Assisitve, Rehabilitation, and Surgical Robots from the Perspective of Medical and Healthcare Professionals

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Abstract

The presence of robots in the medical and healthcare fields is increasing. Commercially available medical and healthcare robots are in use by hospitals and nursing homes. Many more assistive, rehabilitation, and surgical robots are being developed at research institutions. In this paper, we examine the awareness of medical and healthcare professionals with respect to robotic applications and the social and psychological impacts of human-robot interaction.

Introduction

Medical and healthcare services are in demand. Microeconomic theory applies: if a patient can be operated on more safely and with minimal recovery time, a surgical facility can accommodate more patients. Similarly, if patient rounds can be completed in less time, then a facility can also accommodate more patients. Robots in the medical and healthcare fields address a variety of areas, including surgery, rehabilitation, and mobility, while increasing the quality of service to the patient.

Two of the most well known medical and healthcare applications are robot guided surgery and telepresence systems; commercial successes in these domains are Intuitive Surgical's *da Vinci* Surgical System and InTouch Technologies' Remote Presence System [Intuitive Surgical, InTouch Health]. The *da Vinci* Surgical System renders a 3D visualization and allows the surgeon to control the robotic manipulators in minimally invasive surgeries. It was approved by the U.S. Food and Drug Administration in 2000 for specific surgeries, and approximately 500 units have been sold to hospitals [Intuitive Surgical, Engler 2007]. The RP-7 Remote Presence System allows doctors to check on patients remotely with real-time video [InTouch Technologies]. Approximately 100 units have been sold to hospitals and nursing homes [Engler 2007].

Another facet driving the demand for medical and healthcare is assistance for disabled people. The Technology-Related Assistance for Individuals with Disabilities Act of 1988 (Tech Act) improved the funding for assistive technology to create these devices through state and federal efforts [U.S Congress 1988]. The support of these goals was renewed twice during the 1990's [U.S. Congress 1994, 1998]. These U.S. laws increased the awareness for the need for assistive devices and services to improve the quality of life, as these devices also would minimize the cost to the individual and society. Commercial products for mobility and manipulation for people with physical disabilities are available, including the iBOT wheelchair [iBOT Mobility System] and the Manus [Exact Dynamics] and Raptor [Alqasemi *et al.* 2005] robotic arms.

While there are some commercially available medical and healthcare robots, many more assistive, rehabilitation, and surgical robots are being developed at research institutions worldwide. Research institutions pair with medical facilities for clinical user trials. Researchers are careful to collect patients' sentiments towards the technologies developed, which can be used for improvement upon the next iteration. Medical and healthcare professionals gain an understanding of a particular technology. In this paper, we examine the awareness of a sampling of the medical and healthcare professionals as a community with respect to robotic applications and the social and psychological impacts of human-robot interaction. From this, we hope to generalize human-robot interaction for the medical and healthcare fields to aid in the ease of acceptance of the increasing number of robots into the fields.

Methodology

A survey was conducted to understand robotics from the perspective of medical and healthcare personnel and associated social and psychological impacts. We sought to understand the education and awareness level of medical and healthcare students with respect to robot technologies. From medical and healthcare professionals such as doctors, nurses, and physical therapists, we sought their collective level of awareness of robotic applications, their desired human-robot interaction, and resulting social and psychological impacts. The survey was comprised of the following non-leading questions.

- What is the level of your personal familiarity with robots used with autistic patients, for companionship, as exoskeletons, as intelligent wheelchairs, for manipulation (Activities of Daily Life such as feeding, etc.), for physical therapy, as prosthesis and orthothesis, for surgery, for telepresence and/or delivery (in a hospital, nursing home, etc.), and for visually impaired navigation?
- What is your personal attitude towards robots in the medical and healthcare fields?
- What is your personal attitude towards the growing presence of these robots in hospitals, rehabilitation centers, medical offices, nursing homes, etc.?
- In your opinion, which aspects of healthcare and the medical field do you feel might be significantly impacted?
- In your opinion, describe the acceptance of these robots by medical and healthcare professionals at large.
- In your opinion, what services and functionality can these robot provide that medical and healthcare professional cannot, and conversely?
- Discuss your thoughts about social and/or psychological impact created by these robots on the medical and healthcare professionals at large and the patient population.
- Describe a robot that would help you in your profession and its functionality and interaction capabilities.

