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Knowledge and Perceptions of Hospital Care Staff towards Medical Internet of Things and the Role of Awareness Videos: A Quasi Experimental Study

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Abstract

Introduction: The healthcare industry continues to adopt and integrate smart technology into its operations. However, the adoption of the eHealth solutions has not been smooth in the Kingdom of Saudi Arabia (KSA) due to negative beliefs about the technology, lack of awareness and motivation and resistance to change. Thus, this study was developed to investigate the knowledge and perceptions of hospital care staff towards the Medical Internet of Things and to explore the role of awareness videos in changing negative perceptions. **Methods:** One group pre-test post-test quasi-experimental study design was incorporated, and 116 participants from Ministry of Health hospitals in Riyadh, KSA, were included. A series of four videos were developed to observe their influence on the knowledge and perceptions of mIoT. **Results:** The findings showed that participants had more knowledge about the individual components of mIoT (particularly wearable devices) compared to the processes or functions of mIoT. Similarly, just over half (56.0%) of the individuals think that the current systems in the hospital are enough to deliver mIoT. However, 90% think mIoT is the future of digital health. Similarly, PE, SI, BI, EE and CESE were considered facilitators and PTA and CC were considered grave barriers to mIoT adoption. The awareness videos positively influenced knowledge and perceptions of PE, EE, CESE and SI. **Conclusion**: The study concludes that hospital staff in Riyadh (excluding doctors) possess basic mIoT knowledge, consider various adoption factors as enablers, and awareness video can play a critical role in effectively introducing the technology to the hospital care staff.

Keywords

Internet of Things, Healthcare Professionals, eHealth Knowledge, Awareness

Intervention, Experimental Study

1. Introduction

Information technology advancements continue to transform service delivery and efficiency in various industries. It has led to modern smart objects that create a new era of applications that are powered by Internet of Things (IoT)-based networks. The healthcare industry continues to adopt and integrate innovative technology, from advanced medical devices to state-of-the-art managing operations. However, the adoption curve has not been smooth and the previous technology adoption track record in the Kingdom of Saudi Arabia demonstrates the presence of several known and unknown issues, which also vary substantially with the type of Information technology [1] [2]. Regarding eHealth technology adoption, the research in the Kingdom's healthcare sector has particularly shown various issues associated with negative beliefs about the technology, lack of awareness and motivation and resistance to change due to adverse perceptions about the technology [1] [2] [3]. Therefore, there is a need to investigate the knowledge and perceptions of hospital care staff towards the Medical Internet of Things and explore the role of awareness videos in changing negative perceptions.

"Internet of Things" or IoT, was first proposed by Kevin Ashton almost two decades ago [4] [5]. Although the masses have extensively used this term since the start of the millennium, a standardised definition of IoT remains largely missing [6]. However, broadly it can be explained as the system of gadgets, for example, vehicles, home machines, hardware, programming, sensors, and actuators, which autonomously communicate with each other over the web, collect data, and make informed decisions without human involvement [7]. Medical Internet of Things or mIoT is the inclusion of IoT in the health sector to support the health and well-being of patients and to support the systems in place and procedures conducted by healthcare professionals and the management [8] [9].

mIoT has countless applications in the field of health, which range from individual-level care, such as remote patient monitoring, including the collection of critical patient data and prediction and prevention of fatal life events, to advance and complex global-level influence, such as the timely management of the lethal communicable diseases such as COVID-19 [10] [11] [12]. However, despite the enormous application of mIoT, the shift towards mIoT technology adoption will likely be challenging in the Kingdom of Saudi Arabia as the past IT technologies implemented in the country still need to overcome adoption barriers.

For instance, one of the earliest studies conducted by [1] examined 19 hospitals in KSA. The study concluded non-compliance from the doctors and nurses due to negative beliefs associated with security and confidentiality and lack of incentives and motivation as critical barriers to the adoption of electronic health record (EHR). It was also found that the workload pressure and inadequate EHR

training were also responsible for the lack of motivation and negative belief towards the technology [1]. Moreover, another study conducted in Riyadh, KSA, showed that healthcare professionals lacked interest in EHR due to low computer literacy [2]. The findings related to computer skills inadequacy are also supported by Farooq & Shaker, who conducted a study with 451 physicians from seven hospitals in Makkah, KSA and concluded that participants required more training in even basic computer software such as Microsoft Word and PowerPoint [13].

These findings were further validated by the robust research conducted on EHR systems in the Kingdom by [14]. The study found that EHR functionalities were underutilised across the board in the hospital. For example, no digital tools, such as email or fax, were used during patient communication [14]. Moreover, doctors had no remote access to the medical records when they were outside the hospital. Apart from these, the doctors reported data entry time, lack of adequate IT training and support, the complexity of technology, lack of customizability option of the EHR system according to user's needs, and disturbance in communication between doctors and patients as grave barriers linked with EHR adoption [14].

Apart from these issues, the healthcare staff in KSA also highlights the English language as a significant barrier. References [15] [16] conducted two studies in two different periods and regions of KSA. Both studies, apart from the complexity of software and inadequacy of computer knowledge and experience, highlighted the English language as a barrier to EMR adoption in healthcare [15] [16]. Similarly, professional respect and prestige are other issues associated with accepting digital solutions in the health sector. Healthcare professionals, in particular doctors, hold a substantial position in Saudi society, and the qualitative research by [17] suggests that professionals fear that they might lose respect and privileges with the introduction of eHealth solutions in the Kingdom. Regarding mIoT adoption, there are limited studies conducted globally and in KSA on the adoption and use of mIoT. Concerning mIoT perception and satisfaction among hospital care staff, no quantitative studies are available from the Kingdom, as the technology is still new and has not been implemented comprehensively anywhere in the country. Below is a discussion of a few studies that include mIoT or AI (an integral component of mIoT) from KSA.

