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SHORT PAPER

Elderly's acceptance of companion robots from the perspective of user factors

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Abstract
Taiwan has entered the aged society in March 2018, meaning that more social and technological resources are needed to solve the problems related to the elderly's companion service. Companion robots are considered a solution to effectively meet the elderly's service needs for family escort. However, little is known about the elderly's acceptance of companion robots. The purpose of this study is to explore the elderly's acceptance of companion robots from the perspective of user factors. The research was carried out by a mixed method of interviews and questionnaires. Independent sample *t* test and one-way analysis of variance were used for analysis. The results showed that there were significant differences in the attitude and perceived usefulness of companion robots in terms of education level, living conditions, professional background and technical experience. The research found that the elderly living with parents, with master's (or doctor's) education, medical professional background and experience in the use of scientific and technological products expressed more positive attitudes in the responses to the items on the constructs of attitude and perceived usefulness, while the attitude of those with primary school education and humanities professional background, with no experience in scientific and technological products, was relatively negative. Research shows that the acceptance of companion robots by the elderly was affected to some extent by user factors. These findings can provide reference for robot designers, industrial designers and other researchers.

Keywords Companion robot · The elderly · Acceptance · User factors perspective · Taiwan

1 Introduction

1.1 The elderly in Taiwan

According to the World Health Organization report, the population around the world is ageing rapidly with the increase in people's life expectancy and the decline of birth rate [1]. According to the Taiwan Population Estimation Report [2], Taiwan entered an ageing society in 1993 (with the elderly population accounting for more than 7% of the total population) and entered an aged society (with the elderly population accounting for more than 14% of the total population) in March 2018. Taiwan is expected to become a super-aged society (with the elderly population accounting for more than 20% of the total population) by 2026. At the same time, it is estimated that there will be only 50,000 births in 2065 and the problem of super-replacement fertility will be very serious. In addition, according to data from the Ministry of Health and Welfare, Taiwan, in 2015 there were 183.851 foreign caregivers in Taiwan's families [3], mainly from Southeast Asian countries such as Indonesia, Philippines and Vietnam. However, the population of Southeast Asia and other countries is also facing an ageing situation. This shows that Taiwan, where ageing and super-replacement fertility are serious, will face the same shortage of labour as western countries.

Under the background of ageing, super-replacement fertility and labour shortage in Taiwan, in order to solve the problem of labour shortage caused by ageing, we need not only more nursing service personnel but also more high-tech products [4], such as developing home intelligent solutions

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including medical care and family companions [5]. In recent years, social robots such as companion robots have been regarded as an effective solution to meet the family service demand brought about by ageing, thus arousing the attention of academia and industry [6–8]. Therefore, it is of certain practical significance to study the Taiwan's elderly's acceptance of companion robots.

1.2 The concept of companion robots

In Broekens et al. [9] and Robinson et al. [10], assistive robots for elderly were clearly divided into two categories, including rehabilitation robots and socially assistive robots. Rehabilitation robots are mainly devices that provide physical rehabilitation assistance to the elderly, such as intelligent wheelchairs [11]. Socially assistive robots are mainly robots that can communicate with users [9], including service-type robots and companion-type robots [9–11]. Service robots are auxiliary devices that assist, guide and remind elderly people in their daily life (such as eating and dressing) or going out for activities (such as navigation) in order to ensure the basic living needs and finally realize an independent and dignified life for the elderly [9]. Companion robots are robots that depend entirely on their own social ability [10]. Their main function is to improve users' physical and mental health level [9], such as Paro, a robot resembling a seal. However, the boundary between service robots and companion robots is not very clear. Some robots can sometimes be either service robots or companion robots, such as Aibo [9, 12].

Companion robots are machines that can understand and communicate in a manner similar to human communication (e.g. touch, hearing, etc.) [13]. They are usually designed to resemble pets and are presented in the form of animals, etc. and mainly used to improve the mental health of users [11]. Companion robots can also provide some help to the elderly, such as helping them remember appointments [14]. At the same time, some studies also argue that it is a good companion device [5, 14–18], which will help the elderly to live independently for a longer time and reduce their loneliness [19]. The most representative companion robot is Paro, which is a seal-shaped bionic robot [20, 21], wrapped in white fur, with a weight of about 2.7 kg and size of about 0.25 m. It was launched for sale in 2008 and was developed by the Institute of Intelligent Systems (ISRI) of the National Institute of Advanced Industrial Science and Technology (AIST), Japan [22]. Its main function is to provide psychological comfort, physiological activation, communication and company to the elderly [19]. Touch sensors and infrared sensors are embedded inside, which enable it to respond to changes in the external visual and auditory environment, move like seals and make cute sounds of young seals [9]. It has been widely used in the testing of applications and services for the elderly. For example, McGlynn et al. [23] used 30 senior citizens as research subjects. Through videos of senior citizens and Paro and semi-structured interviews, it was found that senior citizens think Paro is useful to themselves and others. Research shows that Paro may become one of the ways to provide social or emotional support for senior citizens. Robinson et al. [10] compared the robot Paro with the robot Guide in their study. Through the interactive experience of people with dementia, their families and medical staff, the study found that Paro increased their interaction with each other and the interaction between the elderly and the robot Paro, while the number of smiles and conversations was also significantly higher than that of Guide. They gave Paro a higher evaluation. The study found that Paro was more acceptable for patients, their families and their medical staff. In addition, Zsiga et al. [24] also conducted acceptance tests and evaluations of companion robots. They tested the use of companion robots for a total of 758 days with eight single elderly people in a real home environment. The acceptance and practicability of companion robots for single elderly people were tested from three aspects of satisfaction, usability and reliability. The research found that the acceptance of robots by the subjects was very good, especially for those elderly people who had no computer experience before. The research shows that companion robots can become real partners in the elderly's home life.

1.3 The elderly's acceptance of robots

At present, academic circles have conducted many studies on the users' acceptance of robots. For example, Prakash and Rogers [25] studied the perception and attitude of the elderly towards robots through the similarity of robot faces with 32 elderly people as the samples. Wu et al. [15] conducted a survey on the cognition and attitude of social robots among 20 elderly people with mild cognitive impairment. They found that such robots are not of great significance to the people in their current physical condition for the time being, but may be helpful in the future. Chen et al. [26] studied the acceptance of robot partners among 16 healthy elderly people. They found that these people generally accept robot partners as useful and comfortable; however, the study was carried out in a controlled environment. Xu et al. [5] used prototype robots as experimental materials to study users' needs and attitudes from the multi-generation perspective of the same family. It was found that family members of all ages hope that home robots could help with household chores. However, the study did not discuss the change of the attitude towards a robot due to the age difference of a single ethnic group. Cortellessa et al. [27] studied the acceptance of robots in Italy and Switzerland. The research shows that both Italians and Swedes want to have a robot for emergency use, although robots should not look like human beings. At the same time, Swedish interviewees also worry that they

may rely entirely on robots and lose their autonomy and independence.

