Assessing attitudes towards autonomous mobile robots in hospitals

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Dissertation submitted in partial fulfilment of requirements for the MSc in Management at the Universidade Católica Portuguesa, September 12th 2024.

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Abstract

This research contributes to the general assessment of attributes towards autonomous mobile robots in healthcare. In this new field of research, the general attitude towards robots scale that was designed to measure general attitudes towards autonomous robots in a social context was adapted to be able to measure attitudes towards autonomous mobile robots in hospitals. This was the first time that GAToRS was used to measure attitudes towards autonomous mobile robots, a specific subset of robots. The results have shown that an adapted GAToRS was able to reproduce similar findings of attitudes towards autonomous mobile robots in hospitals compared to general robots. It was able to show similar correlations among the four dimensions of personal and societal attitudes, reinforcing the assumption that multidimensionality is key in assessing attitudes. The results indicate that among young people in Germany, a positive view towards AMRs is dominant and that most potential patients would not mind interacting with an AMR when in hospital. Furthermore, societal attitudes may have a pivotal role in the acceptance of potential patients towards AMRs.

Keywords: Autonomous mobile robots, attitudes, patient's acceptance

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Sumário

Esta investigação contribui para a avaliação geral dos atributos dos robôs móveis autónomos na área da saúde. Neste novo campo de investigação, a escala de atitude geral em relação aos robôs, concebida para medir as atitudes gerais em relação aos robôs autónomos num contexto social, foi adaptada para poder medir as atitudes em relação aos robôs móveis autónomos nos hospitais. Esta foi a primeira vez que a GAToRS foi utilizada para medir as atitudes em relação aos robôs móveis autónomos, um subconjunto específico de robôs. Os resultados mostraram que um GAToRS adaptado foi capaz de reproduzir resultados semelhantes de atitudes em relação a robôs móveis autónomos em hospitais em comparação com robôs gerais. Foi capaz de mostrar correlações semelhantes entre as quatro dimensões das atitudes pessoais e sociais, reforçando o pressuposto de que a multidimensionalidade é fundamental na avaliação das atitudes. Os resultados indicam que, entre os jovens na Alemanha, é dominante uma visão positiva em relação aos AMR e que a maioria dos potenciais doentes não se importaria de interagir com um AMR quando está no hospital. Além disso, as atitudes sociais podem ter um papel fundamental na aceitação dos potenciais doentes em relação aos AMRs.

Palavras-chave: Robôs móveis autónomos, atitudes, aceitação do paciente

Título: Avaliação das atitudes em relação aos robôs móveis autónomos nos hospitais

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1. Introduction

While Western civilization has succeeded in significantly increasing the life expectancy of its population over the past 50 years, this has been accompanied by a sharp increase in per capita health care spending. This relationship led the OECD to believe that the increase in health care spending could be explained by the increase in life expectancy [1]. While research is attempting to establish the ultimate causal relationship between population aging and health care spending, it is already clear that overall costs will continue to rise. However, key determinants such as national income growth, technological progress, wages and prices will have a major impact on the burden of future health expenditure [2]. Therefore, technological advances and their implementation are expected to have a significant impact on healthcare spending. Another major challenge, even greater than the financial burden, according to many experts, is the shortage of healthcare workers [3]. There are many reasons for this shortage, but the most pressing is the demographic shift in Western societies, where aging health workers will leave a huge gap as they retire. In 2016, the United Nations Secretary-General announced the creation of a Commission on Health, Employment and Economic Growth. According to Secretary-General Ban-Ki-Moon, founder of the initiative: "Its mandate is to [...] make recommendations to stimulate and guide the creation of at least 40 million new jobs in the health and social sectors by 2030, and to reduce the projected shortfall of 18 million health workers [...]". [4].

The shortage of healthcare workers such as nurses is likely to add more work to an already difficult and stressful job. Not only can this be detrimental to a person's physical and mental health, but it can also have a negative impact on the workplace and result in additional costs. According to the International Council of Nurses, the financial burden of stress alone in the U.S. is estimated at $200-300 million annually [5]. Several peer-reviewed studies on the positive correlation between the quality of work life of healthcare workers and the quality of care have confirmed that more needs to be done urgently to at least maintain the current level of care that patients can expect [5], [6], [7].

To alleviate these challenges, a new technology in general, but widely applicable in healthcare, is robotics. In this case, autonomous mobile robots (AMRs). AMRs could play a pivotal role in many healthcare challenges, especially in hospitals where nurses often travel long distances throughout the day. They can relieve exhausted staff by performing heavy lifting or walking long distances instead of humans. Ultimately, they enable caregivers to focus their full attention on patient care, improving the quality of care. Also, to reduce costs over time, as the human resource remains the most expensive cost point within any hospital [8].

However, while robots in healthcare seem like a great solution, implementing new technologies into existing systems in general has always been a difficult task. Predicting their success, failure, or speed of implementation has long been a topic of research [9].

Acceptance of any new technology depends on many different variables, and robots are no exception to this phenomenon, especially in healthcare where they present an additional challenge: Acceptance of robots must come from both caregivers and patients. Typically, when considering the implementation of new technologies, the user is the one who buys and works with the new technology. In the future, patients will neither buy nor work with robots, but will have to "accept" them in order for healthcare professionals to implement robots for patient care. This fact makes studies on patient acceptance in healthcare particularly interesting, as most research methodologies on acceptance models are not perfectly applicable. In addition, robots are not just a new technology. A study of robots in hospitals suggests that the socio-technical challenges associated with robots in healthcare are likely to be significant. Sociotechnical means that social and technical systems are seen as interdependent and mutually shaping over time. The development of many technologies is influenced by the societies in which they exist, for example through changes in their design. Conversely, social structures are thought to be shaped by characteristics of new technologies, for example when the introduction of a new technology changes the way its users work [10]. While these findings must be treated with caution, as robots in health care are expected to have a wide range of roles and appearances in the future, and only small sample sizes point in this direction. Nevertheless, the socio-technical challenges presented are still relevant and valid, and highlight the sociological background surrounding this issue. Due to the high complexity, researchers have come up with many different approaches to measure attitudes towards robots, but no consensus has yet been found. This dissertation will contribute to the challenge of measuring attitudes towards robots, especially in the field of autonomous mobile robots in healthcare. An empirical study among potential patients to assess their attitudes towards robots in healthcare could provide further insights into the acceptance of robots in healthcare. Acceptance of robots in general, but specifically in healthcare, is still a very unknown area. This study assesses attitudes towards autonomous mobile robots in healthcare using a new scale that has just been developed and validated by Koverola et al. 2022, with the aim of contributing to the assessment of patients' attitudes towards this new technology. Time is running out to control the immense costs. While the low birth rates in the Western world cannot provide the necessary caregivers, the baby boomers will retire in the coming years. Healthcare systems must act quickly to support caregivers so that the quality of care does not decline. Understanding the concerns, fears, and

expectations of healthcare robots will not only facilitate the introduction of robots in healthcare, but also allow developers to design robots that meet the needs and preferences of patients and caregivers, increasing the likelihood of patient acceptance.

This research aims to generate new knowledge about patients' attitudes towards a new technology such as autonomous mobile robots in healthcare. The two main research questions that guided this work were:

1. Is the General Attitudes Towards Robots Scale an appropriate scale to assess attitudes towards autonomous mobile robots in healthcare?

2. What is the willingness of potential patients to interact with autonomous mobile robots in the hospital?

The following chapter presents the current state of robotics in healthcare. How the field of healthcare robotics has grown over time and what are some of the key characteristics of robots. Then, the basics of measuring acceptance are presented to understand why measuring attitudes can predict future acceptance of a new technology such as robotics.

2. Background

To assess attitudes toward AMR in healthcare, previous research on the development of robots in healthcare and the tools used to measure attitudes and acceptance were reviewed. The following chapter will introduce how robotics has evolved in the healthcare sector and some areas of differentiation among robots. This is followed by a general introduction of how acceptance of new technologies is measured in general, in order to understand how patient acceptance of AMRs could be assessed.

2.1 Robots in healthcare

As defined by NASA, all robots are machines designed to perform tasks. Robots operate at different levels of autonomy. While some assist under direct human supervision, others operate partially to fully autonomously [11]. Ultimately, robots in healthcare are expected to become more autonomous over time as skills and trust evolve. For now, the level of autonomy depends heavily on the complexity of the task [12]. The following chapter explains where robots in healthcare come from and how their tasks evolved over time.

2.1.1 The origins of robots in healthcare

Robots in healthcare have come a long way. The first robots used in healthcare were for surgical procedures. The landmark case of integrating industrial robotics into surgery dates back to 1985, when an industrial robotic arm was used to perform a stereotactic brain biopsy with a remarkable accuracy of 0.05 mm [13]. From then on, new innovations and applications were gradually introduced. Today, the best-known robotic application in healthcare is the "Da Vinci" surgical system, which was introduced to the European market in 1999. A pioneer in minimally invasive robotic-assisted surgery, it consists of an ergonomic surgeon's console, a patient-side cart with four interactive arms, and a powerful vision system that enables the system's components to communicate. It scales, filters and translates the surgeon's movements into more precise movements and is an established assistive robotic system that is found in more than 7500 hospitals around the world and has turned parent company INTUITIVE into a multi-billion-dollar public company [14] [15].

2.1.2 Current state of robots in healthcare

Today, the Da Vinci surgical system operates without any level of autonomy, mostly due to legal and ethical restrictions instead of engineering capabilities [16]. However, most robots outside of surgery have moved well beyond assistive tasks and are acquiring some degree of autonomy. Today's healthcare robots assist in drug manufacturing, nursing, medication management, medication dispensing, monitoring patient vital signs, performing surgery, and facilitating telemedicine. Most of these applications are still in their infancy and are mostly being used in pilot studies, but a recent scoping review found that there are already 10 different roles in healthcare where robotic systems are being used today. The largest areas of research continue to be in surgery, rehabilitation and mobility [17]. The main difference from the origins of robotics in healthcare is that most of the new developments incorporate some level of autonomy, meaning that artificial intelligence is found in almost all new robotic developments [18].

