A Survey on Medical Robotic Telepresence Design from the Perspective of Medical Staff

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Abstract

Background With the development of robotic technology, including Artificial Intelligence (AI), robotic telepresence is slowly making its way into our surrounding environment through a variety of commercial products that allow people to communicate remotely. Previous research about Robotic Telepresence for the Medical environment (RTM) mainly focused on developing or improving systems designed for specific application domains, such as surgical operations, elderly care, educational training, and Intensive Care Units (ICUs). This paper instead focuses on understanding the design factors for robotic telepresence with medical purpose that better address the needs and the points of view of the diverse staff members who operate these systems.

Methods We conducted a qualitative user study to investigate the perspectives of various medical staff (14 doctors, two nurses, and one administrator), and we asked them which main factors may influence their perception and usage of RTM. We conducted semistructured in-depth interviews and an open-ended survey to understand the participants' current way of using telecommunication systems and their expectation about RTM, with focus on three points: context of use, additional functionalities, and appearance.

Results The results showed that medical staff has concerns about how to operate systems for medical services and opinions about the viability of the physical interaction between the medical staff and the patients through the robotic systems. Based on the collected data, we organized the results into three parts: usage context, functionality, and appearance design.

Conclusions In this paper, we explore possible design directions for medical RTM based on the opinions of various medical staff. We then discuss the main design factors, and we suggest general features of RTM related with trust, the suitable number of people interacting with the system, the level of expertise of the medical staff, the type of disease treated, and the appearance of the robot itself (e.g., height, humanoid features). In addition, we suggest three design directions to explore unique usage purposes: advanced visual communication, attachment of a required medical unit, and integration into the environment.

Keywords Robotic Telepresence, Medical Staff, Operator's Extension, Design Direction

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1. Introduction

Robotic Telepresence for Medical environment (RTM) supports audio-visual telepresence and allows medical staff to physically interact with remote patients and the surrounding environment through mechanical actuation. In previous studies, researchers have applied RTM in the areas of postoperative care after minor invasive surgery, for orthopedic postoperative care with long hospitalization, for intensive care units (ICU), and for surgery procedures and training [6]. Also, companies like "Intouch Health" are focusing their efforts on building similar platforms [3].

Past studies accounting the users' perspective mostly focused on the satisfaction and acceptance of users of RTM in specific areas with systems that were already designed and built, leaving little room to explore different design alternatives. Thus, in this paper, we aim to understand and collect the design features expected by the medical staff from diverse domains, who will be the main operators of the RTM systems. By doing so, we aim to include potential users in the early stage of the development, as the previous study suggested [5].

Specifically, we use a user-centered design approach based on interview and a questionnaire to investigate three aspects of RTM: medical usage context, additional functionality required for medical applications, and appearance.

2. Previous Works

Previous work focused on the satisfaction and acceptance of patients treated with RTM during hospital rounding [2] or in Surgical Intensive Care Units (SICU) [12]. Sucher et al. [12] conducted an observational study at the SICU, investigating the satisfaction level with the use of robotic telepresence with critically ill patients. The results revealed that 92% of the patients felt comfortable with the robot and did not perceive a diminished level of service from the doctors. Also, related to tele-rounding, previous work investigated the impact of tele-rounds on patient satisfaction with postoperative care [2]. The results showed the considerably beneficial effect of tele-rounding resulting in high satisfaction.

Other researchers focused on the general awareness of medical staff about healthcare robots including robotic telepresence [12] and RTM's applications in specific domain areas such as surgical operations, elderly care, educational training, and ICUs [1,5,8,9,10]. Becevic et al. [1] conducted a pilot study to examine healthcare providers' attitudes and satisfaction level for communication and patient care when using RTM at the ICUs. The author concluded that RTM is an effective tool to communicate with patients, bedside staff, and families. The author also pointed out the factors that increase acceptance, including detailed training and orientation, identification of roles, and administrative support. Smith et al. [10] investigated whether RTM can realistically simulate a proctor in an operation room, providing quality guidance and supervision. The experiment was conducted during an anatomy class for a cadaver dissection, with medical students and a surgeon. The students and the surgeon felt a realistic feeling of telepresence and were satisfied with the system. Sampsel et al. [9] dealt with RTM in nursing education and questioned whether the nursing faculty and undergraduate nursing students would accept RTM technology.