The qualitative study by [18] conducted with hospital administrators investigated the determinants that may affect the adoption of IoT in the healthcare sector in Jazan, KSA. The results showed that some participants provided a view on IoT and said that IoT in healt-hcare would make work easier and faster, increase connectedness in the system, will improve safety compared to previous systems and can assist in the monitoring of the patients [18]. However, these were the top management's views, and their views cannot be generalised to the rest of the hospital staff who will use these technologies, will be directly responsible for them and ultimately will be affected by them. Similar to [18] [19] conducted another qualitative study to provide views and opinions of top-level ad-

ministrators in Saudi hospitals towards IoT. Despite being top in the field, [19] found out that the majority of the participants were not clear about the potential of mIoT in KSA. Further, the participants expressed that patient privacy, security, safety, reliability, and accessibility with respect to mIoT will be a big concern with the technology adoption.

It is clear that past eHealth technologies were not introduced in an optimum way in the Kingdom, and that is why even after more than ten years of experience with the eHealth technologies, the hospital staff is still not completely aware of their complete range of uses and has not fully adopted these technologies. Therefore, for the smooth uptake of the mIoT, it is mandatory to investigate the knowledge and perceptions of the hospital staff towards mIoT. Based on this, the following study objectives were developed:

Explore hospital staff knowledge and perception about mIoT.

Develop and test the role of evidence-based awareness videos on the knowledge and perceptions of mIoT.

2. Methodology

One group pre-test post-test study design was incorporated in this study. This study type is a sub-category of quasi-experimental design, which incorporates an intervention but no randomisation [20]. Over 250 participants (including doctors, pharmacists, nurses, IT individuals and managers) were initially recruited (after receiving informed consent from them) from the Ministry of Health hospital in Riyadh, KSA. However, only 116 completed the pre and post-video questionnaires (which were administered one month apart); thus, they were selected for the final analysis. The study questionnaire (attached as **Appendix A**) was designed on the factors identified from the past literature in KSA, and eight key domains were assessed; basic mIoT knowledge, basic mIoT perception and perception of potential barriers {Effort Expectancy (EE), Computer and English Language Self-efficacy (CESE), Perceived Threat to Autonomy (PTA) and Confidentiality Concerns (CC)} and facilitators {Performance Expectancy (PE), Social Influence and Behavioural Intention to adopt mIoT (BI)}.

The study was approved by the Ministry of Health of the Kingdom of Saudi Arabia (ethics no: 21 - 79 E) and from Latrobe University, Melbourne, Australia (ethics no HEC19482).

3. The Experimentation: 4 Awareness Videos

The importance of technology knowledge and awareness is very critical for the adoption and is particularly highlighted in the Diffusion of Innovations (DOI) theory, which suggests that new technology cannot be taken up immediately but requires a period to go through a five-step decision process [21]. The first step in the technology diffusion process is "knowledge", which includes acquiring adequate information about a new technology considered for adoption [21]. Moreover, the healthcare industry, in comparison to other industries, is well-known

to resist the use of online communication technologies (a core component of mIoT) due to inadequate perceptions [22].

Educational interventions are an efficient tool to raise knowledge and awareness among hospital staff. However, inadequately planned and poorly managed educational programs can fail to illustrate their expected outcomes. Therefore, the video content created for this study was thoroughly planned and taken from peer-reviewed journals and real-life scenarios. The content was particularly designed considering the key factors; mIoT knowledge, PE, EE, SI, CESE and PTA, since the past literature suggested that the components above may hold critical importance for the adoption of mIoT. Four videos were created, and their overview, including rationale and explanation of the components is attached as **Appendix B**.

4. Results

Regarding the demographic distribution of the study participants, almost equal proportions of males (52.6%) and females (47.4%) participated in the study. A similar trend can be observed in the age distribution as 47.4% of the participants were young (18 - 35 years), and 52.6% were middle-aged (36 - 52 years). Interestingly there were no old participants. In addition, the majority of the participants were non-Saudi (77.6%) and had previous experience outside Saudi Arabia (57.8%).

4.1. Basic mIoT Knowledge among Professionals and the Role of Awareness Videos

Table 1 details the proportion of participants aware of different statements related to the basic knowledge about mIoT. Out of all basic knowledge statements, the majority of the participants (85.3%) were aware that wearable devices, such as wristbands and armbands, which measure and collect biological parameters such as heart rate or blood pressure, were one of the IoT devices (Q3). However, only 57.8% knew that data collected through sensors and devices sent to healthcare providers via an internet connection is a major component of IoT (Q1). The post-video data illustrates a similar trend and highlights that 95.7% of the participants acknowledged knowing statement in Q3. Similarly, the most significant increase in knowledge was observed in Q1 (57.8% to 77.6%, $p < 0.001$) following the administration of awareness videos. Interestingly awareness videos substantially ($p < 0.05$) raised basic knowledge across all statements and overall knowledge level from 74.4% to 87.5% (Table 1).

4.2. Basic mIoT Perception among Professionals and the Role of Awareness Videos

The basic perception included three questions—the first one about the capability of the current technology in the hospital to deliver mIoT, the second about the innovativeness of mIoT and the third about mIoT as the future of digital health. The results (Table 2) show that just over half (56.0%) of the individuals think

Table 1. Current level of basic knowledge among professionals (n = 116).

