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Research Paper

Impact of human-robot interaction on user satisfaction with humanoid-based healthcare

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Abstract

Background/Objectives: The advent of self-service technology (SST) (e.g.,kiosks and Automatic Response System), has made it possible for service providersto make use of non-face-to-face channels to meet users'needs and decrease users'costs and time. On the other hand, however, more complex technology and/or services inhibit users' satisfaction and,consequently,the intention to adopt SST, because such SST can instill fear in users. Nevertheless, at present, patients and other people who are interested in their own health and well-being are paying great attention to healthcare robots (as a form of SST)and,consequently, it has become crucial to investigate how these healthcare robots can positively influence users' satisfaction with them. Hence, this study aims to empirically investigate the factors that affect users' satisfaction with healthcare robots, especially in regard to human-robot interaction (HRI).
Methods/Statistical analysis: We focused on the theory of heterophily and applied a series of factors identified in previous robot-adoption studies.Uniquely, this study focuses on users' heterophily with healthcare robots, examining heterophily through three fundamental elements, empathy, professionalism, and personality, which we considered to be suitable fordetermining user satisfaction with HRI-based communication.To prove the validity of our hypotheses, we conducted an empirical testthat involved participants receiving a short health assessment from a robot.
Findings: The findings of our empirical test supported our hypothesis that the lower the difference in empathy between a user and robot, the higher the level of user satisfaction with the humanoid-style healthcare service. Further, our results also suggest that heterogeneity between a user and healthcare robot is positively associated with user satisfaction.
Improvements/Applications: First, to increase user satisfaction,robots must be provided with the ability to somehow recognizea user's personality and adjust their own accordingly before beginning the robot-based healthcare service. Secondly, users' behavior patterns should be analyzed by the healthcare robot. Overall, our study empirically shows the importance of ensuring thatprofessionalism is present in healthcare-domain-related HRI.

Keywords: *Humanoid; Human-Robot Interaction; Health-Care Robot; User Satisfaction; Heterogeneity.*

1. Introduction

Recently, the advent of human-robot interaction (HRI) has expanded the application of humanoids to a variety of roles, including in the military, education, manufacturing, and healthcare. A particularly notable example issocially assistive robots (SARs), which are robots that are designed to assist humanswho have social difficulties by engaging in social interaction with them1. In particular, studies in the field of healthcare have considered SAR to be a promising technology for assisting patients2,3. Healthcare robots generally monitor patients' behaviors and assist them by providing appropriate treatments for patients' situations4,5;for example, the PARO robot, a type of pet, was designed to conduct psychotherapy and,consequently decrease stress levels6.
A clear factor that affects the performance of healthcare services is the relationship between a patient and his/her doctor. In particular, user satisfaction in this regard has been considered a critical factor for retaining patients7. For instance, it is common in health-communication fields to find references to the building of a rapport between medical doctors and patients. Here, the term "rapport" is used to indicate a meaningful human experience concerning a close and harmonious connection that involves a common understanding. The formation of a rapport is frequently based on familiarity, the sharing of a common background, and personal extra attention. For example, in the service-marketing area, the rapport between users and service providers is very important for marketing success;concurrently, a strong link between users and service providers can result in positive relationships and, hence, user satisfaction8,9. In particular, the more professional the service, the more important the relationship between service providers and users10. From this point of view, healthcare-service quality, which requires a higher level of knowledge and more communication, is greatly affected by the strategies professional medical doctors use to successfully communicate with patients. Moreover, since healthcare service provides intangible goods, the moment a patient and doctor to meet, which is called the "moment of truth,"has a strong impact on the patient's satisfaction. Thus, for better communication and satisfaction, the client's favorability in regard to the service provider, the provider's professionalism, and the fostering of a good relationship between the two parties is very important and should be appropriately facilitated11, 12.
In regard to healthcare robots, robots thatfulfill the role of a medical doctor as a service provider should be well designed in order to be

consistently accepted by patients or any other people who are interested in retaining their own healthy condition. Consequently, existing healthcare robots are designed to interact with clients, manage the relationship with clients, and to improve ties with the clients 13. However, robots are not yet capable of intelligently and autonomously adapting themselves to clients. For example, existing healthcare robots are invariably neutral or very optimistic when they make contact with people. In spite of this impressive technical readiness, the factors that must be considered in order to establish more sophisticated communication have not yet been examined.

