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Human-Automation Interaction

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The Automation, Collaboration, & E-Services series (ACES) publishes new developments and advances in the fields of Automation, collaboration and e-services; rapidly and informally but with a high quality. It captures the scientific and engineering theories and techniques addressing challenges of the megatrends of automation, and collaboration. These trends, defining the scope of the ACES Series, are evident with wireless communication, Internetworking, multi-agent systems, sensor networks, cyber-physical collaborative systems, interactive-collaborative devices, and social robotics – all enabled by collaborative e-Services. Within the scope of the series are monographs, lecture notes, selected contributions from specialized conferences and workshops.

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ACES Series Editor Foreword

Our Springer ACES Series is delighted to welcome the unique three-book excellent collection of editors, chapter co-authors and contributors on human–automation interaction. This collection includes:

- Human–Automation Interaction: Mobile Computing
- Human–Automation Interaction: Transportation
- Human–Automation Interaction: Manufacturing, Services and UX

When we consider collaboration today, during the age of cyber-collaborative world and society, we cannot limit it any longer to human–human collaboration, the foundation and future of any human civilization. At the same time, we cannot ignore the fact that automation, while invented and implemented by humans, is made solely for the sake of humans. Hence, our essential need to understand and explore the science, engineering and management of HAI, human–automation interaction. After all, the purpose of interaction is collaboration. That is the theme defined by the committee for the Gavriel Salvendy International Symposium for Emerging Frontiers in Industrial Engineering. (The committee includes Robert Proctor, Chair; Vincent G. Duffy, Shimon Y. Nof and Yeuhwern Yih.) While during the pandemic years it could not be held in person, it was possible to engage many colleagues worldwide, who are the participants in this three-book important, collaborative endeavor.

Thanks again to all the participants and contributors, all of us who for many years have been inspired and learned from the leadership of Prof. Gavriel Salvendy. Thanks also to Springer team, who supported the publication of these books. We would like to welcome and invite many readers of various academic backgrounds to enjoy these exciting articles as part of their exploration of HAI.

West Lafayette, IN, USA
June 2022

Shimon Y. Nof
Editor, Springer ACES Series

Preface

Human–automation interaction (HAI) has become present, and design considerations are now important in so many aspects of our lives. The themes of the three books are transportation, mobile computing and manufacturing and services and user experience (UX). This initiative is intended as a look toward the future and a tribute to our esteemed colleague, Gavriel Salvendy, who contributed to research literature and the infrastructure development in engineering, human factors and ergonomics over the past six decades.

We celebrate Prof. Salvendy's birthday this year with a compilation of articles in three main themes of *human–automation interaction.* He reviewed and expressed interest in very many of the articles contributed this year. Over the past forty years, he has been the editor of handbooks and journals in the areas of overlapping research interest with most of our contributing authors. Dr. Salvendy is the founding chair of Human-Computer Interaction International (HCII) and Applied Human Factors and Ergonomics International (AHFE).

We all appreciated the opportunity to cooperate with the co-editors and invite you prospective authors to contribute chapters within a HAI theme of their interest. We look forward to sharing these articles with a general audience that has interest in human factors and ergonomics. We greatly appreciated the opportunity to celebrate international collaborations and contributors through this initiative. We are grateful to those who contributed to this special compilation of articles.

Papers from these volumes were included for publication after a minimum of one single blind review from among the co-editors within the thematic areas. I would again like to thank the co-editors for their contributions, cooperation, support and efforts throughout. Seventy-five contributing authors from 13 countries contributed 37 articles to the book. The authors and editors in this book are representing Australia, Brazil, China, Germany, Greece, Hungary, India, Italy, Malaysia, Norway, Portugal, South Africa and the USA.

The co-editors are Martina Ziefle, Pei-Luen Patrick Rau and Mitchell M. Tseng. The main parts for the HAI Mobile Computing book are shown below:

Part One: Health, Care and Assistive Services

Part Two: Usability, User Experience and Design
Part Three: Virtual Learning, Training, and Collaboration
Part Four: Ergonomics in Work, Automation and Production
Part Five: Interaction with Data and User Modeling in Special Applications

On behalf of the co-editors

West Lafayette, IN, USA Vincent G. Duffy

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Health, Care and Assistive Services

Don't Stand so Close to Me: Acceptance of Delegating Intimate Health Care Tasks to Assistive Robots

Vivian Lotz, André Calero Valdez, and Martina Ziefle

Abstract **Background**: As the share of older adults worldwide increases, the supply of affordable and accessible health care may not match the pace with the growing demand. Thus, assistive care robots receive growing attention. However, while their potential is great in terms of preserving the patients' sense of autonomy and meeting staff shortages, scepsis remains from a social science perspective. Care tasks often require close physical contact between caretaker and -receiver. This can be difficult, whether it is a human caregiver, or a robot. Notwithstanding that, everyone in need of care tends to hold different expectations, requirements, and prerequisites. Thus, acceptance issues might vary on the acceptance of assistive care robots and preference regarding who should handle which tasks. **Objective**: Using a quantitative empirical approach, we focused on identifying factors influencing assistive care robots' acceptance. The overall aim was to understand the requirements of accepting robotic care assistance, comparing human vs. robotic assistance preferences in various caring tasks. **Method**: We used an online survey ($N = 294$) in which different Human-AI-Interaction-related scenarios and issues were investigated. In detail, we examined the locus of control (LoC), prior experience with care, gender, task delegation preferences, and acceptance of receiving care by a human versus a robot caretaker for various tasks. **Results**: The results reveal that care robots are equally well-received as their human counterparts. However, this changes considerably depending on the tasks at hand. The more intimate and shameful a task is considered, the more likely the robotic caretaker is preferred. Regarding user factors, gender and LoC showed to be impactful. **Conclusion**: The results of the present study offer insights into the current state of user acceptance of assistive robots in the health care sector. Moreover,