Questions	Pre-video data Yes (%)	Post-video data Yes (%)	Binominal test (p-value)
1. Internet of things (IoT) in healthcare uses devices and sensors to collect the health data. Those collected data will be sent to healthcare provider via internet connection. Have you heard of IoT before?	57.8	77.6	<0.001
2. Do you know that IoT is a system of wireless, connected digital devices that doesn't require human interaction or assistance to complete a job?	77.6	89.7	<0.001
3. Do you know that the wearable devices such wristband and armband can measure and collect the heart rate or blood pressure, are one of the IoT device?	85.3	95.7	<0.001
4. Do you know that those wearable devices can be used in healthcare monitoring purpose?	77.4	91.4	<0.001
5. Do you know that camera is also one of the IoT devices that it can be used for telehealth?	78.4	85.3	= 0.040
6. Have you heard about Remote Patient Monitoring and Telehealth before?	71.6	85.3	<0.001

Table 2. Basic perceptions of study participants related to mIoT (n = 116).

Questions	Pre-video data Yes (%)	Post-video data Yes (%)	Binominal test (p-value)
Do you think that the current channels/platforms and medias in hospitals are enough to deliver the information of mIoT?	56.0	76.7	< 0.001
Do you think mIoT such as Remote Patient Monitoring and Telehealth is an innovative idea?	77.6	88.8	= 0.002
Do you think that the mIoT is the future of digital health?	90.5	95.7	= 0.031
Total.	74.7	87.1	

that the current systems in the hospital are enough to deliver mIoT. However, 90% of them think that mIoT is the future of digital health, with 77.6% of them considering that mIoT is an innovative idea. The awareness videos significantly impacted the perceptions of the participants and produced positive changes across all three questions, with the total average increasing from 74.7% to 87.1%. However, the most prominent change (56.0% to 76.7%) was observed in the perception of the individuals related to the capability of the current systems in the hospital to deliver mIoT (Table 2).

4.3. Perceptions of Potential Barriers and the Role of Awareness Videos

The higher values in EE and CESE suggest agreement against the barrier, and higher values in PTA and CC suggest agreement with the barrier (Table 3). The overall results showed that, in general, study participants did not perceive EE and CESE as mIoT adoption barriers (Table 3). The average of all four statements was 4.04 (SD: 0.66), demonstrating that participants agreed with the ease of use of mIoT devices. Moreover, a similar trend was observed concerning

Table 3. Results of the potential barrier statements (n = 116).

Barrier statements	Pre-video Mean (SD)	Post-video Mean (SD)
Effort Expectancy:		
1. Learning how to use mIoT devices is easy for me.	3.98 (0.78)	*4.16 (0.77)
2. I think that mIoT devices are easy to use.	4.09 (0.72)	*4.29 (0.70)
3. I think that using mIoT devices will not interrupt my workflow.	4.05 (0.73)	*4.22 (0.78)
4. I think that using mIoT devices will not interrupt communication with the patients.	4.06 (0.73)	4.18 (0.82)
Average	4.05 (0.66)	*4.21 (0.70)
Computer and English Language Self-efficacy:		
1. I think that I have adequate English language skills to use mIoT systems.	4.13 (0.73)	*4.29 (0.77)
2. I think that I have adequate computer (IT) skills to use mIoT systems.	4.09 (0.77)	4.21 (0.83)
3. I think that I can efficiently use mIoT systems if adequate training is provided.	4.22 (0.69)	4.33 (0.73)
4. I think that I can efficiently use mIoT systems if adequate technical support is provided.	4.22 (0.76)	*4.38 (0.75)
Average	4.17 (0.66)	*4.30 (0.71)
Perceived Threat to Autonomy:		
1. I think that the introduction of mIoT systems can increase the control of the hospital management.	4.17 (0.71)	4.28 (0.82)
2. I think that the introduction of mIoT systems will decrease or limit my professional autonomy.	3.97 (0.91)	3.97 (1.10)
3. I think that the introduction of mIoT systems will decrease or limit my professional privacy.	3.80 (1.08)	3.84 (1.13)
4. I think that the introduction of mIoT systems will decrease or limit my professional respect.	3.73 (1.11)	3.59 (1.36)
Average	3.92 (0.82)	3.92 (0.96)
Confidentiality Concerns:		
1. I think that there would be high potential for loss of patient data with the introduction of mIoT systems.	3.75 (1.06)	3.63 (1.24)
2. I think that there would be increased liability on me for privacy and security breaches of patient data with the introduction of mIoT systems.	3.95 (0.90)	3.83 (1.12)
3. I think that the privacy of mIoT systems is not up to the mark to protect the information of the patients.	3.77 (1.00)	3.72 (1.19)
Average	3.82 (0.90)	3.72 (1.12)

*Indicates post-video values that significantly differs from pre-video values at $p < 0.05$ level, please note Wilcoxon Signed Rank Test was incorporated to establish the significance as the data was not normally distributed.

CESE and participants agreed that they have adequate English and computer skills and suggested that they can efficiently use mIoT if adequate training and support is provided (average: 4.17, SD: 0.66).

However, participants considered PTA and CC as grave barriers related to mIoT technology. Participants agreed that the introduction of mIoT would compromise their autonomy (PTA) (average: 3.92, SD: 0.82) and the highest agreement (average: 4.17, SD: 0.71) was found in the statement about the in-

crease in hospital control after the introduction of mIoT. Similarly, CC were flagged as a significant issue, and the average score (3.82, SD: 0.90) suggested that participants did not consider mIoT technology to safeguard the privacy and confidentiality of patients' personal information. The highest agreement (3.95, SD: 0.90) was found in the statement related to increased liability on hospital staff with respect to privacy and security breaches of patient data with the introduction of mIoT systems in CC. The post-video results showed that awareness videos positively influenced EE and CESE. The agreement level significantly increased towards "strongly agree" (average - EE: from 4.05 to 4.21 and CESE: 4.17 to 4.30, $p < 0.05$) in these two constructs in the post-video results. However, awareness videos did not introduce any significant changes in the PTA and CC construct results (Table 3).