The traditional view is that the elderly are unwilling, unable or even afraid to use scientific and technological products [11], and even their attitude towards scientific and technological products such as robots decreases with the increase in their ages [28]. However, some studies show that when the elderly realize that scientific and technological products are convenient and useful, their acceptance of scientific and technological products will increase [29]. Broad Bent et al. [30] investigated the effectiveness of the robot iRobi in providing telemedicine care and in the satisfaction of the elderly. Twenty-five elderly people with chronic obstructive pulmonary disease said that robots did not bring about significant changes in their lives, but they can improve adherence to medication to a certain extent and increase their exercise. Meanwhile, the study of Mitzner et al. [31] found that the elderly are positive about the scientific and technological products currently being used. In addition, Smarr et al. [32] conducted a research on the priority and acceptance of assistive robot technology products in daily life tasks by 21 elderly people through questionnaires and structured interviews. The results show that the elderly people have higher acceptance of medical reminders, laundry and other help provided by robots, while they have lower acceptance of personal care assistance provided by robots, such as hairdressing. This finding has good reference value for the functional development of follow-up robots.

The lack of user experience in product use may be one of the reasons why people feel "fear" about robots [33]. Koay et al. [34] stated that people's acceptance of robots would gradually increase with the passage of time and the increase in product use experience. Czaja et al. [35] mentioned that users' educational level and technical experience are also factors affecting their acceptance of new scientific and technological products. Older people may have more difficulties in using technology equipment because of their lower educational level or less experience in using scientific and technological products than younger people who receive more education [36]. However, the study did not explore the impact of differences in educational level and technical experience among older people on their acceptance. At the same time, the concept of robots originated from outer space exploration, movies (such as Star Wars, Transformers), novels and cartoons may also affect the way people interact with robots in real life and the degree of acceptance [11, 37]. The Almere Model is an acceptance model adapted from the Unified Theory of Acceptance and Use of Technology (UTAUT) [38]. The Almere Model was developed to test the acceptance of social assistance technology products by the elderly. Based on the implementation of non-physical tasks, the model found that age has a significant impact on the intention and attitude towards using social assistance robots for non-physical tasks, especially in the aspects of attitude, perceived usefulness, etc. However, the Almere Model does not take user factors such as education level and gender into consideration [39], and these factors should be considered as comprehensively as possible.

The research results show that acceptability is also a key determinant of users' acceptance or rejection [40]. According to the above research, some robotic acceptance studies hardly take into account the important aspect of user factors. A few are only studied from the perspective of individual factors, considering only one or a very small number of demographic variables. In addition, little is known about the consideration of demographic variables such as professional background, occupation background and living conditions. However, in real life, the elderly are affected by more user factors when buying or evaluating robot products. In addition, due to the differences between various regions and cultures, people in Taiwan and the rest of the world may also have different views and attitudes towards the same thing. Apart from Chang et al. [41] on robot users' voice preferences in Taiwan, no research on robot users' acceptance in Taiwan has been found, especially for the elderly. Therefore, under the social background of Taiwan's ageing, super-replacement fertility and labour shortage, it is of practical significance to explore the acceptance of companion robots by Taiwan's elderly people under the culture that is different from Japan, the USA and Germany. According to the above discussion, there are many factors that affect the acceptance of products by users, but this study only discusses the perspective of user factors. This study attempts to explore the individual attributes of user factors on the user acceptance of companion robots and the influence of user factors on elderly's acceptance of companion robots. More specifically, this study intends to discuss the influences of educational level, professional background, occupation background, living status, gender, age and experience in using scientific and technological products of elderly in Taiwan, on their acceptance of companion robots. The findings are expected to provide a comprehensive understanding of elderly's acceptance of companion robots in Taiwan from the perspective of user factors, in order to offer targeted reference for the designers as well as the research and development institutions of companion robots, and in turn, enhance the elderly's acceptance of companion robots.

2 Method

This study mainly includes two stages: semi-structured interviews in the early stage and a questionnaire survey in the later stage. The study site was Taipei, Taiwan. Interviewers and questionnaire respondents were all selected from public places such as MRT stations, parks, residential areas and

markets. The inclusion criteria for questionnaire respondents were local Taiwanese elderly, over 60 years old, and able to communicate with the researchers fluently. During the initial period of the interviews, the researchers found that although the elderly were willing to participate in the survey, when the researchers asked for their consent for photographic recording, they appeared to be hesitant. Thus, in order to protect the privacy of the participants, reduce their sense of defence and facilitate them to provide honest answers, all interviews and questionnaires were kept confidential, and no photographs were taken. Oral consent was obtained from the participants for both the semi-structured interviews in the first stage and the questionnaire survey in the second stage. The participants understood the motivation of the research and expressed their willingness to support the interview and research. Most of the participants accepted the facial tissues or pens we gave away free of charge.

2.1 Semi-structured interviews

In the early stage of this study, we conducted six semi-structured interviews at Shuiyuan Market, Gongguan Station, Daan Park Station, Zhongxiao Fuxing Station and Daan Forest Park in Taipei, Taiwan. The senior citizens who participated in the interview ranged in age from 66 to 75, with an average age of 69.5 years, including four males and two females, with each interview lasting approximately 10 min. The interview was conducted around the following themes: (A) Do you know the companion robot? (B) Can you accept robots to accompany you? (C) Will you buy a companion robot someday in the future? (D) What user factors do you think should be considered in designing companion robots for elderly users? The preliminary results of semi-structured interviews provided some basis and reference for the design of the questionnaire in the second stage.

2.2 Questionnaire survey

In order to evaluate the acceptance of robots by the elderly more comprehensively, besides the semi-structured interview method in the first stage, this study also adopted the questionnaire survey method. In the design of the questionnaire items and options, we first sorted out the main answers according to the feedback from the early semi-structured interviews and extracted and summarized the keywords from the main answers, thus obtaining the information on the residential conditions, occupation, professional background, education, age and other demographic factors, as well as positive and negative acceptance attitudes of the elderly. Then, we referred to the personal factors such as educational level [42], technical experience [42, 43], gender [44] and age [19], which affect the acceptance of robots by the elderly, as pointed out in the relevant literature. For example, Heerink [42], after playing a film to the subjects, conducted a questionnaire survey and found that gender, age, education and computer experience are four factors of relevance to the acceptance of robots by the elderly. Based on the above interviews and research findings, the topic selection for the personal user factor part of this research questionnaire was designed. Finally, reference was made to Almere Model, which is an acceptance model adapted from the Unified Theory of Acceptance and Use of Technology (UTAUT) [38]. According to the Almere Model [38, 45], attitude refers to positive or negative feelings about the application of technology. It is pointed out that the positive or negative attitude of users will affect their interaction with robots [38, 46], as well as their acceptance of robots [19, 47]. It has a significant impact on the use intention and is a key factor affecting acceptance [38, 45, 47, 48]. Attitude and perceived usefulness are very important for predicting the acceptance of robots and technical products [45, 47] and are closely related to the acceptance theme of this study. In addition, in previous interviews, the elderly were more concerned with usefulness. Therefore, this study adopted the two constructs of attitude and perceived usefulness in the Almere Model, which have a particularly significant impact on acceptance. Each construct has three items, and the questionnaire items are shown in Table 1. During the survey, the participants used a 5-point Likert scale to score (1 = absolutely cannot accept, 5 = absolutely can accept). It should be pointed out that since the elderly did not have a neutral answer to the attitude of companion robots in the first-stage semi-structured interview, and there were some weak positive responses such as “may” and “should”, the middle option of this research questionnaire was set to “May accept”. It should also be noted that before the questionnaire

Table 1 Questionnaire Items

Items
Gender
Age
Education level
Professional background
Occupation background
Living conditions
Technical experience
I think it’s a good idea to use the companion robot[a]
The companion robot would make life more interesting[a]
It’s good to make use of the companion robot[a]
I think the companion robot is useful to me[b]
It would be convenient for me to have the companion robot[b]
I think the companion robot can help me with many things[b]

[a]Item of the construct of attitude

[b]Item for the construct of perceived usefulness

was filled in, the researchers explained to the participants the motive of the survey and gave them oral introduction of the companion robot. At the same time, the researchers supplemented it with some simple body and facial expressions. (These actions are aimed at deepening the understanding of the elderly on the companion robot.) It is worth mentioning that during the survey, because some elderly people have poor eyesight, the researchers informed the participants orally of the questionnaire information, and then, the researchers filled in the answers on behalf of the participants according to their answers. A total of 148 valid questionnaires were collected in this survey, from 87 male and 61 female respondents.

