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Older People's Attitudes to Personal Robots

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Abstract

Robots are increasingly becoming an important part of older people's lives as they bring many benefits. However, it is not clear in current research whether older people's attitudes toward robots are influenced by the robot type. What are the general attitudes of older people toward personal robots and what are the relationships between older people's general attitudes to robots and attitudes to particular personal robot types? This study recruited 126 older people over the age of 65 from the UK and asked them to watch videos of three different robot types (pet robot, humanoid robot, tabletop robot). They answered the Almere model about each robot type and the Negative Attitude Scale towards Robots (NARS) and Robot Anxiety Scale (RAS) about their general attitudes toward personal robots. The results found that participants expressed more positive attitudes and pleasurable feelings towards the humanoid and tabletop robots than pet robots, and found them more useful and convenient. Principal components analysis showed that participants' general attitudes towards personal robots related to anxiety about interacting with personal robots, comfort with personal robots, and anxiety about conversing with robots, and anxiety about the influence of robots in society. Comfort with robots was the best predictor of attitudes to the three personal robots types. In conclusion, pet robots, humanoid robots, and tabletop robots are still new to older people, and they are not widely used in their lives yet, but this study showed that they have a positive attitude toward these types of robots, especially for humanoid robots and tabletop robots, which they are willing to use in their lives.

Subject Areas

Artificial Intelligence, Computational Robotics

Keywords

Older People, Personal Robots, Attitude, Questionnaire Survey

1. Introduction

People are living longer than before because of the advances in medicine and technology, and the number of the older population is gradually increasing every year [1]. However, as the physical condition of older people declines with age, it has become a major challenge to maintain the quality of older people's later life. Robotics has been extensively studied and developed by researchers and there are currently many different types of robots on the market, including humanoid robots, pet robots, and tabletop robots. In addition, these different types of robots have many functions to provide a lot of support in different aspects of older people's lives and help older people to live more independently, such as doing basic daily chores, reminding them of schedules, broadcasting the weather, news and interacting with a wide range of entertainment activities. Robots also help older people monitor their health, remind them to take medicines, and make doctor's appointments [2]. To better understand people's perceptions of robots, many researchers have explored the specific factors that influence general people's attitudes toward robots and developed the measurement tools to measure general people's attitudes toward robots. For example, the Negative Attitude Scale towards Robots (NARS) [3] and the Robot Anxiety Scale (RAS) [4] were developed to measure general people's attitudes toward robots. Moreover, some other researchers explored the specific factors that influence older people's attitudes toward robots and proposed a series of measurement tools for the older people's attitudes toward robots. For example, the Almere model was used to measure the acceptance of socially assistive robots by older users [5].

However, while there is extensive evidence that older people's attitudes towards robots are influenced by a variety of factors, careful attention to the needs of older users is still lacking in most studies. On the other hand, there is also a lack of using measurement tools to measure and compare older people's attitudes towards several different types of robots at the same in a study. In particular, as robotics continues to improve with the development of technology and the possibility of a change in the attitudes of older people towards robots, it is necessary to use the current mainstream robots on the market to conduct more new research on older people. In addition, the majority of the older people recruited in most studies were from Japan and targeted participants in older people's care facilities [2]. Finally, researchers also lack more in-depth research on individual variables in older populations, which are a diverse group with a variety of individual abilities and experiences.

Therefore, to explore the specific influences on older people's attitudes towards different types of robots, firstly, this report provides a literature review of the current situation of older people and the different types of robots that older people may use in their life, as well as the differences in attitudes toward robots between younger and older people, and the relevant available measurement tools for attitudes towards robots, I then started my research based on the shortcomings identified in the literature review. Thus, in this specific study, I recruited participants over the age of 65 located in the UK and used three short video clips of different types of robots (a pet robot, a humanoid robot, and a tabletop robot) in the research. The Almere model, Negative Attitudes towards Robots Scale (NARS) and Robot Anxiety Scale (RAS) were used in the questionnaire to measure the key core factors that influence older people's attitudes towards different types of robots. Finally, I provide a comprehensive analysis and discussion of the results of the study.

2. Related Work

2.1. Robots for Older People

In the latest United Nations report on the ageing of the world's population in 2020, it estimated that there are approximately 727 million people are aged 65 years or older, and the older adult population is expected to increase to approximately 1.5 billion in 2050 [1]. In addition, older people's physical condition declines as they age, making it difficult for them to maintain independence in their daily lives, especially if they lack mobility due to physical decline. On the other hand, older people who do not receive help and support from their family members are likely to be placed in nursing homes. Furthermore, physical decline and reduced mobility are associated with the risk of falls, which have been studied as the leading cause of injury-related deaths [6]. In addition to the physical decline in older people, cognitive decline and dementia can also lead to older people entering nursing homes and requiring more care [7]. Moreover, an increasing number of older people are affected by chronic illnesses and long-term medication which can enable them to maintain a normal physical condition. However, they need good management of their medication and reminders from family members. Finally, a lack of social and emotional skills can leave older people vulnerable to loneliness and isolation. In addition, prolonged isolation can lead to a range of psychological disorders, such as depression. Therefore, it is also important to expand social interaction and maintain a normal social network for older people [8].

Robots have entered human work and home life at an extremely rapid pace. Robots can help older people in various fields. In particular, robots can perform repetitive or dangerous tasks that humans do not want to do [2]. Three types of robots currently on the market or in development as research projects are pet robots, humanoid robots, and desktop robots. Pet robots are one of the typical forms. Pets have therapeutic and preventive effects on mental illness, especially for people who have had pets before [9]. Most pet robots are designed in the shape of animals. For example, cats, dogs, rabbits, seals, etc. As shown in **Figure 1** left, Paro is a furry baby seal robot, it can respond to touch and be hugged by older people. Paro also provides positive effects similar to those of real pets, including psychological comfort, physical arousal, and social communication [10]. It is currently being used with older people in nursing homes and prior studies that have mentioned the use of Paro to interact with older people in nursing

Figure 1. Example of a figure caption.

homes have reported that it reduced feelings of loneliness and depression [11]. Similarly, in Figure 1 right, is another pet-like robot, Miro. When interacting with older people, Miro can respond to being stroked by moving its head, ears, and tail and changing colour. In addition, it also makes animal-like sounds and shows different emotions with these features. Moreover, Miro can move freely around the house and monitor the surroundings to ensure the safety of older people [12].

Humanoid robots have also been designed to assist older people. These robots can walk and communicate like human beings, and in some cases, they can do tasks that people do not want to do. As shown in Figure 2 left, one such example is the Zorabot Pepper, a 1.2 m tall, wheeled humanoid robot with a touchscreen interactive tablet. It can display body language, move around and monitor the surroundings. Furthermore, Zorabot Pepper can also analyse a person's expressions and tone of voice through a camera to communicate with the user gently and complete user-assigned tasks [13]. This type of robot has been used in nursing homes and researchers have experimented with the Zorabot Pepper and found that it provides a great deal of assistance to older people, not only by increasing communication between them and caregivers but also by reducing the burden on caregivers [14]. Similarly, in Figure 2 right, is Sanbot a humanoid robot. It can also move as freely as the Zorabot Pepper and users can interact with it by touching the screen. In the area of health, the Sanbot robot can be connected to wearable devices such as the Fitbit to track vital signs. It automatically contacts healthcare institutions when monitoring health at the point where the older people's life is in danger. In addition, the Sanbot reduces loneliness for older people living independently through features such as companionship and entertainment [15].

A desktop robot is another form of robot that can save a lot of space in the house compared to a humanoid robot. A desktop robot is a screen-based agent and combine robot features with those of personal intelligent assistive devices. In Figure 3 left, Afobot is a companion desktop robot which offers great assistance to older people. It offers many important functions such as measuring blood pressure, and blood sugar, making doctor appointments, reminders for medication and exercise, providing information about the weather and news. As shown in Figure 3 right, another robotic assistant for older people in their daily lives is ElliQ. ElliQ is called the "ageing companion", It has a touchable screen that

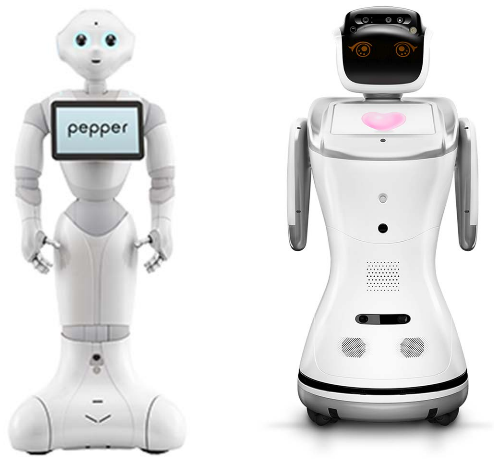

Figure 2. (left) Zorabot Pepper (Source: https://robots.ros.org/pepper/), (right) Sanbot (Source: https://robot.omitech.it/en/about-us/).