4.4. Perception of Potential Facilitators and the Role of Awareness Videos

The results showed that study participants perceived mIoT devices as beneficial, productive and effective (Average PE: 3.93, SD: 0.83) (Table 4). Also, the participants agreed with the expectations of the social environment concerning the use of mIoT (Average SI: 3.94, SD: 0.75) and with the BI (Average BI: 4.27, SD: 0.42). These results showed that PE and SI were perceived facilitators for the adoption and use of mIoT. Similarly, awareness videos positively influenced these variables as the averages increased significantly in the post-video results. The agreement level significantly increased towards "strongly agree" (average - PE: from 3.93 to 4.26 and SI: 3.94 to 4.07, $p < 0.05$) in two constructs in the post-video results. However, awareness videos showed no significant impact on the BI (Table 4).

5. Discussion

Domain-specific knowledge is a critical component of technology awareness and is substantially associated with adoption behaviour [23] [24]. Also, adequate acquisition of new technical knowledge is particularly significant for the healthcare staff in Saudi Arabia. Since past research in the Kingdom has categorically highlighted resistance shown by doctors (with inadequate technology knowledge) towards adopting and using information systems [17]. In this study, only 57.8% participants knew that data collected through sensors and devices sent to healthcare providers via an internet connection is a major component of IoT. However, most participants (85.3%) were aware that wearable devices, such as wristbands and armbands, which measure and collect biological parameters such as heart rate or blood pressure, were one of the IoT devices.

This shows that participants had more knowledge about the individual components of mIoT (particularly wearable devices) compared to the processes or functions of mIoT. The possible reason for this discrepancy could be the rapid growth of wearable technology in the general Saudi public [25]. It has been

Table 4. Results of the potential facilitator statements (n = 116).

Facilitator statements	Pre-video Mean (SD)	Post-video Mean (SD)
Performance expectancy:		
1. Do you agree that the use of mIoT devices is beneficial?	3.97 (1.05)	*4.23 (1.02)
2. Do you agree that the use of mIoT devices can increase productivity in hospitals?	4.01 (0.97)	*4.31 (0.88)
3. Do you agree that the mIoT devices are reliable and can reduce medication and other healthcare errors?	3.89 (0.90)	*4.27 (0.86)
4. Do you agree that the use of mIoT wearable devices can assist in the early detection of communicable and non-communicable diseases?	3.85 (0.97)	*4.24 (0.90)
Average	3.93 (0.83)	*4.26 (0.79)
Social influence:		
1. People who are important to me would think that I should use mIoT devices.	3.99 (0.75)	4.07 (0.90)
2. My colleagues would think that I should use mIoT devices	3.86 (0.87)	*4.03 (0.93)
3. The hospital management would think I should use mIoT devices	3.95 (0.82)	*4.09 (0.87)
4. The overall social society would prefer that I should use mIoT devices	3.96 (0.86)	4.09 (0.87)
Average	3.94 (0.75)	*4.07 (0.85)
Behavioural intention:		
1. I intend to use mIoT systems in the future.	4.34 (0.62)	4.40 (0.85)
2. I intend to use mIoT systems in every opportunity in the future.	4.19 (0.71)	4.28 (0.81)
Average	4.27 (0.42)	4.34 (0.55)

*Indicates post-video values that significantly differs from pre-video values at $p < 0.05$ level, please note Wilcoxon Signed Rank Test was incorporated to establish the significance as the data was not normally distributed

suggested that Saudi healthcare consumers are eager to track their health using wearable devices [25]. These results are partially aligned with the previous research on hospital care staff concerning IoT knowledge. Research conducted by [26] concluded that 76% of 350 nurses in their study had little knowledge of IoT technology. Similarly, [27] suggested insufficient awareness of mIoT use among physicians. Further, [28] found that employees lacked knowledge regarding artificial intelligence (an essential component of IoT). Another research by [29] in the hospitals of Mina, KSA, suggested that participants' knowledge was limited about telemedicine with robotic technology (classified under mIoT) [29].

5.1. Perceptions Including Potential Barriers and Facilitators

The perception section of the study was divided into three sub-parts; basic perception, perception of potential facilitators and potential barriers.

The basic perception included three questions, and the results showed that just over half (56.0%) of the individuals think that the current systems in the hospital are enough to deliver mIoT. However, 90% of them think that mIoT is the future of digital health, with 77.6% considering mIoT an innovative idea.

These results align with past research on IoT or components included in mIoT. For example, [26] conducted a study on Malaysian nurses and assessed their perception towards mIoT. More than 65% of the nurses said that mIoT would have an impact on the future of nursing in the hospital. Similarly, the study by [27] found that only 4.7% of the participants were against integrating mIoT in the hospital. Also, [30] conducted research with 450 doctors in Riyadh, KSA. The study suggested that despite participants having low knowledge of telemedicine, more than 70% agreed that telemedicine (a component of mIoT) could be integrated into the existing hospital systems.

5.1.1. Performance Expectancy (PE)

Performance expectancy was hypothesised as a facilitator for the adoption of mIoT, and the study findings supported the hypothesis. The overall result showed that study participants perceived mIoT devices as beneficial, reliable, productive and effective. This demonstrated that hospital care staff considered mIoT effective in general and for medical practice. These findings are consistent with [26] research on IoT in healthcare in Malaysia, where nurses agreed that mIoT could reduce workload in health services, reduce hospitalisation time, will improve healthcare service efficiency and will assist in minimising medical errors. Similarly, in the study by [31], participants agreed that these tools could improve understanding of health conditions. In another study by [32], over 80% of the doctors said telemedicine helped them during covid. However, just 60% of them said that telemedicine efficiently uses time. Also, 59.8% of doctors preferred office visits compared to telemedicine [32].

