Exploring New Opportunities for Mental Healthcare Through the Internet of Things (IoT)

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Abstract. The Internet of Things (IoT) provide new opportunities for healthcare to enhance the quality of life and safety of mental-health patients. However, only limited studies explore how IoT can be adopted to this end, and this study tries to fill this particular gap.

This research includes a literature review and five cases with semi-constructed interviews that position the use and adoption of IoT applications in Dutch mental healthcare. This paper presents an explorative, interpretative, and mainly qualitative multiple case study. The outcomes show that privacy, security, knowledge of new technology, and opposition from traditional medical professionals are essential factors that currently reduce the acceptance of IoT in mental healthcare and lead to low IoT use.

Keywords: IoT · Internet of Things · Mental healthcare · Sensors · Privacy

1 Introduction

Are the Internet of Things (IoT) appliances at a point of a revolutionary expansion? The IoT adoption in different business contexts, particularly manufacturing, is continuing to rise [1], and there have been many developments since then. One specific area that could benefit significantly from IoT adoption is healthcare [2] because the development of healthcare systems is expanding to almost every desired level by artificial intelligence (AI) [3]. The benefit of IoT in healthcare could decrease healthcare costs, rapid access to quality care, and extending the quality of life of patients [4]. However, despite these positive consequences, the adoption of IoT in mental healthcare has only been the focus of limited research and empirical studies.

IoT applications are numerous and are still growing in number. In 2025, the number of IoT connections on the internet is predicted to be more than 100 billion [5]. IoT's applications in healthcare, also known as "internet of health things" (IoHT), are ubiquitous because healthcare lends itself exceptionally well to IoT due to the various practical options [2]. This characteristic can be seen in many applications and information technology (IT) methods for IoT-enabled healthcare [6]. In 2020, the share of healthcare-related IoT applications will even be more than 40% [7]. An analysis of IoT applications in healthcare shows that home healthcare services are the most important

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and most significant group of IoT applications [8]. Besides that, according to Ahmadi et al. (2018), mobile, e-health, and hospital management are also essential areas that could benefit from the adoption of IoT applications within healthcare.

Mental healthcare is an integral part of National Healthcare in the Netherlands. Mental health is primarily concerned with the prevention, treatment, and the cure of mental disorders. Those with mental illnesses have to be supported through various means so that they can efficiently participate in society. When people are addicted or confused about seeking help independently, mental healthcare will assist these people. With approximately 723 mental healthcare institutions in the Netherlands, many providers offer mental health support and assistance [9]. Based on the expected positive effects of IoT in healthcare, it is likely that both patients and institutions in mental healthcare will experience positive benefits. Indications are that IoT's adoption and use in mental healthcare could improve a 'patient's quality of life and the effectiveness of his or her received medical services [10]. For example, when sensory data is used to enhance medical decision-making and enhance patient care [11]. With these positive effects of IoT adoption and use in mental healthcare, it is remarkable that limited studies about the opportunities, not to mention the threats or "hindering factors," have been conducted to point out the acceptance and implementation process of IoT in mental healthcare. From the perspective of this explorative research, it is necessary to get an answer to the following research question: *What are the main opportunities and threats associated with the adoption and use of IoT in mental healthcare?* The theoretical starting point for this explorative research is that new opportunities for IoT should add organizational value to mental healthcare institutions, benefitting both patients and practitioners. In that respect, this paper aspires to get an overview of IoT adoption and usage, specifically in the Dutch mental healthcare system.

1.1 Literature Review Method

The literature review method used in this research is a grounded literature review method in order to identify key themes related to "*IoT adoption and use in mental healthcare*". The following platforms were used to search key articles related to the topic of this study: Science Web, Google Scholar, EBSCO host, ScienceDirect (Elsevier), Science, PubMed, and the IEEE Digital Library.

