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Mobile robots for isolation-room hospital settings: A scenario-based preliminary study

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ABSTRACT

Isolated patients pose physical challenges to medical staff owing to the need for protective gear. Additionally, communication issues arise within isolation rooms, hampering patient care. Mobile robots offer potential solutions, allowing for contactless communication and efficient task delegation, thereby reducing the risk of cross-contamination and minimizing staff workload. This preliminary study assessed the usability, acceptability, and potential for improvement of mobile robots in clinical nursing scenarios, focusing on nurses' perspectives. A preliminary test was conducted using mobile robots in a simulated hospital environment with 30 experienced nurses responsible for isolated patient care. Data were collected through interviews, surveys, and scenario-based tasks. Two scenarios were designed to evaluate the usability and effectiveness of mobile robots in real-world nursing situations. Nurses regarded mobile robots as highly usable and useful in healthcare settings. Robots efficiently handled tasks like remote supply delivery and medication distribution. Nurses recognized the potential for improved communication and efficiency with mobile robots; however, concerns were raised about the robots' limitations in providing emotional support and potential safety issues during emergencies. This research emphasizes the promising role of mobile robots in enhancing healthcare delivery within isolation rooms. While these findings indicate the potential for mobile robots, careful planning, training, and scenario development are crucial for their safe and effective integration into clinical settings. Further research, tailored scenarios, and a reevaluation of the evolving role of nurses in a technology-augmented healthcare environment are necessary, emphasizing the importance of understanding the capabilities and limitations of robotic assistance in patient care.

1. Introduction

Dealing with the increase in isolated patients during a pandemic, such as coronavirus disease 2019 (COVID-19), presented numerous challenges, particularly because of unpreparedness. Following COVID-19, hospitals made significant efforts to actively manage and respond to isolated patients who are infected or suspected of being infected, requiring a great deal of human resources and time [1,2]. However, these measures, implemented in a manner heavily reliant on existing human resources, were deemed inefficient [2]. Therefore, there is still a need to improve existing processes and prepare operational measures for different infections in anticipation of possible future infectious diseases [3].

The issues that medical staff encounter in caring for isolated patients are prominently manifested in two aspects. First is the physical difficulty that comes with having to wear protective gear [4,5]. To perform duties in the isolation room, the medical staff who wear protective gear take a long time when entering and leaving the room, in addition to having physical difficulties associated with having to wear the protective gear for a long time and a relatively reduced patient care time owing to the time spent on putting on and taking off the gear [4]. Another issue is the difficulty in providing care owing to the absence of efficient communication among the medical staff within the isolation room [6,7]. In the isolation room, smooth communication becomes difficult owing to physical factors such as protective gear and noises when medical staff who are in protective gear are trying to communicate with patients [4,6]. This could interfere with resolving the health demands of patients or accurately assessing patients, ultimately lowering the quality of medical service [8].

Thus, to resolve the issues that could arise in the context of infectious

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disease, a medical institution needs to consider introducing a system that uses scientific technology for effective communication, in addition to providing care by adding more medical staff [6,9]. Particularly, if contactless communication is enabled using a mobile robot, an information communication technology (ICT) device, this can reduce the time required to put on and take off the protective gear, thereby decreasing the likelihood of cross-contamination. Additionally, it is anticipated that delegating tasks such as drug delivery to mobile robots will enable medical staff to reduce their workload and focus more on direct patient care [10]. Further, automated supply delivery using mobile robots minimizes mistakes or delays as they accurately and quickly move to the destination, which can be monitored in a real-time system [11].

We conducted a survey targeting nurses to assess the utilization of ICT for communication both inside and outside isolation rooms [7]. The results revealed that nurses expected that utilizing robots would enhance nursing efficiency. They suggested that conducting remote consultations through robots, enabling patients to make requests without the physical presence of medical staff, and performing simple tasks such as delivering medications remotely could improve nursing efficiency [7]. However, while the introduction of mobile robots is expected to enhance medical service quality by increasing the efficiency of nursing and reducing burnout among medical staff [12,13], contrary to this, some studies have reported the possibility that the use of robots may only change the nature of nurses' work but not alleviate their actual workload [14,15]. In particular, these studies emphasize that environmental factors must align with robot usage to foster teamwork between humans and robots, leading to the improvement of healthcare service quality in a clinical setting. It underscores the importance of aligning the environmental conditions in the actual implementation with the working conditions and current workflow [14,15]. Neglecting the physical environment within medical institutions, including network infrastructure and the placement of medical devices, could lead to unexpected issues, becoming obstacles to continuous use [9]. Additionally, ICTs used in hospitals may be developed in directions that diverge from the needs of the end-users, such as nurses. Therefore, before introducing new technologies into clinical settings, performance evaluations should be conducted in advance, actively involving medical staff.

In this study, the integration of mobile robots into clinical settings has a threefold objective: to develop scenarios involving robot use, assess their applicability in clinical settings, and investigate nurses' perspectives on the usability of these scenarios. This study aims to determine the effectiveness of these scenarios in addressing practical considerations in real-world healthcare situations. A set of survey questions has been carefully crafted to facilitate this exploration.

Our study strategically utilized isolation-room nursing scenarios with mobile robots among clinical nurses, investigating critical aspects such as usability, acceptability, expected utilization, and potential areas for improvement. In addition, to understand potential challenges in the application of robots, we investigated whether there were differences in usability and difficulty of robot-related tasks among nurses based on their general characteristics and levels of digital literacy. Through this process, we anticipated that nurses' participation in the technology design process would facilitate the development of technology in harmony with its intended application. Furthermore, by conducting a thorough evaluation, we aim to contribute valuable insights for the seamless integration of mobile robots in authentic clinical settings.

2. Material and methods

2.1. Study design

This study was designed as a cross-sectional study for assessing the usability, acceptability, and effects of the mobile robot, among the ICTs available for isolation room patient care. As a preliminary study to validate scenarios and usability of utilizing a mobile robot, this study only conducted post-measurement, as it was not feasible to assess usability before the introduction of the robot.

2.2. Participants

Given that nurses are the primary users of mobile robots in medical settings [16], inclusion criteria focused on nurses with experience in medical institutions who provide care to isolated patients. Nurses with less than one year of experience were excluded because a solid understanding of nursing tasks is essential. In usability tests for new technologies, there is no specific number of participants required to find all usability issues. However, obtaining considerable validity is achieved when 12 to 20 users participate in the user testing [17]. Following a previous study with a similar purpose, the sample size for this study was 30 nurses [18].

2.3. Data collection

Data were collected from January to February 2023. The initial participants were recruited through announcements posted in social networking site chat rooms frequently accessed by individuals in the relevant industries. Employing purposive snowball sampling, participating nurses took an active role in recruiting additional participants to assess the usability of mobile robots in various hospital environments, including the intensive care unit (ICU), ward, and emergency department (ED), and to gather assessments from nurses of diverse age groups. While acknowledging the potential for bias and the difficulty of generalization inherent in snowball sampling methods, this approach was chosen to ensure the participation of individuals from specific departments within the hospital and to capture a range of perspectives across different age demographics.