These findings contrast with this study findings, but there is a rationale for this discrepancy. The study by Altulaihi and his colleagues included telemedicine used by doctors during covid in KSA. As it is a sub-component of mIoT, which does not include AI and other tools to support healthcare professionals in decision-making, thus it is quite probable that it did not meet the performance expectations of the Saudi doctors, or it could be the point of view of doctors towards new emerging technology. This study had less than 10% of doctors and more than 80% of nurses (in the clinical group); thus, the study's conclusion cannot determine doctors' point of view. Therefore, it is just to conclude that hospital care staff excluding doctors hold positive perceptions of the performance of mIoT technologies.

5.1.2. Effort Expectancy (EE)

The results showed that study participants generally did not perceive EE as a barrier to adopting mIoT. These findings are consistent with the mIoT research conducted by [26] [27], where participants agreed that IoT would allow instant communication between healthcare professionals (physicians & nurses) and patients and mIoT will develop a new type of communication as equals. Moreover, a Saudi study by [31] found that healthcare professionals suggested that digital health tools improve the quality of communication between patients and profes-

sionals (3.83, SD: 1.1). These findings are also aligned with the systematic review conducted by [33], where Perceived Ease of Use and Effort Expectancy was repeated eight times as a facilitator in their included studies.

However, similar to PE, the findings of this study might not apply to doctors as past research on physicians and their perception of EHR in Saudi Arabia suggests otherwise results. For example, around 71% of the participants (doctors) in [14] research agreed that EHR disturbed their communication with the patients [14]. Also, a US study on doctors (who had partially adopted or not adopted EHR technologies) indicated that EHR had increased their workload and working hours at the hospital, and it was considered a barrier to adoption [34]. Hence, EE may not be considered a barrier for mIoT adoption for Saudi hospital nurses, administrators and IT personnel, but it could be for doctors.

5.1.3. Computer and English Language Self-Efficacy (CESE)

Similar to EE, the overall results showed that the participants had adequate CESE, and it was not considered a barrier to the adoption and use of mIoT. These findings align with the recent research by [35], where 70% of 362 doctors from Riyadh, KSA affirmed that they are skilled at telemedicine, and 54% said they can independently solve technological issues during telemedicine visits. Furthermore, CESE is substantially associated with the willingness to use digital health tools, and this is supported by [31] research in KSA. The participants (doctors, nurses and medical students) who indicated a willingness to use digital health tools showed higher confidence in their digital self-efficacy {mean: 5.4 (SD: 1.3) on a 6-point scale} compared to those who showed reluctance to use digital health tools {mean: 3.8 (SD: 1.5)}.

Likewise, [15] found a significant positive association between English language competency, computer literacy and EMR knowledge among healthcare professionals in KSA. The study suggested that participants had adequate computer skills and English language proficiency. However, the research by [2] [13] reported otherwise and indicated low computer competency and the need for more training to use basic computer tools such as Word and PowerPoint. The possible reason for this discrepancy could be due to the composition of the study sample (77.6% non-Saud and inclusion of non-clinical personnel) or due to the time difference between the past studies and this research.

5.1.4. Social Influence (SI)

The overall results of SI demonstrated that it was considered a facilitator for the study participants' adoption and use of mIoT. The findings indicate that the study participants acknowledged the mIoT awareness of hospital staff, the management, and the general public of the society. It also showed that the participants expected/perceived that the general public (including the patients) had a positive view towards mIoT technology, which is why they would try to meet their expectations. These results are consistent with the research conducted by [35] with 362 doctors from Riyadh, KSA, where most of the participants said

that their patients positively consider telemedicine, and 76% of them said that their patients would believe that telemedicine saves time. Similarly, a qualitative study by [36] in Saudi hospitals noted that the participants did not have problems with the top management concerning the adoption of mIoT. In fact, according to the participants, the top management led the hospital's digital transformation and requested more IoT-based solutions, which shows their positive attitude towards IoT. However, the participants did share some concerns regarding the patient's expectations towards mIoT [36].

Moreover, [37] suggested that cultural barriers have been a critical factor behind the failure of eHealth technologies due to limited interaction. They noted that Saudi Arabian citizens are substantially influenced by their native culture and prefer face-to-face interaction over a virtual one [37]. Moreover, [38] found that the lack of a relationship between doctors and patients is a major factor preventing the implementation of eHealth systems, as 71.2% of the participants preferred face-to-face contact with physicians rather than online consultations. However, these concerns were not visible in this research, and this could be due to the factor that Saudi society is undergoing a major social change. The ruler's (Prince Muhammad bin Suleiman) progressive approach and the COVID-19 epidemic have introduced some major changes in the Saudi culture, which might have also influenced the patient's expectations about the care provided by healthcare professionals.

5.1.5. Perceived Threat to Autonomy (PTA)

PTA was considered a barrier to the adoption and use of mIoT by the study participants. The participants showed agreement to all these statements in PTA, and the highest agreement was provided to the statement about an increase in hospital management control after the introduction of mIoT. This indicated two main sectors of issues for the hospital care staff. First, from the top management, as according to participants, mIoT will increase their control and reduce professional privacy, and second, from the management and patients, which is indicated by a decrease in professional autonomy and respect.

The area of PTA is not well researched in KSA and elsewhere in the world, but this is particularly important to mIoT as this technology is quite different from the other past technologies introduced in the health sector [39]. The key differentiating component is AI or machine learning (which has not been a major part of other past technologies), which is there to replicate human performance in a very sensitive way and in a very sensitive field. The understanding of this concept creates a new type of barrier for the adoption of IoT. The research conducted in KSA and elsewhere supports the current study findings and acknowledges the presence of this relatively new type of threat.