An initial classification for autonomy of surgical robots was made in 2017 and since the whole sphere of autonomy was new it leans on the levels of autonomy the car manufacturers use. The following table is an overview of the different level of autonomy for robots in healthcare.

Level 0	No autonomy. Robots respond to commands, E.g. Tele-operated robots or prosthetic's that follow orders of user
Level 1	- Robot assistance. Robot provides mechanical guidance but human has continuous control of system. E.g. Surgical robots with virtual fixtures
Level 2	Task autonomy. Autonomous for specific tasks initiated by a human. Difference to Level 1 robot is that the observation of surgical robot is discrete rather than continuous.
Level 3	Conditional autonomy. Robot generates task strategies but human selects which strategy. E.g. Surgical robot can perform a task without close oversight.
Level 4	High autonomy. Robot can make decisions under supervision of doctors. E.g. Full surgery under supervision of a surgeon.
Level 5	– Full autonomy. E.g. Robotic surgeon. No need for a human surgeon to supervise.

Figure 1: Different levels of autonomy among robots [19]

AMRs are an example of a level four to five autonomous robot. While their classification is not unanimous, as recent advances in navigation technologies blur the line of their level of autonomy, a strong case can be made that they are either level 4 or level 5. Furthermore, healthcare robots can be categorized into different groups to provide a better overview. The categories are as follows:

Healthcare Robot Categories		Definition
Surgical Robots		Service robots supporting surgeons during surgical procedures
Assistive Robots	**Socially Assistive Robots**	Service robots assisting users through social interaction
	Physically Assistive Robots	Service robots supporting users through physical interaction
Healthcare Service Robots		Service robots in healthcare settings performing tasks useful to the facility and the medical staff

Figure 2: Categories of healthcare robots [20]

AMRs are a typical example of Healthcare Service Robots and do not qualify as Physical Assistive Robots because they do not physically interact with humans. Now that the autonomy of AMRs and the scope of robots in healthcare have been narrowed down to Healthcare Service Robots, the assessment of what an AMR actually is will be elaborated

2.1.3 Autonomous Mobile Robot in Healthcare

In In healthcare, a service robot is any machine used in a healthcare environment that is capable of performing tasks either semi-autonomously or fully autonomously to support healthcare services. These tasks include monitoring patients, assisting healthcare workers, performing diagnostic tests, disinfecting environments, or managing logistics. A large subset of healthcare service robots are AMRs, which are primarily used to support hospital logistics [20]. Nurses often spend much of their time on non-patient related activities, such as service or logistical tasks that often involve walking long distances. Not only are these activities tiring and time-consuming, but they take time away from patient care. It has been shown that there is a positive correlation between the number of interruptions nurses face and the quality of care. As a result, many innovative healthcare service technologies are aimed at helping nurses improve the quality of care [21]. One such technology that has been introduced to the healthcare

sector is autonomous mobile robots (AMRs). AMRs in healthcare are, at their core, autonomous vehicles that, among other things, are capable of carrying things from point A to point B and back. They are able to navigate through an integrated AI that enables path planning in dynamic environments [22], [23], [24]. A solution designed for the extensive movement of materials within hospitals, including pharmaceuticals, medical supplies, lab samples, food and linen. The healthcare sector is perfect for this application, which is also used in the hospitality industry. In addition to the logistical efficiency aspect, AMRs also have the advantage of reducing human errors such as accidents, as advanced navigation systems are more accurate and safer for people than they are for themselves. They can also help minimize the risk of spreading infections by reducing human-to-human contact during meal delivery. This can be particularly useful during pandemics or in environments where the risk of infection is high. Finally, advantages such as nearly 24-hour robotic shifts and easy scalability make it easy to see the financial aspect of robots. Especially in very large healthcare facilities, the implementation of AMRs can lead to significant cost savings by reducing the need for humans to deal with transportation and logistics of goods [20]. These facts are supported by a scoping review of assistive robotic systems in nursing, which identified "fetch and bring" activities as an important aspect of assistive nursing. The main activities identified as "fetch and bring" for caregivers were Food and beverage service, medication delivery, contact reduction in infectious environments, and user-related delivery services [21].

To date, several different AMRs have been used in small numbers in hospital logistics. Models such as Keenon's T5, Aethon's TUG and URG's Plato are AMRs that have been adapted for healthcare purposes, specifically for transporting food in the confined spaces of hospitals [25], [26].

All three are equipped with common mobile robotics technologies, such as proximity sensors for obstacle avoidance and path planning algorithms, to safely maneuver through hospitals [27].

2.1.4 Market for autonomous mobile robots in healthcare

It should be noted that the healthcare market is very unique. Innovations usually take much longer, mostly due to government intervention. Why business behaves differently in healthcare is beyond the scope of this dissertation. However, in a business context, it is important to note that patients' willingness to deal with AMR does not necessarily mean that their preferences will be taken into account soon. Forecasts for the future market are therefore likely to be more volatile than for other markets [28], [29], [30].

Despite the circumstances, according to various projections, the global market for AMRs in healthcare was valued at $3.6-3.9 billion in 2023. Its CAGR is expected to be between 15.4%-16.2% by 2030, reaching a market size of $10.4-$14.2 billion [31], [32], [33].

But let's take a look at a simplified calculation of the potential return on investment for a hospital implementing the latest version of TUG:

The implementation cost per AMR is expected to be between 40k and 100k, depending on the customizations but also the IT infrastructure of the hospital. According to the manufacturer, Aethon, it is recommended that at least 4 TUGs be deployed simultaneously. Ongoing maintenance of a service robot can be expected to account for 10-20% of the purchase price [34]. However, implementing TUGs in a hospital would also involve many hidden costs, such as staff training or restructuring of responsibilities.

Savings:

Much of the hospital's logistics could be handled by TUGs, which would free up a lot of time. Furthermore, the extent to which robots would keep hospitals more sterile is hard to predict and even harder to quantify as a savings. The average annual income of a nurse in the US is $86,000 per year. [34]. To further simplify: One year of a nurse's salary equals the implementation of one TUG, ignoring many smaller factors. Assuming that nurses can almost double their productivity with the help of one TUG assisting one nurse, the TUG would pay for itself in less than two years. Again, neglecting that it would drastically change the overall job of a nurse, most likely making the job much more attractive [24], [35].

Although the introduction of more AMRs in healthcare is a costly endeavor, it appears to be an economically sound move. However, the implementation of new technologies, especially a disruptive one like robots, is notoriously difficult [36]. In particular, the adoption of assistive robotics in healthcare appears to be even slower than in other sectors, and the reasons for this seem unclear. Research on the barriers to assistive robotics in healthcare identified a lack of awareness among policymakers as one reason, but acknowledged that no research has examined this issue specifically for robotics in healthcare [37].

We can consider three main “users”

a) Healthcare organizations like hospitals - that are capable of introducing a new technology like robots;

b) Healthcare professionals like nurses or doctors - who are working and using the robots; and, finally
c) Patients - who have to interact with the robots when receiving care at a healthcare facility.

All may face barriers in adopting these technologies, but it seems likely that successful adaptation can only occur if all three are willing to adopt and accept robots.
Since time is of the essence, the aforementioned socio-technical effects may take too long to shape each other towards eventual adoption. The study of attitudes towards robots in healthcare could accelerate patient acceptance, as barriers could be removed in advance by taking into account the respective attitudes. Models have shown in the past that assessing attitudes is the first step in assessing acceptance. The goal of studying attitudes in this context is to accelerate smooth implementation [38].

2.2 Attitudes towards robots

Attitudes toward robots are generally considered to be a very stable personal trait and have become an interesting topic for researchers in robotics, psychology, and engineering in recent years. Many studies have shown that people's attitudes toward robots can predict their expectations and willingness to use them during human-robot interaction (HRI). Insights are being explored to help facilitate the integration of robots into everyday life, or in this case, healthcare [39].

Previous studies on HRI have revealed different attitudes. For example, Torrent-Sellens et al. conducted an analysis of confidence in robotic surgical systems across Europe. Their findings suggest that the use of these surgical robots depends largely on patient preferences [40]. In robotic surgery, however, patients do not interact directly with the robot because they are typically under anesthesia. Therefore, their acceptance of the technology depends primarily on the public's confidence in the statistical success rates of robotic surgery. While these findings hold true for robotic-assisted surgery, the dynamic is expected to change when robots interact with a fully conscious patient, where acceptance is influenced by more immediate and personal factors. AMRs are an example of healthcare robots that primarily interact with conscious patients [41].
To achieve an understanding of the different methodologies to measure attitudes of robots, the following chapter introduces the fundamental literature of technology acceptance.

2.2.1 Measuring Technology Acceptance

Research on technology acceptance, or user acceptance of technology, has come a long way. It has been shown to be critical to the adoption of new technologies. Knowledge of acceptance can be used to predict how quickly a new technology will be adopted by users. Overall, the most common models for measuring acceptance are the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT), which is an extension of the TAM. TAM was developed to assess why technologies are accepted or rejected based on perceived usefulness and perceived ease of use. Both beliefs are determinants of attitude toward use, which has been shown to be a reasonably good predictor of behavioral intention to use. Behavioral Intention to Use is commonly interpreted as technology acceptance. Actual usage is then determined by acceptance. A critical review of TAM as a predictor in healthcare has shown that it was able to predict 30-70% of the variance in Behavioral Intention to Use, which is considered quite strong [42]. Figure 3 visualizes the TAM model and its interconnections.