Figure 3. (left) Afobot (Source: https://afobot.qnap.com/zh-tw), (right) ElliQ (Source: https://www.thesofia.org/partnerships).

lights up when the user uses it. ElliQ has multiple functions, it can answer phone calls, read emails, play music, schedule appointments and provide reminders of them. ElliQ can also be used as an exercise coach, recommending healthy activities and encouraging older adults to exercise [16]. Therefore, the emergence of robots has brought great improvement to the quality of life of older people.

2.2. Younger People's Attitudes to Robots and How They Have Been Measured

In an early study, Nomura *et al.* [17] investigated the attitudes of people toward robots through the Negative Attitudes toward Robots Scale (NARS). Participants were 400 Japanese university and special training school students. The results showed that type of robot and task can lead to differences in attitudes. In another study, Nomura *et al.* [18] recruited 38 Japanese university students to explore the relationship between negative attitudes, anxiety, and behaviour toward robots. Participants and a humanoid robot Robovie were engaged in simple interactions including meeting, greeting, self-introduction and physical contact. In addition, two psychological scales were used in the study: Negative Attitudes toward Robots Scale (NARS) and the Robot Anxiety Scale (RAS) to measure attitudes. Results showed a relationship between negative attitudes, anxiety, and communication avoidance behaviour, meaning that people with high negative attitudes or anxiety about interacting with the robot would avoid emotional conversations with the robot. However, a humanoid robot was used in the study and it is uncertain whether these findings would apply to a pet-like robot. Similarly, De Graaf and Allouch [19] used the humanoid robot NAO in research with 60 students from a university in the Netherlands. Their results confirmed that usefulness, adaptability, enjoyment, sociability, companionship, and perceived behavioural control were the key variables explaining the acceptance of social robots. However, while the researchers have identified multiple factors in people's attitudes towards robots, more testing needs to continue with different robots in different environments and with different user groups.

Many researchers have developed measurement tools from a variety of perspectives, taking into account the context of their time and technological developments. Bartneck *et al.* [20] developed a measurement tool to help robot developers design better robots by summarising five key concepts that influence attitudes towards robot use, which they called the "God speed" questions. The key concepts were anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety. The questionnaire they developed used a semantic differential scale, "in semantic differential scales the respondent is asked to indicate his or her position on a scale between two bipolar words" (p. 73). In addition, they also found that there was some overlap between anthropomorphism and animacy which both appear as artificial or lifelike items. As a result of these findings, Bartneck *et al.* [20] also believe that to make the measurement results more adequate, many factors need to be considered, such as the participants' cultural background and previous experience with the robot.

Further, Shin and Choo [21] conducted a study to recruit 210 Korean participants (both young and old) and proposed a model for socially interactive robots which emphasizes the importance of perceived adaptability and sociability, both of which influence attitudes as well as influence perceived usefulness and perceived enjoyment. However, this model contains only a small number of influencing factors. Sanders *et al.* [22] found more influential factors in their research, they developed a refined three-factor model based on previous research, classifying it into three categories: human (including ability-based and characteristic factors), robot (including robot performance-based and attribute-based factors), and environmental (including team collaboration and task-based factors). However, there is inadequate evidence in the study and more researchers are needed to conduct experiments.

Finally, to measure the attitudes and anxiety in relation to human-robot interaction (HRI), Nomura *et al.* worked with students from Japanese universities, focusing on the application of robots in daily life services, and successively developed two psychological scales: the Negative Attitude Scale towards Robots (NARS) [3] and the Robot Anxiety Scale (RAS) [4]. The NARS was developed to determine the impact of negative human attitudes towards robots and is divided into three subscales, "Negative attitude toward interaction with robots" (S1); "Negative attitude toward the social influence of robots" (S2); and "Negative attitude toward emotional interactions with robots" (S3). Each item was answered with five responses: Strongly disagree; Disagree; Undecided; Agree; Strongly agree. In contrast to the NARS, the RAS was designed to determine human anxiety about robots in real and imagined HRI situations, measuring the level of anxiety about interacting with robots with communication capabilities in daily life. This scale is divided into three subscales: "Anxiety toward communication capacity of robots" (S1); "Anxiety toward the behavioural characteristics of robots" (S2); "Anxiety toward discourse with robot" (S3), with each item rated on a six-point scale, "I do not feel anxiety at all; I hardly feel any anxiety; I do not feel much anxiety; I feel a little anxiety; I feel quite anxious; I feel very anxious". These scales have been used extensively in other studies to assess the acceptability of the robot [11] [13] and the findings have shown high reliability.

2.3. Older People's Attitudes to Robots and How They Have Been Measured

Heerink *et al.* [23] explored the attitudes and acceptance of a social robot among 28 older inhabitants in a first study and 40 older inhabitants of institutions in a second study; the iCat (a desktop robot) was set up with more and less social communication conditions. The results showed that the more socially communicative condition made participants feel more comfortable and more motivated to interact with the iCat. In addition, Heerink *et al.* [5] measured the acceptance of social robots (*i.e.*the iCat) and screen agents. They included measures of social presence in a study with 40 older people who lived in nursing homes. The results showed that the participants showed more expression, and the more expression is shown, the more obvious it is in social presence. Similarly, Heerink *et al.* [24] used the same iCat robot for older people in another study which found that perceived enjoyment would have a great impact on the intention to use the robot system.

In addition, the adaptability of robots may be important for older adults as their physical conditions change over time and robots need to adapt to these changes. Heerink [25] explored how older users of the socially interactive robot experienced adaptiveness, adaptability, and user control in a study of 88 older participants who lived in flats near or nursing homes in Almere and Amsterdam. The researchers used four conditions of assistive social robot video material developed by the Robocare project and also explained the definition of adaptable as "the user adapts the robot to his or her changing needs"; adaptiveness with user control: "the robots adapt to observed changing needs of the user after the user has agreed to this"; Adaptive without user control: "the robot adapts to observed changing needs of the user without seeking agreement of the user" (p. 80). The results showed that compared with the adaptive robots, the older people preferred the adaptable robots and they still wanted to keep control of the robots. However, it is uncertain in these Heerink *et al.* studies whether these results are applicable to other types of robots and most older people were recruited in flats near nursing homes. Therefore, more studies in different setting of conditions are needed to explore more influencing factors toward different types of robots.

In addition to the findings of Heerink *et al.*, emotional support can make life less lonely for older people who live independently, and whether the robot can successfully express emotion and vulnerability to humans and other social cues is also very important for the older people to accept the robot. Díaz *et al.* [26] reviewed the emotional dimensions of robot-based home older people assistance systems for older people and found that emotional factors associated with assistive technology for aging at home influence technology acceptance, effective use, and improvement in quality of life.

Samaddar and Petrie [27] studied the attitudes of 24 older people towards different types of robots using a semi-structured interview based on the context of the home environment. Participants were asked what they would like robots to do in their homes. The results showed that the older people had many daily tasks and needs at home, such as being reminded that the stove is on, providing cooking instructions, and ways to play games with other older people, which they expected the robot to help with. Furthermore, Frennert *et al.* [28] asked 88 Swedish older adults to imagine having a robot in their homes. Participants believed that using robots as "friends" was stigmatizing and even affected their self-image, sending signals of loneliness and vulnerability to others. Therefore, the researchers suggest that having a robot play the role of a servant may be somewhat acceptable and satisfying for older people. Based on these findings, when considering older people living at home independently, it is most important to design robots that are suitable for them and meet their needs, as well as to consider the moral and ethical factors. In a recent study, Lehmann *et al.* [29] used robot videos and pictures of robots to investigate the emotions and attitudes of 142 older adults toward robots of different appearances and in different situations. The results contribute that the specific context in which a robot interacts with a human has a significant impact on positive and negative emotions and intention to use the robot. Besides, the researchers also found that appearance influenced intentions to use the robot and unpleasant feelings about the robot. However, a previous study found that older people were more focused on functionality than the appearance of the robot [27]. More importantly, to explore older people's attitudes towards robots, it is also important to assess the expectations and needs of other relevant stakeholders. Bedaf *et al.* [30] explored what characteristics a service robot should have to be accepted by older users in a multinational focus group study using a service robot (Care-O-bot 3). The scenarios were presented to three different types of potential users: older people without cognitive decline; informal caregivers; and professional caregivers. The research identified that older participants and professional caregivers wanted the robot to have human characteristics, in addition, older people also preferred the robot to obey the user's commands, while informal caregivers and professional caregivers preferred to have the robot perform tasks with the user to keep older people active. Therefore, different stakeholders have different attitudes toward robots and it is clear that robots are "designed for everyone" will not be accepted by users. Also, designers should always keep in mind the importance of user-centered design when developing robots. However, Bradwell *et al.* [31] has found that end users and potential developers have different preferences when it comes to developing robots for older people. Bradwell *et al.* [31] investigated the significant differences in companion robot design between "robot users" and "robot creators". The researchers separately observed and recorded eighteen robotics experts in research centers and seventeen older people in nursing homes interacting with each of the eight pet robots. The results concluded that older people prefer soft, furry, interactive, familiar and realistic animals, in contrast of the majority of robotics experts who avoided these robot features in their designs. Moreover, older people responded positively to features such as simulated life functions, eye contact, robot personalization and obedience to commands, which were underestimated by robotics experts. Overall, it is vital to involve end users in the design and development of robots. Finally, there are also human-related factors that influence older people's attitudes towards robots, and these factors are relevant when many researchers have conducted studies. For example, Broadbent *et al.* [32] summarized not only the robot variables (appearance, size, gender, ergonomics, role, personality) but also the user variables (age, needs, gender, cognitive ability, education level, experience and culture). However, the researchers used a literature review that included other populations besides the older population. After that, Heerink [33] explored the influence of human-related factors on the acceptance of robots by older people. He used robot videos (RoboCare) to conduct a study with 66 older people and found that age, gender, education level and computer experience could affect the attitude of the older people towards robots. Therefore, it is necessary to study individual variables to help make more findings in studies.