Consequently, the purpose of this study is to propose a novel model and corresponding hypotheses that explains the association between robot functionalities and user satisfaction. Contrary to existing studies on the role of homophily, we newly focus on users' heterophily with healthcare robots, and examine the impact of heterophily in regard to three fundamental elements: empathy, professionalism, and personality, which have previously been consideredto be appropriate for explaining user satisfaction with HRI-based communication. To show the validity of our hypotheses, we conducted an empirical test. The results suggest the importance of the presence of heterophily between users and healthcare robots who play the roles of doctors, and alsothat heterogeneity should be consciously considered when designing HRI.

The remainder of the paper is organized as follows: related work concerning healthcare robots is described in Section 2;in section 3, the research model, with corresponding hypotheses,is delineated;then, the method of this empirical study and its results are described in section 4 and 5, respectively;the paper concludes with a description of the findings in section 6.

2. Related work

2.1. Homophily and heterophily

Previous psychology researchhas studiedmethods of appealing to others and,as a result of these efforts, credibility and homophily have been found to have the biggest influence on attraction 14. In particular, homophily plays a primary role in creating a relationship15, this is because it relates to cases where two individuals share a common characteristic andinvolves high intimacy. Specifically, homophily is comprised of two attributes: status homophily and value homophily. First, status homophily concerns seemingly revealing or personal information such as race, gender, or age;meanwhile, value homophily relates to intrinsic elements such as behavior and values 16. Thus, homophily is definedas thedegree to which two individuals who interact are similar with respect to these attributes17. Further, this suggests that if a healthcare robot has a common character or similar personality to a user, the user'slevel of repulsion in regard to the robot may be reduced.

Homophily-related research has been conducted in the HRI field. In one example, researchers presented participants with computer-generatedavatars and asked them to evaluate the images in terms of homophily18, while another studytested the effect varying degrees of human-likeness in regard to robots' appearances with humanoid forms have on perceived trustworthiness 19.

Meanwhile, another study found that the presence of homophily assists network formation and when entering a network15; however,the effect of this may not be balanced, as astudy on the use of SNS in job seeking found thatfemales are more likely than males to be successful using this method. Similarly, homophily has also been found to be very effective in transactions between employees and customers;however, heterophily could have a greater effect in this regard than homophily 20, depending on customer features (heterophily is defined as a degree involving individuals with different characteristics 17).

On the other hand, according to the results of another study21, when there is a difference between a service-provider's professionalism and a customer's professionalism, the customer's intention to use the service is affected. Thus, in the field of healthcare, where professionalism is required, differences in professionalism can help increase user satisfaction or intent to use.

The primary goal of the above research efforts was to develop smooth communication between robots and humans. However, most previous studies have examined status homophily; thus, investigations into value homophily are necessary to balance and improve this study field. Homophily can help build relationships, but heterophily can increase user satisfaction. Further, it has not yet been determined how homophily and heterophilycan be combined in a healthcare robot. Therefore, in this study, we will demonstrate, based on existing theory, how patient satisfaction and intent to use can be affectedbydifferences in tendencies, expertise, and empathy between the patient and a healthcare robot.

2.2. Healthcare robot

A healthcare robot is a kind of robot designed to promote or monitor health, such as by assisting patients in tasks that they find difficult as a result of their health problems, or by preventing further health decline 22. There are many different types of healthcare robots, mainly because of the diversity of the domain in which they are applied. Consequently, they perform a range of activities, such as prevention and diagnostics;administering curesby performing medical interventions ranging from surgery to therapy;and providing care, including short-term care supporting recovery and long-term care supporting independence 23. However, the categorization of the domain of healthcare robots is still somewhat unclear. For example, while, according to a robot user,there are three categories of healthcare robots: doctor healthcare robots, nurse healthcare robots, and home healthcare robots24. Also, health care robot can be classified into surgical robots, rehabilitation robots, assistive robots, and social robots depending on the use of the robot. Furthermore, with the recent advent of AI and its application to these robots, healthcare robots can now be categorized according to their "intelligence." For example, humanoids such as Pepper, Nao, and Saracen make use of their AI functionality to provide healthcare for patients;they achieve this through being linked with smart devices (smart watch, etc.) and/or intelligent healthcare services.