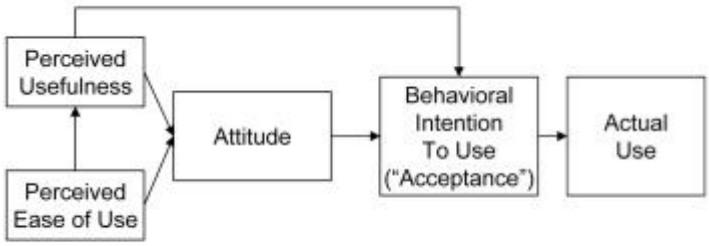

Figure 3: Technology Acceptance Model (TAM) [43]

TAM and various extensions of it are widely used models for measuring attitudes to predict future technology implementations, but they lack the ability to include the acceptance of people who don't operate the technology - such as patients. Healthcare innovations such as robotics that directly affect patients are technically implemented by hospitals, but acceptance must also occur within the patient. That's why there was a need for a more general attitude scale that goes beyond the implementation of a technology in the workplace or product design [43]. But first, the assessment of attitudes toward assistive robotic surgery studies, since these are the first robots in healthcare and have been a topic of research for longer. The study designs of the following findings were all based on the TAM model with various adaptations.

2.2.2 Attitudes towards assistive-robots for surgery

A closer look at robotic surgery reveals that not all technologies are accepted or rejected at the same rate. For example, two studies on the general acceptance of robotic assistance in surgery

showed that some patients expressed concerns about a robot failing or not being able to perform certain tasks, which led to a lower willingness to accept the technology for surgery. However, patients also recognized that robotic surgery is associated with smaller incisions (typically minimally invasive surgery), reduced risk of infection, faster recovery and less pain. Overall acceptance of robotic surgery was significantly influenced by trust in the technology, perceived benefits, familiarity, and gender. For example, men expressed more positive attitudes than women, while age was not significant. Perceived benefits, when effectively communicated, were shown to contribute to a much more positive view of the technology. But it also showed that the final decision of a patient's willingness to accept robotic surgery is very personal and goes beyond rational decision-making [40], [44].

These studies shed light on attitudes toward surgical robots in healthcare and how attitudes toward robotics in healthcare may vary overall. However, studies that reveal attitudes toward different types of robots in healthcare, such as autonomous robots, are still lacking.

To fill this gap, a number of different scales have been invented and validated, many of them for social robots. Social robots are robots that interact robot to robot and robot to human in a human perceptible way. This means that they are a type of fully autonomous robot [45].

A critical review by Krägeloh et al. evaluated various questionnaires to measure acceptance of social robots and concluded that of all the psychometrically validated questionnaires, only three were able to measure attitudes towards robots in general. An instrument that would be needed to assess patients' attitudes toward autonomous mobile robots in healthcare [46]. These three questionnaires were: NARS - Negative Attitude towards Robots Scale, Frankenstein Syndrome Questionnaire - measures attitudes towards humanoid robots, and the Multi-dimensional Robot Attitude Scale, which consists of 12 variables, mainly to assess the needs and desires of future users of domestic robots such as vacuum cleaners [47]. Unfortunately, none of these instruments are suitable for assessing patient attitudes towards AMR. One assesses only negative attitudes, another only humanoid robots, and the third is not applicable at all in a healthcare context. To fill the need for a suitable scale, researchers have started to develop several ideas [48].

2.2.3 General Attitudes towards Robots Scale (GAToRS)

Fortunately, in 2022, Koverola et al. introduced a validated instrument for assessing general attitudes towards robots. First of all, as explained, because there were no suitable instruments for surveys among the general public, but secondly because of the lack of measuring the multidimensionality of attitudes towards robots. As we have seen, there is a scale for measuring

negative attitudes towards robots, but what about positive attitudes? The idea was to combine the previously known and validated scales such as NARS and the Frankenstein Syndrome Questionnaire to create the General Attitudes Towards Robots Scale (GAToRS). A new scale that is neutral and emphasises on multidimensionality.

According to Koverola et al., hopes and fears are inherently different, not just opposites on the same line. Someone can be excited about something and afraid of it at the same time, like enjoying cars for their speed but worrying about accidents or pollution. Putting fear on one end of a scale and hope on the other doesn't show the difference between people who are both very hopeful and very fearful and those who are not much of either. It's not an either/or situation - some actions are driven by fear alone, some by hope alone, and some by both. Another factor of multidimensionality is the difference between personal attitudes toward robots and societal attitudes toward robots. On a personal level, feelings about robots are natural. We may love the idea of playing with a robot or feel uncomfortable at the thought of it, without really knowing why. On a societal level, concerns and hopes are more about the big picture, like worrying that robots might take jobs and cause unemployment, or hoping that smarter cars will lead to fewer traffic accidents and help health care systems. Further studies suggest that it's useful to consider personal and societal attitudes toward robots as two different things, even if the boundaries between them are not always clear. [49]. Overall, the consideration of multidimensionality is well known among researchers and is not new to the measurement of attitudes towards new technologies. Other researchers have mentioned its importance in the context of motives for using social media as a new technology, or as a reason for developing the multidimensional Robot Attitude Scale for domestic robots [48], [51]. Therefore, Koverola et al. built this new instrument called GAToRS to measure the multidimensionality of attitudes based on four different variables.

1. Personal level positive (P+): comfort and enjoyment around robots
2. Personal level negative (P-): discomfort and fear around robots
3. Social level positive (S+): rational hopes for robots in general
4. Societal level negative (S-): rational concerns about robots in general [48].

Each dimension is determined by five sub-questions that have been shown to be reliable in predicting the dimensions. This new questionnaire, designed to measure general attitudes towards robots on a large scale, is expected to be applicable to AMR in healthcare as well as a subset of robots in general. Therefore, it was chosen for this purpose.

3. Research Methodology

This dissertation aims to understand the attitudes and perceptions of potential patients towards autonomous mobile robots (AMR) in healthcare. The previously introduced GAToRS questionnaire was used to gain insight into this matter. However, some questions had to be slightly adapted to fit the measurement of AMR. The criterion items, which are intended to be reliable variables for later regression analysis, are not part of the scale in the first place and therefore do not need to be changed. However, retaining some of the original criterion items may provide insight into the validity and reliability of the scale. These dependent variables are later described using multivariate regression analysis to show the explanatory power of the scale. The predictability of the criterion items using the scale will finally assess the usefulness of the scale in the context of autonomous mobile robots in healthcare. To confirm that the original study is applicable to the context of AMRs in healthcare, the regression on the identical criterion items should be very similar. It is worth mentioning that the original questionnaire was developed as a scale to collect and evaluate attitudes, while this research uses the scale and therefore adds demographic insights of the participants. Finally, the online survey was distributed to the general public, mainly in Germany.

3.1 Distribution

The scope of the population had to be narrowed down, since a potential patient fits the description of every human being on earth. The WEIRD criterion of Western, educated, industrialized, rich, and democratic was not only anticipated, but proved to be true [49]. However, the survey was conducted among the general public with an average age of 37 years. It was distributed primarily in eighteen different waiting rooms of doctors' offices, hospitals, dentists, and retirement homes in Heidelberg and parts of Cologne. To increase the sample size, the questionnaire was also distributed to fellow students, family and friends. All distribution of the survey was done via direct link and QR code to further narrow down the population, as it required the use of a smartphone, which ultimately led to a low participation rate among older people. As most participants were expected to be German, the survey was available in both English and German.

3.2 Questionnaire design

The survey began with an introduction to AMRs. The participant was given a brief introduction to the core capabilities and use cases of an AMR, as well as a representative image of a typical AMR (TUG). The original questionnaire was slightly adapted from the original by Koverola et

al. in 2022 to fit the purpose of measuring only attitudes towards AMRs instead of all robots. Participants were asked to rate 24 different statements on a seven-point Likert scale. All of these statements were either part of the GAToR scale, which measures attitudes on four different dimensions, or were criterion items that were asked to be used later as reliable variables. At the end of the survey, participants were asked to provide their gender, age, education level, and health system affiliation. Only minor changes were made to maintain the integrity of the original scale, and one question was excluded because it didn't fit the context. Most of the adaptations were the replacement of the word “robots” with “AMRs”, but Figure 4 provides an overview of each change made to the criterion items. The criterion items, which are intended to be reliable variables for later regression analysis, are not part of the scale in the first place and therefore need no justification to be changed. However, retaining some of the original criterion items may provide insight into the validity and reliability of the scale. These dependent variables were later described using multivariate regression analysis to show the explanatory power of the scale [48].

3.3 Hypotheses

The hypotheses were chosen to contribute to the overall assessment of attitudes based on previous research as well as GAToRS itself. The first hypothesis is intended to answer the overarching question of whether today's potential patients would mind interacting with an AMR while in the hospital. The second and third hypotheses control for the suitability of GAToRS to assess the multidimensionality of attitudes. Hypothesis four controls whether trust in the respective healthcare system is a predictor of positive attitudes towards AMRs.

Hypotheses 1: *The majority of potential patient’s would not mind interacting with an AMR when in hospital.*

Hypotheses 2: *The correlations among the four dimensions are significant.*

Hypotheses 3: *Personal level attitudes are not translatable to societal level attitudes.*

Hypotheses 4: *The trust in respective healthcare system is positively correlated with positive attitudes towards AMRs (P+).*

Original Criterion Items	This Survey's Criterion Items
Generally speaking, I have a positive view of robots	Generally speaking, I have a positive view of robots
I have personal experience of using robots	I am interested in scientific discoveries and technological developments
I am interested in scientific discoveries and technological developments	Generally speaking, I have a positive view of AMRs
Robotics is a familiar topic to me	I have trust in my national healthcare system
	I would not mind interacting with an AMR when in hospital

Figure 4: Comparison between Criterion Items of Koverola et. al and this study

The omission of criterion item two, *I have personal experience with robots*, is due to the fact that the sample size would not be large enough to distinguish between participants who have experience with robots or AMRs and those who do not. Similar reasoning is behind criterion variable four. The criterion *I have confidence in my national healthcare system* was added because of an expected positive correlation between confidence in the healthcare system and interaction with AMRs. Criterion five specifically mentions ... *when in hospital* instead of the entire healthcare sector. The reason for this is that interaction in the hospital is more confrontational. As the first AMRs are currently being implemented in hospitals, it is expected that this will lead to higher efficiency than in other areas of the healthcare sector.