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they shall help identify tasks for which such robots can provide the most significant benefit for those in need of care. Overall, assistive care robots seem to be best suited as supplementary caregivers rather than a complete substitute. Although they were generally perceived positively, this assessment was task- and user-dependent.

Keywords Assistance robots · Social acceptance · User diversity · Elderly care

1 Introduction

In light of the enormous challenges posed by the need to care for a growing number of older adults in many countries around the world, innovations in the assistive technology sector promise to bridge the expected gaps in the care sector by providing substantial support in caring, assisting, and supporting older adults thereby enabling them to keep living independently at home as long as possible. Technical innovations and assistive technologies in the health care sector cover a broad range of different approaches, implants for monitoring physiological signals as internal body devices, but also devices equipped with mobile technologies to be integrated into a number of everyday objects (as, e.g. bracelets, clothes, belts, floor elements, or even walls). Moreover, intelligent robot assistants might be useful to take over caring and monitoring tasks in the overall care of older adults.

Beyond the technical functionality, security, and availability, the willingness of users to accept and voluntarily use these devices is essential. Especially in the fragile context of care and frailty of older adults in general, and usage of such technologies in the intimacy of the own home, in particular, represents a very sensitive topic that needs to be balanced with the "human factor". Thus, human values, individual norms, and acceptance on the one hand and individual requests for usage on the other need to be considered.

In this study, we focus on the social perception of domestic robots for the care of older adults at home. We explore under which circumstances future users would be willing to accept robotic assistance and in which situations they would prefer a human care person over the robotic care assistance. Before we detail the empirical procedure, we briefly refer to the state of the art regarding forms of assistive care robots and key facts of technology acceptance in this regard.

2 Related Work

In this section, we first look at different usages of assistive care robots and survey existing prototypes for a frame of reference. We then look at how acceptance and user diversity have been studied to impact acceptance in other domains and transfer it to our context at hand.

2.1 Assistive Care Robots, Technologies, and Systems

With the term Assistive Care Robots (ACR),[1] we refer to robotic systems designed to be used for health and elderly care. In this context, there are essentially three different ways in which the robot can be utilized for care-related tasks: (1) monitor the health condition, (2) assist the elderly/patients/caregivers with daily tasks, (3) and provide companionship for the elderly/patients [1, 2]. Apart from the different tasks for which the robots can be used, they vary in their outer appearance, ranging from small devices for internet-of-things applications to human-sized or even larger physical robots. In the present study, we focused on human-sized physical robots, which have assistance and companionship as their primary use cases. Recently, many robots have been developed to enable independent living in old age and increase the quality of life for the elderly. In the following, some examples of such robotic systems are briefly presented.

There are ample examples of robots developed to assist caregivers and care-receivers in their daily routines. One such example is the Care-O-Bot, designed to perform supporting tasks such as fetching and carrying objects in a home environment [3]. Other examples include the automatic feeding robot "My Spoon" [4], the "Riba" robot [5]—which can pick up and carry humans, e.g. to transfer them from a wheelchair to their beds—a robotic shower system [6], and a hair-washing robot developed by Hirose et al. [7]. A relatively recent example is the autonomous robot "Lio," a personal assistant robot for care institutions that proactively performs care-related tasks [8]. Such robots could be used in care facilities and clinics to support the staff, as well as at peoples' homes, thereby enabling older adults to age gracefully at home.

As it is suggested that social robots may prove useful to provide company for the elderly and thereby prevent a prolonged lack of engagement and social interaction, so-called companion robots have been developed. Such robots are often designed to look like pets. The perhaps most widely known and mentioned example is the seal-like robot "Paro" [9]. Paro was developed especially for Alzheimer's patients and is aimed to increase their well-being by providing a similar therapeutic effect as pets do. When petted, it responds with movements of its tail and closing its eyes. Another example is the robotic dog AIBO by Sony, which mainly serves to entertain its user but has also been used in research concerning robotic companionship [10].

2.2 Acceptance, User Diversity & Assistive Care Robots

Previous research on the acceptance of assistive care robots paints a somewhat inconsistent picture. In their analysis of three surveys in Germany [11–13], Rebiteschk & Wagner, e.g. showed that despite the great potential of care-robots to preserve the

[1] We use the term Assistive Care Robots to refer to robots that were especially designed to assist with health and elderly care tasks.

patients' sense of autonomy and to bridge anticipated care-staff shortages, only a minority of Germans would currently accept the use of such robots [14]. Moreover, precisely those who would have the most frequent contact with care-robots—care-staff and the elderly—appear to be particularly critical towards their use. This result contrasts starkly with the 82% of respondents who, according to a FORSA-survey, can imagine using a service robot at home, if by using it, they could age at home [15]. This somewhat positive assessment is not an isolated case either, but can also be found in several other studies (e.g. [16–21]). The common ground between all of these empirical findings is that acceptance seems to be granted only under the premise that the robot supports the nursing staff, meaning it shall not replace them.