Despite the growing attention attributed to the viability of healthcare robots, earlier studies suffered from unreliable results concerning the relationship between the determinants and robot adoption and/or user satisfaction; this was due toa scarcity of studies referring to adoption theory models, such as the theory of planned behavior and the theory of reasoned action. Consequently, these early studies only focused on whether a robot's design and technical functions could impact users' satisfaction.

Recently, however, studies on healthcare robots have focused more on the mechanism behindusers' adoption of healthcare robots. Indeed, it seems that research on robot and agent acceptance can be subdivided into two areas: "acceptance of the robot in terms of usefulness and ease of use (functional acceptance) and acceptance of the robot as a conversational partner with which a human or pet-like relationship is possible (social acceptance)"25. Technology Acceptance Model (TAM) shows that, for the elderly, perceived enjoyment and trust affects intention to use healthcare robots, which is in turn related to perceived ease of use and perceived usefulness. Of these, the significance of perceived ease of use in regard to predicting elderly people's intention to use healthcare robots was later reconfirmed in another study 26.

Importantly, it has been found that users' adoption of healthcare robots is generally related to their socio-demographics (e.g., age, gender, cultural background, intellectual property, knowledge about the robots), complicated robot elements (e.g., functionality and shapes), and also their perceptions of robot elements (e.g., perceptions of ease of use and usefulness) 27.

Some studies have successfully applied theories on user adoption such as TAM and Unified Theory of Acceptance and Use of Technology (UTAUT), withone such study adoptingthe UTAUT model in order to explain patients' intention to use healthcare robots28. This study consequently found that performance expectancy, effort

expectancy, social influence, facilitating conditions, and trust are positively associated with patients' behaviors. Also, among the influential factors, social influence was found to be the strongest determinant. These findings provided insights into how home-healthcare service providers and robot designers may improve the success of robot technologies. These findings were later reconfirmed by the same researchers in another study 29, this time focusing on home healthcare robots.
In sum, unfortunately, studies that investigate the factors associated with users' satisfaction concerning healthcare robots and their services are still very scarce. Thus, it would be very meaningful and useful to examine the characteristics of these robots in order to develop a more adoptable healthcare robot for academia and practitioners of healthcare services.

3. Research Model

The proposed research model for this study is shown in Figure 1. Basically, we adopted three elements: empathy, professionalism, and personality, which have previously been used in HRI models. Further, we incorporatedthe theory of heterophily, which states that heterophily affects user satisfaction. Hence, taking a novel approach, the three determinants, empathy heterogeneity, professionalism heterogeneity, and **personality** heterogeneity are suggested as means of illustrating user satisfaction concerning the use of humanoid-style healthcare robots.

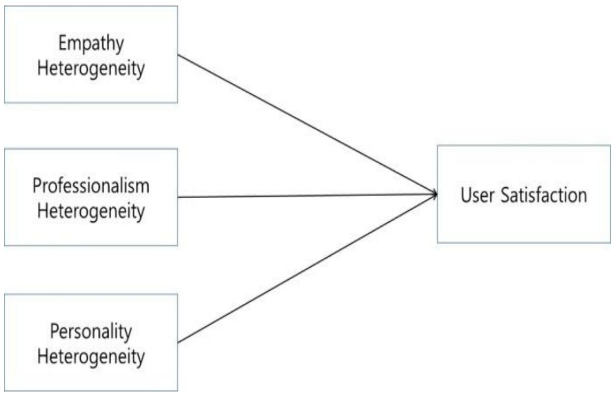

Fig. 1: Research model.