The results showed more than 80% acceptance of faculty and students. Kristoffersson et al. [5] conducted a video-based survey about health professionals' attitudes toward RTM for elderly care at home. The participants were teachers and students majoring in nursing, occupational therapy, and audiology. As a result, the authors showed a common concern about replacing people with technology. Moreover, the study suggested to apply the technology in the early stage of education, because the tools already in use during the work process are important factors to consider for the acceptance of RTM technology. To compile opinions from different groups, the author suggested to include different potential users in the early stage of the development.

3. Methodology

We conducted a qualitative user study to investigate the perspective of medical staff about the factors influencing their perception and usage of RTM. We conducted semistructured in-depth interviews and a survey to understand the current tele-communication procedure, and the expectations of medical staff when engaged with RTM technology. With the survey, we aimed to gain more detailed and quantitative insights about the preferred design factors that are considered most important by the medical operators. A survey with open-ended questions was used to overcome the access to the doctors with limited time availability.

3. 1. Participants

For the interviews, we recruited five doctors in different fields, two nurses, and an administrator from two general hospitals (number of beds: 797, 304) in Seoul and a clinic (11 medical subjects) in Daejeon (Republic of Korea). Participants consist of four males, four females and their age ranged between 30 and 60 years of age. Doctors were from radiology, internal medicine, gerontology, family medicine, rehabilitative medicine. One nurse was from a nursing clinic and the other was from a community nursing home. The administrator is the vice president of a general hospital in Seoul. The survey was conducted with nine doctors at a general hospital from different fields: radiology, nuclear medicine, neurology, ophthalmology, other. They are seven males, two females and their ages ranged from the 30s to 40s. Participants were recruited through email, and the interview was conducted in person. None of them had prior experience with RTM.

3. 2. Setup and material

We conducted the interviews in quiet spaces such as the participant's personal office in the hospital, a lounge, a meeting room, or their homes. We recorded the voice and noted the answers with the consent of the participants. For a better understanding how participants perceive RTM technology, we described the basic concepts of robotic telepresence with images of previous robotic telepresence research and products, such as the InTouch Vita medical robot, and explained how the remotely located user can control the robot and communicate with patients and other medical staff. The interviews consisted of open-ended questions to accommodate individual responses.

Each interview took about 30 minutes to an hour. For the survey, the data was collected using an online survey tool. Questions were posed as multiple choices with keywords or numerical values, and open-ended questions to explain about specific selections. The survey, like the interviews, focused on three main parts: usage context, function, and appearance design. We focused on these points to find possible design directions for RTM used in specific contexts and to highlight the unique features of RTM compared to ordinary telepresence robots. Specifically, during the interviews, we asked participants about their experiences with telecommunication systems, their need for telecommunication, and their opinions regarding the particular contexts where they would see fit to use RTM technology. The survey provided more detailed questions such as proper usage contexts, type of patient, proper number, and age of the target users. Additionally, we asked participants about the negative aspects of their current way of communication and their expectation about RTM basic functionalities. Along with that, the survey asked more detailed questions about additional medical functions. Finally, we asked participants' opinions on the aesthetic design of RTM, in light of the proposed contexts of use. To help participants' understanding these questions, we showed the images of two existing RTM products: InTouch Vita (robot like an example), InTouch Light (medical-device like an example). Furthermore, the survey asked questions about what participants thought would be the best form-factor for the RTM (humanoid vs tool), their physical aspect, their height, and other opinions related to the robot appearance design.

3. 3. Data collection and analysis

Open-ended responses from the interviews were keywords labeled for analysis based on affinity diagrams, a process similar to that in previous work [13]. The keywords used were "cost," "additional function," "physical environment," "social environment," "reliability/trust," "replacement," "support," "privacy/security".

4. Result and Disucussion

Through the interviews and the questionnaire, the medical staff expressed concerns related with the adaptability of RTM technology to the currently available medical services. These concerns are summarized below in three distinct groups: usage context, functionality, and appearance.

4. 1. Usage Context

4. 1. 1. Interaction with Low Critical Patients

Almost half of the participants (45%) considered that RTM is proper for chronic patients, while the other half (55%) identified general patients as the proper users of RTM. No one chose the usage of RTM for emergency situations. This is because chronic patients are more likely to be conscious and therefore be able to communicate with doctors and explain about their current situation (symptom, vital signs). Our interviewees described that RTM can be used for checking patients with known conditions and that it would be difficult to use RTM to deal with complex or unexpected situations.

One of the doctors also talked about using RTM for VIP patients, who may require simple treatments but demand and expect continuous and direct care from the medical staff.