The data were analyzed by IBM SPSS Statistics version 25. First of all, we calculated the reliability of the questionnaire Cronbach's alpha [49]. The result shows that the score is 0.941, exceeding 0.7, thus indicating a high reliability. At the same time, we also calculated Cronbach's alpha of the reliability of a single construct, and the internal consistency reliability of the attitude scale ($\alpha = .861$) and perceived usefulness scale ($\alpha = .893$) was also high. Then, we made descriptive statistics such as mean and percentage and applied independent samples t tests and one-way analysis of variance method.

3 Results

3.1 Semi-structured interview results

In the six semi-structured interviews, the researchers conducted four question interviews with senior citizens.

Table 2 Summary of interview themes and main answers

Themes	Main answers	Keywords
Do you know the companion robot?	"It seems that I have heard of it" (Female, age 66) "I have seen it on TV" (Male, age 75) "Never heard of it" (Male, age 68)	On TV (product promotion approach)
Can you accept robots to accompany you?	"I can't accept it because I prefer the company of my children" (Male, age 75) "I am a doctor, and I think companion robots are very important to my patients. Of course, I also need similar companion products, so my patients and I can accept them" (Male, age 68) "I don't have any children with me right now. If I have a robot with me, I may accept it, because then I might not be so lonely" (Female, Age 71) "I may accept a robot, but my wife will definitely not accept it" (Male, age 69)	Doctors, patients (occupational conditions) Without children as companions, Loneliness Cannot accept Very important Very much needed Can accept May accept Absolutely cannot accept
Will you buy a companion robot someday in the future?	"I will buy it, as I want to experience this amazing robot" (Male, age 68) "I will consider buying it for my wife and parents so as to better accompany them, because I visit them once a week at my parents' house" (Male, age 69) "I'm only 66 years old now, and I won't buy a robot to accompany me. When I'm 80 years old, I am likely to purchase it if necessary (Female, age 66)	Once a week Parents' home (living condition) 66 years old, 80 years old (different ages) Spouses, parents (product users) Will purchase May purchasing Will not purchase Likely to purchase
What factors do you think should be considered in designing robots for the elderly?	"They must satisfy our preferences before we can accept them" (Female, age 71) "My wife has poor eyesight and is not very literate. I hope they can consider more similar situations" (Male, age 69) "I am a mechanical major, and I hope the companion robot can make us feel the magic of mechanical structure" (Male, age 75) "I hope they can think more about the needs of old people like us. For example, my wife likes small animals and she will be very happy to see them" (Male, age 68)	Illiterate (education) Mechanical specialty (professional situation) Small animals (product modelling) Wife (gender), Preference, Mechanical structure.

Table 2 lists the themes of the interviews and the main answer records. In the interviews, the researchers made a summary record of the main answer contents based on the senior citizens' answers, taking into account the environmental characteristics of the interview sites and time needed for the senior citizens, and further extracted keywords based on these answer records, as shown in Table 2. In the interview answer to the question "Do you know the companion robot?", we mainly got the answers of "Yes, I have heard of it" and "No, I have never heard of it". Interviewers who answered that they had heard of companion robots said they had seen it mainly from TV and other media. In this regard, we further extracted the keyword "product promotion approach". In the question "Can you accept robots to accompany you?", the interviewee mainly considered his or her current living condition, occupation and others (such as patients) and expressed his or her attitude. For example, one of the male interviewees said he could not accept it, and he preferred the company of his children. From the question "Will you buy a companion robot someday in the future?", the researchers obtained information about age, living conditions and so on. In the interviewee's answer, the elderly people answered that they will buy mainly out of curiosity or think that they will only consider buying when they are older and in need. Regarding the question "What user factors do you think should be considered in designing companion robots for elderly users?", a lot of interesting information about the interviewees was obtained. For example, a 68-year-old male hopes to consider his wife's preference for small animals when designing robots. Another 69-year-old male said his wife has poor eyesight and cannot read very well and hopes to take their situation into consideration if a robot is designed for them. Based on the interview records at this stage, we sorted out and summarized the key information such as occupation, living conditions, different ages, product users, professional conditions, education, gender, product modelling and product promotion channels as indicated in Table 2. In addition, in these six interview records, the researchers also recorded and extracted some answers about attitudes in the answers to the question "Can you accept robots to accompany you?"; mainly "Cannot accept", "Very important", "Very much needed", "Can accept", "May accept" and "Absolutely cannot accept", divided into two types of attitudes, negative and positive. Among the answers to the question "Will you buy a companion robot someday in the future? answers like "Will purchase", "May consider purchasing", "Will not purchase" and "Likely to purchase" were mainly extracted. The six interview answers at this stage and their keywords provided an important reference for the follow-up questionnaire.

3.2 Questionnaire survey results

We investigated the elderly's acceptance of companion robots from the user factor, mainly including the aspects of attitude and perceived usefulness. The specific questionnaire results are as follows.

3.2.1 Respondents

A total of 148 valid questionnaires were collected in this survey. In terms of social demography, there were 87 male (58.8%) and 61 female respondents (41.2%). The proportion of males is slightly higher than that of females. The age is mainly between 60 and 69 years old, with 21 (14.2%) over 80 years old. In terms of educational level, 26 (17.6%) have primary school education, 27 (18.2%) have junior high school education, 29 (19.6%) have high school (or higher vocational school) education, 40 (27%) have undergraduate (or junior college) education, and 26 (17.6%) have master (or doctor) education. In terms of living conditions, 23 (15.5%) elderly people live alone, 68 (45.9%) with their spouses, 24 (16.2%) with their children, 17 (11.5%) with their parents and 16 (10.8%) with their children and parents. In terms of professional background, 18 (12.2%) have medical professional background, 39 (26.4%) have humanistic professional background, 26 (17.6%) have engineering professional background, 40 (27%) have science professional background, and 25 (16.9%) have other professional background. At the same time, statistics were also made on their current (or pre-retirement) occupation backgrounds, mainly including education 34 (23%), military 9 (6.1%), civil servants 34 (23%), service staff 40 (27%) and production and technical staff 31 (20.9%). In addition, 129 (87.2%) of the elderly had experience in using scientific and technological products and 19 (12.8%) had no experience in using scientific and technological products.