Since care-related tasks often require close contact between caregiver and -receiver, being cared for almost always implies allowing another person to intrude into one's personal sphere and hand over control. In that regard, the human-robots interaction in the context of health care fundamentally differs from that in industrial applications, where the robot seldom comes into direct contact with the user. Due to this difference, aspects such as the user's personal preferences, prerequisites, and requirements may considerably alter how willing a person is to allow the care-giver to perform specific tasks—be it a human or a robot. In sum, acceptance is likely influenced by the nature of tasks performed and by the users' personal characteristics.

When looking at the insights from previous research, the respondents' age and gender showed to influence ACR acceptance [22, 23]. The results of the Eurobarometer 2017 [23] revealed, for example, that women and older people generally regarded ACR more negatively. The influence of age on care robot acceptance is particularly significant as the elderly can be considered the primary target group for ACRs and usually require more assistance in their daily tasks. So far, it remains unclear why these two groups tend to reject robots for care purposes to a greater extent. One reason could be that women and older adults generally tend to have a lower sense of control in dealing with technology (Locus of Control) [24]. Since a person's LoC score and the acceptance of new technologies were shown to be correlated, lower acceptance of ACR might be a consequence of a lower technical self-efficacy, rather than the elderly and women having a more negative attitude towards care robots per se. Therefore, we examined the influence of age, gender, and LoC on ACR acceptance and subsequently examined which of these individual factors exerted the most decisive influence on acceptance (H 1.1, H 1.3 and H 1.4).

A different group of people, who repeatedly evaluate care robots more critically, is professional caregivers (e.g. [25, 26]). While the staff more or less approves of delegating chore tasks (i.e., indirect care tasks) to the robots, especially those that include heavy labor, they see little added value in delegating tasks with direct patient contact. In this context, aspects such as data protection, the unspecified legal framework, and the importance of human contact still pose enormous obstacles [26, 27]. Having experience with care tasks through one's profession seems to diminish the acceptance of ACR. In the present study, we examined whether this result is transferable to lay people who have care experience (H 1.2).

Such individual factors are not the only aspects influencing how positively or negatively a care robot is evaluated. Depending on which tasks are performed by the robots, their acceptability varies. A study by Radic et al. [26] revealed that robots that support personal hygiene have the lowest perceived benefit from the professional caregivers' point of view. However, this view is not necessarily identical to the opinion of those in need of care. For the elderly or disabled, robots might hold substantial perceived benefits, especially if they enable them to perform personal hygiene tasks independently. Firstly, care robots offer the patients autonomy despite their need for assistance. Secondly, robots might offer advantages in preserving the patients' dignity by minimizing feelings of shame and the loss of control. It may be easier to rely on a robot than to allow a family member or professional caregiver to perform intimate tasks such as bathing or helping with going to the toilet. Hence, we argue that the more intimate a care-related task is, the higher is the probability that the robot caregiver is preferred over a human caregiver (H 2.1). In this context, high intimacy means that relying on someone else to perform the task is perceived as embarrassing and that the task entails a high degree of physical contact between caregiver and -receiver.

2.3 Research Aim

Apart from the technologies' technical feasibility, it is essential to understand what is socially acceptable in current contexts. Thus, we investigated laypeople's decisions regarding which care tasks would be acceptable to hand over to a robot. Based on the above-outlined insights from previous research, the following research questions have emerged and were addressed in this study.

RQ 1:Which user-related factors influence the acceptance of assistive care robots?

H 1.1: Locus of Control (LoC) is correlated with the acceptance of assistive care robots: the higher the LoC, the higher the acceptance.
H 1.2: People who have experience with care (caring for family members or a need for care themselves) assess assistive care robots differently than people without care related experience.
H 1.3: Gender is correlated with the acceptance of assistive care robots, with women showing lower acceptance levels.
H 1.4: Age is correlated with the acceptance of assistive care robots, with older adults showing lower acceptance levels.

RQ 2: Does the degree of intimacy of care related tasks influence the user's preferences regarding which tasks can be delegated to a robot and which tasks are preferred to remain under human responsibility?

H 2.1: The more intimate, i.e., shameful, care-related tasks are perceived, the more likely the patient prefers to delegate those tasks to a robotic caregiver over a human caregiver.

3 Method

To investigate the acceptance of assistive care robots, we conducted a web-based survey. In the following section, the empirical design is presented. After a brief description of the questionnaire, the sample's characteristics are detailed.

3.1 Survey Design

The questionnaire was structured into different sections, covering demographics (age, gender, and occupation), LoC (8 items), experience with care, and five different AI and robotics-related scenarios, one of which was the care-scenario. Both LoC and experience with care were assessed on a 6-point Likert scale.