Reference [40] conducted a qualitative study with health informatics specialists from Saudi healthcare services (including some of the biggest hospitals in KSA). Some participants in the study said that healthcare professionals are resistant to adopting eHealth technologies due to the fear that they might lose their

privileges, which suggests a loss of respect and autonomy. [28] conducted a study with healthcare employees in KSA to assess their perceptions of artificial intelligence (AI). The study found that the item "AI could replace me in my job" received the highest mean score (3.11, SD 1.17), showing moderate agreement on the Likert scale. Similarly, another study by [41] noticed that 32.1% of the participants (doctors from the radiology department in KSA) said that AI would replace their job. Similarly, many other researchers [42] [43] have also concluded the significant negative impact of PTA on doctors' decision to adopt new IT technologies. Thus, the findings of this research are well aligned with the past research, not only including hospital staff in general but also doctors, and PTA is suggested as a grave concern by the Saudi hospital care staff without any discrepancy.

5.1.6. Confidentiality Concerns (CC)

Similar to PTA, CC was flagged as a significant issue, and the average score (3.82, SD: 0.90) suggested that participants did not consider mIoT technology to safeguard the privacy and confidentiality of the personal information of the patients. This shows that participants not only acknowledged the issue of data loss due to mIoT but also highlighted the fact that they might be liable for those losses, which may also influence their respect/position (PTA) in the hospital. The confidentiality concerns raised by the current study are consistent with the past research conducted in KSA. For instance, [30] conducted a study with 450 doctors from Riyadh, KSA. The study found that 90% of the doctors showed concerns about patient privacy (among other concerns) for the adoption of telemedicine.

Similarly, [36] conducted a qualitative study in Riyadh, KSA, with hospital technology specialists. The study noted privacy and security issues as major obstacles that prevent Saudi healthcare from adopting IoT technology. Similar observations were also made concerning other eHealth technologies that have been used for a long time in KSA. For instance, [44] conducted a study with Saudi healthcare professionals, IT specialists and citizens. The study found that the majority of healthcare professionals reported security and privacy issues. However, citizens and IT specialists did not report security or privacy concerns [44]. This indicates that the CC concerns highlighted by the current study participants were actually the product of issues with other eHealth technologies used in the past. Thus, it is worth raising awareness about how mIoT is different to other technologies in terms of data collection, management and privacy and introducing mIoT technology considering these factors and developing a robust plan to manage these issues.

5.1.7. Behavioural Intention to Adopt mIoT (BI)

The BI showed a very positive response from the study participants. Despite PTA and CC concerns, more than 95% of the participants said they intend to use mIoT in future and more than 85% (said they intend to use mIoT in every

opportunity in future. This positive intention towards technology use is also visible in other studies conducted in the Kingdom. For example, [30] conducted a study with 450 doctors from Riyadh, in which 90% to 95% of participants showed a willingness to implement telemedicine and likeness to watching a procedure conducted under telemedicine. Similarly, [41] conducted a study with doctors from a radiology department in Saudi Arabia. More than 92% of participants in the study supported the introduction of AI in the radiology department despite 32.1% of the participants saying that AI will replace their job. However, special consideration should be taken in interpreting these results as the reported high percentage of BI agreement cannot be translated into the understanding of the extent to which the participants are ready to use mIoT technologies adequately. Since the above discussion (in PE, PTA, CC etc.) has clearly explored various issues indicated by the current study and the past closely related studies.

5.2. Influence of Awareness Videos on mIoT Knowledge and Perceptions

The success of the adoption and use of any new technology depends on a myriad of factors. However, as suggested in DOI, adequate knowledge provides basics to the adoption pyramid [30] [20]. Healthcare staff are on the front line of using modern medical technology. However, rapid evolution has superseded the abilities of these hospital employees to remain up to date with the technology evolution, which suggests the requirement for new kinds of training and education [45]. The awareness video intervention introduced in the current study produced significantly positive results and raised basic mIoT knowledge among study participants. The post-video data illustrates that 95.7% (increased from 85.3%) of the participants acknowledged knowing wearable devices as one of the key components of IoT. The comparison literature is scarce, but limited available research supports these findings. [46] conducted a study with hospital care professionals to evaluate the effectiveness of an educational video program developed to increase Aging Service Technology (AST) knowledge.

The study suggested the success of the video program and concluded an increase in the objective enhancement of AST awareness among hospital employees [46]. Regarding basic perception, the awareness videos significantly impacted the participants' perceptions and produced positive changes across all three statements, with the average increasing from 74.7% to 87.1%. However, the most considerable change (56.0% to 76.7%) was observed in the perception of the individuals related to the capability of the current technology in the hospital to deliver mIoT, and it can be correlated with the increase (57.8% to 77.6%) in knowledge statement related to the processes or functions of mIoT. This suggests that raising knowledge may influence basic mIoT perception in a positive way. This observation is also supported by [47], where videos short as 4 minutes and 30 seconds were effective in improving the attitudes of nurses towards individuals with mental illness. The study concluded an immediate positive increase

in the attitudes of almost one-third of the nurses towards people with mental illness following the administration of videos [47].

Moreover, the awareness videos in the current study also positively influenced PE, SI, EE and CESE. The agreement level significantly increased towards "strongly agree" in these four constructs in the post-video results. The significance of awareness and education is also supported by the technology specialist in the hospitals of Riyadh, KSA [36]. The participants said that education programs could raise awareness among users about the power of IoT technology and its value to the health sector [36]. However, awareness videos in this study did not introduce any significant changes in the PTA, CC and BI constructs. This indicates that awareness videos successfully raised knowledge and enhanced the perception toward mIoT facilitators but did not reduce the perception of barriers (PTA and CC). The possible reason for this failure could be related to the factor that changing hospital staff's perception of barriers requires much more than awareness videos (may require adequate training and hands-on experience) as it is built on past technology experiences (as concluded in the CC discussion section above).