3.1. Empathy heterogeneity

A previous research paper argued that empathy is an act of understanding and responding appropriately to another's emotions and thoughts30. Thus, empathetic behavior can involve responding to the thoughts, feelings, etc., of another person with an appropriate verbal act. Empathy can be expressedthrough facial expressions, gestures, linguistic expressions, and processes, all of whichare linked to oneanother31. Empathy is particularly important in service-related industries because it is a communication tool that can assist the development ofa strong bond between the service provider and receiver.
Further, according to the service profit chain, the quality of theservice provided influences customer satisfaction, customer loyalty and, finally, profit improvement and profitability;therefore, it is very important to manage service quality. In response to this, many researchers have developed and applied factors affecting customer satisfaction in various fields by using the servqual model (this model consists of five dimensions:tangibles, reliability, responsiveness, assurance, and empathy)32. In fact, the servqual model has been used in banking, fast food, telecommunications, retail chains, information systems, library services, and the healthcare sector service industry33. Notably,empirical studies have shown that satisfaction is also significantly affected by empathy 34,35. Thus, empathy is one of the most important factors in healthcare36, as ithas the ability to alleviate patients' illnesses37, reduce stress levels, reduce psychological problems, and increase patient satisfaction.
Since a healthcare robot can be said to be the same as a healthcare professional, except in regard to appearance, it is probable that the empathetic power of a healthcare robot is a very important factor. One previous studyargued that such a robot can, by showing empathy, be a true companion that can compensate for the sense of loss felt when family or friendspass away38. However, it is very difficult task to express empathy for user. Nevertheless, some investigations into robot empathy have been conducted using simple expressionsto convey empathy 39, 40.
Successfully designing a robot to convey empathy through facial expressions is quite complex, and it the success of the reception of these expressionsis largely dependent on the recognizer, because decision-making is based on complex algorithms. Consequently, in this study, we will focus on verbal queues; specifically, we felt that "really?,""uh-huh," and "sure" are words that could make participants feel that a robot is expressing empathy.
Considering this, we hypothesize that:
Hypothesis 1.The difference between users' level of empathy and the perceived empathy of a healthcare robot is negatively associated with user satisfaction with the healthcare robot.

3.2. Professionalism heterogeneity

Professionals are people who can not only solve difficult problems based on their experience and ongoing knowledge, but who can also solve problems technically41. Therefore, a healthcare robot is also a professional. Service providersare becoming increasingly important in many societies 42. The professionalism of robots can make them very important as service providers, as their information is updated in real time and the robot becomes more intelligent as it makes decisions. Therefore, such professionalism constitutes an important factor that not only increases the reliability of the information provided by the service provider, but also improves the satisfaction of the user. For example, in general sales situations, salespeople who have high professionalism and empathy increase their clients' willingness to pay 42.Further, the higher the professionalism and the stronger the relationship with the service provider, the more likely the customer will be satisfied.
Thus, a service provider who has rich experience and professionalism can be said to have a positive effect on their customers' trust in the service and can also create a favorable relationship with the customers43. Although the quality of a healthcare service is dependent on the attitude of the staff and the continual upgrading of related facilities, patient satisfaction has been found to decrease when the expertise of diagnoses is considered to be poor44. The expertise of the healthcare robot can be perceived in two aspects: technical aspects and functional aspects. Technical aspects relate to the ability of the service provider to perform the given role, while functional aspects can be considered to relate to the service provider's attitude and empathy 45. In other words, the technical aspects can be divided into core services and the functional aspects can be divided into additional services.
A core service indicates the functions that are provided by a service 46. Therefore, in regard to healthcare robots, core-service professionalismconcerns the accuracy of their diagnosis and recommendation. On the other hand, supplementary service professionalism is related to how the service is delivered, which is in turn related to the attitude of the robot and the efficiency of the information provision.
It is unknown whether humanoid-type healthcare robots are considered equal to human expertsin regard to its expertise. Therefore, in this study, we investigate how a robot's expertise affects user satisfaction.
Thus, we hypothesize that:
Hypothesis 2. Professionalism heterogeneity is negatively associated with user satisfaction with healthcare robots.