4. Results

The survey was able to collect 114 valid responses overall. It was accessible for fifteen days between the end of April and the beginning of March 2024.

4.1 Descriptive Demographics

The following descriptive statistics will help to understand the demographics of the participants. It will be assessed to see if our sample size fits the demographics of the population intended to assess.

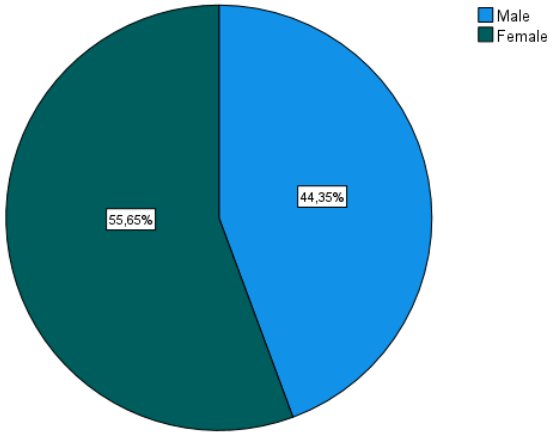

Figure 5: Gender distribution

All participants of the survey identified themselves as either Male or Female with a slight overrepresentation of women. However, nothing outside of the expected variance [50]. The age distribution was heavily skewed towards the younger generations.

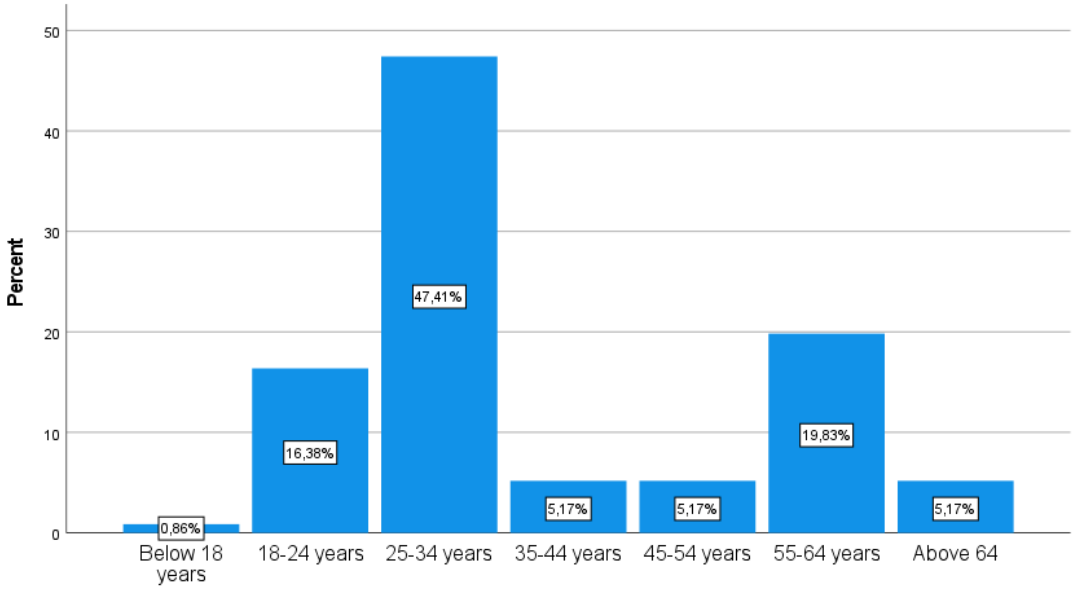

Figure 6: Age distribution

Almost half of the participants (47,4%) were between the age of 25 to 34 years old. All age groups above 34 years of age accumulated to just 35,3% while only one person was below 18 years of age.

The sample showed that the majority of its participants hold a master degree with 42,2%, while another 30,2% of participants hold a bachelors degree. Altogether, the sample has 78,4% of its population with at least a bachelors degree, showing that it was a highly academic sample.

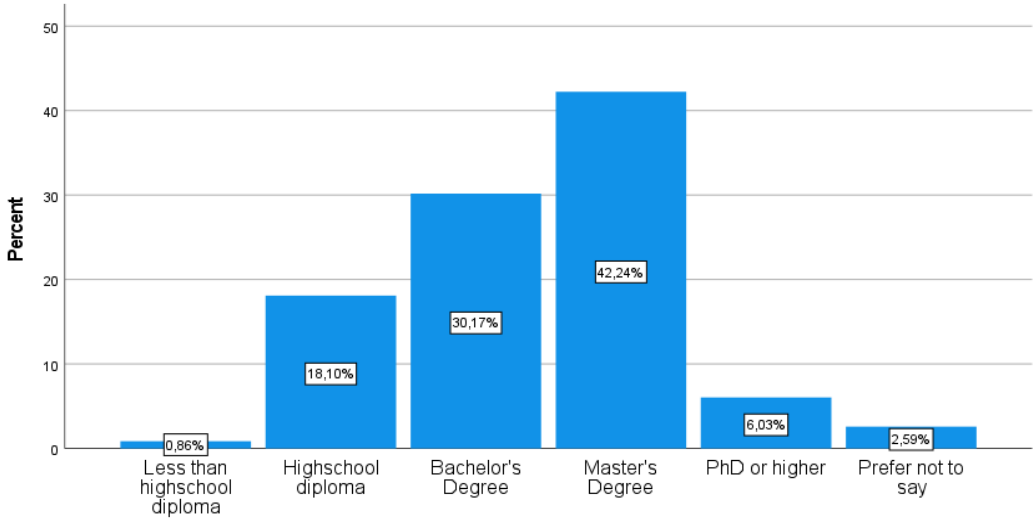

Figure 7: Level of education

Finally, the belonging to respective healthcare system show that an overwhelming 93,1% of participants belong to the German healthcare system. Others were Portuguese with four respondents, Swiss with three respondents as well es one participant from Sweden.

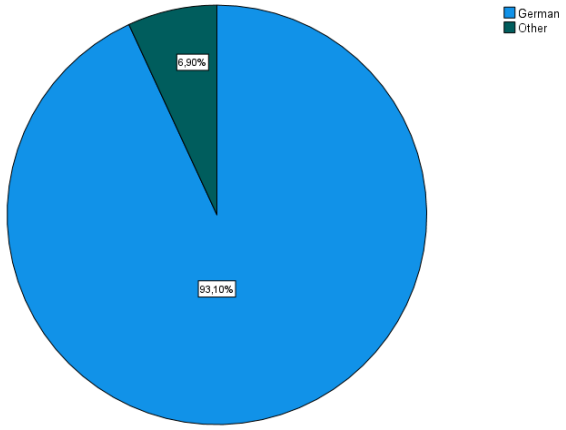

Figure 8: Healthcare system

4.2Descriptive Control Items

The control items were measured to capture the overall attitudes regarding robots, technology, AMRs, trust in healthcare and comfortability to interact with an AMR when in hospital.

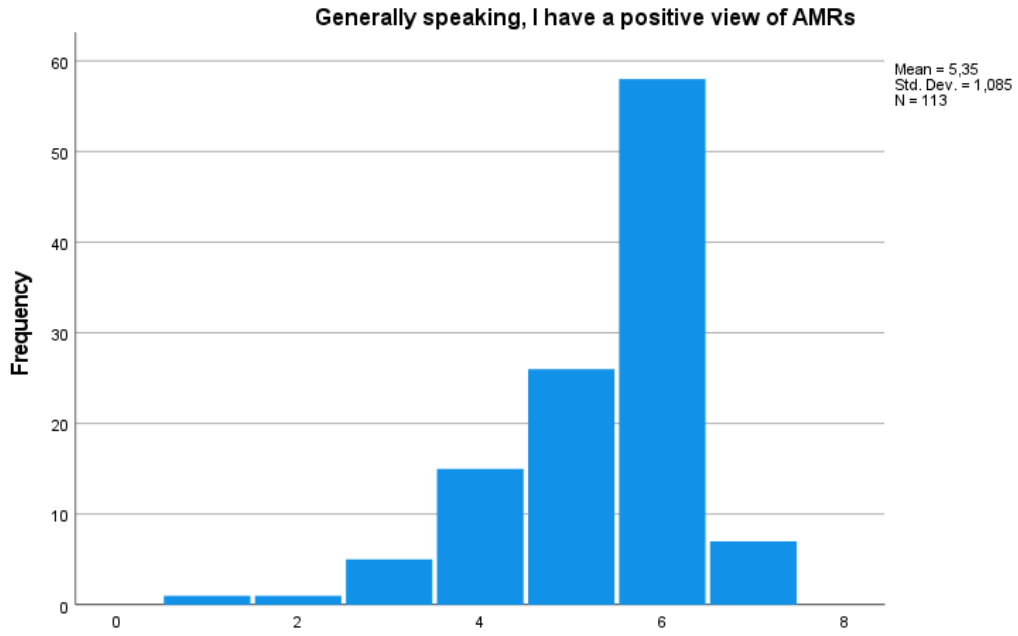

Figure 9: Positive view of AMRs on a 7-point Likert scale

The majority of respondents assured that they have a positive view on robots as well as AMRs. Only 6,1% of respondents disagreed with the statement regarding robots while the same amount disagreed with the statement regarding AMRs. 84,2% of the sample at least somewhat agreed with the first statement while 80,5% did with the latter.