3.2.2 Attitude towards companion robot

We calculated the average score of items to obtain the scores of attitude and perceived usefulness and then conducted independent sample t test. The results show that there are significant differences in attitude among the elderly with different scientific and technological experiences, with $t(146) = -2.19$, $p = 0.030$. The attitude of the elderly with scientific and technological experience to companion robots ($M = 2.59$, SD = 0.968) is better than that of the elderly without scientific and technological experience ($M = 2.07$, SD = 1.016), as shown in Table 3. In our survey, most of the elderly (87.2%) think they have experience in using scientific and technological products. Among them, 25 (19.4%) expressed an acceptable and totally acceptable attitude towards "I think it's a good idea to use the companion

Table 3 *T*-test of scientific and technological experience on attitude and perceived usefulness

Construct	*M* (SD)		*dt*	*t*	*p*
	Have experience ($N=129$)	No experience ($N=19$)			
Attitude	2.59 (0.968)	2.07 (1.016)	146	−2.189	0.030
Perceived usefulness	2.61 (0.978)	2.09 (0.908)	146	−2.202	0.029

robot", while 32 (24.8%) of the elderly chose a "may accept" attitude. The majority (78.9%) of the elderly who have no experience in the use of scientific and technological products expressed unacceptable and totally unacceptable negative attitudes towards them. In addition, nearly half (48%) of those with scientific and technological experience expressed the positive attitude of "may accept, can accept or absolutely can accept" in the reply of the item "The companion robot would make life more interesting ". The elderly with no experience in science and technology did not express the attitude of "absolutely can accept", but the proportion of them choosing "may accept or can accept" reached 31.6%.

We used the one-way analysis of variance test method, and the analysis results are shown in Table 4. The results show that there is a significant difference in attitude construct among the elderly with different living conditions (F (4, 143) = 2.62, $p = 0.038 < 0.05$). Bonferroni's post hoc test shows that the elderly people living with their parents ($M = 3.24$, SD = 1.01) had a significantly higher acceptance attitude towards robots ($p = 0.029$) than those living with their spouses ($M = 2.44$, SD = 0.88). There was no significant difference between those elderly living with their parents and living alone ($p = 0.12$) and no significant difference between those living with their parents and those living with their children ($p = 0.056$). The results show that nearly 80% (76.5%) of the elderly living with their parents have chosen the positive attitude of "absolutely can accept, can accept or may accept" to the item "The companion robot would make life more interesting", while 43.4% of the elderly living alone have chosen a similar attitude. However, 66.6% of the elderly people living with their children expressed the negative attitude of "absolutely cannot accept or cannot accept". Less than 20% of the elderly people living with their parents expressed the negative attitude of "cannot accept or absolutely cannot accept" to the item "It's good to make use of the companion robot", while such an attitude exceeded 50% of the elderly in most other living categories.

The research results show that there were significant differences in the attitude towards companion robots among different professional backgrounds (F (4, 143) = 4.22, $p = 0.003 < 0.05$). The Bonferroni's post hoc test showed that the attitude towards companion robots among the senior citizens of medical specialty ($M = 3.13$, SD = 1.13) was significantly higher ($p = 0.006$) than that of science specialty ($M = 2.19$, SD = 0.78), also significantly ($p = 0.037$) higher than humanities specialty ($M = 2.33$, SD = 0.94), see Table 4.

Table 4 ANOVA of user factors in attitude and perceived usefulness

Dependent variable	Source	SS	*df*	MS	*F*	*p*	η_p^2
Attitude	Living conditions	9.759	4	2.440	2.616	0.038	0.068
	Error	133.355	143	0.933			
	Corrected total	143.114	147				
	Professional background	15.124	4	3.781	4.224	0.003	0.106
	Error	127.990	143	0.895			
	Corrected total	143.114	147				
	Educational levels	9.590	4	2.397	2.568	0.041	0.067
	Error	133.524	143	0.934			
	Corrected total	143.114	147				
Perceived usefulness	Living conditions	0.905	4	0.226	2.551	0.042	0.067
	Error	12.679	143	0.089			
	Corrected total	13.584	147				
	Professional background	1.638	4	0.409	4.900	0.001	0.121
	Error	11.946	143	0.084			
	Corrected total	13.584	147				
	Educational levels	10.072	4	2.518	2.733	0.031	0.071
	Error	131.739	143	0.921			
	Corrected total	141.811	147				

The study found that regarding the item "I think it's a good idea to use the companion robot", the proportion of the elderly with medical professional background who chose the positive attitude of "absolutely can accept, can accept or may accept" reached 66.6%, the proportion of the elderly with science professional background was only 25%, and the proportion of the elderly with humanities professional background was only 25.9%. The study also shows that for the item "The companion robot would make life more interesting", the proportion of senior citizens with medical professional backgrounds expressing positive attitudes of "may accept, can accept or absolutely can accept" reached 33.3%, 33.3% and 5.6%, respectively, while the proportion of senior citizens with science professional backgrounds in these attitudes was 30%, 2.5% and 0.0%.

The results also showed that there were significant differences in attitude construct among the elderly with different education levels (F (4, 143) = 2.57, $p = 0.041 < 0.05$), as shown in Table 4. LSD post hoc comparison indicated the acceptance of the elderly with master's (or doctor's) education ($M = 2.90$, SD = 1.07) was significantly higher ($p = 0.011$) than that of the senior citizens with primary school education ($M = 2.21$, SD = 0.86) and also significantly higher ($p = 0.015$) than the senior citizens with secondary school education ($M = 2.25$, SD = 1.06). In addition, the acceptance attitude of the senior citizens with undergraduate education ($M = 2.70$, SD = 0.90) was also significantly higher ($p = 0.044$) than the senior citizens with primary school education. The results show that 18 (69.3%) of the senior citizens with primary school education expressed the negative attitude of "absolutely cannot accept or cannot accept" in terms of the acceptance degree of the item "The companion robot would make life more interesting". However, only 15 (37.5%) of the senior citizens with bachelor's degree (or college degree) and only 10 (38.5%) senior citizens with master's degree (or doctor's degree) have chosen the negative attitude of "absolutely cannot accept or cannot accept". In addition, 15 (51.7%) senior citizens with high school (or higher vocational school) education have chosen the negative attitude "cannot accept".

3.2.3 Acceptance of perceived usefulness of companion robots

The results of the independent sample t-test analysis, as shown in Table 3, indicate that there were significant differences in the acceptance degree of perceived usefulness among the elderly with different scientific and technological experiences, with t (146) = −2.20, $p = 0.029$. The degree of acceptance of perceived usefulness of companion robots ($M = 2.61$, SD = 0.978) for the elderly with scientific and technological experience was higher than that for the elderly without scientific and technological experience ($M = 2.09$, SD = 0.908). Nearly, 30% of the senior citizens with scientific and technological experience chose "may accept" when answering the item "I think the companion robot is useful to me". The proportion of choosing "can accept or absolutely can accept" was also 19.4%, far higher than the 5.3% of the senior citizens without scientific and technological experience.

Since the data did not conform to the homomorphic hypothesis of the variance, an attempt was made to convert the original score into an open root sign. After conversion, it conformed to the homomorphic hypothesis. One-way analysis of variance was used to analyze the effect of living conditions on the construct of perceived usefulness. The results are shown in Table 4. The results showed that there were significant differences in perceived usefulness among different living conditions (F (4, 143) = 2.551, $p = 0.042 < 0.05$). Bonferroni's post hoc test indicates that the elderly living with their parents ($M = 1.78$, SD = 0.32) scored significantly ($p = 0.022$) higher in perceived usefulness than the elderly living with their spouses ($M = 1.53$, SD = 0.27), while there was no significant difference with other living types. The results show that the proportion of elderly people living with their parents who expressed a positive attitude towards the item "I think the companion robot is useful to me" was 70.6%, of which those expressing the attitude of "absolutely can accept" scored the highest among all living types, accounting for 17.6%, while most (61.8%) elderly people living with their spouses chose the negative attitude of "absolutely cannot accept" or "cannot accept". In addition, in the reply of "it would be convenient for me to have the companion robot", 23.5% of the elderly living with their parents chose "absolutely can accept", while none of the elderly living with their children expressed this attitude. More than half of the senior citizens living with their children expressed the negative attitude of "absolutely cannot accept or cannot accept". Also, it is worth mentioning that among the senior citizens living with their spouses, 24 and 23 chose the attitude of "cannot accept" and "may accept", respectively.