1.2 Search Criteria

Empirical papers published between 1-3-2010 and 1-3-2020 with blind peer review were selected. Furthermore, journals pertaining to nursing, public health, occupational therapy and rehabilitation, psychology, social sciences, medicine, pharmacy, and therapeutical pharmacy, education, engineering, social welfare, and social work were selected. The articles were searched based on keywords such as "IoT," "mental health," "internet of things," in their title, abstract, search words, and phrases.

1.3 Literature Review Process

After finetuning and conducting a thorough search in the chosen online databases following the search criteria, a total of 70 peer-reviewed academic papers was identified.

After a filtering process, 20 academic papers were selected. Each article was read and documented in a literature review table. From this document, a layout was made based on IoT usage in mental healthcare.

2 Literature Synthesis

The literature indicates that IoT is used for different goals and purposes in mental healthcare. Based on these, the fundamental motives for adopting and using IoT can be divided into the following: 1) conducting IoT monitoring, 2) establishing control systems, 3) collecting large volumes of data (big data), and 4) performing business analytics [12]. Lee et al. (2018) based this categorization on technology trends and a performed literature review [12].

An insulin management application for diabetes with a continuous glucose monitor (CGM) is an example of an IoT device that can be used to monitor glucose level and control insulin injection. Using an IoT device, the insulin pump can be activated at a certain glucose level. This IoT system monitors and controls glucose concentration in a way the pancreas should do [13]. An example of big data and business analytics is research that profiles daily patterns of people with dementia in a Technology-Integrated Health Management (TIHM) system using IoT [11]. In this study, automated observation and sensor data through IoT are used to arrive at better clinical decisions and increase healthcare support. Based on the literature review, four critical applications associated with IoT adoption were identified. The next four sections will describe these applications: 1) Use of IoT Applications and Sensors in healthcare and 2) Use of IoT and wearables in Healthcare 3) Innovation – Use of IoT and Collaboration between IT management & Health Professionals, 4) Threats – Use of IoT and Privacy & Security. All these four sections could match one or more Lee et al. (2018) categories.

2.1 Use of IoT Applications and Sensors in Mental Healthcare

Many sensor-based applications can be used for both mental healthcare and comprehensive healthcare. For example, sensors can detect when a patient gets out of his/her bed, or sensors hidden in the floor can detect movement when somebody is out of bed, walking around. Sensors and IoT can be used to prevent social isolation with the elderly who live alone. Social isolation can cause depression or other mental health-related problems [14]. In a study performed with six older adults in the real-world, in-home experiments were carried out to see what the participants' experience was with the Internet-of-Things in terms of isolation. The method for this study drew on machine learning and sensors with IoT to monitor the activity patterns of the elderly [15]. This system is referred to as Ambient Assisted Living (AAL), a technology that facilitates independent living and keeps social connectedness between the elderly, their relatives, and medical professionals [15]. The response from the elderly regarding Forkan's study with AAL was positive. Another way of using sensors, IoT, and machine learning in daily pattern recognition is Technology Integrated Health Management (TIHM) [11]. In this method, activity patterns are used to detect changes in the daily activity of the patients. The recorded data is used to enhance the care and support given to patients and their caregiver(s). Enshaeifar's

conclusion regarding the primary input of TIHM is to learn and determine variations in the patient's health and mental state. The combination of physical and mental health states are challenging issues for IoT use in mental healthcare. This combination of physical and mental health also counts for a systematic review of IoT in a new study by [16] emphasizing the trends and challenges of research on physical activity recognition and monitoring (PARM) in which IoT is an essential factor. In this review, it is believed that PARM is a crucial paradigm for smart healthcare due to the advantages of physical and mental health in rehabilitation programs. These advantages could also be visible without PARM but only monitoring the patient status with a SmartHabit system. This SmartHabit system was studied to research parameters affecting the user interaction with IT/IoT [17]. It gives the monitoring system continuous information about the status of a patient using sensors in a "smart-home setting." An important finding is that the SmartHabit system using the IoT and sensors improves the quality of care for patients who live in smart homes.