Many researchers began to try to develop measurement tools to assess the attitudes of older people towards robots. The Technology Acceptance Model (TAM) [34] and the Unified Theory of Acceptance and Use of Technology (UTAUT) [35] were developed and tested extensively in various domains. Although they could predict user acceptance of a system, however, "traditional technology acceptance models do not take into account social aspects of interaction with embodied agents such as robots or on-screen characters, nor are these models developed with older users in mind" (p. 362) [36]. Thus, to measure older people's attitudes towards robots, Heerink *et al.* [36] made the first attempt to develop a toolkit based on previous research and including a number of influencing factors: Anxiety, Attitude, Facilitating Conditions, Intention to Use, Perceived Adaptability, Perceived Enjoyment, Perceived Ease of use, Perceived Sociability, Perceived Usefulness, Social Presence, and Trust.

However, there were still some shortcomings in this toolkit and the researchers only recruited a small number of participants aged 65 - 94 years old (n = 30) in the study, which was not sufficient to show the validity of the results. Subsequently, Heerink *et al.* [37] recruited a total of 188 participants over 65 years of age and conducted four studies with different conditions to develop an attitude measurement instrument for older adults towards robots. Finally, an assistive social robot acceptance model (*i.e.* the Almere model) was proposed specifically for the older population. The questionnaire consisted of 41 items on a Likert-type 5-point scale and measuring 12 constructs: Anxiety, Attitude towards technology, Facilitating conditions, Intention to use, Perceived adaptiveness, Perceived Enjoyment, Perceived Ease of Use, Perceived Sociability, Perceived Usefulness, Social Influence, Social Presence and Trust. This model is based on data from theoretical and empirical studies on the integration of technology acceptance and uses a structural equation modeling approach to form the final model. It has been shown to be reliable in a variety of situations.

Although many studies have been conducted by researchers, the following problems are unresolved or insufficiently researched with specific older people's attitudes towards robots and the corresponding measurement methods. Firstly, in most of the previous studies by [5] [23] [24], a variety of factors were found to influence older people's attitudes towards robots, however, these studies were only focused on one type of robot, and lacked a more comprehensive analysis and comparison with other different types of robots. for example, As mentioned in 2.3 section: Heerink *et al.* [23] explored the acceptance of a social robot (iCat) by older users and Heerink *et al.* [24] studied the enjoyment, intention to use and actual use of a conversational robot (iCat) by older users, and Heerink *et al.* [5] researched relating conversational expressiveness to social presence and acceptance of an assistive social robot (iCat) and more. In addition, with advances in technology, especially rapid developments such as artificial intelligence, robots have made huge strides in intelligence, and attitudes of older people towards robots may be shifting. It is also necessary to re-conduct a study of older people based on the current mainstream robots on the market and explore the changing trends in older people's attitudes towards robots. Moreover, most of the older adult population recruited in the study came from Japan and targeted participants in older people's care facilities [2]. Also, with a growing population of older people and a diverse group with a wide range of individual abilities and experiences. Finally, few studies in the current literature review have used older people's attitude measurement instruments to measure more different types of robots and used more different measurement attitude instruments from different aspects.

To address these problems, this project conducted an online questionnaire survey with participants located in the UK and used three short videos of different types of personal assistive robots (a pet robot, a humanoid robot, and a desktop robot) which are currently the most mature in the commercial market, and then used three measurement instruments, the Almere Model, the NARS, and the RAS to analyze factors that influence older people's attitudes towards robots. Thus, the main research questions of this study are:

1) Are older people's attitudes toward robots influenced by the robot type?

2) What are the general attitudes of older people toward personal robots?

3) What are the relationships between older people's general attitudes to robots and attitudes to the three personal robot types?

3. Method

3.1. Design

This study is a within-participants design in which older people viewed videos of three different types of personal robots: a Pet robot, a humanoid robot, and a tabletop robot, to measure their attitudes towards personal robots. Three questionnaires were used in the study. At the beginning of the questionnaire participants' attitudes towards robots in advance of participating in the study were measured with an open-end question "What do you think of when you hear the term 'personal robot'?". Subsequently, the questionnaire presented three short video clips of different types of personal robot: MiRO (pet robot), Sanbot (humanoid robot), and Afobot (tabletop robot). These three types of robots were chosen as the literature review has shown that there is considered research and development on these three types. Then participants answered an adapted version of the Almere Model Questionnaire [36] about each robot type to assess their attitudes toward different robot types. After viewing the three robots, participants answered the Negative Attitude Scale toward Robots (NARS) [3] and the Robot Anxiety Scale (RAS) [4] to their general attitudes towards personal robots. Finally, participants provided demographic information.

3.2. Participants

A total of 130 older people in the UK were recruited through the Prolific research participant platform (prolific. co) and completed the online survey. The inclusion criteria for participants were that they were British, lived in the UK and the average age of the participants was over 65 years old.

The quality of the questionnaire data was checked. It was found that four participants did not answer the questionnaire carefully, based on the attention check questions (see **Table 1**). Therefore, the responses of these participants were dropped and the response data of 126 participants were analysed.

56 participants (44.4%) identified as male, and 70 participants (55.6%) identified as female. It is clear that more female participants volunteered to help answer the questionnaire. This is probably because men do not live as long as women so in the older age group there are more women and men. There is no clear definition of when older people become older, but many researchers usually recruit people over the age of 65 for the studies. Therefore, the average age of the participants was 69.2 years old (Min = 63, Max = 87) and there was only one participant of 63 years old, the other 125 participants were 65 years old or more. In addition, the largest group of participants who responded to the questionnaire was distributed between 65 to 70 years old. According to the data on

Table 1. Attention check questions for the three different robot videos.

Type of robot	Attention check questions
Afobot	1) Which two calls did Afobot help with? (The choices: Elderly man calling his son, daughter calling her father; Elderly man calling his son, man calling his aunty; Man calling his wife, elderly man calling his son) 2) What else did Afobot help with? (The choices: Helped the girls show her father her drawing; Helped take a photo of the family; Both of these)
MiRo	1) Which movement of MiRo is not shown in the video? (The choices: Wagging its tail; Blinking its eyes; Flapping its ears) 2) Two MiRos are shown "cudding up" to each other in the video. (The choices: True; False)
Sanbot	1) Sanbot warns the man watching football that. (The choices: His blood pressure is too high; His heart rate alarm has gone off; He is cheering too loudly) 2) Sanbot reminds the man working at the desk. (The choices: that he should call his father; that he can change his appointment; that he has five important notifications)

educational level, the majority of the participants had a high school or a bachelor's degree, 58 (46.0%) and 39 (31.0%) of participants respectively. Only a few participants had a higher degree or a professional qualification, with 15 (11.9%) and 14 (11.1%) participants respectively. 98 (77.8%) of participants were retired and not currently working, which is the majority. However, a small number of older people have full-time employed or self-employed, or part-time employed or self-employed, 15 (11.9%) and 13 (10.3%) participants respectively. Participants' current and former occupations covered a very wide range, mainly professional occupations.

In addition, an analysis was conducted of participants' ratings of their confidence with computers and computer software, and their confidence with using the Internet, One-sample Wilcoxon signed rank tests were used and compared of the observed ratings with the midpoint of the rating scale. The median rating in both cases was 6.0 and both ratings were significantly higher 4 than the midpoint of the scale. This indicated that the participants were very confident in using computers and computer software and the Internet.