At the same time, because the data did not conform to the homomorphic hypothesis of the variance, the original score was tried for square root conversion, and after conversion, it conformed to the homomorphic hypothesis. One-way analysis of variance was used to analyze the effect of professional background on perceptual usefulness construct. The results are shown in Table 4. There were significant differences in perceived usefulness between different professional backgrounds (F (4, 143) = 4.900, $p = 0.001 < 0.05$). Bonferroni's post hoc comparison indicates that the average value of perceived usefulness ($M = 1.73$, SD = 0.36) of senior citizens with medical professional background was significantly higher ($p = 0.020$) than that of senior citizens with science professional background ($M = 1.48$, SD = 0.23). It was also

significantly ($p = 0.015$) higher than that of the senior citizens with humanities background ($M = 1.47$, SD = 0.30). In addition, the average value of the senior citizens with engineering background ($M = 1.68$, SD = 0.29) was significantly ($p = 0.040$) higher than that of the senior citizens with humanities background ($M = 1.47$, SD = 0.30). The research showed that for the item "It should be accepted for me to have the companion robot", the proportion of the elderly with medical professional background who chose "may accept, can accept or absolutely can accept" was 72.2%, far higher than the proportion of 40% with science professional background and 41.1% with humanities professional background. Similarly, the degree of acceptance of "I think the companion robot can help me with many things" among the senior citizens with medical professional background was significantly higher than that of the senior citizens with humanities and science professional background. There were 7 (38.9%) senior citizens with medical professional background who can accept this item. However, there was no senior citizen with a major in science accepting this item. The proportion of senior citizens with a major in science who chose "cannot accept" was 47.5% higher than that of senior citizens with a major in medicine, which was 16.7%.

The results also showed that there were significant differences in perceived usefulness among the elderly with different educational levels (F (4, 143) = 2.73, $p = 0.031 < 0.05$). LSD post hoc comparison showed that the acceptance attitude of the elderly with master's (or doctor's) education ($M = 2.97$, SD = 1.13) was significantly ($p = 0.009$) higher than that of the elderly with primary school education ($M = 2.27$, SD = 0.75) and significantly ($p = 0.023$) higher than that of the elderly with secondary school education ($M = 2.37$, SD = 1.06), which was also significantly ($p = 0.015$) higher than the senior citizens with high school education ($M = 2.33$, SD = 1.00). There was no significant difference between the undergraduate education ($M = 2.72$, SD = 0.86) and the senior citizens with master (or doctor) education ($p = 0.288$). For the acceptance of the item "I think the companion robot is useful to me", data show that 11 (42.3%) of the senior citizens with master's degree (or doctor's degree) expressed a positive attitude "may accept", 3 (11.5%) expressed the attitude "can accept", 4 (15.4%) expressed a positive attitude "absolutely can accept", while only 9 (34.6%) of the senior citizens with primary school degree expressed an attitude of "may accept", while the rest all expressed the negative attitudes "cannot accept" or "absolutely cannot accept". In addition, more than half (62.9%) of the senior citizens with junior high school education also chose the negative attitudes of "cannot accept" or "absolutely cannot accept".

Among the factors of gender, age and occupational background, according to the test analysis, it was found that the elderly in each group did not show statistically significant differences in the acceptance of the related issues of attitude and perceived usefulness of companion robots, but their acceptance of some issues also deserves our attention. For example, the proportion of men and women expressing the attitude "cannot accept" in the answers to all questions posed by the aspects of attitude and perceived usefulness exceeded 1/3 of the category, some even as high as 50%, while the proportion of people choosing "absolutely can accept" was less than 10% of the category. The responses of the elderly with various occupation backgrounds to these questions were mainly concentrated on "cannot accept" and "may accept". In addition, it is worth mentioning that more than 10% of the elderly over 80 years old have chosen "absolutely can accept" in the statements "I think the companion robot can help me with many things", "I think the companion robot is useful to me", "The robot will make life more interesting" and "I think it's a good idea to use the companion robot".

4 Discussion

Due to the increase in the number of elderly people in Taiwan and the serious problem of low birth rate, the demand for accompanying and nursing the elderly is increasing gradually. High-tech products such as robots have great potential in helping the elderly to complete basic tasks and improving emotions. However, people know little about the acceptance of companion robots by the elderly in Taiwan. This study attempted to understand the elderly's acceptance of companion robots from the perspective of user factors. The results show that there were significant differences in the attitude and perceived usefulness of companion robots among the factors of education, living conditions, professional background and technical experience. The study shows that these user factors affected the elderly's acceptance of companion robots to a certain extent. Therefore, when designing companion robots for the elderly, the user factor is a factor that the robot designer needs to fully consider in the research and development process.

Attitude is the key aspect that affects users' acceptance of robots [45, 47]. The attitude aspect in the Almere Model includes three important test items related to attitudes. Understanding users' attitudes through these items is very meaningful to understand their acceptance of scientific and technological products. Perceived usefulness is the key factor that affects users' acceptance [45, 47] and willingness to use [50]. The Almere Model also includes issues related to perceived usefulness. Studying the acceptance degree of user factors in these aspects and items is helpful to understand the acceptance degree of elderly people for companion robots.

As pointed out earlier, technical experience is very important to the acceptance of users, and it is necessary to consider

[51]. The study found that there were significant differences in the constructs of attitude and perceived usefulness among the elderly with different scientific and technological experiences. The study showed that the attitudes of the elderly who had experience in scientific and technological products scored significantly higher than those of the elderly who had no scientific and technological experience in terms of statements such as "I think it's a good idea to use the companion robot", "The companion robot would make life more interesting" and "The companion robot would make life more interesting". For example, regarding the statement "The companion robot would make life more interesting", 48% of the senior citizens with scientific and technological experience expressed positive attitudes of "may accept", "can accept" or "absolutely can accept", while none of the senior citizens without scientific and technological experience expressed the attitude of "absolutely can accept". However, the proportion of elderly people who had no experience in science and technology expressing that they "may accept" or "can accept" also reached 31.6%, which shows that these people agree that companion robots can make life more interesting. However, the majority (78.9%) of elderly people who had no experience in using science and technology products expressed the negative attitudes of "cannot accept" or "absolutely cannot accept" to the statement "I think it's a good idea to use the companion robot". Apart from their lack of experience in the use and guidance of relevant products and technologies, these negative attitudes may also be due to their fear of trying new things and their failure to realize their real demand for the use of scientific and technological products [52, 53] and may also be due to their failure to experience these scientific and technological products and their failure to feel the satisfaction brought about by these scientific and technological products [31]. However, if these participants who did not have scientific and technological experience can have more opportunities to understand and be familiar with robots, their acceptance should be improved. Beer et al. [54] conducted a comparative study on the changes in the acceptance attitude of the subjects before and after familiarizing the subjects with the demonstration and operation of the robot's home functions. The study found that people's cognition of robots has changed. Especially regarding the perceived usefulness of the robot function, the study also pointed out that the participants' perception of product usefulness is also one of the main aspects that affect the degree of acceptance, and the changes of this condition are largely based on the participants' experience of scientific and technological products.