6. Conclusion

This study concludes that the hospital care staff in KSA demonstrated basic knowledge of mIoT components but lacked essential process information, which holds substantial significance in the hospital environment. The study suggests that despite having low knowledge, most participants held a positive perception of mIoT. In particular, the participants agreed that mIoT devices are beneficial, reliable, productive, effective, easy to learn and will not disturb communication in the hospital. However, these inferences could not be applied to doctors due to their low percentage in the current study. Moreover, the participants also suggested having adequate English language and computer skills to use mIoT. The hospital staff also perceived the element of social influence as a facilitator for adopting mIoT. However, the participants perceived PTA and CC as grave barriers and asserted that mIoT would decrease their professional autonomy and respect and would increase the chance of data loss. The awareness videos included in this study successfully enhanced positive perceptions. However, they showed no role in overturning negative ones. Future large-scale studies are suggested incorporating a large number of participants, particularly doctors, and specialised hands-on experience modules.

Data Availability Statement

Study data cannot be shared due to ethical considerations.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendices:

Appendix A: Study Questionnaire

Items	Options	Reference
What is the current level of basic knowledge among professionals in the hospital sector with respect to mIoT?		
Internet of things (IoT) in healthcare uses devices and sensors to collect the health data. Those collected data will be sent to healthcare provider via internet connection. Have you heard of IoT before?	Yes Yes, but not very clear No	[21]
Do you know that the wearable devices such wristband and armband can measure and collect the heart rate or blood pressure, are one of the IoT device?	Yes, I do No, I don't	[21]
Do you know that those wearable devices can be used in healthcare monitoring purpose?	Yes, I do No, I don't	[21]
Do you know that camera is also one of the IoT devices that it can be used for telehealth?	Yes, I do No, I don't	[21]
Have you heard about Remote Patient Monitoring and Telehealth before?	Yes No	Adopted and modified from [21]
What are the current perceptions of the professionals in the hospital sector towards mIoT?		
Do you think that the current channels of and medias are enough to deliver the information of IoT?	Yes No	[21]
Do you think IoT in healthcare such as Remote Patient Monitoring and Telehealth is an innovative idea?	Yes, it is Not really No it is not	Adopted and modified from [21]
Do you think that the IoT healthcare is the future of digital health?	Yes No	[21]
Section 3		
Performance Expectancy:		
Do you agree that the use of mIoT devices is beneficial?	1 - Strongly disagree 2 - Disagree 3 - Neutral 4 - Agree 5 - Strongly agree	Adopted and modified from Dafni and Haiman (2016)
Do you agree that the use of mIoT devices can increase productivity in hospitals?		
Do you agree that the mIoT devices are reliable and can reduce medication and other healthcare errors?		
Do you agree that the use of mIoT wearable devices can assist in the early detection of communicable and non-communicable diseases?		
Effort Expectancy:		
Learning how to use mIoT devices is easy for me.	1 - Strongly disagree 2 - Disagree 3 - Neutral 4 - Agree 5 - Strongly agree	Adopted and modified from [48] [49]
I think that mIoT devices are easy to use.		
I think that using mIoT devices will not interrupt my workflow.		
I think that using mIoT devices will not interrupt communication with the patients.		

Social Influence:		
People who are important to me would think that I should use mIoT devices. My colleagues would think that I should use mIoT devices. The hospital management would think I should use mIoT devices. The overall social society would prefer that I should use mIoT devices.	1 - Strongly disagree 2 - Disagree 3 - Neutral 4 - Agree 5 - Strongly agree	Adopted and modified from [50] [49]
Computer and English language Self-efficacy:		
I think that I have adequate English language skills to use mIoT systems. I think that I have adequate computer (IT) skills to use mIoT systems. I think that I can efficiently use mIoT systems if adequate training is provided. I think that I can efficiently use mIoT systems if adequate technical support is provided.	1- Strongly disagree 2 - Disagree 3 - Neutral 4 - Agree 5 - Strongly agree	Adopted and modified from [49]
Perceived Threat to Autonomy:		
I think that the introduction of mIoT systems can increase the control of the hospital management. I think that the introduction of mIoT systems will decrease or limit my professional autonomy. I think that the introduction of mIoT systems will decrease or limit my professional privacy. I think that the introduction of mIoT systems will decrease or limit my professional respect.	1- Strongly disagree 2 - Disagree 3 - Neutral 4 - Agree 5 - Strongly agree	Adopted and modified from [51] [49]
Confidentiality Concerns:		
I think that there would be high potential for loss of patient data with the introduction of mIoT systems. I think that there would be increased liability on me for privacy and security breaches with the introduction of mIoT systems. I think that the privacy of mIoT systems is not up to the mark to protect the information of the patients.	1- Strongly disagree 2 - Disagree 3 - Neutral 4 - Agree 5 - Strongly agree	[52] [49]
Behavioural intention to adopt mIoT:		
I think that there would be high potential for loss of patient data with the introduction of mIoT systems. I think that there would be increased liability on me for privacy and security breaches with the introduction of mIoT systems. I think that the privacy of mIoT systems is not up to the mark to protect the information of the patients.	1- Strongly disagree 2 - Disagree 3 - Neutral 4 - Agree 5 - Strongly agree	[53]

Appendix B: Video Components

Video component 1

The term Medical Internet of Things is composed of two aspects—"Medical" and "Internet of Things"; thus, it was important to improve knowledge about these basic concepts at early stages. The first video's content was designed to establish a strong fundamental concept about the Internet of Things, which can later support the understating of the medical Internet of things. The necessity of this step can be adopted from the research conducted in the area of education, which highlights the significant need for evaluation and acknowledgement of prior knowledge in instructional design and curriculum planning [54]. Since there was a wide range of participants in the current study with varying educational and professional backgrounds, initiating the videos with basic concepts was feasible.