Concerning experience with care, the participants were asked to indicate whether they have ever received care (1), whether they are related to a person in need of care (2), whether they know a person in need of care (3), or whether they ever performed care-related tasks (4).

Since it can be expected that most people lack any previous experience with robots, we decided to design a scenario and define what kind of robot the participants should evaluate. Thereby, we aimed to control the variance of mental models the respondents might have about robots and ensure that participants evaluate the ACR based on the same information. The participants should imagine that an assistive care robot can perform every given task equally well as a human caregiver and was put at their disposal.

Subsequently, respondents were asked to assess how acceptable it is to delegate eleven different care-related tasks to the introduced robotic system and in comparison to a human caregiver. For all tasks, acceptability was assessed on a 6-point Likert scale ranging from "*not acceptable at all*" (1) to "*very acceptable*" (6). The assessment of how appropriate it is to hand over a task to a robot always involves balancing benefits on different dimensions, from which different stakeholder groups benefit to a varying degree—or not at all. For example, physical relief is more likely to benefit the nursing staff while reducing shame first and foremost benefits the patients. Thus, the queried tasks were varied regarding their degree of associated shamefulness, fine-motoric requirements, and physical strain to get a holistic overview of people's assessment. We included: cutting and combing hair, applying facial cream, applying body cream, washing hair, helping with getting in and out of the bathtub, helping with getting in and out of bed, helping with washing, massaging, administering medication, feeding, helping with going to the toilet. To evaluate how shameful, delicate, and physically demanding the queried tasks were perceived, we conducted a brief preliminary survey ($N = 16$; see Fig. 1).[2]

[2] The participants were asked to assess each task on a 6 point Likert-scale, ranging from *not at all shameful* and *no fine motoric requirements/physical strain at all* (1) to *very shameful/high fine motoric requirements/high physical strain* (6).

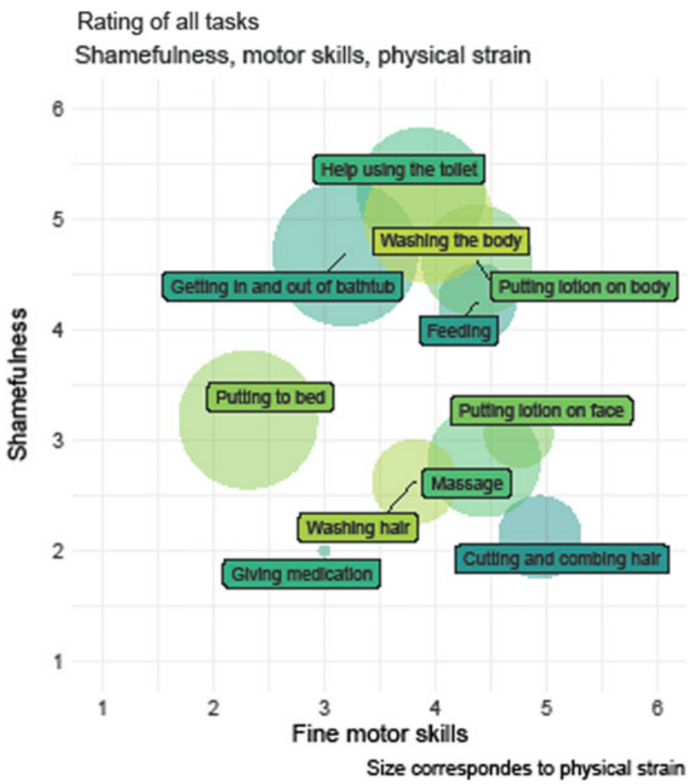

Fig. 1 Queried tasks ranked according to (1: x-axis) the degree of precision required to execute the tasks successfully, (2: y-axis) the shamefulness associated with the task, and (3: bubble size) physical effort on the part of the caregiver linked to the execution of the task

In Table 1, all measured constructs with their respective descriptive statistics are listed.

To further examine the influence of sensitivity of queried tasks on Acceptance (H 2.1), the 11 acceptance-items were subjected to a principal component analysis, the results of which are detailed in Sect. 4.3.

The finally used subscales with their corresponding descriptive statistics are reported in Table 3.

Table 1 Overview reliability of used scales

Scale	*n* items	Cronbach's α	*M*	*SD*
Locus of control (LoC)	8	0.918	4.324	1.023
Experience with care	4	0.628	2.579	1.126
Robot care acceptance	11	0.939	3.953	1.194
Human care acceptance	11	0.921	4.183	0.957

3.2 Data Analysis

For data analysis, only complete answers were used. Prior to analysis, all measured constructs were checked regarding their internal consistency (Cronbach's α, see Table 1). In the case of *experience with care* (*Cronbach's* $\alpha = 0.628$, 4 Items), the calculated value was below the critical threshold of 0.7. As item exclusion could not sufficiently improve this value, the items were not combined. Instead, each of the four items' relationships with the respective dependent variable was examined. The remaining scales all showed satisfactory internal consistency.