Before engaging in the study, potential participants received an information sheet detailing their voluntary involvement, ensuring anonymity, and confirming their right to withdraw from the study at any point. Written informed consent was then obtained from all participants before their participation in the intervention.

Data on general characteristics and digital literacy were collected before robot usage, and data on the usability scale (perceived usefulness, perceived ease of use, intention to use), and usage experience were collected after robot usage. An interview of about 20 min in length was conducted in a meeting room where participants could speak comfortably, and the contents were recorded. Field notes were completed to be used in data analysis.

2.4. Mobile robot

The mobile robot utilized in this study is equipped with autonomous driving and following driving functions, along with collision prevention capabilities. It features a single display and can be operated through voice commands (Fig. 1). Detailed functions and specifications are presented in Supplemental Table 1.

2.5. Scenarios and tasks for the preliminary test

To investigate the functions and usability of the mobile robot, the assessment was performed in a nursing college laboratory designed to simulate a virtual isolation-room environment (Fig. 2). The four-bed cohort isolation room was equipped with a mobile robot, stationed to respond from the nursing station. When patients with infectious diseases are admitted to general wards, they use single isolation rooms or cohort rooms. In the case of intensive care units or emergency rooms, single isolation rooms are utilized primarily [19]. Since cohort isolation rooms are larger and more obstacle-filled than single isolation rooms, we assumed that robots evaluated in such environments could also be used in single isolation rooms. In the clinical setting where the robot was utilized, nurses worked in 8-hour shifts, with each nurse caring for 10 to

Fig. 1. Mobile robot used in the study.

12 patients. As a standard practice, one nurse was assigned to three rooms in a four-bed setup. According to a previous study, on average, the frequency of room visits was approximately 6 times per room, resulting in a total of 18 entries and exits for the three rooms [20]. The scenario in this study assumed that a nurse inside the isolation room would care for the patient while communicating with a nurse at the station.

Before conducting the preliminary test, the research team completed various preparations. These included designating the mobile robot station and conducting robot mapping, designating the nursing station outside the isolation room, installing the necessary software program on the computer at the nursing station, and preparing tray items such as those needed for an IV change and Tylenol. We utilized the pre-installed software on the Temi robot without developing a custom program for the scenarios. This software includes functions such as remote control, collision prevention, video conferencing, and voice commands.

The usability assessment involved two scenarios using mobile robots. Before developing the scenarios, the research team conducted a preliminary needs assessment study to investigate the situations where nurses felt the need for a robot and the functionalities they expected from the robot [7]. The scenarios were then developed based on the findings of this study, and the resulting scenarios were subsequently reviewed and confirmed by two nursing college professors and two nurses with over five years of clinical experience. Table 1 displays the complete text of the scenarios and tasks employed in the examination.

After the survey on general characteristics and digital literacy, participants received a brief (approximately 10 min) orientation on operating the mobile robot, including explanations about associated scenarios and tasks. In Scenario 1, the mobile robot performs remote rounds requesting necessary supplies while communicating with a nurse at the station during nursing. In Scenario 2, the robot delivers medications requested by a patient without a nurse entering the room. Following a 20-minute utilization of the mobile robot in accordance with the provided scenarios, participants executed the designated tasks. An adept research assistant, well-versed in the scenarios, assumed the role of a standard patient. To assess the usability of mobile robots using the think-aloud protocol, every aspect of task performance was video-recorded via a rear-mounted camera, and audio recordings were made using a front-facing voice recorder. While executing the tasks, participants vocalized their experiences and perspectives, elucidating their actions, motivations, and anticipated outcomes. After the test, an evaluation survey was administered, and a brief interview was conducted to pinpoint any additional issues or areas for enhancement concerning program usability. These interviews were conducted by one researcher for each participant and lasted approximately 10 min. The interview consisted of questions about participants' experiences using the robot, and all interviews were recorded. Another researcher wrote field notes, including the participants' facial expressions and actions during the interviews, and used them as reference material when analyzing the data.

Table 1
Preliminary test scenario and tasks for the mobile robot.

• Summary of the Scenario	
The assessor is a nurse caring for an isolated patient. The assessor intends to use the mobile robot for patient nursing.	
Scenario 1)	
The assessor is a COVID-19 ward nurse working the day shift. While performing their rounds by remotely controlling the robot at the nursing station outside the cohort isolation room (four-bed room), the assessor finds that the IV injection of the patient in Bed 3 is dislocated. The assessor goes to the cohort isolation room, performs the necessary action, and requests the necessary items from Nurse, who is outside the isolation room using the robot.	
Scenario 2)	
The patient hospitalized in the isolation room self-measured his body temperature through the eardrum and found it to be 38.5 ℃. They request a video call to the nursing station through the robot and report having a fever and a headache. The nurse remotely controls the robot to move it to the front of the door and back toward the patient, and pursuant to the doctor's order, administers Tylenol without entering the room. At the nursing station, the nurse checks the patient's status and whether they have consumed the medicine.	
Tasks for Scenario 1	
1	Log in to the Temi program installed on the laptop placed at the nursing station.
2	Make a video call to the robot in the cohort room using the Temi program installed on the laptop at the nursing station.
3	Remotely control the robot and move it to Bed 3.
4	Check whether the patient has any problems through the video and voice calling functions.
5	Regulate the volume of the microphone and speaker, if necessary, during the conversation.
6	Determine whether the IV injection was dislocated. Send Temi to the docking station and end the video call.
Wear the protective suit and enter the room with a tray prepared with IV items to replace the existing ones.	
7	Place the tray on the robot and use its tracking driving function to approach Bed 3 by touching the upper side of the robot's monitor.
Confirm that the patient's clothes and bed sheet need to be changed.	
8	Make a video call to the station using the robot and ask for help from Nurse 1 by saying, "I need a new bed sheet and patient clothes. Please come with those items and help me.
9	Send the robot to the docking station and charge it by using the voice order function (Hey, Temi, charge).
Tasks for Scenario 2	
10	Using the laptop at the nursing station, take the video call with the robot in the isolation room.
The patient self-measured their body temperature through the eardrum and found it to be 38.5 ℃; they are asking for Tylenol.	
11	Ask the patient additional questions to check their current status.
12	Regulate the volume of the microphone and speaker, if necessary, during the conversation.
13	Remotely, move the robot to the front of the door.
The nurse opens the door of the isolation room and places Tylenol on the robot.	
14	The nurse returns to the station and remotely moves the robot back to the patient.
15	Ask the patient additional questions via video call to check their status and confirm whether they have taken the medicine.
16	End the video call and log out.
17	Remotely move the robot to the docking station and charge it.