Posttraumatic stress disorder (PTSD) is a mental disorder that can appear after undergoing an awful or harrowing experience. By merging data from sensors, the IoT, and wearables in a proposed home automation system, it could be possible to predict PTSD and act in a specific way towards the patient, e.g., by suppressing nightmares slowly and waking them up quietly [18]. A health monitoring system with the combined effect of these elements could increase the quality of life for patients with PTSD.

In the major group for IoT applications, home healthcare parameters can be monitored remotely for older or sick people. Personal Healthcare Devices (PHDs) are used for this. These are portable electronic healthcare devices that record and measure the biomedical signals of users [19]. With the help of IoT technologies, PHDs can provide care professionals with supplementary information about specific characteristics of the health condition of a patient to anticipate care if needed. IoT has many benefits not only for patients but also for seniors living independently. As the elderly nowadays have longer life expectations, smart homes are a solution to allow them to live independently and for longer. Smart houses are houses in which environmental and portable medical sensors, actuators, and modern communication and IT devices are integrated [20]. These smart homes allow the elderly to live in a good home situation instead of a much more costly healthcare facility.

2.2 Use of IoT and Wearables in Mental Healthcare

A study was conducted to keep track of depression statistics and data used from GPS and smartphones in a surveillance system [21]. Poonkodi et al. (2016) used data to investigate how an unsafe moment of a patient can be detected and to keep track of the behavior of a patient and compute his/her depression level. The study of Poonkodi et al. (2016) shows that a remedying precaution can be taken to prevent negative consequences for the patient at a certain depression level. This depression level is calculated, but other systems where judgment from a health professional is needed could be possible to. Like a study with an innovative approach for a human-centered IoT model-based app that was performed. This study concerns developing a smart, responsive app that should be able to advise instantaneous activities and procedures for the patients and medical professionals. The data gathered came from IoT wearable applications. Safety protection

for these medical data was a fully secured homomorphic encryption algorithm [22]. Another IoT combination with wearables is when temporal small piece patterns from patients' health are monitored. How can this be done effectively with the IoT? This is done in a case that involved remote monitoring of time-sensitive health data from students using wearables and IoT in their environment to measure and predict potential diseases based on temporal small piece pattern, for which the researchers used several grouping algorithms [23]. The developed framework was used for regaining outcomes within a specific time for medical professionals.

2.3 Opportunities - Use of IoT and Collaboration Between IT Management and Health Professionals

The collaboration between health professionals and developers/IT professionals can be improved through new IoT application development and use. The information and knowledge of these medical professionals can be embedded in the development of IoT systems and applications. [24]. Dadkhah's study also showed that there are different stages where health professionals can contribute to IoT development.

In a study, the design and development of a data integration platform with heterogeneous integrated data sources, such as data from portable or non-portable IoT devices could enable stakeholders in a patient-centered care environment to actively participate in decision-making around the patient [25].

2.4 Threats – Use of IoT and Privacy and Security

IoT data in mental health is medical data. In that case, a new environment where IoT data is applied must be well protected. The protection of IoT data also applies to the cloud. IoT requires a new security infrastructure that is based on modern technical standards. With new security design for IoT, these new standards must be taken into consideration with various attention points for security and privacy [26]. Another fact is that most IoT devices and related communication networks do not have any security procedures which make them exposed to security matters [27].

Safe data access and transport is an essential issue for medical data in the cloud. A study has been performed based on the Healthcare Industrial Internet of Things (HealthI-IoT) with ECG monitoring data and other medical data using a watermark. The use of a watermark is for extra security and safety [28]. The medical monitoring data from wearables and sensors could be sent securely and stored in the cloud. Here, health professionals can then access the medical data. When the Industrial Internet of Things (IIoT) will be enabled for continuous health monitoring, it could offer quality patient care [28]. This study is ongoing with a focus on safety and security issues.

2.5 Summary

IoT is not a single device. It is an information system that links applications like sensors, wearables to the internet, for instance, for monitoring, management, or machine learning purposes. The gathered information could, as the references indicate, be used for monitoring personal movements, health situations, machine learning, or living patterns.