For data analysis, descriptive and inference statistics were used (i.e., mean scores, correlation analysis, principal component analysis, and t-tests). Before conducting the tests, analyses were performed to check the data for violations of assumptions. In cases where the assumptions were not met, the corresponding non-parametric test procedure was performed for comparison. In the case of a different result, the result of the non-parametric procedure is reported.

3.3 Sample Description

The web-based survey was distributed through personal contacts (convenience sampling). Hence, a sample representative for the German public could not be achieved. In total, 335 respondents participated, of which 294 could be used for analyses (male: $n = 121$, 41%; female: $n = 170$, 58%). On average, the subjects were 31.9 ($SD = 13.627$) years old, with the women being slightly older (Male: $M_{Age} = 31.5$, $SD_{Age} = 13.096$; Female: $M_{Age} = 32.4$, $SD_{Age} = 14.009$). This is not a significant difference ($t(289) = 0.554$, $p = 0.580$).

4 Results

In the following, we report on the study results, starting with the general acceptance of being cared for by a robotic vs. human caregiver, followed by an analysis of the impact of user factors on acceptance. We end with the influence of the tasks intimacy and sensitivity on acceptance. For the analysis, we use descriptive and inference-statistical testing). The level of significance was set at 5%.

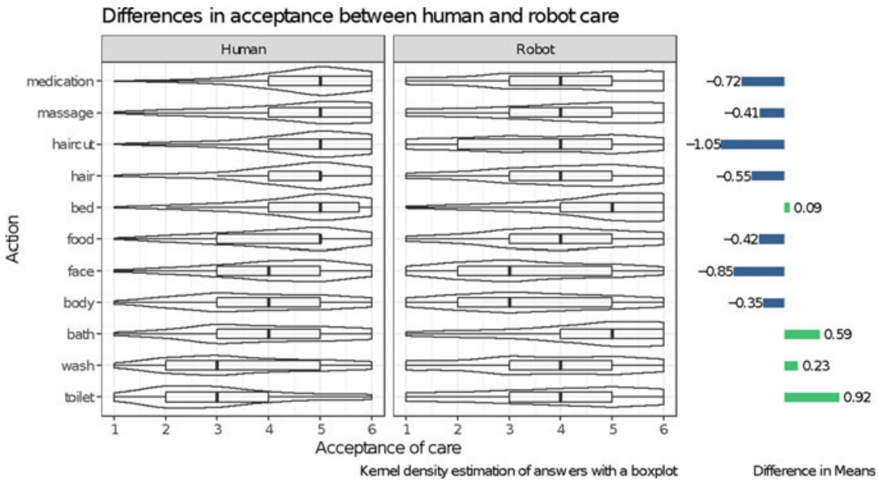

Fig. 2 Distribution of results for both human and robot (left). Results of mean value comparison for the 11 items of robot acceptance and human caregiver acceptance (right). $N = 294$

4.1 General Acceptance of Being Cared for by a Robot Versus a Human

In general, the use of robots for care-related tasks was assessed positively ($M = 3.953$, $SD = 1.194$). Nevertheless, human-caregivers were evaluated slightly better ($M = 4.183$, $SD = 0.957$). Figure 2 shows the distribution for the individual items for the robotic caregiver and the human caregiver.

It is noticeable that for most tasks, the human caregiver was preferred. Only for the four tasks: getting in and out of bed, getting in and out of the bathtub, helping with going to the toilet, and helping with washing (body), the robot scored better. However, it is worth mentioning that there was quite a large variance in all item responses, meaning that respondents used the entire scale range. In other words, while some seem to be happy with letting the robot handle their medication, personal hygiene, and nutrition input, others were completely opposed to it. This result, on the one hand, hints at individual-level differences between the respondents. On the other hand, it may also indicate that people are generally quite ambivalent about the issue.

4.2 The Role of User Diversity

For the analysis of potential relationships between Locus of Control (*LoC*) and the *acceptance* of being cared for by a robot, Pearson correlation analyses were performed. There was a significant positive correlation between *Robot Care Acceptance* and *LoC* ($r = 0.262$, $p \leq 0.001$) and no significant correlation between *LoC* and *Human Care Acceptance* ($r = -0.003$, $p = 0.988$). These observations indicate that the higher the technical self-efficacy, the higher a subject's *acceptance* of a robot caregiver.

Concerning the relationship between *experience with care* and assistive care robot *acceptance*, a correlation analysis was conducted. Here, the only item which had a significant correlation with *Robot Care Acceptance* was "I know a person in need of care" ($r = -0.138$, $p = 0.018$).

To test if men differed from women in their *Robot Care Acceptance*, an independent-samples t-test was conducted. The result revealed that there was indeed a statistically significant difference in *Robot Care Acceptance* between male and female respondents ($t(289) = -3.380$, $p \leq 0.001$), indicating that men viewed the robots more positively (men: $M = 4.231$, $SD = 1.192$; women: $M = 3.763$, $SD = 1.145$). In contrast there was no significant difference regarding the acceptance of being cared for by a human caretaker ($t(289) = 0.153$, $p = 0.878$; men: $M = 4.183$, $SD = 1.030$; women: $M = 4.201$, $SD = 0.879$). To check whether the observed difference between male and female respondents was still significant when controlling for the effect of LoC, we ran a one-way between-groups analysis. The results showed that after adjusting for LoC scores, the difference between the male and female group was no longer significant ($F(1) = 3.741$, $p = 0.054$, partial eta squared $= 0.013$). Furthermore, the relationship between the LoC scores and the scores for acceptance of assistive care robots showed to be significant but relatively weak, as indicated by a partial eta squared of 0.041. So overall, the gender effect is in reality an effect of the differences in locus of control.