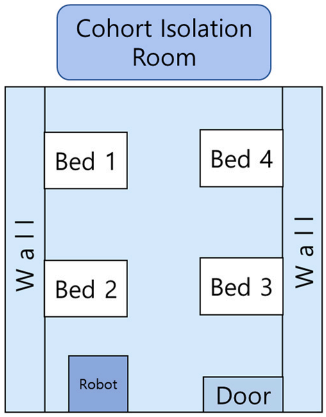

Fig. 2. Layout of the virtual four-bed cohort isolation room.

2.6. Measurements

Before the robot usage according to the scenarios, general characteristics and digital literacy were measured. Digital literacy was assessed to investigate whether there were differences in users' evaluations of usability based on it. After the robot usage, an interview was conducted to explore the usability scale (perceived usefulness, perceived ease of use, intention to use) and usage experience (Supplementary material 1).

2.6.1. Usability scale

No assessment tools in South Korea or abroad have been developed and used for the objectives of this study; thus, a tool from a previous study was adapted to suit the study objectives.

•Perceived usefulness: This concept refers to users' perception of the value of a service delivered to the client being superior to that of an existing service. In this study, this concept refers to the perception of how using mobile robots for communication inside and outside isolation rooms could provide efficiency and effectiveness. Six items related to perceived usefulness were measured using a modified technology acceptance model (TAM), originally developed by Davis [21] and revised and upgraded by Gagnon et al. [22]. For instance, the survey item "The use of telemonitoring system is beneficial for the care of my patients" from Gagnon et al. [22] was modified to assess the perceived usefulness of the mobile robot in accordance with the purpose of this study, becoming "The mobile robot's communication feature will be beneficial for the care of my patients." This tool comprises a seven-point Likert scale ranging from − 3, indicating "strongly disagree" to + 3, indicating "strongly agree." Cronbach's α was 0.94 in Gagnon et al. [22] and 0.82 in this study, indicating good internal consistency.

•Perceived ease of use: This concept refers to individuals' degree of perception about the convenience and ease of using a particular technology. In this study, this was defined as the level of perception the user has about the convenience and ease of using ICT for communication inside and outside the isolation room. Six items related to perceived ease of use were measured using the modified TAM, originally developed by Davis [21] and revised and upgraded by Gagnon et al. [22]. For instance, the survey item "I think that I could easily learn how to use telemonitoring system" from Gagnon et al. [22] was modified to assess the perceived ease of use of the mobile robot, becoming "I think that I easily learned how to use the mobile robot." This tool comprises a seven-point Likert scale ranging from − 3, indicating "strongly disagree" to + 3, indicating "strongly agree." Cronbach's α was 0.94 in Gagnon et al. [22] and 0.89 in this study, indicating good internal consistency.

•Intention to use: This refers to users' strength of intention to use, representing users' attitudes toward the information system, such as reuse and recommendation intentions. Three items related to intention were measured using the modified TAM, originally developed by Davis [21] and revised and upgraded by Gagnon et al. [22]. For instance, the survey item "I have the intention to use telemonitoring routinely for the care of my patients" from Gagnon et al. [22] was modified to assess the intention to use the mobile robot, becoming "I have the intention to use the mobile robot routinely for the care of my patients." Two items were developed by Lewis [23]. This tool comprises a seven-point Likert scale ranging from − 3, indicating "strongly disagree" to + 3, indicating "strongly agree." Cronbach's α was 0.89 for the three items used in Gagnon et al. [22] and 0.94 for the five items used in this study, indicating excellent internal consistency.

2.6.2. Digital literacy

The technology domain of the digital literacy scale developed by Kang [24] was used to compare the differences in ICT usability and satisfaction based on digital literacy. This 22-item survey consisted of nine items on the ability to use software, ten on the ability to use smart devices, and three on the ability to use hardware, each rated on a five-point scale. Cronbach's α of the tool was 0.93 at the time of development [24] and 0.92 in this study, indicating excellent internal consistency.

2.6.3. Degree of difficulty of each task based on the scenario

The difficulty level of nine tasks based on the scenario was measured from one point "very easy" to five points "very difficult."

2.6.4. Interview questions

Structured open-ended questions were used to conduct individual interviews on the advantages and disadvantages of implementing mobile robots, and additional questions were asked based on the participants' responses (Supplemental Table 2).

2.7. Data analysis

Quantitative data analysis was conducted using SPSS 24.0 (IBM, Armonk, NY, USA). SPSS stands as a widely favored statistical software program, extensively employed by healthcare professionals and researchers in the field of health sciences [25]. It facilitates both parametric and non-parametric analyses, providing versatility in catering to the needs of diverse analytical approaches [26]. Descriptive statistics were used to derive real numbers, percentages, means, and standard deviations for quantitative data. We used the Shapiro-Wilk test to test the data distribution for normality. The Shapiro-Wilk normality test for the usability scales and the degree of difficulties indicated a p-value less than 0.05, indicating a non-normal distribution. As a result, the Mann-Whitney U and Kruskal-Wallis tests were performed to investigate the differences in usability and the degree of difficulties based on digital

Table 2
Participant characteristics ($n = 30$).

Characteristics		*n*	%
Gender	Male	1	3.3
	Female	29	96.7
Age (years)	< 30	19	63.3
	≥ 30	11	36.7
	Mean ± SD	28.97 ± 2.36	
Hospital department	ICU	9	30.0
	Ward	17	56.7
	ED	4	13.3
Work experience (years)	< 5	15	50.0
	≥ 5	15	50.0
	Mean ± SD	5.09 ± 2.74	
Education	B.S.	27	90.0
	M.S.	3	10.0
Digital literacy	< 4.5	12	40.0
	≥ 4.5	18	60.0
	Mean ± SD	4.42 ± 0.47	

B.S., bachelor of science; ED, emergency department; ICU, intensive care unit; M.S., master of science; SD, standard deviation.

literacy and participants' general characteristics. The Mann-Whitney U test was used for the comparison of usability for two groups, while the Kruskal-Wallis test was used for the comparison of scale scores for more than two groups.

The participants' statements, collected from the interviews during the evaluation of robot usability, were analyzed using conventional content analysis [27]. The transcribed data were read repeatedly, and key concepts were classified and coded based on meaningful passages and sentences. Codes with similar meanings were categorized into sub-themes and the effects as well as limitations of utilizing mobile robots were derived as the final theme. The assessment was performed based on four criteria including credibility, fittingness, auditability, and confirmability to secure validity in the qualitative results.

To secure credibility, interviews were conducted in a comfortable atmosphere. The interviews took place in a separate space where the research team and participants could converse quietly. The content was recorded to ensure that no data was omitted. To secure fittingness, data were collected and used until saturation. To ensure auditability, all recordings were transcribed, and the content analysis method was strictly followed when analyzing the results. To ensure confirmability, the results were confirmed by members, and representative opinions on the theme are presented in quotations to improve understanding [28].