The focus in the literature references is mostly on the technical content and development. Some of the references show solutions that not have been tested in practice [18, 19, 21], and the benefits given could be interpretative conclusions. References tested in practice with a small group of elderly with dementia are the TIHM [11] and SmartHabit [17]. When applications are tested like the AAL, IoT systems could use too advanced used technology, which could increase the gap between the offered and a really needed system. When the knowledge gap is too big, the acceptance of the technology by the stakeholders could be less as well. In that respect, it could be difficult to generalize "a one size fits all system" because an AAL fluctuates deeply in targeting diverse client requirements [17]. A group where the knowledge gap, as discussed with AAL, does not play a role is the TIHM. The patients do not have to decide and understand because it is done for them using the "Mental Capacity Act Code of Practice" [11]. The benefits for the TIHM could be with the health professional who has the data and the ability to judge the mental state of the patient. These benefits could play a role for the patients as well.

3 Case Study Research Method

3.1 Method

This explorative study embraces a qualitative interpretative approach. The reason why this research method was chosen is: 1) There were limited studies available about IoT use in mental healthcare, 2) The number of semi-structured interviews was low, 3) In this case, there was a need to describe and explain the main opportunities and threats associated with the adoption and use of the IoT in mental healthcare using interviews before adopting a research approach.

The research design is qualitative with an inductive research approach. This is due to the limited information in the literature and to develop a richer theoretical perspective [29]. This explorative study is based on the four themes that resulted from the literature review and five semi-structured interviews with five employees from the IT management of different mental healthcare institutions. The requirement to make a good selection for the interviewee is that the person must have decision-making powers for the IT strategy using LinkedIn search queries. The qualitative exploratory research is done using open questions with semi structured interviews based upon three subjects, IoT use, privacy and innovation [29].

3.2 Dutch Healthcare System and Case Background

The Dutch mental healthcare association has around 100 connected members, and in total, 89,000 employees work there. These employees provide care to almost one million patients per year. Every healthcare organization that deals with mental healthcare can become a member of the Dutch mental healthcare association. Among the members, there are umbrella organizations. In total, there are 1768 mental healthcare institutions in the Netherlands. Many providers in the Netherlands offer mental healthcare, and they can join the Dutch mental healthcare trade association [30]. In total, there are about 723

mental healthcare institutions [9]. 42.7% of the Dutch population between the ages of 18 and 64 have to deal with a psychological disorder during their lifetime [31] and in 2015, 1 million people were treated in a mental healthcare clinic [32].

Case size: Five organizations (representing five cases) participated in this case study and were represented by an interviewee per case; *Case I*: *Interviewee I (IT manager)* - an organization with 14.450 employees, 59 departments; *Case II*: *Interviewee II (IT manager)* - an organization with 1.333 employees, 12 departments; *Case III*: *Interviewee III (IT-policy manager)* - an association with 723 members – representing 86.000 employees; *Case IV*: *Interviewee IV (IT consultant)* - an organization with 1.306 employees, 7 departments; *Case V*: *Interviewee V (IT manager)* - an organization with 2.654 employees, 31 departments. These cases cover relatively 22.8% of the total employees and 15% of the entire Mental healthcare departments as part of the association. In total, there are 1723 Dutch mental healthcare institutions, including "not association members" [33].

Data Collection Method Details. As part of the case study protocol preparing data collection, procedures were taken concerning the major tasks for collecting data [34]. This included selecting organizations and interviewees, data collection procedures, case study questions, evaluations/validation of the transcribed interviews, and analysis.

Selection Criteria Interviewees. The crucial points for selecting the management of consulting roles to be interviewed were that the person must be a decision-maker who is responsible for IT/IoT adoption and implementation in mental healthcare.

Selection Organizations/Interviewees. Ultimately, five senior IT management roles from four Dutch mental healthcare institutions and one from the Dutch mental healthcare association were selected via LinkedIn and invited to participate in an interview. There would be four face to face interviews and one interview by phone. Five persons agreed to participate in the interviews: one IT policy manager, one IT consultant, and three IT managers.