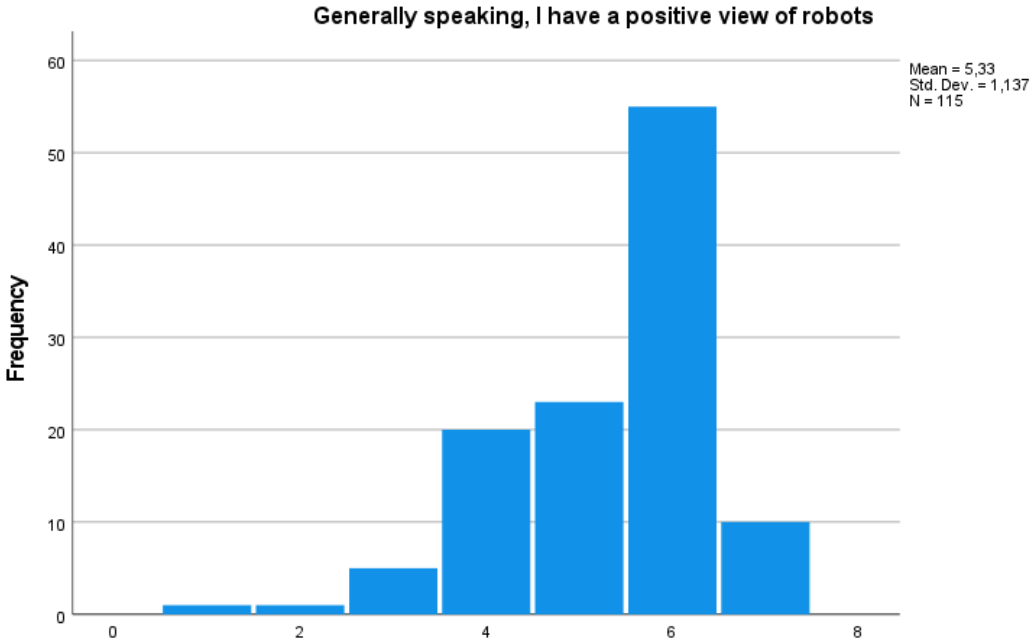

Figure 10: Positive view of robots on a 7-point Likert scale

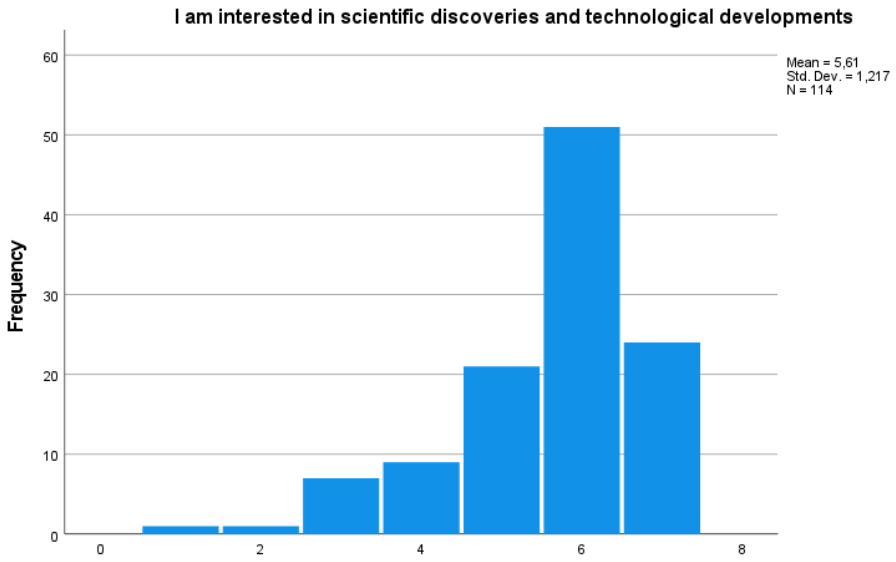

Figure 11: Interest in tech developments on a 7-point Likert scale

When it comes to the interests in scientific discoveries and technological developments, participants were mostly agreeing. At least 84,2% were agreeing to some extend.

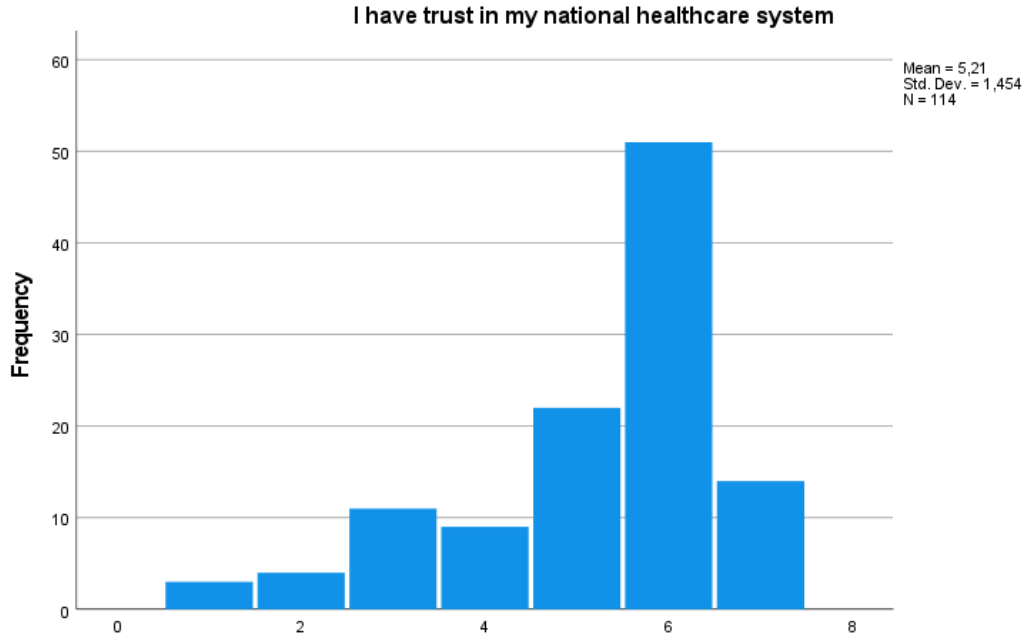

Figure 12: Trust in respective healthcare system on a 7-point Likert scale

The evaluation of participants trust in respective healthcare system was high. Only one participant outside of Germany somewhat disagreed on the trust in healthcare system. Out of the remaining 106 valid German answers, 16% at least somewhat disagreed, disagreed or even strongly disagreed.

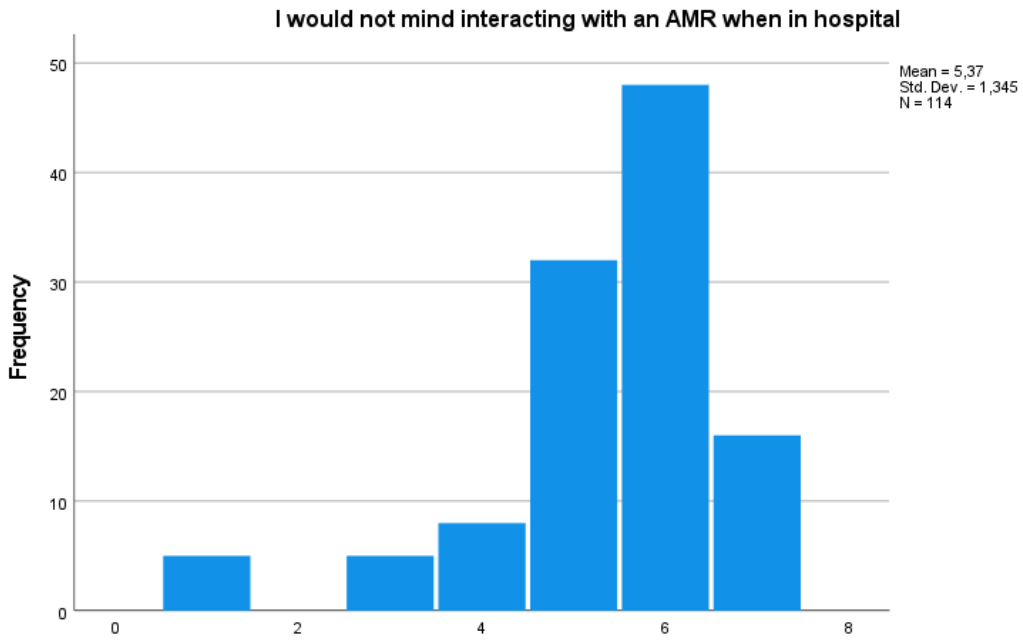

Figure 13: To not mind interacting with an AMR when in hospital on a 7-point Likert scale

When asked if participants wouldn't mind interacting with an AMR when in hospital the overall acceptance was quite high. Including participants that entered neither nor, 91,2% wouldn't mind. Indicating that the acceptance among this sample is very high.

4.3Factor analysis

The factor analysis was conducted to see if the question sets were suitable to explain the four different dimensions (P+), (P-), (S+) and (S-). The original questionnaire by Koverola et al. was designed to assess these four dimensions, so this sample is expected to fit these dimensions as well.

Before starting the factor analysis, the Kaiser-Meyer-Olkin (KMO) criterion, which controls for partial correlation, and Bartlett's test of sphericity, which tests the hypothesis that the correlation matrix contains variables that are unrelated and not suitable for factor analysis, were evaluated. [51]. Both tests were passed and factor analysis was performed. The initial eigenvalues greater than one suggested a total of five factors. However, the cumulative percentages did not indicate a specific number of factors to include, since the cumulative variance explained did not imply a specific number of factors between four and six.

Number of Factors	Initial Eigenvalues	Cumulative % of Variance explained
1	5,975	31,448
2	2,334	43,733
3	1,427	51,246
4	1,152	57,310
5	1,028	62,721
6	0,957	67,756

Figure 14: Factor analysis, Eigenvalues

Therefore, an analysis with four factors is reasonable to conduct. Appendix 8.2 shows the rotated component matrix in detail. To follow the interpretation easier, Figure 15 shows the subsets used for the survey as well as the factors for which they were intended.