2.8. Ethical considerations

This study was conducted after obtaining approval from the Institutional Review Board of Gachon University on December 13, 2022 (no. 1044396–202210-HR-200–01). The study was conducted only with participants who gave informed consent for participation and completed written consent. During the execution of the robot usage tasks, it was clarified to participants that video and audio would be recorded using the rear-mounted camera. The recorded video files and anonymized transcriptions of the audio would be encrypted to ensure access only by the researchers. It was explained to the participants that their identities would be edited out to ensure non-identifiability when creating images for describing the research process within the videos. Participants were informed that they could withdraw participation at any time.

3. Results

3.1. General characteristics

The participants were 30 clinical nurses (29 women). Their mean age was 28.97 ± 2.36 years. Concerning department, 56.7% worked in the general ward, 30.0% in the ICU, and 13.3% in the ED. The mean level of experience was 5.09 ± 2.74 years. Concerning education, 90% held a bachelor's degree. On average, participants demonstrated a high level of digital literacy, scoring 4.42 ± 0.47 out of 5, with software utilization ability at 4.28 ± 0.58 points, device utilization ability at 4.65 ± 0.40 points, and hardware utilization ability at 4.10 ± 0.89 points (Table 2).

3.2. Assessment of functional difficulty according to mobile robot scenario

For each scenario, difficulty was measured on a scale of 1 to 5, in which 1 is very easy and 5 is very difficult. All participants could use the functions easily without difficulty, as the difficulty of using Temi was 1.32 ± 0.42 points and 1.23 ± 0.37 points on average for Scenario 1 and Scenario 2, respectively, with an overall mean of 1.28 ± 0.38 points (Table 3, Fig. 3, Fig. 4). The task with the highest difficulty was "Send Temi to Home base / End the video call (1.47 ± 0.68)," followed by "Make a video call to the station by Temi (1.40 ± 0.50)." There were no significant differences in difficulty according to participants' general characteristics or digital literacy (Supplemental Table 3).

Table 3
Degree of task difficulty in mobile robot scenarios.

Functionality		Degree of difficulty		
		Mean ± SD	Max	Min
Scenario 1				
1	Log in	1.30 ± 0.60	3.00	1.00
2	Make a video call	1.23 ± 0.43	2.00	1.00
3	Remotely control the robot / move it to bed #3	1.30 ± 0.47	2.00	1.00
4	Check if anything makes the patient uncomfortable	1.37 ± 0.61	3.00	1.00
5	Regulate microphone & speaker volume	1.27 ± 0.45	2.00	1.00
6	Send Temi to home base / End the video call	1.47 ± 0.68	4.00	1.00
7	Place the tray on Temi / Command Temi to move to bed #3	1.37 ± 0.61	3.00	1.00
8	Make a video call to the station using Temi	1.40 ± 0.50	2.00	1.00
9	Give the voice command / Send Temi to its home base for charging	1.27 ± 0.45	2.00	1.00
Sub-total (Scenario 1)		1.32 ± 0.42		
Scenario 2 (One bed isolation room)				
10	Receive a video call at the station initiated through Temi	1.17 ± 0.38	2.00	1.00
11	Conduct an extra examination	1.27 ± 0.45	2.00	1.00
12	Adjust the volume of the microphone & speaker	1.20 ± 0.41	2.00	1.00
13	Remotely control Temi to move it in front of patient's room	1.23 ± 0.43	2.00	1.00
14	Remotely control Temi to move it back to the patient	1.30 ± 0.47	2.00	1.00
15	Check the patient's condition / Check the patient's medication by video	1.30 ± 0.47	2.00	1.00
16	End the video call / log out	1.20 ± 0.41	2.00	1.00
17	Send Temi to the home base for charging	1.20 ± 0.41	2.00	1.00
Sub-total (Scenario 2)		1.23 ± 0.37		
Total		1.28 ± 0.38		

3.3. Usability of mobile robot

The perceived usefulness of the mobile robot was 2.47 ± 0.51 points on average, while the perceived ease of use and intention to use were 2.58 ± 0.57 and 2.36 ± 0.84 points on average, respectively, indicating not only high perceived usefulness and ease of use but also a strong intention to use. When differences in usability were analyzed according to the general characteristics of participants and digital literacy, no significant differences were observed (Table 4).

3.4. Clinical nurses' robot use experience

In addition to the high usability shown in the quantitative results of this study, the opinions of participants supporting the usefulness of the robot use scenario were confirmed through interviews. Furthermore, specific aspects and considerations for the clinical application of the robot, which were challenging to derive through quantitative results, were supplemented through interviews. The expectations and limitations of using mobile robots in nursing situations were identified based on the usage experience of 30 nurses. Two themes were identified, which were "catalysts for efficient nursing" and "improvements for clinical nursing application (Table 5)."

3.4.1. Catalysts for efficient nursing

The nurses evaluated the usability of robots in the presented scenario highly as indicated by the survey results, expressing interest in the

Fig. 3. Simulation setting and mobile robot: (a) Medical staff outside the isolation room displayed on the robot screen, (b) Communication between the isolation room and the outside through the robot, (c) Remote consultation from outside the isolation room, (d) Video calls between the patient and the outside of the isolation room, (e) Robot delivering medication along mapped paths, (f) Robot autonomously tracking medical staff without physical contact.

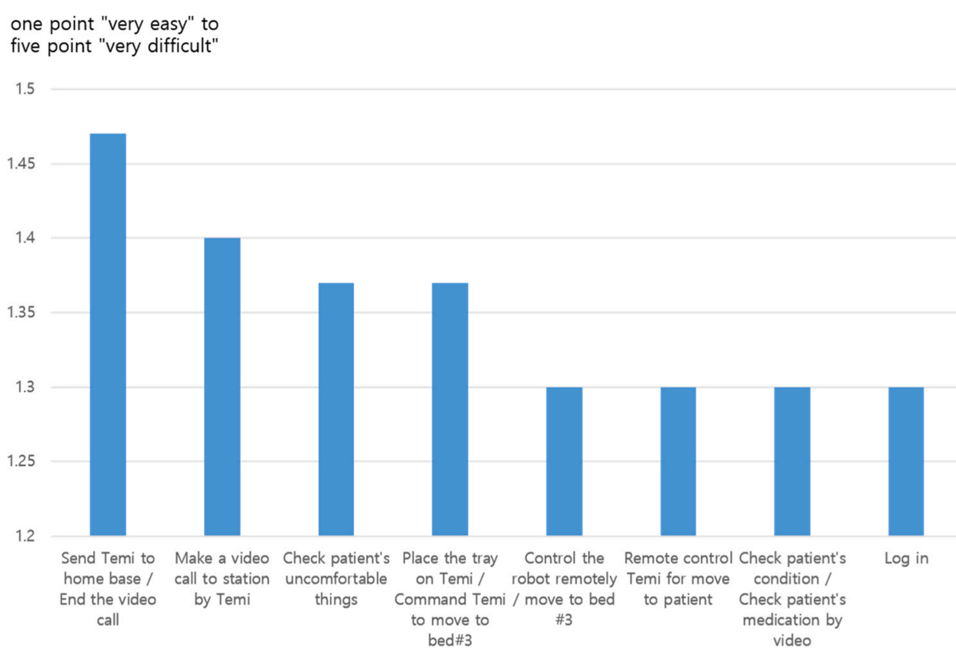

Fig. 4. Functional difficulty according to mobile robot scenario.

potential use of robots in a hospital setting. The nurses found it interesting that robots can be used in the hospital setting, stating that eliminating the need to put on and take off a uniform was the advantage. They were hoping that the robots could be used to reduce their workload and improve efficiency after experiencing the role of the robots in aiding real-time communication with patients in the isolation room and performing simple and repetitive isolation room duties.