Case Study Questions and Evaluations. All interviewees received a list of interview questions before attending the interview. The interviews were between 30 and 60 min in duration and recorded & transcribed before they were sent to the interviewees for validation.

Data Analysis. The data analysis proceeded with the three coding steps: 1) framework setup for coding, 2) starting initial coding, 3) defining and naming themes. Before starting with the coding, a mind map was made to code all possible connections between IoT and mental healthcare. These codes were the initial coding without seeing the transcribed interviews. The coding began with the initial coding of the transcribed interviews using NVivo and qualitative analysis. While analyzing the transcribed interviews, these codes were finetuned by adding and deleting codes along with classifying. Finally, four themes were selected based on the findings in the literature review and its match with the coding and categorization of the transcribed interviews.

4 Findings

4.1 Theme 1: Use of IoT Applications and Sensors in Mental Healthcare

Is IoT actually used in combination with sensors in the Dutch mental healthcare? From all five cases, there was only one interviewee that responded positively on the question if sensors are being used in combination with IoT. According to the interviewee's information, the main usages are sensor-based applications to detect patients coming out of bed and fall detection. When asked which IoT was used more by them in mental healthcare, one of the respondents clearly states, "*What we do further is we use sensors more often fall protection with patients. …. And what we also do is protection or a type of sensor that we can use to see if someone is still in bed." (IT manager).* Interviewee-V was using IoT to give more and more independence to the patients with their specific access to the care center. This will avoid extra workforce to support the 'patient's thanks to IoT and stimulate more patient-centered care. In that way, IoT improves the quality of life. When asking more about their IoT use, the respondent replies, "*In fact, we are increasingly endeavoring to give more control to a patient." (IT manager).* Currently, Interviewee-V is now in a pilot phase testing IoT-applications (also wearables) in cooperation with scientific institutions. New experiences learned during this pilot phase will be applied in new construction projects for mental healthcare.

4.2 Theme 2: Use of IoT and Wearables in Mental Healthcare

Wearables produce data, and Case IV is trying to work with the wearable suppliers to see if an application interface (API) could help with data integration for the EPD.

Wearables could be used to monitor the sleep rhythm and increasing the stress level of a patient. This could be of interest for mental healthcare as mentioned by a respondent: "*And we are now also doing some tests to combine that with wearables. With the idea to see whether you can also see how 'someone's sleep rhythm is based on such a wearable, but also whether you can see whether someone is increasing stress levels." (IT manager).* According to interviewee-III, with privately used wearables for health purposes, users acknowledge that privacy-sensitive medical data may be transported through the internet according, this straightforward way could be possible for medical data coming from sensors as well and used for medical monitoring.

4.3 Theme 3: Opportunities – Use of IoT and Collaboration Between IT Management and Health Professionals

To promote existing and future IoT applications, they work together with another care center in a living lab project. In this living lab, nurses, practitioners, and students can get familiarized with new technologies like sensor/IoT-applications, care robots, and apps. "*Living lab: And we hold meetings to allow nurses to become acquainted with this. So that they just get more confidence in that and a little less fear actually." (IT manager).* The 1723 members take care of their own IoT coordination. Among the five interviewees, only Interviewee-V has an official innovation steering committee. "*And from that steering group, we mainly try to get fertile ground to establish as many local*

initiatives as possible concerning innovative applications" …. "And we also have an Innovation committee." (IT manager).

4.4 Theme 4: Threats – Use of IoT and Privacy and Security

IoT could be used at home or in a hospital setting. With devices that are provided by commercial parties and purchased by the patients, the Dutch mental healthcare cannot promise safe and secure medical data transportation. Also, for cloud-based applications like wearables, there is uncertainty about the GDPR. This is an essential issue at the Dutch mental healthcare from withholding using IoT. "*…of course, what do you do with the data? People must permit them to use their data. And that, of course, is something we find quite difficult as an organization." (IT manager).* Some interviewees mentioned that the main reasons the IoT is not currently used were privacy and security issues. Interviewee IV stated: *"That is the problem, originally that stuff is not yet protected in such a way." (IT Consultant).* All interviewees mention the conventional standpoint of the medical professionals, and they recognize this threshold for accepting and implementing an innovative therapy with IoT. "*No. The big problem, of course, is that a trained psychologist or psychiatrist will always assume that his observation is accurate, which electronic measuring device you can put against it" (IT manager).* & "*It is, there is a lot of resistance to innovations and things" (IT manager).*