Regarding the hypothesized link between *age* and *assistive care robot acceptance*, no significant relationship could be detected ($r = -0.056$, $p = 0.342$). The same is true for *age* and the *acceptance* of being cared for by a *human caregiver* ($r = 0.015$, $p = 0.795$). Age, it seems, does not play a role in the acceptance of care—be it by a human or a robot.

4.3 Tasks Intimacy and Sensitivity and Its Influence on Acceptance

It was assumed that the more shameful a care-related task is perceived, the more likely people would prefer this task to be executed by a robotic caregiver rather than a human caregiver. To test this hypothesis, we first conducted a principal component analysis to form new acceptance sub-scales based on the tasks' intimacy level. Before running the analysis, the data was checked regarding violations of assumption (sample size, factorability of the correlation matrix, linearity, and outliers). No issues were found (Robot Acceptance: $KMO = 0.992$, $p_{\text{Bartlett-test}} < 0.001$; Human

Caretaker Acceptance: $KMO = 0.895$; $p_{Bartlett\text{-}test} < 0.001$; [28]). The results indicated two underlying components with a cumulative explanatory value of 68% for the human caretaker-scale and 72% for the robot scale. To aid interpretation, we performed Varimax rotations. The results, including factor loadings, are reported in Table 2.

Based on these results, four new scales were formed. Namely, the acceptance of a robot performing tasks with low intimacy, the acceptance of a human caretaker performing tasks with low intimacy, the acceptance of a robot performing tasks with high intimacy, and the acceptance of a human caretaker performing tasks with high intimacy, which are listed with their respective descriptive statistics in Table 3.

A paired sample t-test revealed a significant difference between the mean scores of robot acceptance and human caregiver acceptance for high intimacy tasks and low intimacy tasks. The robotic caregiver was preferred over the human caregiver for

Table 2 Pattern structure for coefficients of "acceptance human caretaker" and "acceptance robot" scale

Item	Human caretaker		Robot	
	Component 1	Component 2	Component 1	Component 2
Cut hair	0.850		0.832	
Wash hair	0.771		0.791	
Apply facial cream	0.709		0.857	
Wash (body)		0.878	0.661	0.551
Help with going to the toilet		0.851		0.716
Help with getting in and out of the bathtub		0.772		0.885
% of variance explained	56.196	11.511	62.981	9.039

Varimax rotation of the two-factor solutions ($N = 294$)

Table 3 Acceptance sub-scales derived from principal component analysis with their corresponding descriptive statistics

Scale	Included items	*n* items	*Cronbach's α*	*M*	*SD*
Acceptance low intimacy robot	Cut hair, wash hair, apply facial cream	3	0.889	3.701	1.374
Acceptance low intimacy human	Cut hair, wash hair, apply facial cream	3	0.864	4.243	0.906
Acceptance high intimacy robot	Wash (body), help with going to the toilet, help with getting in and out of the bathtub	3	0.884	4.039	1.402
Acceptance high intimacy human	Wash (body), help with going to the toilet, help with getting in and out of the bathtub	3	0.875	3.451	1.244

Table 4 Paired samples t-test results for AHIR—AHIH and ALIR—ALIH ($N = 294$)

	$\otimes M$	t	df	p
Acceptance high intimacy robot (AHIR)—Acceptance high intimacy human (AHIH)	0.587	5.644	293	$\leq$0.001
Acceptance low intimacy robot (ALIR)—Acceptance low intimacy human (ALIH)	−0.542	−8.520	293	$\leq$0.001

high intimacy tasks. For low intimacy tasks, the respondents preferred the human caregiver. The results are listed in Table 4.

5 Discussion

In light of an aging population and impending staff shortages, especially in the elderly care sector, it seems necessary to understand if people are ready to be cared for by a robot and which influence user diversity has on their readiness. Hence, this study's motivation was to gain further insights into the willingness to delegate health and elderly care-related tasks to an assistive robot and account for individual-level differences between respondents. Previous research, especially in Germany, came to somewhat inconclusive findings concerning how well people receive robots in the health care sector. Earlier studies mainly focused on gender, age, and occupation to explain individual differences in care robot acceptance. The present study extended the list of influencing factors by adding the factors *LoC* and *experience with care* as potential acceptance determinants. Additionally, it was examined which of these four variables exerted the most substantial influence on acceptance.

Social Acceptance is a complex matter, specifically in health and elderly care, where the patient's wish for dignity and self-sufficiency conflict with their need for aid in their daily tasks. Therefore, it is essential to understand which tasks the user would be willing to hand over to a technical system and identify those tasks where the robot offers the greatest benefit. Thus, we further examined for which care-related tasks a robot would be desirable.