> "RTM will be useful in VIP rooms. VIP patients have lots of requirements, maybe because they are high-class people; however, those requirements are not urgent but a simple and easy one which can be solved immediately." (Doctor A)

Finally, also the administrator was most convinced with the application of RTM focusing on VIP patients with chronic diseases. He thought RTM would be an appropriate healthcare device because VIP patients often expect special and comprehensive care.

4. 1. 2. Information exchange between medical staff

RTM was proposed for increasing the interaction between medical staff and improving the quality of care by filling the gap between possible imbalanced medical resources.

> " RTM will be useful when conducting a teleconference, asking transfer to an emergency room, consulting a doctor (intern) at long-term care hospitals. If the specialist at a general hospital helps with the decision making and can get a small fee, that will be good."
> (Doctor D)

From the interview Doctor E, a radiologist mentioned that radiology units have usually limited resources (medical staff), so not every hospital can afford 24/7 services. Therefore, in the case of a small size hospital, telemedicine would work best for interpretation of radiographic images that could not be examined otherwise. Similarly, nurses showed interest in using RTM for distant communication with doctors and other medical staff such as nutritionists, or ambulance workers. From the survey as shown in Figure 1, the doctors chose the proper usage context in the following order: medical education, long-term patient care, abroad medical treatment, intensive care unit, guide, and recipe, patients' care. During the interviews, doctors were the most concerned about sudden accidents and responsibilities, preferring to avoid the anxiety resulting from delegating their work to RTM systems. In the survey, they describe the reasons behind their selections with these keywords: mobility, limitation in speed, difficulty in dealing with complex situations. Participants further highlighted the need for information exchange between medical staff through RTM, and for remote medical education and consultation.

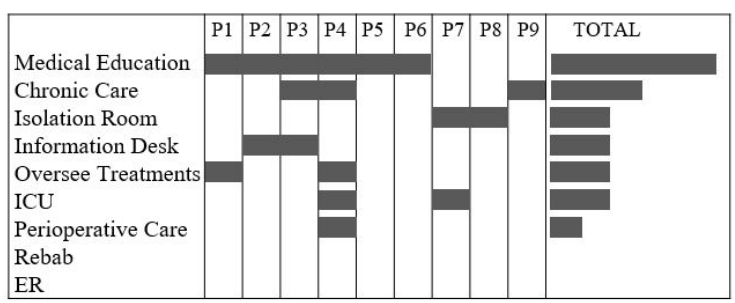

Figure 1 Expected context of RTM usage

4. 1. 3. Usage in the restricted area

In the case of limited physical access to hospitals due to distance or physical constraints (e.g., remote locations, distance, area highly contaminated areas, etc...), RTM can be used to replace traditional medical assistance as well. For example, participants suggested the usage of RTM for hospital isolation rooms to protect medical staff from infections. Also, the administrator described the potential of using RTM in certain countries with deserts that lack the medical staff or deal with specific diseases.

> "We can specialize RTM's usage according to the region, especially for areas with chronical diseases." (administrator)

4. 1. 4. Medical service systems

Most of the participants said that, without a well-structured infrastructure, it would be hard for them in practice to use RTM technology. That is related to the efficiency and the usage costs. Doctors from internal medicine showed more concerns than others, not only because of the characteristics of their treatment but also because of the restrictions and the medical fees in their fields. Doctor E said that when considering medical fees and installation charges, general hospitals are more suitable for RTM technology than private hospitals. Doctors suggested that it would be better to start using RTM as hospital services, and if it shows potential, then try to break into the market. Doctors explained that, in their opinions, RTM technology currently faces opposition simply because it appeared on the market prematurely. Doctors also said to be worried about the time management of the medical staff, because RTM technology is currently not completely autonomous and requires supervision from a medical assistant. Finally, doctors expressed concerns about the patients' privacy and the responsibility of the medical treatment, as it becomes more difficult to assess individual responsibilities when RTM technology, remote operators, and in-situ caregivers are all simultaneously involved.

4. 2. Functionality

4. 2. 1. Need for trust

Trust between a remote operator and local users is required for collaborative medical care because of the sensitive nature of the medical work that deals with serious health care issues, compared to other telepresence activities. Doctor E expressed concerns about checking the remote patients and whether the remote caregiver is the right person to be in charge of the treatment.

> "(in the case of joint care) it would be better if there were a clear medical delivery system and a trust between the staff involved." (Doctor E)

Especially in the case of internal medicine, doctors are more cautious about the introduction of RTM for patient care. The results showed that trust between RTM and medical staff requires the intervention of medical staff in the local areas. Doctors expressed the need of conducting thorough observations that require a higher functional extension of their physical capabilities.