Response	***Keyword***
"Impact is financial. Very expensive to buy, run, and maintain."	cost
"Introducing inanimate objects into the process chain of [medical and health] care may allow some to distance from compassionate care."	misuse, loss of human element
"With proper education, robotics could be accepted and integrated into the healthcare field."	education
"Health care coverage"	coverage
"There is potential for abuse if they [robots] serve as a substitute for human contact."	misuse, loss of human element, replacement

Table 1: Example open-ended response translations to keywords.

Data Collection

Data was collected using the survey itself in the form of multiple choice and open-ended questions. The online survey was anonymous and implemented using a commercially available survey web service [SurveyMonkey]. It was disseminated via email to mailing lists. Interested participants were required to be at least 18 years of age to take part in the survey.

Twenty-seven responses were gathered using the online survey for three weeks during April and May 2007. Of the responses, sixteen were regarded as actual data points. Of the eleven surveys considered invalid, one participant was under 18 years old, and thus was not allowed to complete the survey, eight participants exited the survey before completion and two participants were not healthcare or medical professionals.

Open-ended responses were keyword labeled for analysis. The keywords used were "misuse," "loss of human element," "replacement," "coverage," "cost," and "education." (See Table 1 for example translations.)

Participants

There were nine female and seven male participants; their age ranged from twenty-four to sixty-eight inclusively. Figure 1 details their occupational breakdown. All participants had prior experience with computers; including both job related and personal use: 94% spend over twenty hours per week using computers, and the remaining 6% spend between ten and twenty hours per week. Almost half (44%) had prior experience with robots. Of these, two attributed their robotic experiences to a middle school educational program and iRobot's Roomba, a commercially available robot vacuum [iRobot]. The remaining five participants have collective experience with assistive, surgical, and rehabilitative robotics, including the *da Vinci* robot and an intelligent robot wheelchair.

Results

This section describes the results of the survey. With our small sample, we are able to discuss some attitudes, but do not claim to have a significant sampling of healthcare personnel represented in our group. Of the sixteen participants, only fourteen answered the open-ended questions on the survey. Percentages can total over 100%, since people could enter multiple answers.

Level of Awareness of Robotic Applications

Of the sixteen participants, only three had no familiarity with assistive, surgical, or rehabilitation robots. The other thirteen had a varying knowledge of the robot applications; Figure 2 shows the familiarity of these participants.

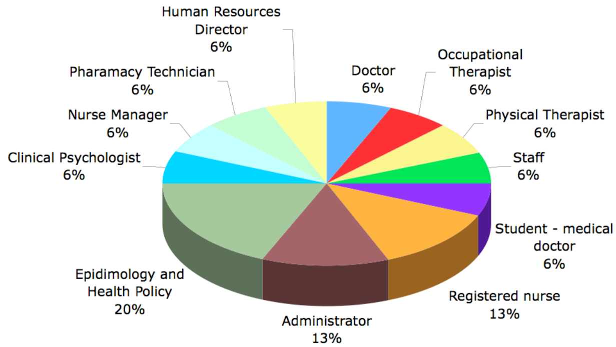

Figure 1. Occupational breakdown of sixteen healthcare and medical professionals.

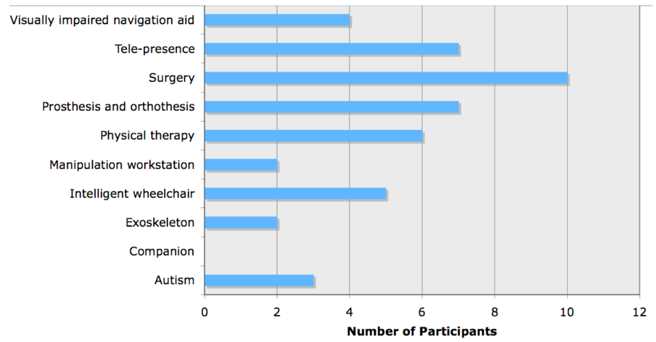

Figure 2. Participants' familiarity of healthcare and medical robotic applications.