According to Cortellessa et al. [27], elderly people living with their spouses are more likely to accept companion robots than those living alone, because they think robots are of great help to personal safety and as daily medication reminders. However, our research showed that those elderly people living with their parents were more receptive to companion robots than those living with their spouses. For example, in the answer to the statement " The companion robot would make life more interesting", 66.6% of the senior citizens living with their children expressed the negative attitude of "absolutely cannot accept or cannot accept", while 76.5% of the senior citizens living with their parents expressed the positive attitude of "absolutely can accept, can accept or may accept". Elderly people who live with their parents play the role of a son (daughter). At the same time, they are also a member of the group of elderly people. They may think more from the perspective of their parents' needs. Therefore, we may clearly know that elderly people with different living conditions may consider their spouse, parents, children and other family members as some factors in their choice of companion robots besides their own needs, just as the elderly people answered in the interview.

Giuliani et al. [55] conducted a questionnaire survey on 123 elderly people living in Rome, Italy. The results showed that education level is related to people's acceptance of technical solutions to everyday problems, and people's enthusiasm will also decrease with age. However, the focus of that research was to understand the technical acceptance level of elderly people in daily family activities. Therefore, the study did not conduct a more in-depth discussion on the users' attitudes towards robots due to the difference in educational level. Our research showed that there were significant differences in the attitude and perceived usefulness of companion robots among the elderly with different educational levels. For example, the positive attitude of the elderly with primary school education to the statement "The companion robot would make life more interesting" was significantly lower than that of the elderly with undergraduate, master's and above educational levels. The above research results are consistent with the research results of Scopelliti, Giuliani and Fornara [53], that is, the elderly who have only received primary education have more negative attitudes towards companion robots than the elderly who have received higher secondary and higher education. Our research shows that the level of education is also an important factor affecting the elderly's attitude and perceived usefulness towards companion robots. The elderly's acceptance of companion robots increases with the increase in education level.

In the design of robot products, it is necessary to fully consider the occupation background attribute and professional background of product users, because these two factors are also important factors that affect users' attitudes. According to our limited investigation, there is little research on the impact of users' occupation background and professional background on their attitudes towards robots. Our research results indicate that senior citizens with medical professional backgrounds showed the most positive attitude towards companion robots, while senior citizens with

science and humanities professional backgrounds had significantly lower acceptance of robots than senior citizens with medical professional backgrounds. For example, for the statement "I think it's s a good idea to use the companion robot", the proportion of senior citizens with medical professional background who had the positive attitudes "absolutely can accept", "can accept" or "may accept" reached 66.6%, far higher than the proportion of 25% with science professional background and 25.9% with humanities professional background. In addition, there is no statistically significant difference in the analysis of the results of the questionnaire survey for various occupational background factors. According to previous interviews, however, because of their medical care work, they understand more about the shortage of existing human and medical resources and the significance of the robot companion, so they are more likely to have a favourable impression on the robot companion than users of other professions. Just like a 68-year-old male elder said in an interview, "I am a doctor. I think companion robots are very important to my patients. Of course, I also need similar companion products, so I can accept them". Similarly, to the robot attitude study conducted by Turja et al. [56] on men and women representing Finland's medical profession, the results show that men's attitude is the most positive, while women's general attitude is also more positive: They all hold a positive attitude.

Our research shows that the proportion of men and women expressing the attitude "cannot accept" in the answers to all the statements regarding the aspects on attitudes and perceived usefulness exceeded 1/3 of the categories in which they were. Although there were no statistically significant differences in the acceptance of the related items between the attitude and perceived usefulness of companion robots among the elderly in different genders, age groups and occupational background groups, the basic descriptive statistical results show that they are still somewhat unfamiliar with, or even strange with, the novelty of companion robots, though there are also some curiosities that lead to the attitude of "may accept", which is why this study is more valuable. In addition, the positive attitude of the over 80 years old towards "The companion robot would make life more interesting" and other issues also reflects their needs and desires for companion robots, which is consistent with the findings of research on living conditions. That is, the elderly people living with their parents are obviously more positive in their attitude towards accepting the robot and its perceived usefulness than the elderly people in other living conditions. Most of them have shown the positive attitudes of "absolutely can accept", "can accept" or "may accept". This may be because the elderly people living with their parents may also have parents aged over 80 years old. Of course, this interesting problem needs further investigation and verification.

5 Conclusions

Companion robots have great potential in helping the elderly to improve their health and quality of life. The design and use of robots in the future will depend on people's acceptance of them and the ability of robots to meet the needs of the elderly [57]. Therefore, a clear understanding of the elderly users' attitude towards robots can ensure a higher acceptance of robots in the future. This study attempted to understand the elderly's acceptance of companion robots from the perspective of user factors. The main purpose of the study is to explore the impact of the education level, professional background, occupational background, living conditions, gender, age and the experience in using scientific and technological products on the acceptance of the elderly users of companion robots. The research results can provide some valuable references for robot designers in the subsequent design and development of companion robots and ultimately improve the elderly's acceptance of companion robots.

The results showed that there were significant differences in the attitude and perceived usefulness of companion robots in terms of educational level, living conditions, professional background and technical experience. The research showed that these user factors affected the acceptance of companion robots by the elderly to a certain extent. The research shows that those elderly living with parents with a master's (or doctor's) education, with medical professional background and experience in the use of scientific and technological products, expressed more positive attitudes regarding the constructs of attitude and perceived usefulness, while those with primary school education, no experience in scientific and technological products and science and humanities professional background showed relatively negative attitudes. The results also showed that gender, age and occupational background had no statistical significance in attitude and perceived usefulness. The results show that the acceptance of companion robots by older people was affected to some extent by user factors. The findings of this study are helpful for designers to understand the elderly's acceptance of companion robots from the perspective of user factors. The research results should be fully considered by designers during the design and development stage of companion robots, so as to design companion robots that can meet the characteristics and needs of all kinds of elderly and allow them to accept their use and improve the quality of life of elderly users.

This study has the following aspects of novelty. First, the participants were all elderly living in Taiwan. Until now, the elderly on Taiwan have only been individual research subjects in related research [41]. Previous studies

on the elderly were mainly carried out in the USA [39, 58], Europe [24, 59, 60] and other regions. Therefore, this study helps robot researchers to better understand the attitude of the elderly. Then, this study conducted the research on robots for the elderly from a relatively complete perspective of user factors, which is different from the previous studies conducted from the perspective of individual factors [61, 62]. This helps researchers and designers to better understand the relevant factors that affect the elderly's acceptance of robots. Second, the type of robot discussed in this study is the companion robot, which is different from other types of robots such as restaurant service robot [63] and teaching assistant robots [50]. Finally, this study adopted the method of combining semi-structured interview with questionnaire survey, which is different from the research of single method in the existing researches [51]. The results of this study will also provide some references for industrial designers, engineers and related researchers.