P +	P -	S +	S -
Q1. I can trust persons and organizations related to the development of AMRs	Q5. I would feel uneasy if I was given a job where I had to use AMRs	Q10. AMRs are necessary because they can do jobs that are too hard or too dangerous for caregivers	Q15. AMRs may make us even lazier
Q2. Persons and organizations related to the development of AMRs will consider the needs, thoughts and feelings of their users	Q6. I fear that an AMR would not understand my commands	Q11. AMRs can make life easier	Q16. Widespread use of AMRs in healthcare is going to take away jobs from people
Q3. I can trust an AMR	Q7. AMRs scare me	Q12. Assigning routine tasks to AMRs lets caregivers do more meaningful tasks	Q17. I fear that the use of AMRs will lead to less interaction between caregivers and patients.
Q4. If AMRs had emotions, I would be able to befriend them	Q8. I would feel very nervous just being around an AMR	Q13. Dangerous tasks should primarily be given to AMRs	Q18. AMRs is one of the areas of technology that needs to be closely monitored
	Q9. I don't want an AMR to touch me	Q14. AMRs are a good thing for society, because they help people	Q19. Unregulated use of AMRs can lead to societal upheavals

Figure 15: Overview of Questionnaire, grouped by dimensions

Factor 1: High positive correlations (>0.6) between questions 5-9 as well as 15. Very similar to P-.

Factor 2: High positive correlation between questions 1 to 4 as well as modest correlations (>0.4) for questions 11 and 12. Very similar to P+.

Factor 3: High positive correlations between questions 10 and 13. Very similar to S+.

Factor 4: High positive correlations between questions 18 and 19 as well as moderate positive correlations for question 17. Very similar to S-.

The factor analysis shows that the four dimensions were identified similarly to the original study. Factor 1 is very similar to P-, but also correlates with parts of S-, indicating that the factors are also correlated. Factor 2 is similar to P+, but also correlates with parts of S+. Factor 3 is similar to S+, and Factor 4 is almost identical to S-. Looking at the commonalities helps to understand which questions are particularly well explained by the four factors. A low extraction indicates that there was little or no differentiation in the responses across the factors. For example, questions 14 and 16 didn't contribute much to the factors. Overall, the factor analysis with four factors was successful in showing the four pre-defined different dimensions, indicating that the questionnaire could be useful in measuring attitudes towards AMR on four dimensions. It is worth mentioning that the factor analysis was performed in SPSS with the Promax rotation, while Koverola et al. used the Satorra-Bentler robust estimation method. The Promax rotation was chosen as an alternative because SPSS doesn't allow the Satorra-Bentler method. Although the methods are not directly interchangeable, the Promax rotation allows for correlations between factors compared to an orthogonal rotation. Graph 16 shows the correlations of the four factors.

	Factor 2 (P+)	**Factor 3 (S+)**	**Factor 4 (S-)**
Factor 1 (P-)	-,551**	-,201*	,463**
Factor 2 (P+)		,400**	-,280**
Factor 3 (S+)			-,091

Figure 16: Correlations among the Factors

** Correlation is significant at the ,01 level.

* Correlation is significant at the ,05 level

Factors P- and P+ show an expected negative correlation, while P+, S+ and P-, S- show a positive correlation. This suggests that potential patients' positive or negative views of AMR

on a personal level are similar to their societal attitudes toward AMR. The correlation between the societal dimensions themselves was not significant.

4.4 Multivariate regression

The criterion items can be used as dependent variables. Using regression analysis, the four dimensions were able to partially explain the effect on the criterion items. The goal is to determine whether the dimensions are good predictors of the items.

	Positive robots	**Interest in tech**	**Positive AMRs**	**Trust in system**	**Interacting with AMR**
Factor 1 (P-)	-,317** [-,531; -,103]	-,183 [-,468; ,103]	-,237** [-,418; -,056]	-,036 [-,358; ,287]	-,257* [-,458; -,055]
Factor 2 (P+)	,457***[,246; ,669]	,275* [-,006; ,557]	,641*** [,462; 819]	,485** [,166; ,803]	,785*** [,586; ,985]
Factor 3 (S+)	,124 [-,056; ,304]	-,029 [-,269; ,212]	,014 [-,139; ,166]	,386** [,115; ,658]	,104 [-,066; ,273]
Factor 4 (S-)	-,057 [-,243; ,129]	,050 [-,198; ,299]	-,044 [-,202; ,113]	,108 [-,173; ,389]	-,207* [-,382; -,031]
Model fit	R^2=0,449	R^2=0,101	R^2= 0,567	R^2=0,246	R^2=0,650

Figure 17: Regression outputs for all five criterion items

*** Significant at the ,001 level

** Significant at the ,01 level

* Significant at the ,05 level

It can be shown that the dimensions do indeed explain some of the observed variance. The model was able to explain more than 50% of the variance of the criterion variables *Positive views of AMRs* and *Interacting with AMR*. Also, almost 50% of the variance of *Positive views of Robot* and 25% of the variance of *Trust in Healthcare System* could be explained between dimensions, each with a strong positive correlation of (P+). However, *interest in technology* could not be measured among the four dimensions, as only 10% of the variance was explained. Not minding interacting with an AMR in the hospital was best explained and, as expected, was highly dependent on positive personal attitudes towards AMRs, showing that the assessment of personal views could be a strong predictor of patient acceptance of AMRs in healthcare.

5. Discussion

The purpose of this study was to gain insight into potential patient attitudes towards autonomous mobile robots in hospitals. In order to gain these insights, the general attitudes towards robots scale was adapted and tested to understand if it is applicable to assess healthcare AMRs, a specific subset of robots. The assessment of attitudes towards AMRs based on four different dimensions, as well as their correlation with the criterion items, is also part of the main findings. Taking into account the demographics observed within the sample, it can be shown that GAToRS was able to measure attitudes towards AMRs in a small population. Furthermore, a high willingness to interact with an AMR in the hospital was observed.

First, the interpretation of the descriptive results will be analyzed to understand what the sample contained and to see how these results could be translated to a larger population. Then the hypothesis will be answered to evaluate the main findings followed by a comparison to the original general attitudes towards robots scale to assess its suitability for this purpose as well as to see if the results can share insights for policymakers or healthcare organizations.

5.1 Interpretation of descriptive results

In order to get a perspective of the actual population being surveyed, the questionnaire included four demographic variables to narrow down the results. These were *gender, age, education level,* and *country* of residence. Since the dissertation was distributed to the general public, but also to fellow students, 64.7% of the participants were under the age of 35. The level of education was also very high, which is not representative of the general public. In addition, more than 93% of the participants were German, which further limits the results. The population can be summarized as young, highly educated, and German, which fits well with the WEIRD criteria defined by psychologists as western, educated, industrial, rich, and democratic, with the addition of young age in this case. It is reasonable to assume that the sample represents a higher population than what the sample actually is. Researchers have attempted to measure psychological and cultural distances to better interpret data from such samples. While the original study measured distances between the U.S. and other countries, it is reasonable to assume that the distances between Germany, France, Spain, or the Netherlands would be small. Future research could highlight the cultural distances between European countries or more specifically aim to understand the next closes cultural similarities to Germany, which could broaden the scope of this research. [49]. Assessing the attitudes of people in different European countries towards AMRs could help to expand the significance of this work.

5.2Hypothesis

Hypotheses 1: *The correlations among the four dimensions are significant.*

The first hypothesis was assessed to test for multidimensionality. If there is no multidimensionality in attitudes towards robots, i.e. positive and negative attitudes are polar opposites, the use of a multidimensionality scale would be redundant. Figure 15 shows that the correlations of the four different subscales differ in a meaningful way, indicating that the dimensions are not polar opposites and that the assumption of multidimensionality is valid. The correlation between (P+) and (P-) is -.551, showing the highest correlation. The correlations between (P-) and (S-) as well as (P+) and (S+) show the correlations between the personal and societal dimensions, indicating that the personal views on AMRs correlate with the societal views on AMRs and are worth differentiating. However, the correlation between the two societal dimensions were not significant, rejecting further assumptions in this sample. It is worth noting that the two personal level dimensions, as well as their respective correlations with the societal dimensions, were all significant and very similar to the correlations of the original GATOR scale, suggesting that the adaptations made for this population had no impact on the four dimensions, as well as suggesting that this new adaptation can be used to measure attitudes toward autonomous robots in healthcare to assess the attitudes of potential patients. The hypothesis that the correlations between the dimensions are significant was confirmed, except for the correlation between the societal dimensions. This shows that attitudes towards AMR are not only determined by our personal attitudes, but that the overarching societal impact of AMR significantly influences our perceptions and therefore contributes to the acceptance of AMR.

Hypothesis 2: *Personal and societal dimensions are positively correlated but significantly different*.

The sample shows that (P+) is more positively correlated with (S+) than (P+) is negatively correlated with (S-). These differences show that the dependencies of attitudes are not clear-cut. Societal attitudes towards AMR are reflected in personal attitudes, but by no means show a strong correlation. The differences between the correlations, and especially the low correlations, indicate that the assumption of measuring attitudes across multiple dimensions seems to be valid. The understanding that societal expectations influence our personal attitudes and vice versa was demonstrated by the correlations. Increasing societal expectations would most likely lead to higher positive attitudes and therefore increased acceptance of AMR. This

could be a way for policymakers to accelerate overall acceptance by contributing to the formation of personal attitudes toward robots.

Hypotheses 3: *The trust in respective healthcare system is positively correlated with positive attitudes towards AMRs (P+).*

Not only did the sample show that (P+) correlated with trust in the healthcare system at the 5% significance level, but it also showed that the four dimensions could be good predictors of trust in healthcare systems, as 25% of the total variance could be explained. In addition, previous research has shown that trust in a provider, in this case the healthcare system or organization that has implemented AMRs, has a strong positive correlation with the intention of consumers, in this case patients, to use a new technology. It was shown that trust in a provider should be measured together with trust in the technology, as each variable showed a significant positive relationship with intention to use [52].