Participants were asked whether they had any experience of personal robots, 23 said they had (18.3%), 103 (81.7%) participants said they had not. I conducted a content analysis of responses from the 23 participants who had experience with personal robots of what their experience was. There were five types of robots of which participants had experience. The most frequently mentioned was robotic vacuum cleaners (experienced by 66% of participants), followed by robotic lawn mowers (14%); virtual assistants (e.g. Alexa, Siri) (14%); robotic mops (3%) and robotic swimming pool cleaners (3%), which were both mentioned by the least from participants. The number refer to percetages of total codings (N = 29, percentage = 100%).

3.3. Online Survey

The questionnaire was used in the study to measure the attitudes of older people in the UK to three types of personal robots. The questionnaire is the most mature tool for collecting demographics and user opinions, it also can be set up with different types of questions and collect a large amount of data for analysis in a very short period [38]. The questionnaire was distributed using the Qualtrics online survey tool (www.qualtrics.com). At the beginning of the questionnaire, participants were required to read an information page and confirm the Informed consent form. In the first part of the survey, participants were shown three short video clips (approximately one minute each) of different types of personal robots (a pet robot, a humanoid robot, and a screen-based robot) (see Section 3.3.1) and then answer a set of questions about each (based on the Almere model of attitudes of older people to assistive robots) (see Section 3.3.3). In the second part, participants completed two short questionnaires about general attitudes to robots: the Negative Attitudes to Robots Scale and the Robot Anxiety Scale (see Section 3.3.4). Finally, there was a section about demographic information.

3.3.1. Robot Videos

In the field of HRI (Human-Robot Interaction), the videos used in questionnaires can be compared to live trials [39]. Firstly, the high-quality of three different type of robot videos were downloaded from the YouTube website, and each video clip was kept to around one minute. However, participants were unable to view the video directly in the questionnaire on Qualtrics as the video size exceeded the limit of the Qualtrics platform. Therefore, I created a private YouTube account and uploaded these edited videos, so that participants can watch the videos on the YouTube website by clicking on a link in the questionnaire. Secondly, to make participants concentrate more on completing the questionnaire without being distracted by the noisy sounds in the videos, I turned off the noisy sound when editing the videos, which was accompanied by a display of English text and soft music in the videos. In addition, I counter-balanced the order of presentation of the three videos to avoid fatigue and practice effects [40]. Finally, I provided a short introduction to each of the different types of robots before the participants watched the video. These are as follows:

1) Afobot Personal robot (Desktop robot)

Afobot is a tabletop personal robot. It has a screen that will rotate towards you when you speak to it and will understand your voice commands (like Alexa and Siri). It can assist in a range of activities of daily life such as reminding you of appointments or taking your medicines. It can quickly connect you to your family and friends via voice or video calls and can take and send photos for you.

2) Miro Personal robot (Pet robot)

MiRo is a pet-like personal robot. It can move around independently, but will also be attracted by human movement and sounds. You can train it to respond to particular actions like clapping your hands as you might a pet. It also responds to being stroked by moving its head, ears, and tail and changing colour. It also makes animal-like sounds. It can show different emotions with these features and goes to "sleep" automatically to recharge itself.

3) Sanbot Personal robot (Humanoid robot)

Sanbot is a human-like personal robot with a head and arms and a screen. It can move around independently and can recognise different people using face recognition. It will also understand voice commands. It can assist in a range of activities of daily life such as reminding you of appointments or taking your medicines. It can quickly connect you to your family and friends via voice or video calls and monitor your health by linking with a smartwatch.

3.3.2. Attention Check Questions

Some participants may answer questions very quickly to spend little effort, which can lead to inaccurate study data. Therefore, it was necessary to give participants some attention check questions to avoid this situation [41]. I set a total of six attention-checking questions and each attention-checking was based on the robot videos, which were shown in **Table 1**.

Table 2 shows that a total of 126 (96.9%) participants answered the attention question with one error, two errors or all correct answers. The remaining 4 (3%) participants answered the attention questions with three or more errors that I believed the participants did not answer the questionnaire carefully. Therefore, the responses of these 4 participants were dropped and the final response data of 126 participants were analysed.

3.3.3. Almere Model

The Almere model questionnaire is shown in **Table 3**. The questionnaire consists of 41 items which Heerink *et al.*, asked people to respond to on Likert-type 5-point items (totally disagree-disagree-don't know-agree-totally agree). The questionnaire measures 12 constructs: Anxiety, Attitude towards technology, Facilitating conditions, Intention to Use, Perceived adaptiveness, Perceived Enjoyment, Perceived Ease of Use, Perceived Sociability, Perceived Usefulness, Social Influence, Social Presence and Trust.

In my questionnaire, the Almere questions were divided into four blocks to make answering easier and asked after each different type of robot video. The

Table 2. Results on the attention checks questions (video questions, N = 130).

Number correct	Participants
All correct	73 (56.2%)
1 wrong	45 (34.6%)
2 wrong	8 (6.2%)
3 wrong or more than 3	4 (3%)

Table 3. Almere model questions.

Construct	Items
Anxiety (ANX)	1) If I should use the robot, I would be afraid to make mistakes with it 2) If I should use the robot, I would be afraid to break something 3) I find the robot scary 4) I find the robot intimidating
Attitude towards technology (ATT)	5) I think it's a good idea to use the robot 6) The robot would make life more interesting 7) It's good to make use of the robot
Facilitating conditions (FC)	8) I have everything I need to use the robot 9) I know enough of the robot to make good use of it
Intention to Use (ITU)	10) I think I'll use the robot during the next few days 11) I'm certain to use the robot during the next few days 12) I plan to use the robot during the next few days
Perceived adaptiveness (PAD)	13) I think the robot can be adaptive to what I need 14) I think the robot will only do what I need at that particular moment 15) I think the robot will help me when I consider it to be necessary
Perceived Enjoyment (PENJ)	16) I enjoy the robot talking to me 17) I enjoy doing things with the robot 18) I find the robot enjoyable 19) I find the robot fascinating 20) I find the robot boring
Perceived Ease of Use (PEOU)	21) I think I will know quickly how to use the robot 22) I find the robot easy to use 23) I think I can use the robot without any help 24) I think I can use the robot when there is someone around to help me 25) I think I can use the robot when I have a good manual
Perceived Sociability (PS)	26) I consider the robot a pleasant conversational partner 27) I find the robot pleasant to interact with 28) I feel the robot understands me 29) I think the robot is nice.
Perceived Usefulness (PU)	30) I think the robot is useful to me 31) It would be convenient for me to have the robot 32) I think the robot can help me with many things
Social Influence (SI)	33) I think the staff would like me using the robot 34) I think it would give a good impression if I should use the robot
Social Presence (SP)	35) When interacting with the robot I felt like I'm talking to a real person 36) It sometimes felt as if the robot was really looking at me 37) I can imagine the robot to be a living creature 38) I often think the robot is not a real person 39) Sometimes the robot seems to have real feelings
Trust (Trust)	40) I would trust the robot if it gave me advice 41) I would follow the advice the robot gives me

wording used was: "Please rate the extent to which you agree or disagree with the following statements about the Afobot/Miro/Sanbot personal robot". Some adjustments were made to the original Almere model questions. For example, the names of the robots were added to each item in the Almere model to avoid confusing participants' impressions of the different robots and the wording was change to the hypothetical form, as the participants have not had any actual experience with the robots or the opportunity to have one in the future. For example, the perceived enjoyment item: I would enjoy the Afobot/MiRo/Sanbot robot talking to me.

Many questionnaires used seven-point or five-point scales, and there are also three-point scales, but the longer scales would help to show more discrimination and make an empirical study more accurate [42]. Thus, 7-item Likert items from "strongly disagree" to "strongly agree" was used for the Almere model questions.

3.3.4. Negative Attitude Scale towards Robots (NARS) and Robot Anxiety Scale (RAS)

Participants completed the Negative Attitudes towards Robots Scale (NARS) and the Robot Anxiety Scale (RAS). These were mentioned in Section 2.2 and are shown in **Table 4** and **Table 5**. The NARS was developed to measure the impact of negative human attitudes towards robots and is divided into three subscales (see **Table 4**) [3], it contains 14 items measured by 7-item Likert items ("strongly disagree" to "strongly agree"). The Robot Anxiety Scale (RAS) was designed to measure human anxiety about robots in real and imagined HRI situations, measuring the level of anxiety that prevents individuals from interacting with robots with communication capabilities in daily life (see **Table 5**) [4]. It contains 11 items measured by 7-item Likert items ("Not at all anxious" to "Very anxious"). These scales have been used extensively in other studies to assess the acceptability of the robots [17] [18] and the findings have shown high reliability.