In sum, the present study provided insight into the influence of user factors on acceptance and people's preferences regarding the tasks for which assistive care robots can be used. In the following section, the findings are discussed against the background of previous research concerning the acceptance of robots in health and elderly care.

5.1 General Acceptance of Assistive Care Robots and Task Dependency of Acceptance

The present study empirically validated that laypeople are generally willing to let a robot handle health and elderly care tasks. This finding is in line with the results from previous research (e.g. [15, 18, 19]). However, our results are in contrast with the findings of Rebitschek & Wagner [14], who compared several studies and identified a somewhat skeptical and rather negative attitude towards care robots among the German public.

The analysis further showed that the questioned laypeople, contrary to the nursing staff interviewed by Radic et al. [26], were not averse to the idea that robots could assist in performing tasks related to daily personal hygiene. However, it should be noted that for most surveyed actions, the acceptance score of the robots lagged behind the acceptance score of a human caregiver, indicating that human caregivers are still the preferred option and robots should serve as a substitute option for specific tasks only. Nonetheless, there are tasks for which robots seem to be the favored choice, namely help with going to the toilet, lifting into bed, lifting into the bathtub, and helping to wash. Notably, all four actions can be categorized as either shameful, physically demanding, or as a combination of both, indicating that the underlying motivation for preferring a robot might be to minimize embarrassment for oneself and physical strain for the caregivers.

In contrast, respondents preferred a human caregiver for tasks, which can be described as filigree and risk-prone. Overall, the rejection was highest for the item concerning the willingness to let a robot apply facial or body cream. Apart from the potentially higher associated risk and the high requirement for fine-motor skills, it can be argued that people might reject handing over this specific task for affective reasons. The mental model of a robot could evoke associations conflicting with the attributes associated with such delicate tasks. Comfort and therefore attributes such as softness and warmth are presumably highly relevant for tasks where the caregiver directly touches the patient's skin. If, however, the mental model of a robot is machine-like, i.e., evokes associations like coldness and steeliness, this perception contradicts the requirements of the task. This, in turn, can lead to the robot being regarded as less desirable for the task.

Overall, the results of the present study suggest that the underlying motivations to favor a robot over a human nurse are, on the one hand, a decreased feeling of shame and, on the other hand, the physical relief they offer for the nursing staff. In contrast, perceived riskiness and high fine-motoric requirements associated with tasks seem to impede the willingness to hand over care-related tasks to a robot. However, these are so far only assumptions and not proven causal relationships and need to be investigated further.

Another finding worth discussing is the observed high standard deviations of the task-approval items, indicating that acceptance was not homogenous across the sample. These user-related differences will be discussed in more detail in the section below.

5.2 User Diversity

Our results revealed that depending on a person's LoC-score and gender, their acceptance to assign care-related tasks to a robot changed. As expected, a higher level of confidence in interacting with technical systems and male gender resulted in increased acceptance, which confirms previous research (e.g. [22, 23]). However, it became evident that LoC was the decisive factor. Effects of gender on acceptance were mediated by technical self-efficacy. Hence, the fact that women reported lower levels of *Robot Care Acceptance* is, in part, attributable to them being less confident in interacting with technology. This relationship between technical self-efficacy and gender and its influence on technology acceptance is in line with earlier research (e.g. [24, 28–30]). Still, it should be noted that the strength of the detected influence of LoC was relatively weak and can not explain a lot of the observed variance in acceptance.

Surprisingly, we found no evidence for an influence of age on ACR-acceptance. This result is in contrast to the findings of earlier studies (e.g. [22, 23]). Assumably this is due to the sample selection, where older respondents were underrepresented. Therefore, this finding should be interpreted with care.

Further, only one of the used items of care-experience did significantly correlate with *Robot Care Acceptance*. Like with age, this might be due to the sample. Few respondents had any experience with care, let alone had ever required care themselves, which is not surprising considering that the sample was relatively young. However, the detected correlation can be interpreted as an indication that a more thorough investigation of this relationship between experience and acceptance might be worthwhile. Moreso, because other studies in the context of ambient assisted living (AAL) technologies already found evidence acceptance is influenced indirectly by experience with care. This experience alters how benefits and barriers are weighed against each other and ultimately influences how decisions about the technology are made (e.g. [32, 33]). Hence, the analysis should be repeated with a sample more diverse in age and care-experience.

In summary, it can be concluded that although LoC was identified as an influencing factor on *Robot Care Acceptance*—indeed as the *only* influencing factor—it could only partly explain the observed variance in the acceptance rating. For a more comprehensive understanding of which factors are responsible for the differences in the way people evaluate the technology, additional factors should be considered, i.e., the need for control, mental models of robots, or self-reliance. It can also be argued that, particularly in the care sector, social acceptance can only be achieved if all stakeholders' expectations and demands are carefully assessed, and the advantages and disadvantages associated with the technology are cautiously balanced when developing an assistive care robot.

5.3 *Implications the Implementation of Assistive Technology in Real Care Contexts*

After all, what can be taken from the study for real-world applications? The advantages and disadvantages of assistive technologies in the home environment as perceived by the users play a decisive role in the willingness to use them. However, (un)certainty about possible risks for *all parties* involved are also important for the tolerance towards their integration of technology into private spheres. In our perspective, two major implications should be put into focus.