Hypotheses 4: *The majority of potential patient's would not mind interacting with an AMR when in hospital.*

Among the sample, there was almost unanimous agreement that potential patients do not mind interacting with AMRs in the hospital. However, negative societal attitudes had a significant impact, indicating that societal concerns do play a role in the acceptance of AMR interactions.

5.3Comparison to the original GATOR-Scale

The adapted GATOR scale used was expected to have similar dimensions and predictors of the criterion items as the original scale. A universal scale for robots, which GAToRS appears to be, should be able to measure attitudes toward specific subsets of robots, such as AMRs in hospitals. As suggested in the explanation of hypothesis 2, the adapted GAToRS was very similar in the correlations of the four dimensions. The four dimensions with their respective correlations were reproduced almost identically, showing that the assessment of multidimensionality within four dimensions is reproducible in attitudes towards robots. Similarly, the adapted GAToRS was very successful in explaining the criterion items similarly to the original scale, although some criterion items were changed. This not only strengthens the assumption that the original GAToRS scale is reliable, but also shows that when properly tailored to a specific subset, similar results can be reproduced, despite the fact that the study was conducted among a very specific sample in a different country.

Factor analysis was able to highlight the four different dimensions as it did in the original study.

In addition, not all questions contributed equally to the creation of the four dimensions. For example, factor one in this study (P-) also correlated with question 15: "AMR may make us even lazier". This shows the positive correlation between the negative personal level and the negative societal level of attitudes. However, knowing that correlations exist doesn't necessarily explain how to interpret them correctly. It is not clear to what extent personal and societal attitudes are influenced by each other. Are personal attitudes influenced by societal attitudes, or do our personal attitudes shape our societal perceptions of AMR? What can be said, however, is that while they most likely influence each other, making them distinct and worthy of separate investigation. Understanding the correlations between the four dimensions has to be treated with caution since the correlations do not explain causality. It is equally likely that societal concerns shape a personal attitude towards a specific robot while positive interactions with one could positively impact their societal attitudes. Furthermore, other studies have highlighted how ambivalence the attitudes towards robots can be and suggest that qualitative studies are a necessary complementary to quantitative analysis [53].

The study was able to show that multidimensionality exists and highlighted why it is worth assessing, because it can predict the intention to use [9] [43] [54].

The regression analysis was conducted to evaluate the extent to which the four dimensions can explain the criterion variables. The criterion variables one and three (positive robots and positive AMRs) showed very similar results. Positive personal attitudes toward robots in general or AMRs were able to predict positive attitudes toward robots and AMRs, indicating that the subscale of P+ was successfully aggregated into a predictor. In addition, P- was also significant in predicting positive views of robots and AMRs. Neither of the societal dimensions were able to significantly predict views, suggesting that societal attitudes do not shape our views of robots or AMRs. Interest in technology was only significantly predicted by P+, but since all four dimensions were only able to explain 10.1% of the total variance, it can be suggested that not much information could be accumulated regarding interest in technology. Criterion four was significantly influenced by P+ and S+, indicating that both personal and societal positive attitudes towards robots are significantly influenced by trust in the respective healthcare system. Interestingly, S+ is only significant in this case, suggesting that the measurement of societal attitudes was successful because trust in a healthcare system can be considered a societal issue of interest. On the other hand, both P- and S- were not able to predict criterion four, indicating that negative attitudes towards AMR are not correlated with trust in the respective healthcare system. The last regression, which measures the impact of the four dimensions on the act of dealing with AMRs in the hospital, suggests that P-, P+, and S- are

appropriate predictors. Interestingly, the act of dealing with an AMR while in the hospital seems to be the only time in this study that the negative societal attitudes significantly predicted it, suggesting that societal concerns are particularly dominant when actually interacting with AMRs and outweigh the positive societal attitudes that didn't predict criterion item five. This suggests that societal fears of AMRs in general may hinder willingness to deal with an AMR in the hospital setting. Overall, the regression showed that for this sample, the explanatory power of P+ was by far the highest, being highly significant in all five models.

The reliability of GAToRS on a subset of robots with a different sample has been promising. The data has shown that the majority of participants would not mind interacting with an AMR in the hospital and that their intentions are shaped by personal and societal attitudes towards AMRs. Negative societal attitudes seem to be relevant only when interacting with an AMR and do not affect the view of AMRs in general. This discrepancy may be explained by the actionable impact of actual interaction rather than shared perceptions. One can have a positive perception of something but not want to interact with it. Also, according to the analysis, negative societal attitudes can be a determining factor in the decision to interact with an AMR. Reducing societal concerns about AMRs, but more realistically about robots in general, could be a lever to create a higher willingness to interact with AMRs or robots in general. Overall, when looking at the results of whether patients would mind interacting with AMRs while in the hospital, it seems that most potential patients in the sample wouldn't mind interacting. However, it remains unclear how well this sample can predict the general population.

5.4Limitations

First and foremost, the small sample size has shown some significant findings, but overall, lacks the size and scope to draw general conclusions for all potential patients. In order to draw conclusions about the attitudes of the general public towards AMRs, a study should have included a significant number of people in different demographic and socio-demographic contexts around the world. In particular, it remains unclear how relevant the results are in a general context, as the results here as well as those of Koverola et al. are only found under the WEIRD criterion. The extent to which attitudes may change when evaluating other cultures remains unknown. Further analysis of cultural distance could provide more insight. Elderly care facilities, where labor is especially scarce, could also benefit greatly from the introduction of AMRs [55]. A study that assessed attitudes toward robots among different age groups of 18-44 years, 45-64 years, and 65-98 years did not find a significant difference in sentiment among the age groups [56]. However, the study was done using the negative attitudes towards robots scale

(NARS) which lacks the ability to assess positive attitudes [48]. As shown here, the lack of negative attitudes does not necessarily translate into positive attitudes. Nevertheless, the similarity of sentiments among different age groups is an indicator that they may not differ much in their attitudes toward robots.

In addition, the questionnaire was unincentivized, which could have led to the risk of frivolous responses. Also, since AMRs are new to most people, it remains unclear to what extent the respondents understood the full capabilities of AMRs. Even though a thorough introduction at the beginning explained the relevant features and roles of AMRs in a hospital, it remains unclear how concentrated the participants read and understood everything. An in-depth, face-to-face introduction to AMRs would most likely help participants to better grasp the full potential of AMRs. A good option would be to expose people to real AMRs, as it can be assumed that the survey participants had never seen an AMR in action before. A physical human-robot interaction could have changed many of the attitudes towards them. Also, since the study was designed to gain insight on attitudes toward AMRs, it may have influenced the participants' by thinking about robots in general. The distinction between robots and AMRs may have been influenced by the study design, letting participants associate robots to AMRs from the beginning and neglecting the wide range of robots.

Ultimately, technology acceptance models have shown that attitudes, can be a strong predictor of acceptance. The emergence of autonomous robots is unlikely to stop any time soon, and it is not clear that people are ready to deal with them in every situation. However, the strain on healthcare systems around the world may not allow for waiting any longer to introduce more robots. It remains to be seen whether these results can explain more than just the attitudes of the Germans. Nevertheless, it is most likely that a careful cost calculation is needed to assess whether the introduction of AMRs makes sense for a particular hospital. The obvious benefits and longevity of this technology make it hard to believe that economies of scale will not make its introduction in hospitals feasible. It remains to be seen whether healthcare policy makers, healthcare organizations and healthcare professionals will be able to implement AMRs as quickly as suggested, as it would most likely not be hindered by patient acceptance of AMRs [57].

5.5 Conclusion

As highlighted throughout this research, it is clear that not only personal attitudes play a key role in the acceptance of any new technology. It has been shown that GAToRS can be adapted to measure attitudes towards AMRs in hospitals. The vast majority of young people in Germany

have a positive view of AMRs and most are willing to interact with one in hospital. Attitudes towards AMRs are multidimensional and shaped by both personal and societal attitudes. To accelerate the adoption of AMRs, policymakers need to understand that societal perceptions of robots will influence the acceptance of interacting with an AMR in the hospital. Sharing knowledge and demonstrating how effective and safe these technologies can be could lead to greater acceptance as it could change the societal attitudes of a population.

