality healthcare services to more people at a shorter period through mixed reality. For example, medical professionals have the ability to use mixed reality in issuing guidelines on how to the same type of emergency occurring on different locations but at the same time.

2. OBJECTIVES.

This research aims to evaluate the opportunities in integrating mixed reality with medical devices for better patient care, challenges that exist, and measures that may be undertaken to overcome such challenges. The following are individual objectives of the research.

- To study and understand the current state of adoption of mixed reality tools and technologies within the healthcare domain.



- To study and understand factors limiting the adoption of mixed reality inpatient care.
- To study roles that medical device manufacturers should play can play in terms of integration to improve patient care and adoption of mixed reality technologies among medical professionals.

3. LITERATURE REVIEW.

Different scientists, scholars, and engineers have undertaken numerous researches to evaluate the viability of integrating mixed reality technology in providing better healthcare services. According to Barba & Marroquin, mixed reality is a visual technology that strives to blend both the physical and virtual worlds to provide better interaction capabilities when interacting with computers [1]. Thus, mixed reality strives to infuse computing technology and processes with the real world, thus providing better interaction capabilities between the user and various computing processes. Thus, medical services can integrate such technology with existing medical technologies towards better patient services with such capabilities. Mixed reality has the potential of disrupting how technologies within the medical field can provide better medical services, as indicated below.

3.1. Remote Consultation

The integration of mixed reality technology and medical devices can provide better visual capabilities that display the current state, thus helping with their subsequent remote care and treatment. This may help with caring for elderly patients. Most elderly patients require special care due to challenges associated with old age. In most scenarios, they cannot utilize various digital medical devices due to poor vision and memory loss. Thus, there is a need to use technologies such as mixed reality for better care for the elderly. Through mixed reality, in scenarios where the elderly are physically challenged, such as poor vision or fatigue issues that make it harder to visit healthcare facilities, it is possible to use mixed reality in issuing remote care. Considering that most developed countries such as Canada, Finland, and Japan are grappling with the challenge of having more of their working population retiring and becoming the elderly, there is a need to provide them with better care [20]. Mixed reality may help provide better patient care services at a cheaper cost, considering most elderly don't work.

Mixed reality provides reliable visualizations that may help issue consultation services to patients when it is challenging for them to get the desired healthcare services. For example, in situations where individuals are in a remote geographical area, camp, or work-related activity, they may use mixed reality to consult with medical personnel. Mixed reality may also be beneficial in providing remote consultation services. Remote consultation reduces the needs of patients who are not in critical need to physically various factors and travel to a healthcare facility. This, in turn, reduces time and costs that would have been incurred when traveling to the healthcare facility. The Covid-19 pandemic brought the need for individuals to embrace remote healthcare services due to the challenges and inefficiencies caused by the pandemic [6].

3.2. Preoperative planning

In an era where perfections are required when undertaking various medical operative procedures, there is a need to ensure that preoperative procedures are undertaken with perfection to provide a starting point towards effective medical operations. Mixed reality technologies may provide visual displays of medical technology undertaken on the patient to determine the best strategy for undertaking the medical operation. Surgical site preparation is critical to establishing a conducive operating environment when undertaking medical operations. Mixed reality technology may be integrated with tools for preparing surgical sites to help in providing better visualization on the perfect surgical site setup for successful medical surgeries [14]. Finally, a major procedure before medical surgery involves determining surgical incisions. Thus, mixed reality is being evaluated by medical researchers to be used as a tool for determining surgical incision points within a patient's body for successful surgeries.