Table 4
Perceived usefulness, perceived ease of use, and intention to use of the mobile robot.

Categories		Usability evaluation					
		Usefulness		Ease of use		Intention to use	
		Mean ± SD	p	Mean ± SD	p	Mean ± SD	p
Gender	Male	2.83		3.00		2.80	
	Female	2.46 ± 0.52		2.56 ± 0.58		2.34 ± 0.85	
Age (years)	< 30	2.43 ± 0.56	.727*	2.59 ± 0.61	.705*	2.19 ± 0.95	.238*
	≥ 30	2.55 ± 0.43		2.56 ± 0.54		2.65 ± 0.52	
Hospital department	ICU	2.17 ± 0.65	.281**	2.48 ± 0.75	.520**	1.82 ± 0.99	.096**
	Ward	2.58 ± 0.42		2.58 ± 0.52		2.50 ± 0.71	
	ED	2.70 ± 0.29		2.79 ± 0.42		2.95 ± 0.10	
Region	Seoul	2.17 ± 0.52	.421**	2.41 ± 0.48	.372**	2.40 ± 0.71	.467**
	Incheon	2.50 ± 0.52		2.55 ± 0.64		2.25 ± 0.91	
	Other	2.58 ± 0.51		2.78 ± 0.36		2.70 ± 0.64	
Education	B.S.	2.46 ± 0.54	.889*	2.59 ± 0.58	.542*	2.29 ± 0.85	.080*
	M.S.	2.61 ± 0.26		2.44 ± 0.59		3.00 ± 0.00	
Work experience (year)	< 5	2.32 ± 0.51	.071*	2.50 ± 0.70	.796*	2.17 ± 0.84	.076*
	≥ 5	2.62 ± 0.49		2.65 ± 0.42		2.55 ± 0.82	
Digital literacy	< 4.5	2.36 ± 0.56	.345*	2.64 ± 0.43	.913*	2.50 ± 0.67	.865*
	≥ 4.5	2.55 ± 0.48		2.54 ± 0.66		2.27 ± 0.94	

B.S., bachelor of science; ED, emergency department; ICU, intensive care unit; M.S., master of science; SD, standard deviation.
* Mann-Whitney U test
** Kruskall-Wallis test

Table 5
Clinical nurses' robot use experience.

Themes	Sub-themes	Codes
Catalysts for efficient nursing	Performing a safe helper role for nursing work	Replaces personnel in simple task performance (e.g., delivering water or toilet paper, emptying trash cans, etc.)
		Eliminates the repetitive donning and doffing of the protective gown/suit
		Alternative to manpower shortages
		Minimizes the possibility of infection transmission
	Utilization as a real-time communication channel	Clear communication through voice and video
		Enhances interaction between patient and nurse
Improvements in clinical nursing application	Nursing competency of mobile robot, which is difficult to operate in an emergency	Slow movements, unsuitable for busy clinical settings
		Traffic lines in hospitals are complicated for robots to navigate
		Nurses are accustomed to performing direct care
	Conflict with the needs of patients seeking human nurses	Patients who want an immediate solution from a nurse
		Older patients who are not familiar with machines
		Nurses' ability to understand patients' needs
	Nurses' negative perception of robot use	Economic burden of using expensive equipment
		Worrying about breakdowns when using at night or on weekends
		Anxiety about patient safety issues owing to machine failure (e.g., medication delivery error in a shared room)

1) Performing a safe helper role for nursing work

Nurses believed that the robot could perform simple assisting duties or repetitive duties and supply management that need not be performed by the nurses. They were expecting improved efficiency in nursing work as robots could fill in for the lack of human resources in clinical settings.

It was interesting to see the robot deliver the necessary supplies to the patient on its own. When caring for an isolated patient, it takes a long time to get in and out of the level D gear and it's hot and strenuous. I also worry about being the source of infection. The robot can perform simple duties like delivering water or toilet paper to the patient in the isolation room. It saves time and saves the energy of the nurses—I think it can be very useful considering work efficiency. (Participant 21)

Specifically, participants emphasized that voice commands and automatic docking charging methods are ways to use the robot more conveniently.

Nurses are busy with work and from our standpoint, it would be very convenient if we could move or operate the robot with voice commands without touching it because we can then use it without any concerns for cross-contamination in the isolation room and it can move itself to the docking station to get charged once the work has been performed. (Participant 17)

2) Utilization as a real-time communication channel

Nurses mentioned the advantage of enhanced interaction with patients, as the robot helps in checking the patient both visually and by voice as it moves around the patient in the isolation room. They said that it had the same effect as assessing the patient in person since the patient could be identified through the robot by means of screen sharing.

I think it's useful because I feel like I am talking to the patient face-to-face when the robot directly shares the screen around the patient. It is vital for the isolation room that without the medical staff actually going into the room, the robot is in the isolation room and that it can communicate in real-time with the medical staff who are outside the room. There are numerous limitations in communications in the isolation room since we have to put on the protective gear plus the face mask. It's also better for the patient because now there is a way to communicate more clearly face-to-face through the robot. (Participant 18).

Specifically, the function of the robot changing the angle according to the speaker's direction allows the camera to show the patient or nurse more accurately in the isolation room without the user having to operate it, which improves the sense of having a real conversation.

I really like the function that the robot faces the direction of the command when a voice command is given or during video calls. There is no need to adjust the direction of the camera by touching the robot since the robot recognizes the sound source and changes its orientation, which gives the feeling of having a conversation in the same space. (Participant 5).

3.4.2. Improvements in clinical nursing application

Nurses were concerned about the nursing competence of the robot in terms of difficulty in responding to emergencies that could occur in hospital settings and mentioned difficulties in clinical application in light of patients' needs for human care rather than machine care. Further, nurses also worried about using a high-cost robot and for patient safety.

1) Nursing competency of mobile robots and potential difficulty in dealing with emergencies

   The nurses mentioned that the robot moves slowly in a fast-paced clinical setting and that it could trip on power cords.

   It is difficult to use it in a department where there are many CPR cases with complicated movement lines, although I think it can be used in a stable ward without too many changes or in a children's ward as they could find it interesting. The nurses who are in a rush prefer to do the work themselves rather than give commands to the robot. (Participant 9)
2) Conflict with the needs of patients seeking human nurses

   Nurses believed that the robots could not replace them in providing emotional support to patients who demanded it. They said that patients who need someone to solve their issues immediately require a human nurse rather than a robot and that it was unlikely that the robot could replace the unique role of the nurses.