However, our research also has some limitations. First of all, the interviewees and the initial questionnaire answers were all from Taipei, Taiwan, which to some extent limits the general applicability of our research results to other cities or countries. In future research, our scope will be expanded to other regions or countries, and at the same time, it may be a topic worthy of discussion to try to make a comparative study of the elderly in Taiwan and other countries or cities. This will involve factors such as regional culture and is a challenging topic. Moreover, our research object has not been specifically targeted at those elderly people with mobility difficulties. In subsequent research, it may be possible to specifically study these elderly people, because it is of great social significance to carry out relevant research on this user group. Second, in the second stage of questionnaire option design, the researchers mainly referred to the positive and negative answers to the robot attitude of the elderly people in the semi-structured interview in the first stage and did not include the option of neutral attitude, which may have a certain influence on the research results. However, this does not affect our understanding of the acceptance of the elderly, and active (positive) and passive (negative) attitudes and feelings are exactly an interpretation of the attitude dimension in the Almere Model [38, 45]. Also, just as in the study of Beer et al. [64], there were only positive and negative options for attitudes in the questionnaire with odd numbers. Then, the difference in the sample size of each group of user factors may affect our research results. For example, the statistical analysis results between the elderly with experience in using scientific and technological products (large sample size) and the elderly without experience in using scientific and technological products (small sample size) may affect the accuracy of the research results due to the difference in sample size between the two groups. In subsequent research, we can try to solve such problems by increasing the sample size. Finally, we did not participate in the whole research process with the companion robot in kind. Participants' understanding of the companion robot mainly depended on the researchers' verbal and physical descriptions before the questionnaire was started. This may lead to the deviation of the elderly's feelings and understanding of the companion robot, thus affecting the results of the research. However, for research regarding advanced science and technology products such as robots, there were also some works that did not involve in kind in the past. For example, Ezer et al. [51] only used the form of mailed questionnaire, which allowed participants in Downtown Atlanta, Georgia, USA, and its surrounding areas to complete the entire questionnaire on the willingness of making machines perform tasks based on their own imagination.

Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

References

1. World Health Organization.: World report on ageing and health. https://www.who.int/ageing/events/world-report-2015-launch/en/ (2015). Accessed 10 Dec 2018
2. National Development Council.: Population estimate of the republic of Taiwan (2018–2065). https://www.ndc.gov.tw/Content_List.aspx?n=84223C65B6F94D72 (2018). Accessed 09 Dec 2018
3. Yan, F., Yuze, C.: Quantity can be improved to build a long-term care system of sustainable development. Commun. Dev. Quart. **153**, 5–18 (2015)
4. Miskelly, F.G.: Assistive technology in elderly care. Age Ageing **30**(6), 455–458 (2001). https://doi.org/10.1093/ageing/30.6.455
5. Xu, Q.L., Ng, J.S.L., Tan, O.Y., Huang, Z.Y.: Needs and attitudes of Singaporeans towards home service robots: a multi-generational perspective. Univ. Access Inf. Soc. **14**(4), 477–486 (2015). https://doi.org/10.1007/s10209-014-0355-2
6. Graf, B., Hans, M., Schraft, R.D.: Care-O-bot II—development of a next generation robotic home assistant. Auton. Robots **16**(2), 193–205 (2004)
7. Esposito, R., Fiorini, L., Limosani, R., Bonaccorsi, M., Manzi, A., Cavallo, F., Dario, P.: Supporting active and healthy aging with advanced robotics integrated in smart environment. In: Artificial Intelligence: Concepts, Methodologies, Tools, and Applications, pp 2656–2686. IGI Global (2017)
8. Vandemeulebroucke, T., de Casterle, B.D., Gastmans, C.: How do older adults experience and perceive socially assistive robots in aged care: a systematic review of qualitative evidence. Aging Ment. Health **22**(2), 149–167 (2018). https://doi.org/10.1080/13607863.2017.1286455
9. Broekens, J., Heerink, M., Rosendal, H.: Assistive social robots in elderly care: a review. Gerontechnology **8**(2), 94–103 (2009)
10. Robinson, H., MacDonald, B.A., Kerse, N., Broadbent, E.: Suitability of healthcare robots for a dementia unit and suggested improvements. J. Am. Med. Dir. Assoc. **14**(1), 34–40 (2013). https://doi.org/10.1016/j.jamda.2012.09.006