As expected, the surgical application was the most familiar (62.5%) and telepresence (43.75%) tied for the second most popular robotic application. The commercial availability of systems such as *da Vinci* and RP-7 makes robot surgery and telepresence less of science fiction and more of a reality. Similarly, robotic prosthesis and orthothesis were also well-known applications (43.75%) [Fite *et al.* 2007, Sup *et al.* 2007].

Established assistive and rehabilitative robotics research included intelligent wheelchairs (31.25%) and physical therapy (37.5%). Intelligent robotic wheelchairs range from the iBOT, a commercially available product, to Wheeley, a research prototype [Bailey *et al.* 2007]. Robots have been used in rehabilitation of stroke patients ranging from "hands off" social interaction to exoskeleton augmented physical rehabilitation [Tapus *et al.* 2007, Volpe *et al.* 2000, Weinberg *et al.* 2007].

Less known were robots as used as navigation aids for the visually impaired (such as NavBelt [Shoval *et al.* 1998], HITOMI [Mori *et al.* 1998], and RoboCart [Kulyukin *et al.* 2005]), autistic therapy (such as RollBall [Michaud *et al.* 2007] and Keepon [Kozima *et al.* 2005]), manipulation workstations (such as ProVar [Van der Loos *et al.* 1999]), and exoskeletons (such arm and hand robotic devices [Caldwell 2007, Kiguchi 2007]).

Surprisingly, no one had heard of robots used as companions. One popular companion robot is Paro, a therapeutic seal robot [Wada and Shibata 2006].

Concerns about Robots in Medical and Healthcare Fields

Concerns from medical and healthcare professionals about using robots in their fields were identified using keyword labeling of open-ended responses; see Table 1 for a sampling. From this, we derived that the primary concern was misuse of robots in the medical and healthcare fields, classified into loss of human interaction (78%) and replacing professionals and staff (36%). There were concerns about cost and health care coverage (21%), and also about education (14%).

Robot Caregiver Abilities vs. Human

The precision offered by robots is well known; for example, PUMA robotic arm used for car manufacturing and assembly [Marsh 2004]. This precision has benefited the domain of surgical robotics, as seen by the *da Vinci* robot. Two participants noted directly that robots' abilities for "micro movements" and "micro manipulation" are unmatched, and three more noted their precision, consistency, and predictability.

Several participants noted that robots could be used as assistants. In such a manner, robots can "conserve energy for providers" and "reduce staff burden." They can "extend rehabilitation provided by caregivers." Robots can "help with activities of daily living" can provide a "person's independence."

One respondent offered that "robots can be used to pile up the dead during a pandemic flu outbreak [because] they won't get infected" thus minimizing further casualties and preventing medical and healthcare professionals from being subject to the pandemic more than necessary.

Human caregivers, of course, are able to provide patients with personal 1:1 attention, empathy, compassion, and warmth. They are "aware of social dimensions" and can "allay fears." Human caregivers are able to "make patients feel secure and valued" and can give "more sensitivity to the needs of a patient as they arise."

Psychological and Social Impacts

Historically and currently, the medical and healthcare fields are comprised of personal relationships. One participant said, "Healthcare providers often feel it is their duty to be directly involved with their patients." As mentioned previously, healthcare providers are concerned about a loss of the human element with the use of robots in these fields. The introduction of robots as care givers will alter the level and quality of these personal relationships from the perspective of the patients and the medical and healthcare professionals.

Another participant illuminated a second-degree impact. "For example, does a doctor amputate knowing that the limb can be replaced with a perfectly functioning robotic arm, or does he/she try to save the arm in hopes that it will come back to its original performance with rehabilitation?"

Impact of Awareness on Attitude

On a Likert scale of 1 to 5, where 1 is high, the participants averaged 2 with respect to positive feelings about robots[1]. Eight participants had no prior experience with robots and averaged 2.125. The six participants with prior robot experience averaged 2. This was not statistically significant. Of the eight participants who had prior experience with robots, five had experience with medical robots and averaged 2. This was also not statistically significant.