3.3. Staff safety against contagious disease

The Covid 19 pandemic provided healthcare service providers with the challenge of physical contact with any patients due to transmission of the virus between individuals through touch. This has presented an opportunity to evaluate mixed reality as a tool for providing staff safety against contagious diseases [20]. Thus, in such a scenario, mixed reality ought to have been used as a remote consultative procedure to minimize the number of contacts with patients that healthcare providers are issuing their medical services. Similarly, when the staff is handling other contagious diseases such as Ebola, instead of physically screening or diagnosing such patients and risk being infected with the same disease, they may apply medical diagnosis devices integrated with mixed reality to provide more accurate



visualizations on diagnosing and treating such patients. As the world continues to experience increased populations and industrialization, then more contagious diseases are likely to emerge [18]. It may be challenging for medical providers to provide the desired services safely without contaminating themselves, considering they will likely be handling more patients than expected. Thus, mixed reality will help such personnel provide higher quality medical services without contaminating themselves.

3.4. 3d Annotation

According to research undertaken by the society to improve diagnosis in medicine, between 10%-20% of autopsies across the united states of America indicate that the death of the patients occurred as a result of a misdiagnosis covid [9]. Thus, between forty thousand and eighty thousand Americans die of diagnostic errors yearly from the total deaths. This is a huge number that shows cases may be worse in the middle-developed and developing economies of the world. Mixed reality provides medical professionals with an opportunity to reduce such diagnostic errors by promoting the application of three-dimension (3D) Annotations for diagnostics-related notes. Thus, medical professionals can get better visualizations on diagnosis data collected from the patients to get accurate diagnosis results [10]. This reduces the number of misdiagnosis cases that would have deteriorated the patient's condition or even caused death.

3.5. Medical Visualization

In an era, the ability to deliver high-quality healthcare services is highly dependent on patient data; there is a need to endure that the information is availed to the medical personnel in the desired timeframe. However, patient data exists in different forms and may be collected from different healthcare service facilities visited by the patient over time to help the healthcare service provider determine the best diagnosis procedure to use [15]. Such data may be complex to analyze since it comes in different forms of analysis and diagnosis from different facilities, thus making it time-consuming and challenging for the healthcare service provider to diagnose the patients using such data. However, mixed reality technology may better visualize a patient's medical data, thus making it fast, easy, and accurate to diagnose a patient.

3.6. Remote support for paramedics

Medical emergencies may occur to a patient while not getting immediate physical services from medical personnel. For example, during a hike, an accident may occur in a remote area that is remote to access thus may take time to physically get a medic. Some of such medical emergencies are a matter of life or death to the patient, thus the need to give them the relevant medical attention before a medical professional is available to provide medical help to the individual. Patients may use mixed reality during scenarios of medical emergencies to get the desired help through instructions on how they should manage the emergency before the arrival of a medical professionals [4]. Medical professionals can guide the patient Patients may have better visualizations on instructions provided to them by doctors through better visualizations and demonstrations on how to handle such emergencies before getting proper medical help. This may help save the life of the patient facing the medical emergency or event prevent their situation from further deterioration.

Based on the information provided above, it is clear that mixed reality can disrupt operations within the healthcare field by streamlining them towards providing better healthcare services. However, even with the ability to provide such benefits, it is still at its adoption, and exploratory stages faced by various challenges that ought to be overcome for full integration of mixed reality systems on the subsequent application is still limited [5]. Currently, the adoption of mixed reality technology faces various challenges. They include data latency, privacy, content compatibility, awareness, and portability issues. Thus, to get the full potential of mixed reality technology, the challenges above should be addressed towards a more optimized adoption of mixed reality on medical devices.

4. METHODOLOGY.

The main methodology used in collecting material for this research involved using secondary sources of collecting data, mainly online materials including journals, publications, thesis, and any other form of research publication available and contained information relevant to the application of mixed reality technology integrated with medical devices towards the provision of better healthcare services. All the materials used in the research were subjected to an integrative review, content analysis, and Qualitative Synthesis. Furthermore, questionnaires and surveys concerning the subject topic were reviewed for authenticity before the subsequent data was utilized in developing this research. Thus, to get the relevant materials, different online databases were queried to evaluate information that would be relevant to helping with undertaking the research. The main databases queried are google scholar, research gate, IJRC, and science



direct. The key included when querying the databases include "mixed reality," "augmented reality," "virtual reality," "healthcare," and "medical devices."