   There are many elderly patients in the hospital who prefer to talk to human nurses. They become anxious about not seeing the nurses in person and could complain that a robot is sent for them instead of a real nurse. In reality, patients often feel better when the nurses listen to them and touch them, but this cannot be done by the robot. (Participant 30)
3) Nurses' negative perception of robot use

As the use of mobile robots has not been commercialized in clinical settings yet, the nurses were worried about the cost burden of the expensive equipment. Despite evaluating the robot as easy to use and user-friendly through the survey, they expressed concern about older nurses with potentially lower digital literacy or limited technological experience adapting to using the robot. Further, they were worried about any issues in patient safety owing to the robot's mistake or malfunction over the weekend or at nighttime. They mentioned that there needs to be a clear demonstration of safety while promoting the use of robots to overcome this.

There is the cost burden for repair when broken since the robot is expensive; older nurses could take time to get used to the robot since they prefer to stick to familiar things. Further, I worry that it could be harmful to patients in case of any errors. As rooms with multiple beds are common in South Korea, I am concerned that a drug could be delivered to Patient B instead of Patient A. It would be nice to have a safety system like RFID or something that could identify the patient. As it is not widely used in hospitals, I think safety has to be demonstrated. (Participant 15).

4. Discussion

This study assessed the usability of mobile robots based on the scenarios in a simulation center that implemented a hospital setting with nurses who have experience with caring for patients in the isolation room. When the level of difficulty for each function of the robot was evaluated by the task of different scenarios, the nurses could complete all tasks without difficulty. Therefore, there was no difference in the difficulty of each function of the robot due to nurses' general characteristics or digital literacy. Although the criteria for assessing the level of digital literacy were not explicitly stated during the tool's development [24], a score of 4 or higher was interpreted as a high level in the tool development study. The average digital literacy score of the participants in this study was 4.42 ± 0.47, indicating a high level. Nurses with a relatively high level of digital literacy used the mobile robot without difficulty; however, concerns were raised during the interviews regarding potential difficulties for nurses with limited technological experience. Further research is needed to investigate the seamless use of robots among nurses with diverse levels of digital literacy or technological proficiency.

Nurses successfully performed tasks related to the robot's functions and rated the difficulty uniformly. However, in interviews, they expressed some difficulty with tasks associated with voice commands and remote control. In previous studies evaluating the usability of robots in hospital environments, remote control and voice commands were reported to potentially pose a greater difficulty compared to other tasks [29,30]. However, after brief training on usage, the medical staff could comfortably use most functions without significant difficulty. Voice commands are critical in reducing cross-contamination since they allow the operation of the robot without direct contact [31]. While performing other nursing tasks, the efficiency of nursing can be increased by calling the robot using a starter word, moving the robot using voice commands, or communicating with the outside world through the telepresence function. Thus, it is necessary to present a variety of cases when providing training for robot use so that voice commands can be appropriately used between patients and nurses.

Usability evaluation was high as the result was 2 points and above on a seven-point scale from -3 to 3. This is similar to the findings of Lee et al. [32], where nurses provided positive feedback on using the robot system. This indicates the nurses' acceptance of automating the health care system through robots, particularly when experiencing a pandemic [33]. In general, accepting the use of robots in the public healthcare field requires the motivation of the user, ease of use, and physical/emotional comfort [34]. Nurses agreed on the utilization of the robot in the isolation room based on the various functions of the robot according to the scenarios. They experienced the advantages of the robot through the convenience of function, such as operating smoothly according to the commands or instructions of the user, moving through the mapped routes, and docking automatically at the charging station. However, in a previous study, patients rated the perceived ease of use of robots below average, unlike nurses, due to their lack of technological experience and concerns about the reliability and safety of the robot [33]. While this study focused on evaluating the usefulness and usability of robots from the perspective of nurses, patients, as the other users of robots in hospital rooms, need to be surveyed for their requirements and expectations.

Nurses both looked forward to improved nursing efficiency through support from the robot in the isolation room and expressed concern concurrently. Specifically, they were hoping the robot could perform the role of the safe helper in delivering supplies and performing repetitive tasks. It is appropriate to delegate simple, repetitive tasks in the robot systemization of nursing work so that any work outside of patient contact time can be reduced [12]. To do this, tasks that can be performed by the robot need to be defined first based on a detailed analysis of nursing work and understanding of nursing techniques. Particularly, caution must be used so that the robot does not interfere with the nature and value of nursing [35]. In clinical settings, patient care by robots and cases requiring human interaction must be clearly identified [36]. First, the scope of use and guidelines must be prepared for the robot's work by looking for ways to utilize the robot in tasks that do not have a direct effect on patient health indicators and involve risk factors when directly performed by the nurses.

Being treated in isolation rooms or reverse isolation rooms can be associated with high levels of anxiety, and the call bells that allow communication by voice have limitations in meeting the purpose of emotional care [37]. Thus, clearer and more reliable communication was only possible when the robot turned to the source of the sound and allowed the nurses to see the faces of patients in this study. Communication occurs within human relationships, so there is a negative view regarding the substitution of this role by scientific technology [38]; however, interest in emotional communication using robots has been increasing recently [39]. Among older adults in nursing homes, communicative robots reduce their psychosocial burden and help increase verbal and behavioral engagement [40]. Further, having a comforting conversation with robots that use an emotional voice can be effective in providing encouragement and empathy to participants [41]. These findings are similar to the positive effect of communication identified in the current study and are the basis for considering the utilization of robots to provide emotional care to patients in isolation. In addition, a study performed in a long-term care facility in Japan [42] reported a workload-reducing effect on night-shift nurses by introducing a communicative robot. Currently, there is a lack of consensus on the communicative effects of the robot on communication between patients and medical staff—assessment of the effect on the communication between patients and medical staff in various environments is necessary to provide appropriate support.

Some participating nurses remarked that patients prefer humans to machines, noting limitations in offering emotional support through a robot. Prioritizing automation with robots and efficiency as a means of replacing nurses could potentially neglect the nursing values of empathy, diplomacy, and personalized considerations for patients [13,43]. However, the introduction of robots into nursing should be in an auxiliary role to nurses and not as a complete replacement for them. Categories of utilizing robot systems in nursing are diverse, including information and patient data processing, assistance with patient activities, monitoring, telepresence, communication, safety and navigation [44]. A previous study showed that using a meal assistant robot created a more private and independent eating environment and patients comfortably accepted the robot [45], while another previous study showed patients positively accepting robots instead of fearing them [46], which suggests that there could be a gap between robot acceptance by patients as imagined by medical staff and the actual reality. Some argue that the robot itself does not need social skills, empathy, or emotions to support the user [35]. When using robots, it is important to carefully consider the interaction between the robot and nursing situations in social contexts without being restricted by ethical biases regarding the risk of isolation of humans [35].