3.3. Personality heterogeneity

In a previous study,the explanatory factors of personality used in previous research were analyzed, and it was found that it has five characteristics: extroversion, agreeableness, conscientiousness, emotional instability, and openness47. Personality, in particular, is a factor that attracts people, which results in the creation of relationships, and is a pattern of individual, behavioral, emotional, and mental disposition that is consistent with time and context48. Human personality is formed by individual experience, background, knowledge, and characteristics of the group that the human involved, and is expressed externally through verbal and nonverbal behavior49. Further, personality in human relationships can create trust, respect, and intimacy; however, there is a possibility that personality has a different influence on others, not only in general human relations but also in occupation groups. In regard to the personality types most suited to certain roles, one study argued that teachers, accountants, and doctorsshould be introverted, and that salespeople and managersshould be extroverted 50;jobs such as teacher, accountant, and doctor require introversion 51 because these professionals must be cautious in their roles. These findings are applicable to healthcare robots; in particular, their dialogue. SST-based kiosks and ASR do not focus on interaction because they perform simple tasks;in recent years, however, with the development of machine learning, datamining, and AI, SST has gained the ability to perform complex tasks such as providing counseling, advice, and recommendations. This is important because research has shown that users spend more time interacting with robots or computers when theyhave personality48. Therefore, for a robot to successfully execute tasks such as providing counseling, advice, and recommendations, it is important to show personality during its interactions with patients,as this can increase user satisfaction. In such interactions, the character of the robot can be expressed through both verbal and nonverbal means;representative examples of nonverbal actions include mutual gazes and gestures.

Another previous study argued that users with strong extroversion are more likely to accept the ERP system early than not at all 52, and it also reported that they could achieve better performance in decision-making situation because they use computer-based communication system better.

However, other research has reported that users prefer robots that have the same personalityas themselves53. In addition, it has been empirically demonstrated that it is important for robots to be able to determine the most appropriate personality to adopt by grasping not only the characteristics of its required tasks, but also the personalities of its users54. It is expected that the acceptance intention or satisfaction of a user increases when a robot has a homogeneous personality.

Considering the above, this study, rather than adopting the viewpoint of matching the personalities of a robot and human being,also aims to determine how the difference between the personality of a user and the personality of a robot affects user satisfaction.

Therefore, we hypothesize that:

Hypothesis 3.A difference in personality between a user and their robot's perceived personality is positively associated with user satisfaction with the healthcare robot.

4. Methodology

4.1. Procedure

After participants completed a pre-questionnaire that obtained details such as their demographic information, their opinions on healthcare robots, and their existing knowledge about healthcare robots, they entered the experiment site. Specifically, the experiments concerned conductinga conversation consisting of three questions with a healthcare robot. The personality of the robot could be either introverted or extroverted, and this was randomized for each conversation. There were two versions of the conversation script, one for introversion and one for extroversion. The introverted personality had stuttering, slow,unpleasantspeech;on the other hand, the extroverted personality did not stutter, spoke quickly, and had a high tone of voice. The robot's personality remained the same throughout each experiment. After the test, we recommended a suitable stress therapy for each subject.

Each subject interacted with the healthcare robot by following a stress-diagnosis scenario. In a healthcare scenario, a healthcare robot makes a simple self-introduction and then suggests performing a stress measurement. If the participant agrees, the stress index is measured through three questions. These three questions related to some of the methods used in actual psychiatry. Although the healthcare robot could recognize speech, the users' responses were limited to "yes" or "no" because of the functional limitations of the robot. After the measurement, the medical robot presented the results to the participant; the robot recommended a de-stressing method to every participant, regardless of the result. Specifically, the robot suggested one of the following three ways of relieving stress: writing healing, music healing, and exercise healing. These healing methods were based on the methods used by qualified stress therapists.

4.2. Healthcare robot

For this study, we used the robot NAO. NAO was developed by Aldebaran Robotics;it is 57cm high and weighs 4.5kg and has a humanoid appearance. NAO has 25 degrees of freedom (DOF), which includes its two arms (2×5 DOF), head(2 DOF), pelvis(1 DOF), and legs(2×5 DOF), giving a total of 24 DOF. NAO can communicate with humans, walk, express gestures, speak, recognize faces, and detect sounds. It achieves this through the use of its various sensors (two HD cameras, four microphones, a sonar rangefinder, two infrared emitters and receivers, an inertial board, nine tactile sensors, and eight pressure sensors). Its CPU is Intel Atom @ 1.6 GHz, built-in OS, NAOqi 2.0 (Linux-based) and it can support C++, Python,and JavaScript programming languages on Linux, Windows,and Mac OS environments. NAO is shown in Figure X.

4.3. Experimental design

In this paper, we conducted our experimentsin a large-scalepublic healthcare center located in Kyung Hee University. Each experiment consisted of three steps, a pre-questionnaire, the actual experiment, and a post-questionnaire. The experiment route is shown in Figure 2.