"When I see a patient, I think that these conditions are all equally important: how he/she walks when admitted to the hospital, the tactile response of different body parts, the patient's smell, ... We should touch the patients in hospital rooms and ICUs. We need to use every sensor to see patients." (Doctor D)

4. 2. 2. Communication efficiency

During the survey, doctors suggested additional functionalities for RTM in the following order: high-resolution camera, thermometer, blood pressure measuring device, motion sensors, and light for treatment. Doctors conducting real treatment consider visual inspection as a very important part of the exam, so they highly recommended tools for extended visual inspections. In fact, an ocular inspection is fundamental not only for simple diagnosis of the patients' conditions but also for specific observations using a minimized high-resolution camera. Specifically, HD cameras with a wide range of view can give the sense of "being there" and provide more information about the patient to the operator. These results echo Johnson et al. [4]'s suggestions of using interfaces with wider fields-of-view to capture critical situations such as for doctors who remotely visit multiple urgent-care patients. A beam projector or a screen for local visual support is also a widely requested functional extension for RTMs. In addition, a record/replay function with a simple measuring device was suggested.

" It would be better to show video clips, photos, or charts to patients' family rather than just repeatedly explain the situation." (Doctor A)

Other functionalities, such as a thermometer, motion sensor, and pressure monitor, seem to reflect the need for supporting chronic patient care.

Moreover, in the survey people expressed the preference for small groups of people (below five patients) for interacting with RTM, rather than individual care or large groups. The reasons were as follows: too many people in a conversation make it hard to concentrate, can increase errors, and possibly generate major function setting problems; individual usage is not efficient. Also, they showed a positive attitude toward the possible change of size/height of RTM for ease of movement, and for treating patients both laying on beds or standing.

4. 3. Appearance

Medical staff expressed a preference in having RTM with professional and trustworthy appearance so to communicate a sense of reliability to patients and other staff members. They also expressed interest in RTMs that can adjust their shape to match the physical environment, the usage context or the patient.

From the survey for the image of RTM, doctors chose the keywords in this order: "trustworthy, elaborate, luxurious, comfortable, simple, intimate, cute," and none of them chose the word "novel". They preferred a humanoid-type form factor rather than a tool-type form and indicated as suitable height the dimensions in the range of 100~150 cm for adult patients, and 50~100 cm for children. The words, such as "approachable design," "trustworthy," and "human-friendly" were mentioned to explain the choice. Also from the interview, Doctor A mentioned the importance of reliance of patients on medical staff and the bond of sympathy. That is one of the reasons why patients would usually rather meet their own doctor than a new staff member.

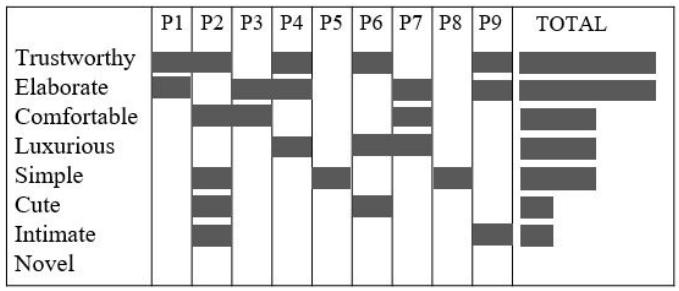

Figure 2 Expected aesthetic features of RTM

In terms of physical features, the administrator and Doctor D suggested using RTM as complementary tools to wearable devices such as smart bands and smart glasses. For example, to use RTM as a hub for patient monitoring, it should be linked with a smart band that the local users-patients wear. To use RTM for attending meetings, the operator can wear the VR glasses, and the RTM's monitor follows the operator's viewpoint and movement. However, in some cases such as an operation, the personal wearable device would be preferred to the RTM due to the size of the device.

> "Now we give a wearable device and two additional sets of devices, one of which needs to be connected to a smartphone to send information back to us. It will be helpful to the patients if those functions can be integrated to RTM." (Administrator)
>
> "I think that a telepresence robot can help doctors during the operation. However, instead of using that, using GoPro and GoogleGlass in the field and having senior doctors seeing the images remotely will be a better alternative. Also, it will be useful if we can use augmented reality (e.g. Oculus rift). Operating fields are small, so adding more features will be difficult." (Doctor D)

5. Implication for Design

There are several prerequisites for the wide acceptance of RTMin medical service systems. These include the cost of RTM systems and the level of trust between remote users. From the results of this study, we reckon that medical staff prefers RTM with medium-low height, partially humanoid form factor, and with the characteristics of a trustworthy and elaborate appearance. Doctors suggested using RTM for chronic and general patient in a small group for the purpose of medical education and visual communication support.