Discussion

Three dominant themes arose in the survey results. First, medical and healthcare professionals are aware of the cost and concerned about it. Robotics researchers and companies should be aware of the cost of construction, sensing, etc. with respect to the initial purchase, maintenance, and insurance reimbursement. A survey respondent pointed out that "payers [meaning health insurance companies, are] not quite there yet with reimbursement… [medical and healthcare robots are] very expensive to buy, run, and maintain."

Second, medical and healthcare professionals realize that robotics in their fields will be a common occurrence in the near future, and they are open to this. The survey results indicated mixed feelings about acceptance rates of patients, staff, nurses, doctors, senior professionals, and others. Education of available technologies will play an important part in the acceptance of robots. As previously mentioned, knowledge of assistive, surgical, and rehabilitation robotics research is local to the medical facilities at which clinical trials are run.

Third, the perception of medical and healthcare professions of robots is that they are tools. When answering the personal helper question, responses were mostly courier and kiosk based. One response specifically called out that robots "should not attempt to simulate human interaction." This perception creates a general barrier for human-robot teams, human-robot interaction, and pervasiveness of robots in the medical and healthcare fields.

Human Implications

The results of this survey provided insights about awareness of medical and healthcare robotic applications, possible social and psychological impacts, and concerns from the medical and healthcare professional perspective. From this, researchers can minimize the projected impact and concerns through cost effective design, cost effective implementation, appropriate task definition, increasing awareness of on-going robotic research, and appropriate human-robot interaction.

Robotics is an active field and still growing. It is difficult to pin-point what exactly needs to be done for the most effective human-robot interaction in the healthcare domain, especially since there is a broad population covered by all of the different healthcare robots. The necessity of effective human-robot interaction is clear; it is becoming its own multidisciplinary field, having already held two international conferences [SIGCHI *et al.* 2006, 2007]. A development and evaluation feedback loop between the researchers, end users, and experts is needed, including all stakeholders from the outset of development, not just in the final testing phase.

In the domain of medical and healthcare robotics, it is clear that robots are not to be used a substitute for human contact. However, as our survey respondents noted, if robots are used to perform more mundane tasks such as appointment check in, getting supplies, and taking some basic vital signs such as temperature from patients, more time will be available for the personal patient care that is necessary in this domain.

Conclusions and Future Work

Our study is consistent with previous findings [Massey 2004, CNN 2006]. People are concerned with the loss of the human element associated with care giving. The field of human-robot interaction is essential to integrating robots as care giving teammates.

Towards this end, more specific questions must be asked of the medical and healthcare professional about their expectations of robots. Is it necessary that the robot have anthropomorphic features, or is the appearance of an appliance-like robot acceptable? Should the robot be able to talk and listen, or should the robot have a touch display screen? Would it be useful to give the robot a to-do list of general items or give very specific instructions to accomplish one objective? Should the robot have one set

[1] The Likert scale ratings were assigned to the participants' opened ended response to their personal attitude towards robots in the medical and healthcare fields.

interaction or have multiple, customizable per person? Some questions derive inspiration from human personal assistants job postings: What skill set does a robot need? Should the robot be proactive and ask for things to do when its objectives have been accomplished or should the robot become part of the background when not needed? Further investigation of specific points like these should yield more detailed guidelines of human-robot interaction for the medical and healthcare domain.

Our results lead to questions about the adoption of robotic technology in the near future. In this survey, awareness of healthcare robots was defined as knowledge of existence, which may have been too loose a definition. A future survey should be more specific, asking where the person had learned of these robots (personal interaction, new story, internet, etc.). Perhaps the concern for loss of human contact comes from the general lack of knowledge about state-of-the-art medical and healthcare robots. For example, no one was aware of companion robots. The question then becomes how to effectively educate consumers about these robots and their benefits. Is it the responsibility of the roboticists to educate medical and healthcare professionals about their technologies, or should they independently be seeking this knowledge? Perhaps education should be a joint effort; for example, cross-publicizing assistive, surgical, and rehabilitation robotic technologies to the robotics and medical and healthcare communities or having representatives from both fileds at relevant conferences.

This survey represents a small number of medical and healthcare professionals and staff. In a more representative study, insights can be gained from comparing responses from students versus professionals and the impact of profession on their attitude towards medical and healthcare robotics.

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