(1) **Acceptance for robotic care is generally positive, but there are conditions for acceptance**. It is very clear from the empirical data that the willingness to use and the acceptance of AAL technologies is not a black-and-white decision for any of the participants but is instead an individual weighing of motives and barriers that are based on different, specifiable, and empirically ascertainable conditions (certain spaces, certain technologies, certain target functions). It is characteristic of users' acceptance that the decision for or, more precisely, against the use of AAL technologies is strongly characterized by individuality and emotionality and is accompanied by a different willingness to accept the loss of control and concerns about dignity.

(2) **User acceptance needs to be integrated into technology development and economic evaluations**

Contemporary and responsible acceptance research must address the complexity of technology use against the background of different contexts of usage and increasing heterogeneity of the user community. This means that it must be understood and respected that user attitudes and usage decisions, especially in the case of technologies that intrude into one's own four walls, may follow an own "metric" than what is "medically indicated", "technically feasible", or even "makes economic sense". Especially for older people who have a wealth of life experience and know very well what it means to be frail and dependent on help, the decision to accept technology is closely connected to the fact that they are heard, and respected. The acceptance decision depends on their wishes being included in the development of the technology, and finally on the chance to try out novel technologies and help shape what is developed for them—possibly out of different motives and needs.

But the experience and responsibility of the nursing and medical staff must also be incorporated into the development of technology and the design of the process and the framework conditions. On the one hand, this claim is a consideration of responsible technology development; on the other hand, it is also a programmatic demand for innovations management and discursive training of experts involved in the implementation and introduction of technology-assisted care technologies.

5.4 Limitations and Future Research

The present empirical study provided valuable insights into which care-related tasks users would be willing to delegate to a robotic caregiver and which user-related factors influence this assessment. Nonetheless, there are limitations to this study, which will be discussed in this section.

First and foremost, the limitations grounded in the selected sample should be noted. As a convenience sample was used, the sample included predominantly young, educated respondents with very limited or no care experience. This proved to be problematic as care-experience and age were two factors assumed to be highly relevant to explain individual-level differences in ACR acceptance. Future studies should aim to achieve a more heterogeneous sample and to capture the whole spectrum of existing beliefs and underlying motivations.

Another limitation is the choice of the method itself. As very few people have any actual experience with robotic systems, the assessment is purely based on perceptions and beliefs. Even if we tried to ensure that all participants evaluate the system based on the same information by choosing a scenario-based approach, such an evaluation is rather complicated for the respondents. Practical experience is indispensable, especially as earlier research showed that experiencing the robot affected acceptance positively [26, 31]. However, scenarios were used in both cases, ensuring that this error is at least symmetrical for both humans and robots. Thus a general tendency in perception remains a valid finding. Future research should verify these findings, possibly using real robots to understand how perception and experience shape the acceptance of robotic care. Moreover, it is expected that a hybrid form of care (i.e., robotic and human-collaborative care) could become a new focus of research and engineering, thus making it necessary to evaluate different allocations of human and robotic care. Such changing scenarios could have completely different evaluations than our “either-or- scenarios”.

As a last sample-related limitation, it should be noted that it offers a very culture-specific perspective as the study was conducted in Germany. Health care systems, policies, regulations, adoption of innovative technologies, and mental models of aging are highly country- or culture-dependent. Therefore, it is reasonable to assume that the cultural background also has an impact on the evaluation of robotic systems in care. Hence, comparing culture-specific views on this issue is crucial. As a possible example with very different evaluations, technology affine cultures such as the Japanese could yield a range of different evaluations, allowing to study the impact of the individual, the societal, and the technological context. Varying levels of cultural dimension (e.g. Hofstede cultural dimension) could help identify other populations to study. As fruitful dimension aspects such as uncertainty avoidance, collectivist vs. individualist, or short-term vs. long-term orientation could play a large role in the acceptance of robotic care. This can be assumed as cultures with lower uncertainty avoidance might be more willing to accept novel technology. Cultures with a collectivist mindset might be more willing to accept care for relatives as unavoidable. Cultures with long-term orientation could be able to predict acceptance from scenarios with higher confidence. A useful result of such a research endeavor would be a culturally specific map of acceptance criteria for assistive care robots.

As we are unsure how the mental model of a robot shaped decision making, future research could explicitly manipulate the mental model in similar experiments. For this purpose, a design fiction approach could be used to embody different assistive care robots using different affective properties (e.g. the Terminator vs. Wall-E) and study their acceptance.

6 Conclusion

In our research we investigated differences in acceptance between human and robotic care. For this purpose we conducted a questionnaire survey with 294 participants. We found that acceptance does not solely depend on the caregiver, but also depends on the task assigned. Tasks that require fine motor skills and human touch are largely preferred to remain in the hands of humans. Tasks associated with shame and physical strain show higher preferences in robotic care. Lastly, we found that technological self-efficacy plays an important role in acceptance of robotic care. Given that it is uncertain whether robots will be able to provide solace and warmth equal to their human counterparts, we propose that hybrid forms of human-robotic care must be developed using a user-centered design approach. This ensures that a humane user experience will remain at the core of care.

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