3.4. Procedure

This project conducted an online survey, recruiting participants on the recruitment platform Prolific. It recruited participants located in the UK, over the age of 65. Assuming the survey takes approximately 15 minutes to complete, they were offered £2.00 through Prolific. The survey started with an information page for participants to read and asked them to complete an online consent form. Participants then viewed three short videos (approximately one minute each) of different types of personal assistive robots (a pet robot, a humanoid robot and a screen-based robot) and after each one, answered a set of questions, based on the Almere model of attitudes of older people to assistive robots. The order in which the three robots are presented to participants was counterbalanced to avoid practice and fatigue effects. Then, participants were asked to complete two short questionnaires about their general attitudes to robots, the Negative Attitudes to Robots Scale (NARS) and Robot Anxiety Scale (RAS). Finally, participants were asked some general demographic questions (such as gender, age, computer and robot experience).

Table 4. Negative attitude scale towards robots scale (NARS).

Construct	Items
Subscale 1: Negative attitude toward situations of interaction with robots	1) I would feel uneasy if I was given a job where I had to use robots. 2) The word "robot" means nothing to me. 3) I would feel nervous operating a robot in front of the other people. 4) I would hate the idea that robots or artificial intelligences were making judgements about things. 5) I would feel very nervous just standing in front of a robot. 6) I would feel paranoid talking with a robot.
Subscale 2: Negative attitude toward the social influence of robots	7) I would feel uneasy if robots really had emotions. 8) Something bad might happen if robots developed into living beings. 9) I feel that if I depend on robots too much, something bad might happen. 10) I am concerned that robots would be a bad influence on children. 11) I feel that in the future society will be dominated by robots.
Subscale 3: Negative attitude toward emotion in interactions with robots	12) I would feel relaxed talking with robots. 13) If robots had emotions, I would be able to make friends with them. 14) I feel comforted being with robots that have emotions.

Table 5. Robot anxiety scale (RAS).

Construct	Items
Subscale 1: Anxiety toward communication capacity of robots	1) Whether the robot might talk about irrelevant things in the middle of conversation. 2) Whether the robot might not be flexible in following the direction of our conversation. 3) Whether the robot might not understand difficult conversation topics.
Subscale 2: Anxiety toward behavioral characteristics of robots	4) What kind of movements the robot will make. 5) What the robot is going to do. 6) How strong the robot is. 7) How fast the robot will move.
Subscale 3: Anxiety toward discourse with robots	8) How I should talk to the robot. 9) How I should respond when the robot talks to me. 10) Whether the robot will understand what I am talking about. 11) Whether I will understand what the robot is talking about.

4. Results

4.1. Older People's Initial Thoughts to Robots

I conducted a content analysis of responses from the 126 participants with the open-ended question "what do you think of when you hear the term 'personal robot'?". The participants' perceptions of the robot in three main areas, which are task, types of robots and characteristics. In the coding of task, the most frequently mentioned was household chores and tasks of daily living (mentioned by 18.5% of participants) ; followed by not specified with the robot tasks (mentioned by 13.4% of participants); mundane and low level (mentioned by 7.5% of participants); for disable/older people (mentioned by 4.3% participants); health-related (2.7%) and tasks people can't or don't want to do (2.7%), which were both mentioned by the least from participants. In the coding of types of robots, only vacuum cleaner was mentioned by 3.7% of participants. Among the conding of characteristics of robots, the most frequently mentioned was personal (isable) to an individual (mentioned by 9.7% of participants); followed by like a science fiction item/character (mentioned by 6.4% of participants); human like/humanoid (mentioned by 4.8% of participants); responds to humanoid commands/under human control, (artificial) intelligent, Useful/helpful and negative emotional reaction were mentioned by the same number of times from participants and were 4.3%; autonomous and can make conversation/be interaction have the same mentioned from participants, which were 3.2%; positive emotional reaction (2.7%) was mentioned by the least from participants. The number refer to percentages of total codings (N = 186, percentage = 100%).

4.2. Older People's Attitudes to Robots as Measured by Almere Questions

4.2.1. Older People's Attitudes to Afobot

Table 6 shows the median construct scores (and SIQRs) for the Afobot robot, as well as the result of the one-sample Wilcoxon tests. These tests show that for the scores for the following constructs were significantly above the midpoint of the scale: Attitude, Facilitating Conditions, Perceived Adaptability, Perceived Enjoyment, Perceived Ease of Use, Perceived Usefulness and Intention to Use. On the other hand, the scores for Perceived Sociability, Social Influence and Trust were not significantly different from the midpoint. Finally the scores for Anxiety and Social Presence were significantly below the midpoint.

Table 6. Medians and semi-interquartile ranges (SIQR) of older people's attitudes toward the Afobot robot.

	ANX	ATT	FC	PAD	PENJ	PEOU	PS	PU	SI	SP	Trust	ITU
Median	1.50	5.00	5.00	5.00	5.00	5.00	4.00	5.00	4.00	1.00	4.00	5.00
SIRQ	0.75	1.50	0.82	1.00	1.00	0.63	1.25	1.00	1.07	0.50	1.00	N/A
Wilcoxon	−9.34	3.34	5.44	7.38	2.13	7.21	−0.27	3.91	1.70	−9.02	−0.63	3.85
p	0.00	0.00	0.00	0.00	0.03	0.00	n0.s0.	0.00	n0.s0.	0.00	n0.s0.	0.00

These results show that participants did not feel anxious about the Afobot robot and did not feel that the social presence toward Afobot. In contrast, participants have positive and pleasant feelings about Afobot, they find it easy to use and think it will help them in their lives, and even want to use it for a longer period and expect that perceived ability to adapt to user needs when using Afobot.

4.2.2. Older People's Attitudes to MiRo

Table 7 shows the median construct scores for the MiRo robot, as well as the result of the one-sample Wilcoxon tests. These tests show that for the scores for the following constructs were significantly above the midpoint of the scale: Facilitating conditions, Perceived Ease of Use and Intention to Use. On the other hand, the scores of Attitude towards technology, Perceived adaptiveness, Perceived Enjoyment, Perceived Sociability, Perceived Usefulness, Social Influence were not significantly different from midpoint. Finally, the scores for Anxiety, Social Presence and Trust were significantly below the midpoint.

The results show that the participants do not feel anxious and do not consider that as a social entity of MiRo. However, there was ambiguity in that participants did not believe that MiRo's performance has personal integrity and reliability, but believed that MiRo was easy to use and desired in their lives, and was even willing to use the robot for a longer period.

4.2.3. Older People's Attitudes to Sanbot

Table 8 shows the median construct scores for the Sanbot robot, as well as the result of the one-sample Wilcoxon tests. These tests show that for the scores for the following constructs were significantly above the midpoint of the scale: Attitude towards technology, Facilitating conditions, Perceived adaptiveness, Perceived Enjoyment, Perceived Ease of Use, Perceived Usefulness, Trust and Intention to Use. On the other hand, the scores of Perceived Sociability and Social Influence were not significantly different from midpoint. Finally, the scores for Anxiety and Social Presence were significantly below the midpoint.

These results show that participants felt less anxiety and less experience of feeling like a social entity about Sanbot. In contrast, they have positive and pleasant feelings about the use of Sanbot and believed that using the Sanbot system will be effortless, reliable, and useful in their lives. In particular, participants were willing to use Sanbot for a longer period and expected the Sanbot system to be adapted to the expected needs of the users.

Table 7. Medians and semi-interquartile ranges (SIQR) of older people's attitudes toward the MiRo robot.

	ANX	ATT	FC	PAD	PENJ	PEOU	PS	PU	SI	SP	Trust	ITU
Median	1.50	4.00	4.50	4.00	4.00	5.00	4.00	4.00	4.00	2.00	3.50	4.50
Wilcoxon	−9.30	1.03	3.00	3.31	1.92	7.49	−0.52	−2.44	−0.95	−7.20	−4.51	1.99
p	0.00	n0.s	0.00	0.00	0.05	0.00	n0.s	0.02	n0.s	0.00	0.00	0.05

Table 8. Medians and semi-interquartile ranges (SIQR) of older people's attitudes toward the Sanbot robot.

	ANX	ATT	FC	PAD	PENJ	PEOU	PS	PU	SI	SP	Trust	ITU
Median	2.00	5.00	4.50	5.00	5.00	5.00	4.00	5.00	4.00	2.00	4.50	5.00
Wilcoxon	−8.23	3.10	2.56	6.69	3.34	5.30	0.82	2.28	0.70	−7.68	3.02	3.23
p	0.00	0.00	0.01	0.00	0.00	0.00	n0.s	0.02	n0.s	0.00	0.00	0.00

4.2.4. Comparison of the Attitudes of Older People towards the Three Personal Robots

Figure 4 shows a comparison of the medians on the 12 Almere constructs for the three personal robots. Table 9 shows the statistical comparison between the three personal robots, conducted by a series of Friedman's related samples tests with post hoc tests to compare the pairs of robots. These results show that for all constructs apart from three (Perceived Enjoyment, Perceived Sociability and Intention of use) there were significant differences in the perceptions of the personal robots. In the majority of cases the Sanbot robot was viewed significantly more positively than either MiRo or Afobot.