The limitations of using robots as identified in this study include difficulty in determining the appropriate speed of the robot, errors in the robot's routes owing to the changing environment of the hospital following the placement of things or equipment, and the robot becoming an obstacle in an emergency. The current robot system developed to help with nursing tasks is not in general use owing to high costs, difficult operational methods, and large volume [12]. However, the robots being used in hospitals recently can detect people or obstacles in a crowded facility and reduce speed, avoid or stop voluntarily [47]. Using the periodic automated re-mapping function, it can serve as a nursing assistant by following preset routes in an isolation or reverse isolation environment to monitor patients in real-time and check on the safety of patients [35]. The usage of robots in the field of nursing should not be viewed as completely good or bad but from a variety of different perspectives [48]. Rather than the critical view that the introduction of robots violates nursing values, such as human dignity, personal privacy, autonomy, commitment, human relationship, compassion, and communication, a practical strategy is needed for integrating robotic technology into the area of patient care with open-mindedness and overcoming its shortcomings [46]. Specifically, efforts are required to set standards and prepare usage regulations to minimize expected risks by planning scenarios to reflect clinical settings in which the robot will be performing tasks prior to introducing it to the medical institution. In addition, introducing the robot when the medical institution is not prepared could lead to various problems for patients and the medical staff. Reinforcing the standard competence of nurses and nursing students as well as thorough preparation and training for using the new technology are required for accepting and interacting with the robot [37,45].

This study has several limitations. First, the robot usability assessment from the perspective of the patient was not performed as we only assessed nurses' perspectives. As such, an assessment of specific effects such as communication, anxiety, self-efficacy, and emotional support must be conducted in addition to the usability assessment by the patient to reflect various perspectives concerning using the robot. Second, this study conducted a usability assessment with two scenarios, but a new scenario reflecting special circumstances such as the ED or the ICU must be developed in the future to identify the feasibility of using robots and their clinical effects by running a simulation module suitable for each department. Third, an interview guide was created with open-ended questions to obtain the participants' free thoughts, but this has limitations in that valuable insights may be missed in the interview, or more complex issues related to robot implementation, such as difficulties with specific functionalities or aspects of the robot's design, may not be captured. Accordingly, to elicit in-depth and diverse answers from participants regarding robot use, it is necessary to develop more detailed follow-up questions and conduct interviews with sufficient time. Finally, this study assessed mobile robot use with two scenarios involving 30 nurses in a limited simulation environment. Thus, mobile robot usage cannot be expanded and implemented in actual hospital isolation settings. Therefore, further evaluations are needed, taking into consideration the physical environment and users.

5. Conclusions

When the mobile robot was assessed by nurses based on scenarios, the nurses gave positive assessments with high usability regardless of their general characteristics. This is expected to provide effective support in isolation-room care. The introduction of robotic technology is anticipated to enhance agility and efficiency in nursing practices. A well-designed contextualized robot can perform simple tasks and help nurses to spend more time on patient care. Simultaneously, these changes demand new expertise and technological competencies from nurses. Redefining the role of nurses and the preparation of clinical nurses are critical to safely use robots in nursing in line with the advancement in scientific technology. Nurses need to continually improve their understanding and acquisition of skills for the latest technologies. In this manner, they will be able to effectively perform their role in patient care in the future healthcare environment by collaborating with robots and leveraging technological capabilities. However, nurses are not mere technicians operating the robots—they need to have a clear identity as caregivers. Studies on the effects of communication through robots show contrasting results; thus, additional research is necessary in various contexts to reinforce the basis for the effects of communication. The results of this study highlight the need to address factors that hinder communication through robots, especially considering how to meet the demands of patients who require human care and the challenges of managing robots. Therefore, it is essential to proactively apply robots in clinical settings where their capabilities can be best leveraged.

In a future study, building upon the positively evaluated scenarios by nurses, we plan to explore the practical application of robots in clinical settings. This will involve addressing issues related to robot management and safety, implementing appropriate direct nursing and robot-assisted nursing distribution based on patient demands. The aim in that study will be to evaluate the efficiency of nursing practices in real clinical environments through the integration of robots. This research will contribute to a comprehensive understanding of the practical implications and effectiveness of implementing robots in nursing, extending beyond the scope of the preliminary study and providing valuable insights for future healthcare practices and research.

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Declaration of Competing Interest

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

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.csbj.2024.03.001.