The basic purpose of general telepresence robots is to give a sense of "being there" by allowing a remote operator to physically interact in another place. However, RTM systems require a higher level of functional extension and differ from the robotic telepresence applied to other fields. For a teleoperator, the sense of self-extension can happen as he/she controls the object. For the medical staff who has a social identity and professional identity, we can divide this sense into two types: social-extension and functional-extension. Social-extension indicates being there as a social entity with a purpose of social communication with local users in a human-like way.

In contrast, functional extension indicates being there as a functional entity in order to complete the given tasks in a tool-like way. To extend the sense of self, both human-like and tool-like approaches can explore different form factors that depart from an anthropomorphic form.

As the need for the extension is different according to the usage context, we are suggesting three types of RTM according to the emphasized purpose of usage (see Table 1).

Table 1 Three types of RTM

Type	Purpose	Description
A. Advanced visualcommunication	Social extension	Reflecting the visual image (e.g., body gesture) of medical staff and also delivering local visual information to the staff
B. Attachment of a required medical unit	Functional extension	A tool with simple medical functionalities/ Convenience in usage by a local user Mixed with autonomous functions
C. Integrationinto the environment	Integration	For limited environment/ Integrated or connected to the existing devices and environment

Type A is most similar with generic robotic telepresence but provides advanced visual communication functionalities for supporting medical treatment and sharing information. Visual communication support is highly required, and demands displays oriented with various angles, and holograms to interact with a small group of patients/staff members. It can be used for simple treatment, telerounding, education, and meetings.

If a chronic patient care needs continuous periodic measurement, the RTM needs to be equipped with a medical package, which is easy to be used and upgraded for specific care. The medical unit can be a functional support for the communication. In that case, the RTM may need to have autonomous measuring and monitoring functionalities (Type B).

Also, there are usage contexts with a limited environment, such as operation rooms and rehabilitation centers, that replicate the home environment. In that case, the RTM needs to be integrated into the environment or equipment. Type C has the most tool-like form factor and function and also needs to be connected with other medical devices. Type C is focused on interaction with the RTM device itself.

6. Conclusion

This paper explores possible design directions of RTM based on the opinions of medical staff. We collected data using a user-centered approach investigating three aspects: usage context, additional functionalities, and appearance. We discussed the design factors and suggested general features for RTM, described as “with an image inspiring trust and sense of elaborate capabilities, for a small group, medium-low height, partially humanoid, for chronic and general patient, for medical education, and visual communication support.” Then, we described three possible design directions of RTM according to the different purposes of usage: advanced visual communication, attachment of a required medical unit and integration into the environment. Future research will focus on more extensive studies with more participants and with various backgrounds to validate the design guidelines proposed in this paper.

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<Appendix>

Survey Questions

1. Usage context.
1) What do you think are the proper usage contexts? Options include intensive care unit, emergency room, rehabilitation treatment, remote overseas medical treatment, medical education, information and recipe, perioperative inpatient care, chronic patient care, elsewhere.
2) In the case of patient care, which type of patient will be a proper user? Chronic patient, emergency patient, general patient.
3) What do you think is a proper number of local users? Individual, small group (below five), large group (over five).
4) What do you think is the proper age of users? Child (14 below), adult (15 to 64), elderly (over 65~), age doesn't matter.

2. Additional functionality
1) Which do you think is necessary for RTM? A high-resolution camera, beam projector, blood pressure measuring device, blood measuring device, thermometer, light for treatment, motion sensor, something else.
2) If you want to add more functions, please write down the name of a function and the reason.

3. Appearance Design
1) Which image is closer to your expected RTM between a humanoid and a tool?
2) Choose adjectives for the image of RTM: cute, comfortable, new, trustworthy, intimate, luxurious, simple, elaborate
3) What do you think is the proper height of RTM: infant (below 50cm), child (50 to 100cm), youth (100 to 150cm), adult (150 to 180cm), taller than adult (over 180 cm).
4) Need of a height change: Yes, no, don't know.
5) Whatdo you think should be considered for designing RTM?
6) Do you think the RTM should be designed for a special usage or for a general usage?

The following sentence was attached to the all questions.
: Please let us know why you chose the answer to the question above.