4.3. Older People's General Attitudes to Personal Robots as Measured by NARS to RAS

Before conducting the a principal components analysis (PCA) , it was necessary to determine whether a total of 25 items from the Negative Attitudes towards Robots Scale (NARS) and Robot Anxiety Scale (RAS) were suitable for principal components analysis. KMO was used to test for correlations between variables. It is very suitable for factor analysis with a range of statistic values above 0.9, suitable between 0.7 and 0.9, fair between 0.6 and 0.7, poor between 0.5 and 0.6, and should be rejected below 0.5. In addition, for Bartlett's test, if the significance is less than 0.05 or 0.01 and the original hypothesis was rejected, it means that PCA can be done. Therefore, the KMO value of 0.876 was much higher than 0.5, which indicated that the data was suitable for principal component analysis. And Bartlett's test of sphericity for significantly less than 0.001, indicated that the data are correlated and also suitable for PCA.

The number of components to be extracted by PCA can be determined from the scree plot. The function of the screen plot was to identify the number of factors to be selected based on the slope of the fall in eigenvalues. As shown in Figure 5, according to the curve changes, there was an inflection point after the fifth principal component. In addition, the slope was relatively equal between the fourth and the fifth principal component. So it was not clear whether the fourth or fifth was selected for the component analysis. Therefore, a recalculation of the Pattern Matrix data showed that only two factors of the 5th principal components have r values greater than 0.5 or less than −0.5. However, this correlation coefficient was too small and not comprehensive. Consequently, to analyze the results, four principal components were included in the study, which accounted for 61.8% of the variance in the ratings.

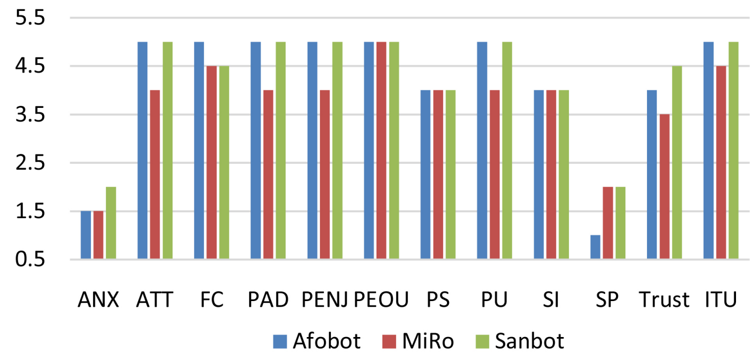

Figure 4. Median Almere construct score for the three robots.

Table 9. Related samples Friedman's tests (Q) to compare the 12 construct scores for the three personal robots (with post-hoc comparisons).

Construct	Q statistic	probability	Significant post-hoc Comparisons (p)
ANX	26.58	0.00	Afobot-MiRo (0.00) MiRo-Sanbot (0.00)
ATT	7.16	0.03	MiRo-Sanbot (0.03)
FC	13.82	0.00	Afobot-MiRo (0.03) Afobot-Sanbot (0.00)
PAD	27.49	0.00	MiRo-Sanbot (0.00) MiRo-Afobot (0.00)
PENJ	5.40	n.s.	n.s
PEOU	17.33	0.00	Sanbot-MiRO (0.02) Sanbot-Afobot (0.01)
PS	2.86	n.s.	n.s
PU	32.49	0.00	MiRo-Sanbot (0.00) MiRo-Afobot (0.00)
SI	8.55	0.01	MiRo-Sanbot (0.23) MiRo-Afobot (0.03)
SP	25.39	0.00	Afobot-Sanbot (0.03) Afobot-MiRo (0.00)
Trust	76.80	0.00	MiRo-Afobot (0.00) MiRo-Sanbot (0.00) Afobot-Sanbot (0.00)
ITU	1.27	n.s.	n.s

As shown in **Table 10**, there were eight items included in Component I, and was labelled Anxiety about interacting with robots (ANX_INT); Component II has four items and was labelled Comfort with robots (R_COMF); Component III has four items and was labelled Anxiety about conversing with robots (ANX_CONV); Component IV has five items and was labelled Anxiety about robot influence (R_INF). A total of 21 items are included in Components I, II, III, and IV. In addition, four items do not meet the conditions to be included: Q7_1, Q7_3, Q7_12, Q8_1.

Table 10. Principal Components Analysis (PCA) on the items from the NARS and RAS.

Construct	Component I	Component II	Component III	Component IV
Q7_1: I would feel uneasy if I had been given a job where I had to use robots.	0.340	−0.222	−0.057	0.480
Q7_2: I would feel comforted being with robots that have emotions.	0.317	0.771*	−0.076	−0.258
Q7_3: The word "robot" means nothing to me.	0.199	−0.296	−0.072	0.073
Q7_4: If robots had emotions, I would be able to make friends with them.	0.025	0.879*	−0.032	0.108
Q7_5: I would feel nervous interacting with a robot in front of other people.	0.562*	−0.019	0.009	0.286
Q7_6: I would feel relaxed talking with robots.	−0.382	0.576*	−0.068	−0.279
Q7_7: I hate the idea that robots or artificial intelligences are making judgements about things	−0.035	−0.111	−0.240	0.719*
Q7_8: I feel that in the future society will be dominated by robots.	0.083	0.559*	0.188	0.428
Q7_9: I would feel nervous just standing in front of a robot	0.657*	−0.136	0.207	0.214
Q7_10: I am concerned that robots would be a bad influence on children.	−0.021	−0.019	−0.104	0.698*
Q7_11: I would feel paranoid talking with a robot.	0.295	−0.255	−0.010	0.547*
Q7_12: I would feel uneasy if robots really had emotions.	0.110	−0.239	−0.034	0.297
Q7_13: I feel that if I depend on robots too much, something bad might happen.	0.263	0.003	0.004	0.617*
Q7_14: Something bad might happen if robots developed into living beings.	−0.012	0.119	−0.078	0.684*
Q8_1: A robot might talk about irrelevant things in the middle of a conversation	0.412	0.225	−0.379	−0.017
Q8_2: Whether I would understand what a robot is talking about.	0.311	−0.034	−0.531*	−0.025
Q8_3: A robot might not be flexible in following the direction of a conversation.	−0.073	−0.045	−0.917*	0.134
Q8_4: Whether a robot would understand what I am talking about.	0.088	−0.058	−0.868*	0.040
Q8_5: A robot might not understand difficult conversation topics.	−0.032	0.066	−0.887*	0.140
Q8_6: How I should respond when a robot talks to me.	0.696*	−0.088	−0.182	−0.059
Q8_7: The kind of movements a robot might make.	0.760*	−0.054	−0.053	0.110
Q8_8: How I should talk to a robot.	0.866*	−0.054	−0.141	−0.137
Q8_9: What a robot might be going to do.	0.646*	0.021	−0.220	0.135
Q8_10: How fast a robot could move.	0.893*	0.148	0.022	−0.043
Q8_11: How strong a robot might be	0.836*	0.089	0.011	0.023

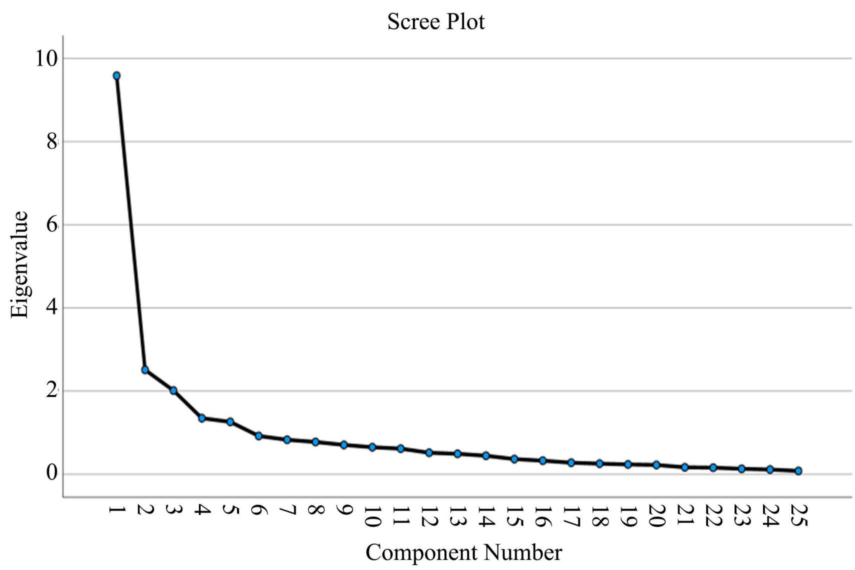

Figure 5. The screen plot of the principal components analysis.