The concept's (Internet of Things) definition and relevance with the current and future world were explained at the start to highlight the topic's significance. Similarly, a brief history was provided to illustrate the gradual development of the Internet of Things and to clarify any doubts about the sudden emergence of this concept. Moreover, in the last, some common examples of everyday use appliances were demonstrated in the video to highlight the practicality and efficacy of the Internet of Things in the current world. The fundamental purpose of this video was to provide basics and prepare a positive attitude of the participants about the forthcoming video, which was about the Medical Internet of Things.

Video component 2

After providing the basic concepts about IoT, the second video mainly focused on mIoT, its need in the Kingdom and some key components present in every mIoT system. The definition of mIoT was included as an introduction to the concept. However, special care was taken to present mIoT as an extension of IoT (about which participants have developed an understanding in the first video) and not as something significantly different. Following that, some prompts and questions were used in the video to keep the participants interested in the topic. Reference [55] suggests that guiding questions in the videos supports active learning, which provides clear advantages over passive experiences. Following the introduction, four critical areas related to the need for mIoT were discussed in the videos—population growth and ageing population, increase in the percentage of chronic diseases, inclusion of Internet of Things in 2030 vision and expectation of the new Saudi generation about the health system of the country.

All these components were carefully selected, considering the framework developed for the study. For instance, the element of population growth and increase in the percentage of chronic diseases was included to establish the need and subsequent Performance Expectancy component of the study framework. Without a significant need for improvement in the efficiency of the health sector, the value (Performance Expectancy) will not be perceived as critical as with the need to improve the system. Similarly, the elements of the 2030 vision and

public expectation were included to address the component of Social Influence. Social Influence is demonstrated as an individual's perception of a product/service, which is influenced by the perception of people in a close circle or who are important to the individual [56]. It was hypothesised that the expectation of the leadership and general public related to the inclusion of the latest technology in the health sector would positively influence the hospital care staff to develop positive perceptions about mIoT and subsequent adoption behaviour.

The last few basic concepts about the key components of any mIoT system were also explained in the video to improve the understanding of its working. It was explained that the working and infrastructure of mIoT are simple and use technology that has already been used in hospitals. Similarly, comparisons were conducted where possible with already-in-use technology (EHR systems) to address the component of Effort Expectancy, which refers to the degree to which an individual believes that using a particular system will be free of effort. Further, these components were also included to address a holistic approach and meet the interest of non-clinical groups and clinical groups in the hospital.

Reference [57] conducted a study on the effectiveness of awareness videos for different professionals working in a hospital. A member of the study suggested that "There is so much focus on working with the patients. It does not apply to me, so you need separate learning for the non-clinical staff." [57]. Similar results were identified in another healthcare setting study, where participants suggested including relevant and role-specific examples and increasing interactivity in the components [58]. Therefore, a holistic approach was adopted in the development of awareness videos.

Video component 3

The third video mainly focused on IoT's fundamental uses in the health sector, along with some real-life examples of currently available mIoT devices. In addition, the potential of mIoT to control the current COVID-19 epidemic was also discussed in the third video. At the start, it was explained that the application of mIoT was not just limited to patients but could support families, healthcare professionals, hospitals and insurance companies. This element was essential to include to highlight the diversity of application, which addresses the Performance Expectancy and Social Influence component. Following that, an example of the application of mIoT for each group was provided to support the understanding of the viewers.

Similarly, this video component also provided the solution through mIoT to the current and future challenges experienced by the Saudi health sector (explained in the second video). In addition, logical statements were included, which were based on the knowledge developed up to that point through these last two videos. For instance, the component of Performance Expectancy was highlighted by demonstrating that mIoT can reduce the cost of healthcare by reducing unnecessary visits to the doctors and re-admissions, can improve diagnosis and treatment through evidence-based real-time information, assist

equipment management by checking all the equipment in the hospital and making sure their availability on time, and can assist in error reduction by providing real-time data.

Apart from the above, some current real-life examples of mIoT applications employed by other developed countries were also included in the video. For instance, the use of a GE Healthcare system called "AutoBed" for the hospitals, which can monitor 1200 beds by New York's Mt. Sinai Hospital, was demonstrated. A COVID-19 management plan using mIoT technology was also briefly explained in the third video to amply the perception about the need and effectiveness of this technology.

Video component 4

The last and fourth video component was all about the concerns related to the adoption and use of mIoT. The fourth video mainly covered three components - Confidentiality Concerns, Perceived Threat to Autonomy and Computer and English Language Self-efficacy. The first issue discussed in the video was Confidentiality Concerns. At the start, acknowledgement related to the existence of this issue was provided. Then to reduce the perception of the severity of this issue, some state-of-the-art solutions were explained. For instance, the use of cryptography to enhance the security of data was explained. The example of WhatsApp was provided to demonstrate that these solutions were practical as they were incorporated by some famous social media platforms, where the Saudi population, including healthcare professionals, readily exchanged private information.

Then the second concern—Perceived Threat to Autonomy was addressed. However, special care was taken to not highlight the technology in a way that physicians think that the introduction can decrease their control over the conditions, processes, procedures, or content of work [42]. However, a scenario-based example was provided to illustrate that mIoT is like a fast and efficient medical assistant who works under healthcare professionals and can provide suggestions and assistance in healthcare management. At last, the component of Computer and English Language Self-efficacy was addressed, and it was explained that this technology does not require healthcare professionals to be super experts in IT. Instead, the healthcare professionals will be provided with a friendly interface, while the IT specialist working on the back will be responsible for all the technical work.