6. References

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7. Table of figures

8. Appendices

8.1Frequencies:

Gender:

What is your gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	51	39,2	44,3	44,3
	Female	64	49,2	55,7	100,0
	Total	115	88,5	100,0	
Missing	System	15	11,5		
Total		130	100,0		

Age:

What is your age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Below 18 years	1	,8	,9	,9
	18-24 years	19	14,6	16,4	17,2
	25-34 years	55	42,3	47,4	64,7
	35-44 years	6	4,6	5,2	69,8
	45-54 years	6	4,6	5,2	75,0
	55-64 years	23	17,7	19,8	94,8
	Above 64	6	4,6	5,2	100,0
	Total	116	89,2	100,0	
Missing	System	14	10,8		
Total		130	100,0		

Level of education:

What is your highest level of education

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than highschool diploma	1	,8	,9	,9
	Highschool diploma	21	16,2	18,1	19,0
	Bachelor's Degree	35	26,9	30,2	49,1
	Master's Degree	49	37,7	42,2	91,4

	PhD or higher	7	5,4	6,0	97,4
	Prefer not to say	3	2,3	2,6	100,0
	Total	116	89,2	100,0	
Missing	System	14	10,8		
Total		130	100,0		

National Healthcare System:

Which national healthcare system do you belong to - Selected Choice

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	German	108	83,1	93,1	93,1
	Other	8	6,2	6,9	100,0
	Total	116	89,2	100,0	
Missing	System	14	10,8		
Total		130	100,0		

8.2Factor Analysis

Communalities, Pattern Matrix, Structure Matrix:

Communalities

	Initial	Extraction
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - I can trust persons and organizations related to the development of AMRs	1,000	,620
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - Persons and organizations related to the development of AMRs will consider the needs, thoughts and feelings of their users	1,000	,468
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - I can trust an AMR	1,000	,633
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - If AMRs had emotions, I would be able to befriend them	1,000	,323
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - I would feel uneasy if I was given a job where I had to use AMRs	1,000	,515
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - I fear that an AMR would not understand my commands	1,000	,368
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - AMRs scare me	1,000	,697
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - I would feel very nervous just being around an AMR	1,000	,684
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - I don't want an AMR to touch me	1,000	,547
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - AMRs are necessary because they can do jobs that are too hard or too dangerous for caregivers	1,000	,785
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - AMRs can make life easier	1,000	,675
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - Assigning routine tasks to AMRs lets caregivers do more meaningful tasks	1,000	,676
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - Dangerous tasks should primarily be given to AMRs	1,000	,790
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - AMRs are a good thing for society, because they help people	1,000	,573
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - AMRs may make us even lazier	1,000	,418
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - Widespread use of AMRs in healthcare is going to take away jobs from people	1,000	,430
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - I fear that the use of AMRs will lead to less interaction between caregivers and patients.	1,000	,433
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - AMRs is one of the areas of technology that needs to be closely monitored	1,000	,706
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - Unregulated use of AMRs can lead to societal upheavals	1,000	,546

Extraction Method: Principal Component Analysis.

Pattern Matrix[a]

	Component			
	1	2	3	4
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - I can trust persons and organizations related to the development of AMRs	,250	,903	-,211	-,186
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - Persons and organizations related to the development of AMRs will consider the needs, thoughts and feelings of their users	,038	,657	,037	-,098
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - I can trust an AMR	-,173	,782	-,139	,245
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - If AMRs had emotions, I would be able to befriend them	,265	,659	-,037	,228
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - I would feel uneasy if I was given a job where I had to use AMRs	,693	-,030	-,062	-,018
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - I fear that an AMR would not understand my commands	,714	,176	,014	-,066
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - AMRs scare me	,727	-,089	,094	,136
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - I would feel very nervous just being around an AMR	,828	,048	-,063	,023
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - I don't want an AMR to touch me	,788	-,026	,061	-,134
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - AMRs are necessary because they can do jobs that are too hard or too dangerous for caregivers	,085	-,020	,903	-,050
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - AMRs can make life easier	-,136	,571	,314	,031
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - Assigning routine tasks to AMRs lets caregivers do more meaningful tasks	-,235	,544	,161	-,111
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - Dangerous tasks should primarily be given to AMRs	,044	-,091	,927	,005
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - AMRs are a good thing for society, because they help people	-,148	,460	,332	-,024
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - AMRs may make us even lazier	,747	,132	,060	-,075
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - Widespread use of AMRs in healthcare is going to take away jobs from people	,332	-,113	,294	,361
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - I fear that the use of AMRs will lead to less interaction between caregivers and patients.	,359	,049	-,002	,434
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - AMRs is one of the areas of technology that needs to be closely monitored	-,261	,033	-,018	,932
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - Unregulated use of AMRs can lead to societal upheavals	,111	,069	-,100	,687

Extraction Method: Principal Component Analysis.
Rotation Method: Promax with Kaiser Normalization.

a. Rotation converged in 6 iterations.

Structure Matrix

	Component			
	1	2	3	4
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - I can trust persons and organizations related to the development of AMRs	-,291	,732	,117	-,303
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - Persons and organizations related to the development of AMRs will consider the needs, thoughts and feelings of their users	-,377	,678	,301	-,268
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - I can trust an AMR	-,462	,753	,187	-,041
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - If AMRs had emotions, I would be able to befriend them	,014	,435	,153	,169
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - I would feel uneasy if I was given a job where I had to use AMRs	,714	-,432	-,212	,317
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - I fear that an AMR would not understand my commands	,584	-,194	-,053	,214
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - AMRs scare me	,820	-,491	-,101	,489
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - I would feel very nervous just being around an AMR	,825	-,440	-,213	,399
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - I don't want an AMR to touch me	,728	-,399	-,096	,233
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - AMRs are necessary because they can do jobs that are too hard or too dangerous for caregivers	-,109	,308	,882	-,087
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - AMRs can make life easier	-,500	,763	,567	-,221
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - Assigning routine tasks to AMRs lets caregivers do more meaningful tasks	-,619	,769	,436	-,387
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - Dangerous tasks should primarily be given to AMRs	-,090	,254	,881	-,034
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - AMRs are a good thing for society, because they help people	-,480	,681	,548	-,252
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - AMRs may make us even lazier	,627	-,235	-,031	,229
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - Widespread use of AMRs in healthcare is going to take away jobs from people	,503	-,280	,149	,520
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - I fear that the use of AMRs will lead to less interaction between caregivers and patients.	,534	-,271	-,094	,587
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - AMRs is one of the areas of technology that needs to be closely monitored	,156	-,091	-,037	,804
Please evaluate the following statements regarding autonomous mobile robots (AMRs) - Unregulated use of AMRs can lead to societal upheavals	,411	-,224	-,157	,728

Extraction Method: Principal Component Analysis.
Rotation Method: Promax with Kaiser Normalization.

8.3Regressions

Criterion Item 1: Positive view of robots

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,670[a]	,449	,427	,866

a. Predictors: (Constant), REGR factor score 4 for analysis 2, REGR factor score 3 for analysis 2, REGR factor score 2 for analysis 2, REGR factor score 1 for analysis 2

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	5,313	,083		64,067	<,001		
	REGR factor score 1 for analysis 2	-,317	,108	-,278	-2,934	,004	,591	1,693
	REGR factor score 2 for analysis 2	,457	,106	,402	4,297	<,001	,607	1,648
	REGR factor score 3 for analysis 2	,124	,091	,109	1,369	,174	,838	1,193
	REGR factor score 4 for analysis 2	-,057	,094	-,050	-,609	,544	,782	1,278

a. Dependent Variable: Please evaluate the following statements - Generally speaking, I have a positive view of robots

Criterion Item 2: Interest in scientific discoveries

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,318[a]	,101	,067	1,155

a. Predictors: (Constant), REGR factor score 4 for analysis 2, REGR factor score 3 for analysis 2, REGR factor score 2 for analysis 2, REGR factor score 1 for analysis 2

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95,0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	5,588	,111		50,496	<,001	5,368	5,807					
	REGR factor score 1 for analysis 2	-,183	,144	-,153	-1,268	,208	-,468	,103	-,257	-,123	-,118	,591	1,693
	REGR factor score 2 for analysis 2	,275	,142	,231	1,937	,055	-,006	,557	,294	,187	,180	,607	1,648
	REGR factor score 3 for analysis 2	-,029	,121	-,024	-,237	,813	-,269	,212	,095	-,023	-,022	,838	1,193
	REGR factor score 4 for analysis 2	,050	,125	,042	,402	,689	-,198	,299	-,092	,039	,037	,782	1,278

a. Dependent Variable: Please evaluate the following statements - I am interested in scientific discoveries and technological developments

Criterion Item 3: Positive AMRs

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,753[a]	,567	,550	,732

a. Predictors: (Constant), REGR factor score 4 for analysis 1, REGR factor score 3 for analysis 1, REGR factor score 2 for analysis 1, REGR factor score 1 for analysis 1

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95,0% Confidence Interval for B	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
1	(Constant)	5,349	,070		76,272	<,001	5,210	5,488
	REGR factor score 1 for analysis 1	-,237	,091	-,218	-2,595	,011	-,418	-,056
	REGR factor score 2 for analysis 1	,641	,090	,589	7,115	<,001	,462	,819
	REGR factor score 3 for analysis 1	,014	,077	,012	,176	,861	-,139	,166
	REGR factor score 4 for analysis 1	-,044	,079	-,041	-,558	,578	-,202	,113

a. Dependent Variable: Please evaluate the following statements - Generally speaking, I have a positive view of AMRs

Criterion Item 4: Trust in healthcare system

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,496[a]	,246	,217	1,305

a. Predictors: (Constant), REGR factor score 4 for analysis 1, REGR factor score 3 for analysis 1, REGR factor score 2 for analysis 1, REGR factor score 1 for analysis 1

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95,0% Confidence Interval for B	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
1	(Constant)	5,196	,125		41,558	<,001	4,948	5,444
	REGR factor score 1 for analysis 1	-,036	,163	-,024	-,220	,827	-,358	,287
	REGR factor score 2 for analysis 1	,485	,160	,330	3,020	,003	,166	,803
	REGR factor score 3 for analysis 1	,386	,137	,263	2,823	,006	,115	,658
	REGR factor score 4 for analysis 1	,108	,142	,073	,763	,447	-,173	,389

a. Dependent Variable: Please evaluate the following statements - I have trust in my national healthcare system

Criterion Item 5: Not mind interacting with an AMR when in hospital

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,806[a]	,650	,636	,816

a. Predictors: (Constant), REGR factor score 4 for analysis 1, REGR factor score 3 for analysis 1, REGR factor score 2 for analysis 1, REGR factor score 1 for analysis 1

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95,0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	5,321	,078		68,048	<,001	5,166	5,476
	REGR factor score 1 for analysis 1	-,257	,102	-,190	-2,521	,013	-,458	-,055
	REGR factor score 2 for analysis 1	,785	,100	,583	7,825	<,001	,586	,985
	REGR factor score 3 for analysis 1	,104	,086	,077	1,210	,229	-,066	,273
	REGR factor score 4 for analysis 1	-,207	,089	-,153	-2,337	,021	-,382	-,031

a. Dependent Variable: Please evaluate the following statements - I would not mind interacting with an AMR when in hospital