4.4. Relationships between Older People's General Attitudes to Robots and Attitudes to the Three Personal Robots

4.4.1. Relationships between Older People's General Attitudes to Robots and Attitudes to Afobot

Table 11 shows the results of the linear regressions, with the result of the prediction from all variables, and the contribution on each of the combined NARS and RAS components. For all of the 12 Almere constructs, the regression between 9.5% and 38.9% of the variance is in the NARS/RAS components.

Among the 48 components for the relationship between older people's general attitudes towards robots and attitudes to Afobot, there were 21 items found to be significant. Comfort with Robots (R_COMF) was the best predictor, being a significant predictor for 10 of the 12 Almere constructs. Therefore, the Attitude towards technology (ATT), Facilitating conditions (FC), Perceived adaptiveness (PAD), Perceived Enjoyment (PENJ), Perceived Sociability (PS), Perceived Usefulness (PU), Social Influence (SI), Social Presence (SP), Trust, Intention to Use (ITU) were determined by Comfort with Robots (R_COMF). Anxiety about robots influence (R_INF) had the lowest number of predictions, with two items, Anxiety (ANX) and Attitude towards technology (ATT) were predicted by Anxiety about interacting with robots (ANX_INT). In addition, the Anxiety (ANX), Perceived ease of use (PEOU), Perceived Sociability (PS), and Trust of the Afobot was determined by Anxiety about interacting with robots (ANX_INT), which were four items. And the Facilitating conditions (FC), Perceived ease of use (PEOU), Perceived sociability (PS), Social presence (SP), and Trust is determined by Anxiety about conversing with robots (ANX_CONV), which were five items.

4.4.2. Relationships between Older People's General Attitudes to Robots and Attitudes to MiRo

Table 12 shows the 12 Almere constructs, the regression model was significant

Table 11. Principal Components Analysis (PCA) on the items from the NARS and RAS.

Predicting	from				
	Overall	ANX_INT	R_COMF	ANX_CONV	R_INF
ANX	<0.001 23.8%	t = 2.784 sig = 0.006	t = −0.298 n.s.	t = 1.204 n.s.	t = 2.384 0.019
ATT	<0.001 26.0%	t = 1.031 n.s.	t = 5.727 0.000	t = −1.114 n.s.	t = −1.995 0.048
FC	<0.001 13.0%	t = −0.727 n.s.	t = 2.483 0.014	t = −2.279 0.024	t = −0.410 n.s.
PAD	=0.003 9.5%	t = −0.127 n.s.	t = 3.257 0.001	t = −1.789 n.s.	t = 0.408 n.s.
PENJ	<0.001 31.7%	t = 0.348 n.s.	t = 6.693 0.000	t = −1.041 n.s.	t = −1.675 n.s.
PEOU	<0.001 17.0%	t = −2.802 0.006	t = 0.299 n.s.	t = −1.996 0.048	t = −0.293 n.s.
PS	<0.001 33.7%	t = 1.798 0.075	t = 6.885 0.000	t = −3.067 0.003	t = −0.900 n.s.
PU	<0.001 16.2%	t = 0.297 n.s.	t = 4.738 0.000	t = −0.995 n.s.	t = 0.505 n.s.
SI	<0.001 23.0%	t = 1.572 n.s.	t = 5.978 0.000	t = −0.942 n.s.	t = −0.834 n.s.
SP	<0.001 25.8%	t = 1.974 n.s.	t = 6.041 0.000	t = −2.036 0.044	t = −0.881 n.s.
TRUST	<0.001 38.9%	t = 2.558 0.012	t = 7.731 0.000	t = −2.732 0.007	t = −1.789 n.s.
ITU	<0.001 22.5%	t = 0.027 n.s.	t = 6.029 0.000	t = −0.222 n.s.	t = −0.282 n.s.

Table 12. Results of liner regressions predicting Miro Almere construct scores from older people's general attitudes towards robots and attitudes.

Predicting	from				
	Overall	ANX_INT	R_COMF	ANX_CONV	R_INF
ANX	<0.001 15.5%	t = 3.230 0.002	t = 0.403 n.s.	t = 0.046 n.s.	t = 1.439 n.s.
ATT	<0.001 31.0%	t = 1.192 n.s.	t = 7.061 0.000	t = 0.397 n.s.	t = −1.961 n.s.
FC	<0.001 19.4%	t = −2.235 0.027	t = 3.225 0.002	t = −1.576 n.s.	t = −0.095 n.s.
PAD	<0.001 13.9%	t = 0.267 n.s.	t = 4.086 0.000	t = 0.210 n.s.	t = −1.677 n.s.
PENJ	<0.001 30.6%	t = 0.721 n.s.	t = 6.778 0.000	t = −0.017 n.s.	t = −2.030 0.045

Continued

PEOU	<0.001 14.4%	t = −3.714 0.000	t = 0.968 n.s.	t = −0.782 n.s.	t = 0.895 n.s.
PS	<0.001 42.5%	t = 1.809 n.s.	t = 8.666 0.000	t = −0.717 n.s.	t = −2.601 0.010
PU	<0.001 26.1%	t = 1.584 n.s.	t = 5.901 0.000	t = 0.314 n.s.	t = −2.623 0.010
SI	<0.001 27.6%	t = 1.610 n.s.	t = 6.366 0.000	t = −0.333 n.s.	t = −2.034 0.044
SP	<0.001 27.6%	t = 2.003 0.047	t = 6.447 0.000	t = −0.448 n.s.	t = −1.877 n.s.
TRUST	<0.001 36.1%	t = 2.016 0.046	t = 6.486 0.000	t = −1.185 n.s.	t = −3.789 0.000
ITU	<0.001 20.3%	t = 0.683 n.s.	t = 5.350 0.000	t = −0.565 n.s.	t = −1.203 n.s.

in predicting the outcome variable. The linear regressions predicted between 13.9% and 36.1% of the variance in the NARS/RAS components.

Among the 48 components for the relationship between older people's general attitudes towards robots and attitudes to MiRo, there were 20 items found to be significant. Comfort with Robots (R_COMF) was the best predictor, being a significant predictor for 10 of the 12 Almere constructs. Therefore, the Attitude towards technology (ATT), Facilitating conditions (FC), Perceived adaptiveness (PAD), Perceived Enjoyment (PENJ), Perceived Sociability (PS), Perveived Usefulness (PU), Social Influence (SI), Social Presence (SP), Trust, lntention to Use (ITU) were determined by Comfort with Robots (R_COMF). However, there was no finding on the Almere constructs from participants' general robot attitudes of Anxiety about conversing with robots (ANX_CONV). ln addition, the Anxiety (ANX), Facilitating conditions (FC), Social Presence (SP), Trust of the MiRo was determined by Anxiety about interacting with robots (ANX_INT), which were five items. And the Perceived Enjoyment (PENJ), Perceived Sociability (PS), Perveived Usefulness (PU), Social Influence (SI), Trust is determined by Anxiety about robot influence (R_INF), which were five items.

4.4.3. Relationships between Older People's General Attitudes to Robots and Attitudes to Sanbot

Table 13 shows the results of the linear regressions, with the result of the prediction from all variables, and the contribution on each of the combined NARS and RAS components. For all of the 12 Almere constructs, the regression model was significant in predicting the outcome variable. The linear regressions predicted between 11.5% and 46.2% of the variance in the NARS/RAS components.

Among the 48 components for the relationship between older people's general attitudes towards robots and attitudes to Sanbot, there were 16 items found to be significant. Comfort with Robots (R_COMF) was the best predictor, being a

Table 13. Results of liner regressions predicting Sanbot Almere construct scores from older people's general attitudes towards robots and attitudes.

Predicting	from				
	Overall	ANX_INT	R_COMF	ANX_CONV	R_INF
ANX	<0.001 46.2%	t = 6.691 0.000	t = −1.870 n.s.	t = 0.888 n.s.	t = 2.583 0.011
ATT	<0.001 39.2%	t = 0.017 n.s.	t = 8.070 0.000	t = 0.872 n.s.	t = −2.376 0.019
FC	=0.001 11.5%	t = −1.600 n.s.	t = 1.768 n.s.	t = −1.189 n.s.	t = −908 n.s.
PAD	<0.001 18.0%	t = −0.153 n.s.	t = 4.409 0.000	t = −0.761 n.s.	t = −1.406 n.s.
PENJ	<0.001 42.5%	t = −0.414 n.s.	t = 8.505 0.000	t = 0.303 n.s.	t = −2.173 0.032
PEOU	<0.001 13.4%	t = −3.184 0.002	t = 1.240 n.s.	t = −1.274 n.s.	t = 0.930 n.s.
PS	<0.001 38.7%	t = 0.050 n.s.	t = 7.981 0.000	t = −1.184 n.s.	t = −1.250 n.s.
PU	<0.001 30.0%	t = 0.205 n.s.	t = 6.480 0.000	t = 0.385 n.s.	t = −2.236 0.027
SI	<0.001 32.4%	t = 0.672 n.s.	t = 7.298 0.000	t = −0.494 n.s.	t = −1.322 n.s.
SP	<0.001 29.1%	t = 1.061 n.s.	t = 7.030 0.000	t = −0.810 n.s.	t = −0.611 n.s.
TRUST	<0.001 37.4%	t = 1.812 n.s.	t = 7.436 0.000	t = −1.438 n.s.	t = −2.620 0.010
ITU	<0.001 34.9%	t = −0.395 n.s.	t = 7.382 0.000	t = 0.115 n.s.	t = −1.641 n.s.