First, the subjectscompleted a pre-questionnaire. The pre-questionnaire obtained details concerning demographics, prior knowledge about robots, frequency of hospital visits, and opinions on service robots. Then, the participantsperformed the experiment.To allow us to focus on the relationship between personality and satisfaction with robot recommendations in a healthcare service setting, we installed the robot in the corridor of the public healthcare center.

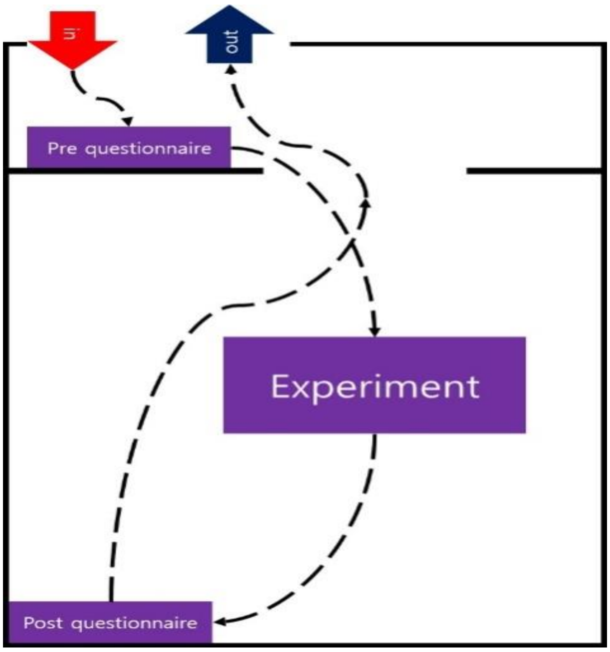

Fig. 2: Experimental Environment.

Before the experiment, the participants were asked to select at random one of two ribbons; for each experiment therobot's personality was determined by the type of ribbon selected. Participants were asked to respond to the robot using only "yes" or "no"; however, if a participant felt uncomfortable during the experiment, he or she had the option of ending the interaction immediately by saying "quit."

In the final part of the conversation, the robot makes a suggestion concerning means of reducing stress; These suggestions were based on the level of stress automatically measured by the robot.If the stress level was very high, the robot suggestedthat the participant attend a consultation with a doctor;if the stress level was intermediate, the robot instructed the participant to perform actions such as listening to music, exercising, or writing;finally, even if the stress level was low, the robot randomly recommended therapy that can help maintain a low level of stress.

For cases when the experiment was ended prematurelybecause of a problem or when the answer to the first question was "no," the data were omitted.

Finally, the post-questionnaire consisted of questions about the robot's personality, the perceived professionalism of the robot, the perceived empathy of the robot, the personality of the respondent, the respondent'sprofessionalism in regard to stress therapy, the respondent's level of empathy, and satisfaction with receiving a healthcare service from the robot. Appendix A shows the questionnaire items used in our experiment.

4.4. Measurement validation

To validate our instrument, convergent validity and discriminant validity were tested using SPSS 22.0. Specifically, the convergent validity was evaluated by examining Cronbach's alpha (CA> 0.7), composite reliability (CR> 0.7), mean extraction variance (AVE> 0.5) and factor analysis results using Straub's guideline55. Reliability scores (0.730–0.862, as shown in Table 1) were consequently found to be well above 0.70. AVE measures the amount of fluctuation from the indicator in a structure and compares this to the amount caused by measurement errors; Table 1 shows that the model was valid because the thresholds of CA, CR, and AVE were met. Specifically, the AVE scores for all structures ranging from 0.730 to 0.862 satisfied the validity requirements of the measurement questions. The factor loadings for all structures should exceed 0.70;we consequently found that the loading of each item met this criterion (Appendix B). In addition, discriminant validity and convergence validity were established, which means that there was intensive validity because the item factor load exceeded 0.50.

Table 1: Results of Validity Testing

Constructs	Composite reliability	Cronbach's Alpha	EMP	PER	PRO	R_EMP	R_PER	R_PROF	SAT
EMP	.850	.793	.730						
PER	.850	.832	.214	.776					
PROF	.867	.852	.154	.089	.759				
R_EMP	.935	.913	.256	.061	.366	.862			
R_PER	.856	.779	.391	.119	.146	.424	.773		
R_PROF	.924	.897	.134	-.119	.194	.509	.301	.843	
SAT	.880	.797	.136	-.043	.227	.697	.502	.589	.843

Note: EMP: level of users' empathy; PER: level of users' personality, PRO: level of users' professionalism; R_EMP: perceived level of robot's empathy; R_PER: perceived level of robot's personality; R_PRO: perceived level of robot's professionalism; SAT: level of user satisfaction.