Once the queries were entered, more than 170 papers, articles, and ted talks were identified to contain mixed reality data and subsequent applications in the healthcare field. However, to ensure accuracy and relevance on the collected information. The first step involved filtering out the results to include publication for the last seven years (since 2015). Further filters included ensuring that the materials were English, and reviews were undertaken to only include reliable and accurate information relevant to the subject matter. Upon initiating the filters, more than 140 publication papers did not meet the designed filter criteria, thus remaining with 30 papers and publications with information relevant to mixed reality integration with medical devices for patient care.

5. ANALYSIS / SYNTHESIS.

Upon reviewing the relevant material through the methodology indicated above, the next step involves analyzing and synthesizing the collected information. 55% of study materials showcase that mixed reality integration with Medical devices does improve patient care. This means that 55% of the materials analyzed for this report included information discussing integrating mixed reality to medical devices towards improving healthcare services offered to the patients. The information is also a clear indicator that the materials used in undertaking this research are relevant to it as they were a source for information in undertaking the research. 45% of the remaining materials either contained information on mixed reality technology and its capabilities, the need to advance visual technologies in providing better patient care services, and current challenges facing medical processes that may be solved through visual reality technologies.

26% of analyzed materials indicate that the integration enabled medical staff to make better clinical decisions related to patient diagnosis and treatment; this promotes optimization when delivering healthcare services. This is a clear indicator that mixed reality can provide better information to medical professionals. Based on this, it is clear that most of the researchers applying mixed reality on medical technologies believe that mixed reality provided medical information to clinical staff in a better way for them to make clear and informed decisions.

32% of findings indicate that mixed reality can improve the collaboration between clinicians, doctors, and nurses from the multi-location scenario. Mixed reality provides both patient and medical professionals with the flexibility of providing patients with the desired medical services without being physically close to them. Visual displays and interaction capabilities associated with mixed reality enable medical professionals to coordinate medical operations across different locations. The parties involved have the desired network connection to execute mixed reality capabilities on the devices.

25% of the materials indicate that the integration of mixed reality to medical devices supports Learning, acquisition of knowledge, and skill development for healthcare professional trainees, thus acquiring the desired skills. In an era where more healthcare professionals are needed to cover the existing gap between medical professionals and patients, there needs to be a faster way of ensuring medical trainees acquire the relevant skills within the shortest time possible to help cover such a gap. Thus, integrating mixed reality into medical devices will help such trainees understand and master the required skills needed to deliver the desired services to patients.

Finally, 45% study indicates that most healthcare professionals are open to adopting mixed reality tools; however, technological limitations create barriers to further adoption. This is a clear indication that more medical professionals are aware of the potential of using mixed reality integrated with medical devices towards providing better services. However, existing technological challenges such as network bandwidth and portability make it challenging to effectively adopt such technologies in managing organizational processes. Thus, there is a need to solve existing technological hurdles for a more effective adoption of the technology.

6. FINDINGS & RESULTS.

Based on the analyzed information, it is clear that mixed reality can enable better healthcare services to patients when integrated with medical devices. The potential of mixed reality in disrupting healthcare is imminent due to the potential benefits that have been previously identified in the report. However, for the disruption to occur and the actual benefits of mixed reality integration to medical devices to be attained, several challenges ought to be overcome. Such challenges are further evaluated below.