5 Discussion and Conclusions

This study shows critical insights into the opportunities and threats perceived by senior IT managers about the adoption and use of the IoT in mental healthcare in the Netherlands. Although it is an explorative study, the five semi-structured interviews give an impression of the opportunities for the IoT use in the Dutch mental healthcare.

Only Case V uses sensors in combination with IoT devices. The gained knowledge about IoT is used to increase the mobility for patients and to act when it is necessary, for more patient-centered care [25]. The IoT technology is planned to use for a smart building project [20]. IoT and wearables are used in Case V. Data from wearables seem to be interesting in both Case IV and Case V. They are investigating how to integrate data from wearables into the EPD or just to monitor the data. By combining data from sensors and wearables into a database, the next step could come closer to IIoT [28] or TIHM [11]. Wearables seem to suffer from the unknown safety from medical data usages. The interviewees from Case V and Case IV are aware of this.

Innovation in Case IV and Case V is a cooperation between both medical professionals as well as IT professionals, not to mention the kind of innovation structures like steering committees and innovation groups. Innovation ideas are initiatives from all levels within the organization. From the five cases, only Case V was actively innovating with IoT, sensors, and wearables.

The conventional standpoint of medical professionals is mentioned a few times as a hindering factor for IoT adoption and use.

IoT is rarely used in Dutch mental healthcare. One of the reasons is safety and privacy. The interviewees cannot promise secure and safe data transportation in a home situation at the client or in a hospital setting.

5.1 Implications for Academia

The qualitative interpretations of the findings could indicate threats and opportunities for the use of IoT in mental healthcare. These findings are essential to analyze possible hindering factors that could withhold the implementation of IoT adoption. Also, it is essential for a better understanding of how innovations through IoT in mental healthcare take place with the managers, healthcare professionals, and other involved stakeholders in the IoT development and implementation process.

Research in the literature, according to the references about adoption and use in mental health care, is more focused on technology and development. The resulting benefits and additional values for the stakeholders and services are not further analyzed based on a theoretical model. Future research could be on the development of a predictive model for the organizational value of IoT within Dutch mental healthcare. Many parameters influence the adoption, use, and organizational value of IoT within mental healthcare. Some of these parameters, for example, the IoT acceptance of health professionals, should be categorized and analyzed in the mental healthcare to set up a theoretical model for the organizational value for IoT.

5.2 Implications for Practice

According to the literature review, IoT could improve the quality of life for patients within the mental health and stimulates more patient-centered care. The findings show that Dutch mental healthcare can adopt and use IoT devices like "out of bed sensors". The use of IoT innovation in Dutch mental healthcare by IoT development initiatives from within the organization in cooperation with the IT department is essential for new IoT initiatives and IoT adoption. Findings show that innovation strategy and organizational modifications such as using an innovation steering committee and innovation teams could be crucial elements to set up innovation projects for adopting and usage of IoT applications. Collaboration between IT & health professionals is part of this innovation process. During this collaboration, healthcare professionals and managers could both influence the development to gain benefits for their professional activities, patients, and the organization.

5.3 Limitations

This study is not without limitations. The findings from the respondents were not enough to extrapolate the outcomes for the whole Dutch mental healthcare. This study gives an interpretation of IoT use in mental healthcare in the Netherlands using the findings from five cases and five interviewees from five different organizations. The qualitative interpretive results from the five cases and single respondents could be useful for an organization-wide perspective follow-up research direction in the Netherlands. A quantitative evaluation of the proposed approaches was not part of this research due to the explorative, interpretative, and mainly qualitative sett-up of this multiple case study.

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