5. Results

In this study, we investigated the effect heterogeneity between a user and a robot has on satisfaction with the service provided by the service. To achieve this, we created three heterogeneity variables to test our hypotheses, PER_HET (difference in personality between the user and robot), EMP_HET (difference in empathy between the user and robot), and PROF_HET (difference in professionalism between the user and robot). Then, we divided into two groups the respondents who had high heterogeneity and those who had low heterogeneity with each variable. At this time, the median valueswere used as the criteria for dividing the groups. Table 2 shows the descriptive statistics in this regard.

After dividing the participants into the two groups, we analyzed how heterogeneity effects satisfaction with the robot's service using an independent samples t-test. Consequently, we found that the group with a large difference in personality had lower satisfaction with the robot's service than the group with a low difference in personality ($t=-2.883$, $p<0.01$). Similarly, the group with a large difference in empathy showed less satisfaction than the group with a lowdifference in empathy ($t=-3.026$, $p<0.01$). Meanwhile, in contrast to the previous results, satisfaction with robot service was higher in the group with a large difference in professionalism. ($t=2.074$, $p<0.05$). The results of the group difference analysis are shown in Table 3.

Table 2: Descriptive Statistics

	EMP	PER	PROF	R_EMP	R_PER	R_PROF	SAT	PER_HET (PER-R_PER)	EMP_HET (EMP-R_EMP)	PROF_HET (PROF-R_PROF)
N	70	70	70	70	70	70	70	70	70	70
Mean	5.537	4.946	3.320	4.594	4.990	3.897	4.642	2.057	2.183	2.263
Median	5.600	5.000	3.200	4.700	5.000	4.000	4.667	1.750	1.800	2.000
Stand.dev	.768	1.033	1.063	1.335	1.018	1.154	1.325	.942	1.185	.954

Note: EMP: level of users' empathy; PER: level of users' personality; PRO: level of users' professionalism; R_EMP: perceived level of robot's empathy; R_PER: perceived level of robot's personality; R_PRO: perceived level of robot's professionalism.

Table 3: Results of t-test

		PER_HET		EMP_HET		PROF_HET	
		High	Low	High	Low	High	Low
Satisfaction	Mean	4.196	5.065	4.177	5.083	4.946	4.303
	Stand.dev	1.475	1.017	1.298	1.210	1.280	1.311
	t-value	-2.883***		-3.026***		2.074**	

Note: PER_HET: personality heterogeneity; EMP_HET: empathy heterogeneity; PROF_HET: professionalism heterogeneity.

Table 4: Results of correlation analysis

	SAT	PER_HET	EMP_HET	PROF_HET
SAT	1.000	-0.250**	-0.396***	0.294**
PER_HET	-0.250**	1.000	0.189	0.028
EMP_HET	-0.396***	0.189	1.000	-0.052
PROF_HET	0.294**	0.028	-0.052	1.000

Note1: *p < 0.1, **p < 0.05, ***p < 0.01

Note2: SAT: satisfaction; PER_HET: personality heterogeneity; EMP_HET: empathy heterogeneity; PROF_HET: professionalism heterogeneity.

Table 5: Results of regression analysis

Dependent variable	Independent variable	Unstandardized Coefficients		Standardized Coefficients		P-value
		B	Standard Error	Beta		
SAT	Constant	5.159	0.515		10.008	0.000***
	PER_HET	-0.272	0.151	-1.93	-1.799	0.077*
	EMP_HET	-0.385	0.120	-0.345	.-3.206	0.002***
	PROF_HET	0.390	0.147	0.281	2.663	0.100***
$R^2 = 0.267$, adjusted $- R^2 = 0.234$						

Note1: * p < 0.1, ** p < 0.05, ** p < 0.01***.

Note2: PER_HET: personality heterogeneity; EMP_HET: empathy heterogeneity; PROF_HET: professionalism heterogeneity.