significant predictor for 9 of the 12 Almere constructs. Therefore, the Attitude towards technology (ATT), Perceived adaptiveness (PAD), Perceived Enjoyment (PENJ), Perceived Sociability (PS), Perveived Usefulness (PU), Social Influence (SI), Social Presence (SP), Trust, lntention to Use (ITU) were determined by Comfort with Robots (R_COMF). However, there was no finding on the Almere constructs from participants' general robot attitudes of Anxiety about convers-ing with robots (ANX_CONV). In addition, the Anxiety (ANX) and Perceived Ease of Use (PEOU) of the Sanbot was determined by Anxiety about interact-ing with robots (ANX_INT), which were two items. And the Anxiety (ANX), Attitude towards technology (ATT), Perceived Enjoyment (PENJ), Perveived Usefulness (PU) and Trust was determined by Anxiety about robot influence (R_INF), which were five items.

In summary, Table 14 shows that there were some interesting findings that Comfort with Robots (R_COMF) is a very good predictor of attitudes to Afobot

Table 14. Related samples Friedman's tests (Q) to compare the 12 construct scores for the three personal robots (with post-hoc comparisons).

Construct	ANX_INT	R_COMF	ANX_CONV	R_INF
Afobot	4	10	5	2
MiRo	5	10	0	5
Sanbot	2	9	0	5
Overall	11	29	5	12

and MiRo, predicting 10 out of 12 Almere constructs. And the Anxiety about conversing with robots (ANX_CONV) was the worst predictor construct of attitudes to MiRo and Sanbot, there was none predictor out of 12 Almere constructs. Moreover, Comfort with robots (R_COMF) was the best predictor construct overall, being a significant predictor in 29 cases out of a possible 36 (80.5%), And the Anxiety about conversing with robots (ANX_CONV) was the worst predictor construct overall, being a significant predictor in only 5 cases. In addition, Anxiety about interacting with robots (ANX_INT) was significant in 11 cases overall, and Anxiety about robot influence (R_INF) in 12 cases overall.

5. Discussion and Conclusions

5.1. Discussion

The analysis of the individual characteristics of the 126 older people was recruited from UK showed that a large number of older people were currently retired and they were not working. And most older people were very well educated and confident in using computer software and using the internet. However, the most of the older people have no experience with personal robots, and the few older people who do have experience with robots report that robotic vacuum cleaner, robotic lawn mower, virtual assistant (Alexa, Siri etc), robotic mop, and robotic swimming pool cleaner were the types of robots they had used before. Also, when surveying older people about their initial thoughts on robots, they only mentioned the Vacuum cleaner the most times and did not pay much attention to other types of robots. Furthermore, they also mentioned about robots can do household chores and perform tasks to assist people in their daily lives that they wanted the robot can be personalised to be able to meet their individual needs.

The first research question that older people's attitudes towards robots are influenced by the type of robot is confirmed. The Almere model was used to measure the participants' attitudes towards three different types of robots in the study. The results showed that the participants feel little anxiety and the presence of social entities about Afobot, Sanbot and Miro. In addition, compared to the Miro robots, participants had a more positive attitudes and a pleasant feelings toward the Afobot and Sanbot robots, and found these robots more useful and convenient, and more adapted to the users' needs. Participants even showed more intention to use Afobot and Sanbot in the longer period of time. However, participants had a neutral attitude about the Miro's use, perceived ability to adapt to the needs of the users, usefulness and convenience.

The explanation for these results is probably that both Afobot and Sanbot have operable touch screens and a wide range of different functions to assist not only with the health aspects of older people, but also by providing assistance with their daily needs. For example, reminders of important matters, connect with family and friends via voice or video calls quickly, play music and weather, etc. And while MiRo is cute and has the appropriate features for a pet, it does not provide a wide range of support for older people in their daily lives. As stated in the study by [27], older people have many daily tasks and needs at home that they would like the robots to help with.

The NARS and RAS were used to measure the older people's general attitudes, and a principal components analysis was conducted on a total of 25 items from the NARS and RAS questionnaires, with four influential components were extracted. Therefore, the second research question found that the general attitudes of older people towards personal robots can be summarized by four components Anxiety about interacting with the robot (ANX_INT), Comfort with robots (R_COMF), Anxiety about conversing with robots (ANX_CONV), Anxiety about robot influence (R_INF).

The third research question asked "What are the relationships between older people's general attitudes to robots and attitudes to the three personal robots types?". To investigate this, I conducted a series of linear regression analyses for each robot type and predicted scores on the Almere constructs from participants' general robot attitudes of four components derived from Negative Attitudes towards Robots Scale (NARS) and Robot Anxiety Scale (RAS) ratings, which were ANX_INT, R_COMF, ANX_CONV, R_INF. The results showed that Comfort with robots (R_COMF) was the best predictor construct. The Afobot's Attitude towards technology (ATT), Facilitating conditions (FC), Perceived adaptiveness (PAD), Perceived enjoyment (PENJ), Prceived sociability (PS), Perceived Usefulness (PU), Social influence (SI), Social Presence (SP), Trust, Intention to use (ITU) were predicted by Comfort with robots (R_COMF), which the same as MiRo's results. However, compared to Afobot and MiRo, the Facilitating conditions (FC) of Sanbot was not determined by Comfort with robots (R_COMF).

5.2. Limitations

Firstly, I have only collected data on the older population in the UK, which is not representative of all older population groups. For example, the three robots used in my study whether developed the same results of older people from other countries. Furthermore, as mentioned in the literature review in Section 2.3, older people's attitudes towards robots were influenced by the stakeholders involved. However, it was only the older population that was studied in my research. Secondly, because of the video size limitation on the Qualtrics platform, the participants had to click on the robot videos link in the questionnaire to watch the video on YouTube, however, they were distracted by the advertisements while watching the video. Therefore, it was uncertain whether the participants' emotions would be affected by these complicated procedures and distractions materials, which would affect the results of the study. Besides, I used only these three types of robots (Afobot, Sanbot, MiRo) in my research, but it is uncertain whether older people have the same attitudes toward the other different types of robots. Finally, the participants watched the three robot videos were provided in the questionnaire online, which are hardly comparable to the experience of using a real robot.

5.3. Conclusions

The robots have started to appear in people's lives, and it brought a lot of convenience to people's daily life. In particular for older people, the robots provided assistance with their health and also provided great support in their lives. However, there is currently not a very clear understanding on attitudes of older people towards personal robots. And even not clear whether older people's attitudes toward robots are influenced by the robot type, what are the general attitudes of older people toward personal robots and what are the relationships between older people's general attitudes to robots and attitudes to the three personal robots types? Therefore, I conducted a study on these research questions.

This study recruited 126 older people over the age of 65 from the UK, and three different types of robot videos (a pet robot: Miro, a humanoid robot: Sanbot, tabletop robot: Afobot) which the robots from the current mainstream market were used for older people to watch in the survey. Then, I used the Almere model to measure the older people's attitudes toward robots and used the Negative Attitude Scale towards Robots (NARS) and Robot Anxiety Scale (RAS) to measure older people's general attitudes toward robots in the questionnaire.

The results of the study showed that robots are still very new to older people and that they also do not have widespread use of robots like tabletop robots, humanoid robots and pet robots in their lives. However, it was surprised found that older people have positive attitudes towards tabletop robots (Afobot), humanoid robots (Sanbot) and pet robots (Miro). In particular, compared with the pet robot, Miro, they showed more positive attitudes and pleasurable feelings towards the Sanbot and Afobot, and find that Sanbot and Afobot were more useful and convenient, they showed more intention to use them in the longer period of time. In addition, the general attitudes of older people towards personal robots mainly include anxiety about interacting with the robot (ANX_INT), comfort with robots (R_COMF), anxiety about conversing with robots (ANX_CONV), anxiety about robot influence. Finally, it was concluded that comfort with robots (R_COMF) was the best predictor by analysing the relationships between older people's general attitudes to robots and attitudes to the three personal robots types. The attitude towards technology, facilitating conditions, perceived adaptiveness, perceived enjoyment, perceived sociability, perceived usefulness, social influence, social presence, trust, intention to use of Afobot were predicted by comfort with robots, which is the same as Miro's results. However, compared to Afobot and Miro, the facilitating conditions of Sanbot were not determined by comfort with robots.

Conflicts of Interest

The author declares no conflicts of interest.

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