- 6.1. Data Latency:** Telemedicine professionals have continuously faced the challenge of data latency and computing capabilities while trying to access patient data in remote locations. This makes it challenging for them to establish reliable connection links between them and remote patients, thus making it hard or slow to establish effective mixed reality telemedicine services to such patients. Thus, most patients would find it slow or challenging to access remote services through mixed reality integrated into telemedicine devices [17]. This drawback requires more investments and research into providing more advanced networks with higher bandwidth capabilities to support mixed reality remotely.
- 6.2. Data Privacy:** over the last decade, data privacy has become a major concern among individuals. People have started becoming more aware of their rights to private data. On several occasions, big technology companies such as Facebook and Google have constantly been accused of accessing user data without their consent for their profitability [3]. This has made the users more aware of their rights and the need to keep their information private. When considering the nature and sensitivity of patient data, patients are concerned about exposing sensitive data and health records from EHR/EMR to external systems. This makes it challenging to convince such patients to allow mixed reality to access their data and transmit the same through mixed reality.
- 6.3. Content Compatibility:** Currently, there is a major challenge of manually converting the existing data into forms compatible with mixed reality. There is a major Need to manually convert the digital x-ray (DICOM) file from radiologist into 3dMax and then convert such data into hologram using Unity3d. This tedious process may be resource-consuming since it may need time and money to complete. Thus, it may discourage healthcare providers from immediately adopting mixed reality in medical devices until more feasible methods are identified to integrate such data into forms compatible with mixed reality.
- 6.4. Awareness:** Previous generations of medical professionals have been accustomed to leveraging desktops and tablets in managing the operations undertaken by various medical devices. However, considering that mixed reality headsets utilize different interfaces compared to tablet and desktop computers, it may become challenging for them to initially use mixed reality headsets in executing their desired data [16]. Thus, such professionals may be resistant to change and slowly accept the idea that mixed reality is revolutionizing the medical field. Such a challenge leads to the slow adoption of mixed reality in providing better patient care services.
- 6.5. Portability:** The current mixed reality headset design occupies a lot of space, thus reducing its mobility or the comfort that would have been expected for patients to travel with it. Currently, there is a challenge of reducing the device's weight without affecting the desired capabilities towards providing the desired medical services [19]. When considering that mobile phones and tablets are highly portable to allow both patients and doctors to travel with them anywhere they go, it may become challenging to convince both the patients and doctors not to use portable tablets or smartphones in favor of mixed reality devices.

7. OUTCOMES.

To effectively overcome the challenges listed above, the following important measures should be undertaken.

- 7.1. 5G Enablement for service layer:** when considering that mixed reality content such as 3d Holograms, Medical Visualization, Digital X-Ray is reliable on heavy network bandwidth, there is a need to establish technologies with better bandwidth capabilities. 5G can enable the transfer of huge bandwidth within the shortest time possible [9]. This would be beneficial to integrating mixed reality on medical devices since they would transmit the desired data through holograms, even with remote patients.
- 7.2. HIPAA Compliance:** Medical Devices, electric health records (EHRs), and Electronic medical records (EMRs) are already designed to follow HIPAA Compliance. However, during the integration of Medical devices, it is possible to create a Web Services layer in JSON that follows the necessary compliance parameters. This will help in enabling medical device manufacturers will be more confident to share data with the Mixed Reality Application.
- 7.3. Middleware:** middleware technology should be developed towards establishing more efficient measures in converting existing data to data compatible with mixed reality headsets [7]. For example, technology ought to convert digital x-ray, body anatomy, and other records into holograms compatible with HoloLens and similarly mixed reality headsets. This would make it easy for healthcare professionals to convert data towards the desired state.



8. CONCLUSION:

Based on the information provided in this report, it is clear that mixed reality and related technologies, when integrated with medical devices, can improve healthcare services for patients. Such potential lies across healthcare services, including caring for the elderly, issuing remote services, generating diagnostic notes, and providing accurate diagnostic visualizations. However, several challenges limit the healthcare industry from realizing the full potential and benefits of integrating mixed reality into existing medical applications. They include data latency, data Privacy, content Compatibility, awareness, portability. Measures to overcome such limitations include widescale adoption of 5G technology, promoting HIPAA Compliance, and enabling middleware technology.

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