Next, we performed correlation analysis between the heterogeneity variables and the satisfaction variable. As shown in Table 4, PER_HET, EMP_HET, and PROF_HET had a significant correlation with satisfaction with the robot's service, but the three heterogeneity variablesdid not significantly correlate with each other.

As mentioned, we investigated how the three heterogeneity variables affected satisfaction with the robot's service. To achieve this, multiple regression analysis was conducted. As shown in Table 5, all three heterogeneity variables had a significant effect on satisfaction, with PER_HET and EMP_HET having a negative effect (t-value of PER_HET = -1.799, t-value of EMP_HET = 3.206). Therefore, hypotheses 1 and 3 were proven. Further, the result also showed that PROF_HET had a positive influence on satisfaction with the robot's service (t-value = 2.663, p < 0.01);thus, Hypothesis 2 was supported.

In summary, based on the results of a t-test, correlation analysis, and regression analysis, all three hypotheses presented in this study were proven.

6. Conclusion

6.1. Implication

Our study aimed to examine the significance of the level of heterogeneity between healthcare robots and users in terms of empathy, professionalism, and personality. Further, we also examined the contribution of this heterogeneity to user satisfaction. Our findings have several implications. First, personality heterogeneity was found to significantly affect user satisfaction (Hypothesis 3 was supported). This result suggests that robotsshould, somehow, recognize a user's personality before providing healthcare.Similarly, recent HRI research has proposedthe identification of users' context beforehand as a means of understanding users' personalities. Such identification would help robots conduct personalized HRI. Considering our findings, it would be worthwhile to design robots that can immediately alter their personalitiesto complement those of users. This could be achieved through the use of a personality-prediction model that includes speech and non-speech cues (e.g. gestures, facial expressions, and eye contact).

Secondly, our results underline the importance of including the ability to show empathy when designing a healthcare robot (Hypothesis 1). As addressed in the introduction, in domains where a rapport with service users is necessary, such as healthcare, empathy has a great impact on user satisfaction with the services provided. The findings of our empirical test suggest that the lower the difference in empathy, the higher the level of user satisfaction with the robot-based healthcare service. In other words, consistency between a user's and a robot's empathy contributes to increased rapport, which results in user satisfaction with the robot. Empathy concerns dyadicresponses, verbal and nonverbal;in other words, gestures, facial expressions, and communication. Hence, users' behavior patterns should be analyzed by the healthcare robot in order to increase the users' satisfaction with the healthcare service.

The importance of the ability to show empathy can also be explained by the expectation-confirmation theory. According to this theory, users' satisfaction levels increase as their expectationsof a service and its actual performance increase. In addition, satisfaction levels also rise when the actual level of empathy shown is greater than expected. From our results, we also found that users' satisfaction levelswere higher when the robot's empathy level was higher than that which the users perceived it to have (t=2.466, p<0.05).

Lastly, our results suggest that heterogeneity between users and healthcare robots is positively associated with user satisfaction (Hypothesis 2). Based on this result, we can conclude that patients do not desire a healthcare robot that appears naïve: even though the robot may express similar personality and empathy, the robot must be professional. Hence, care should be exercisedwhen designing HRI. For example, it is necessary that the robot looks confident in terms of facial expressions, voice, and/or gestures. This is particularly important on occasions when the robot may need to ask or command a user by using a lower level of honorific expression.

A contribution of our study is that we empirically show the importance of professionalism in designing HRI for the healthcare domain. The result of Hypothesis 2 also implies that professional robots, like healthcare robots, should have self-learning ability,mainly because inserting professional knowledge in a manual manner is very costly.

6.2. Future work

In this paper, we adopted, from previous research, three elements that affect user satisfaction. Even though we showed through an empirical test that they are important and significant for enhancing user satisfaction with a process and, hence,create a greater likelihood of a user adopting the process or deciding to use it again, further study to identify additional factors is required.

The design of a more sophisticated HRI that involves empathy, personality, and professionalism remainsanother issue for future study; for example, we used a humanoid that has limited capability in terms of facial expressions.

Lastly, future studies should increase the sample size in order to incorporate more factors, and should apply path analysis to investigate mediators and/or moderators, which can result in the identification offurther implications of better HRI design in healthcare services.

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