References

[1] Chandra M, Kumar K, Thakur P, Chattopadhyaya S, Alam F, et al. Digital technologies, healthcare and Covid-19: Insights from developing and emerging nations. Health Technol (Berl) 2022;12:547–68.
[2] Mo Y, Deng L, Zhang L, Lang Q, Liao C, et al. Work stress among Chinese nurses to support Wuhan in fighting against COVID-19 epidemic. J Nurs Manag 2020;28:1002–9.
[3] Ding X, Clifton D, Ji N, Lovell NH, Bonato P, et al. Wearable sensing and telehealth technology with potential applications in the coronavirus pandemic. IEEE Rev Biomed Eng 2021;14:48–70.
[4] Kang J. Simulation results for contamination comparisons by various use protocols of personal protective equipment. Korean J Med 2018;93:41–9.
[5] Xia W, Fu L, Liao H, Yang C, Guo H, et al. The physical and psychological effects of personal protective equipment on health care workers in Wuhan, China: a cross-sectional survey study. J Emerg Nurs 2020;46:791–801. e7.
[6] Shin S, Yoo HJ. Emergency nurses' communication experiences with patients and their families during the COVID-19 pandemic: a qualitative study. Int Emerg Nurs 2023;66:101240.
[7] Yoo HJ, Lee H. Critical role of information and communication technology in nursing during the COVID-19 pandemic: a qualitative study. J Nurs Manag 2022;30:3677–85.
[8] Shin S, Yoo HJ. Frontline nurses' caring experiences in COVID-19 units: a qualitative study. J Nurs Manag 2022;30:1087–95.
[9] Salman S, Saleem SG, Khatri A, Jamal I, Maroof Q, et al. Inter-hospital communication and transfer practices during COVID-19 Pandemic in Karachi, Pakistan. A brief overview. Pak J Med Sci 2020;36:S118–20.
[10] Moon J, Cho Y. Healthcare robots in the new normal era; outlook for the post-corona era. J Digit Converg 2021;19:509–14.
[11] Vongbunyong S., Tripathi S.P., Thamrongaphichartkul K., Worrasittichai N., Takutruea A., et al. (2020) Simulation of autonomous mobile robot system for food delivery in in-patient ward with unity 15th International Joint Symposium on Artificial Intelligence and Natural Language Processing(iSAI-NLP). 2020.
[12] Jang A, Cho YJ. Robot systemization of ward nursing work. J Digit Converg 2021;19:465–70.
[13] Krick T, Huter K, Domhoff D, Schmidt A, Rothgang H, et al. Digital technology and nursing care: a scoping review on acceptance, effectiveness and efficiency studies of informal and formal care technologies. BMC Health Serv Res 2019;19:400.
[14] Eriksen K.T., Bodenhagen L. (2023, August) Understanding human-robot teamwork in the wild: The difference between success and failure for mobile robots in hospitals. In 2023 32nd IEEE International Conference on Robot and Human Interactive Communication (RO-MAN) (pp. 277–284). IEEE.
[15] Vongbunyong S., Thamrongaphichartkul K., Worrasittichai N., Takutruea A., Prayongrak T. (2021, November) Development of Tele-Operated Mobile Robots for COVID-19 Field Hospitals. In 2021 25th International Computer Science and Engineering Conference (ICSEC) (pp. 319–324). IEEE.
[16] Gibelli F, Ricci G, Sirignano A, Turrina S, De Leo D. The increasing centrality of robotic technology in the context of nursing care: bioethical implications analyzed through a scoping review approach. J Health Eng 2021;2021:1478025.
[17] Alroobaea R., Mayhew J. (2014, August) How many participants are really enough for usability studies?. In 2014 Science and Information Conference (pp. 48–56). IEEE.
[18] Lee H, Kim J, Kim S, Kong HJ, Joo H, et al. Usability evaluation of user requirement–based teleconsultation robots: a preliminary report from South Korea. Methods Inf Med 2020;59:86–95.
[19] Patterson B, Marks M, Martinez-Garcia G, Bidwell G, Luintel A, et al. A novel cohorting and isolation strategy for suspected COVID-19 cases during a pandemic. J Hosp Infec 2020;105:632–7.
[20] Lee H, Lee D, Lee S. Need for information and communication technology during COVID-19: an exploratory study using nurses' activity diaries. Health Inf Res 2023;29:256–68.
[21] Davis FD. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q 1989;13:319–40.
[22] Gagnon MP, Orruño E, Asua J, Abdeljelil AB, Emparanza J. Using a modified technology acceptance model to evaluate healthcare professionals' adoption of a new telemonitoring system. Telemed J E Health 2012;18:54–9.
[23] Lewis JR. Comparison of four TAM item formats: effect of response option labels and order. J Usability Stud 2019;14:224–36.
[24] Kang JM, Song HJ, Kim HS. Development and application of the diagnostic instruments for measuring digital literacy in the smart society. J Korean Assoc Reg Info Soc 2014;17(3):143–73.
[25] Hagen S. SPSS in Practice. Nurse Res 2002;10(2):86–8.
[26] Chan YH. Biostatistics 102: quantitative data–parametric & non-parametric tests. Blood Press 2003;140(24.08):79.
[27] Hsieh HF, Shannon SE. Three approaches to qualitative content analysis. Qual Health Res 2005;15:1277–88.
[28] Sandelowski M. The problem of rigor in qualitative research. ANS Adv Nurs Sci 1986;8:27–37.
[29] Yoo HJ, Kim J, Kim S, Jang SM, Lee H. Development and usability evaluation of a bedside robot system for inpatients. Technol Health Care 2022;30(2):337–50.
[30] Arent K., Jakubiak J., Drwięga M., Cholewiński M., Stollnberger G., et al. (2016, July) Control of mobile robot for remote medical examination: Design concepts and users' feedback from experimental studies. In 2016 9th international conference on human system interactions (HSI) (pp. 76–82). IEEE.
[31] Wang X. Application of big data and artificial intelligence technology in the prevention and control of COVID-19 epidemic. J Phys Conf S 2021;1961.
[32] Lee JY, Song YA, Jung JY, Kim HJ, Kim BR, et al. Nurses' needs for care robots in integrated nursing care services. J Adv Nurs 2018;74:2094–105.
[33] Leslie TA, Dalyop KM, Asonye CC, Sebiotimo CO, Solanke AA, et al. Perceived usefulness and perceived ease of use (acceptability) of robotics in nursing care among nurses and patients, in a selected hospital, south-west, Nigeria. J Med Dent Scie Res 2021;8(9):41–50.
[34] Neumann D. Human assistant robotics in Japan. Minerva Fellowship programme report. Tokyo: EU-Japan Centre for Industrial Cooperation,; 2016.
[35] Song YA, Kim HJ, Lee HK. Nursing, robotics, technological revolution: robotics to support nursing work. J Korean Gerontol Nurs 2018;20(20 Supplement 1):144–53. 144-153.
[36] Kim KJ, Jang BY, Jung JY, Park OW. The coming of the 4th Industrial Revolution and the HRD issues for nurses-prospects and challenges. Korean J Resour Dev 2018;21:137–59.
[37] Fan PEM, Aloweni F, Lim SH, Ang SY, Perera K, et al. Needs and concerns of patients in isolation care units-learnings from COVID-19: a reflection. World J Clin Cases 2020;8:1763–6.
[38] Hong E, Shin S. Nurses' perceptions of care robots in long-term care facilities. J Korean Gerontol Nurs 2019;21:22–32.
[39] Becker M, Efendić E, Odekerken-Schröder G. Emotional communication by service robots: a research agenda. J Serv Manag 2022;33:675–87.
[40] Obayashi K, Kodate N, Masuyama S. Assessing the impact of an original soft communicative robot in a nursing home in Japan: Will softness or conversations bring more smiles to older people? Int J Soc Robot 2022;14:645–56.
[41] Fu C, Deng Q, Shen J, Mahzoon H, Ishiguro H. A preliminary study on realizing human–robot mental comforting dialogue via sharing experience emotionally. Sens (Basel) 2022;22:991.
[42] Masuyama S, Obayashi K, Ogata T, et al. Measuring impacts of introducing communicative robots with infrared radiation monitoring system on workload of night shifts in nursing care facilities. Age Ageing 2017;46(Suppl.3):iii13–59.
[43] McAllister M, Kellenbourn K, Wood D. The robots are here, but are nurse educators prepared? Collegian 2021;28:230–5.
[44] Ohneberg C, Stöbich N, Warmbein A, Rathgeber I, Mehler-Klamt AC, et al. Assistive robotic systems in nursing care: a scoping review. BMC Nurs 2023;22(1):1–15. https://doi.org/10.1186/s12912-023-01230-y.
[45] Park D, Hoshi Y, Mahajan HP, Kim HK, Erickson Z, et al. Active robot-assisted feeding with a general-purpose mobile manipulator: design, evaluation, and lessons learned. Robot Auton Syst 2020;124:103344.
[46] Nielsen S, Langensiepen S, Madi M, Elissen M, Stephan A, et al. Implementing ethical aspects in the development of a robotic system for nursing care: a qualitative approach. BMC Nurs 2022;21(1):1–10. https://doi.org/10.1186/s12912-022-00959-2.
[47] Shen Y, Guo D, Long F, Mateos LA, Ding H, et al. Robots under COVID-19 pandemic: a comprehensive survey. IEEE Access Pr Innov 2020;9:1590–615.
[48] Nieto Agraz C, Pfingsthorn M, Gliesche P, Eichelberg M, Hein A. A survey of robotic systems for nursing care. Front Robot AI 2022;9:832248.