11. Flandorfer, P.: population ageing and socially assistive robots for elderly persons: the importance of sociodemographic factors for user acceptance. Int. J. Popul. Res. **2012**, 1–13 (2012). https://doi.org/10.1155/2012/829835
12. Bartlett, B., Estivill-Castro, V., Seymon, S., Tourky, A.: Robots for pre-orientation and interaction of toddlers and preschoolers who are blind. In: Proceedings of the 2003 Australasian Conference on Robotics and Automation, CD-Rom Proceedings, Citeseer, pp. 0–9587
13. Breazeal, C.L.: Designing Sociable Robots. MIT press, Cambridge (2004)
14. Frennert, S., Östlund, B., Eftring, H.: Would granny let an assistive robot into her home? In: International Conference on Social Robotics, pp. 128–137. Springer
15. Wu, Y.H., Cristancho-Lacroix, V., Fassert, C., Faucounau, V., de Rotrou, J., Rigaud, A.S.: The attitudes and perceptions of older adults with mild cognitive impairment toward an assistive robot. J. Appl. Gerontol. **35**(1), 3–17 (2016). https://doi.org/10.1177/0733464813515092
16. Zsiga, K., Edelmayer, G., Rumeau, P., Peter, O., Toth, A., Fazekas, G.: Home care robot for socially supporting the elderly: focus group studies in three European countries to screen user attitudes and requirements. Int. J. Rehabil. Res. **36**(4), 375–378 (2013). https://doi.org/10.1097/MRR.0b013e3283643d26
17. Wu, Y.-h., Wrobel, J., Cornuet, M., Kerhervé, H., Damnée, S., Rigaud, A.-S.: Acceptance of an assistive robot in older adults: a mixed-method study of human–robot interaction over a 1-month period in the Living Lab setting. Clin. Interv. Aging **9**, 801 (2014)
18. Pino, M., Boulay, M., Jouen, F., Rigaud, A.S.: "Are we ready for robots that care for us?" Attitudes and opinions of older adults toward socially assistive robots. Front. Aging Neurosci. **7**, 15 (2015). https://doi.org/10.3389/fnagi.2015.00141
19. Broadbent, E., Stafford, R., MacDonald, B.: Acceptance of healthcare robots for the older population: review and future directions. Int. J. Soc. Robot. **1**(4), 319–330 (2009). https://doi.org/10.1007/s12369-009-0030-6
20. Wada, K., Shibata, T., Saito, T., Tanie, K.: Effects of robot assisted activity to elderly people who stay at a health service facility for the aged. In: Proceedings. 2003 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2003), pp. 2847–2852. IEEE
21. Shibata, T., Tanie, K.: Influence of a priori knowledge in subjective interpretation and evaluation by short-term interaction with mental commit robot. In: Proceedings 2000 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2000), pp. 169–174. IEEE (2000)
22. Wada, K., Shibata, T., Musha, T., Kimura, S.: Effects of robot therapy for demented patients evaluated by EEG. In: IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2005), pp. 1552–1557. IEEE (2005)
23. McGlynn, S.A., Kemple, S., Mitzner, T.L., King, C.H.A., Rogers, W.A.: Understanding the potential of PARO for healthy older adults. Int. J. Hum. Comput. Stud. **100**, 33–47 (2017). https://doi.org/10.1016/j.ijhcs.2016.12.004
24. Zsiga, K., Toth, A., Pilissy, T., Peter, O., Denes, Z., Fazekas, G.: Evaluation of a companion robot based on field tests with single older adults in their homes. Assist. Technol. **30**(5), 259–266 (2018). https://doi.org/10.1080/10400435.2017.1322158
25. Prakash, A., Rogers, W.A.: Why some humanoid faces are perceived more positively than others: effects of human-likeness and task. Int. J. Soc. Robot. **7**(2), 309–331 (2015). https://doi.org/10.1007/s12369-014-0269-4
26. Chen, T.L., Bhattacharjee, T., Beer, J.M., Ting, L.H., Hackney, M.E., Rogers, W.A., Kemp, C.C.: Older adults' acceptance of a robot for partner dance-based exercise. PLoS ONE **12**(10), 29 (2017). https://doi.org/10.1371/journal.pone.0182736
27. Cortellessa, G., Scopelliti, M., Tiberio, L., Svedberg, G.K., Loutfi, A., Pecora, F.: A cross-cultural evaluation of domestic assistive robots. In: AAAI Fall Symposium: AI in Eldercare: New Solutions to Old Problems, pp. 24–31 (2008)
28. Kowalewski, S., Wilkowska, W., Ziefle, M.: Accounting for user diversity in the acceptance of medical assistive technologies. In: International Conference on Electronic Healthcare, pp 175–183. Springer (2010)
29. Van Dijk, J.A.: Digital divide research, achievements and shortcomings. Poetics **34**(4–5), 221–235 (2006)
30. Broadbent, E., Garrett, J., Jepsen, N., Li Ogilvie, V., Ahn, H.S., Robinson, H., Peri, K., Kerse, N., Rouse, P., Pillai, A., MacDonald, B.: Using robots at home to support patients with chronic obstructive pulmonary disease: pilot randomized controlled trial. J. Med. Internet Res. **20**(2), 15 (2018). https://doi.org/10.2196/jmir.8640
31. Mitzner, T.L., Boron, J.B., Fausset, C.B., Adams, A.E., Charness, N., Czaja, S.J., Dijkstra, K., Fisk, A.D., Rogers, W.A., Sharit, J.: Older adults talk technology: technology usage and attitudes. Comput. Hum. Behav. **26**(6), 1710–1721 (2010). https://doi.org/10.1016/j.chb.2010.06.020
32. Smarr, C.-A., Prakash, A., Beer, J.M., Mitzner, T.L., Kemp, C.C., Rogers, W.A.: Older adults' preferences for and acceptance of robot assistance for everyday living tasks. In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting, vol. 1, pp. 153–157. SAGE Publications Sage CA, Los Angeles (2012)
33. Marcel, I.: Patient and staff acceptance of robotic technology in occupational therapy: a pilot study. J. Rehabil. Res. Dev. **28**(2), 33–34 (1991). https://doi.org/10.1682/JRRD.1991.04.0033
34. Koay, K.L., Syrdal, D.S., Walters, M.L., Dautenhahn, K.: Living with robots: investigating the habituation effect in participants' preferences during a longitudinal human–robot interaction study. In: The 16th IEEE International Symposium on Robot and Human interactive Communication, 2007. RO-MAN 2007, pp. 564–569. IEEE (2007)
35. Czaja, S.J., Charness, N., Fisk, A.D., Hertzog, C., Nair, S.N., Rogers, W.A., Sharit, J.: Factors predicting the use of technology: findings from the center for research and education on aging and technology enhancement (CREATE). Psychol. Aging **21**(2), 333–352 (2006). https://doi.org/10.1037/0882-7974.21.2.333
36. Ellis, R.D., Allaire, J.C.: Modeling computer interest in older adults: the role of age, education, computer knowledge, and computer anxiety. Hum. Factors **41**(3), 345–355 (1999). https://doi.org/10.1518/001872099779610996
37. Sugiyama, S., Vincent, J.: Social robots and emotion: transcending the boundary between humans and ICTs. Intervalla **1**, 1–6 (2013)
38. Heerink, M., Krose, B., Evers, V., Wielinga, B.: Assessing acceptance of assistive social agent technology by older adults: the Almere model. Int. J. Soc. Robot. **2**(4), 361–375 (2010). https://doi.org/10.1007/s12369-010-0068-5
39. Smarr, C.A., Mitzner, T.L., Beer, J.M., Prakash, A., Chen, T.L., Kemp, C.C., Rogers, W.A.: Domestic robots for older adults: attitudes, preferences, and potential. Int. J. Soc. Robot. **6**(2), 229–247 (2014). https://doi.org/10.1007/s12369-013-0220-0
40. Dillon, A.: User acceptance of information technology. In: Encyclopedia of Human Factors and Ergonomics. Taylor and Francis, London (2001). http://hdl.handle.net/10150/105880
41. Chang, R.C.S., Lu, H.P., Yang, P.S.: Stereotypes or golden rules? Exploring likable voice traits of social robots as active aging companions for tech-savvy baby boomers in Taiwan. Comput. Hum. Behav. **84**, 194–210 (2018). https://doi.org/10.1016/j.chb.2018.02.025
42. Heerink, M.: Exploring the influence of age, gender, education and computer experience on robot acceptance by older adults. In: Proceedings of the 6th International Conference on Human–Robot Interaction, pp. 147–148. ACM (2011)

43. Ezer, N., Fisk, A.D., Rogers, W.A.: Attitudinal and intentional acceptance of domestic robots by younger and older adults. In: International Conference on Universal Access in Human–Computer Interaction, pp. 39–48. Springer (2009)
44. Arras, K.O., Cerqui, D.: Do we want to share our lives and bodies with robots? A 2000 people survey: a 2000-people survey. Technical Report 605 (2005)
45. Heerink, M., Krose, B., Evers, V., Wielinga, B.: Measuring acceptance of an assistive social robot: a suggested toolkit. In: RO-MAN 2009—The 18th IEEE International Symposium on Robot and Human Interactive Communication, pp. 528–533. IEEE (2009)
46. Nomura, T., Kanda, T., Suzuki, T., Kato, K.: Prediction of human behavior in human–robot interaction using psychological scales for anxiety and negative attitudes toward robots. IEEE Trans. Robot. **24**(2), 442–451 (2008)
47. Young, J.E., Hawkins, R., Sharlin, E., Igarashi, T.: Toward acceptable domestic robots: applying insights from social psychology. Int. J. Soc. Robot. **1**(1), 95–108 (2009). https://doi.org/10.1007/s12369-008-0006-y
48. Yang, H.-d., Yoo, Y.: It's all about attitude: revisiting the technology acceptance model. Decis. Support Syst. **38**(1), 19–31 (2004)
49. Santos, J.R.A.: Cronbach's alpha: a tool for assessing the reliability of scales. J. Ext. **37**(2), 1–5 (1999)
50. Park, E., Kwon, S.J.: The adoption of teaching assistant robots: a technology acceptance model approach. Progr. Electron. Libr. Inf. Syst. **50**(4), 354–366 (2016). https://doi.org/10.1108/prog-02-2016-0017
51. Ezer, N., Fisk, A.D., Rogers, W.A.: More than a servant: self-reported willingness of younger and older adults to having a robot perform interactive and critical tasks in the home. In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting, vol 2, pp. 136–140. SAGE Publications Sage CA, Los Angeles (2009)
52. Bevilacqua, R., Di Rosa, M., Felici, E., Stara, V., Barbabella, F., Rossi, L.: Towards an impact assessment framework for ICT-based systems supporting older people: making evaluation comprehensive through appropriate concepts and metrics. In: Longhi, S., Siciliano, P., Germani, M., Monteriù, A. (eds.) Ambient Assisted Living, pp 215–222. Springer, Cham (2014). https://doi.org/10.1007/978-3-319-01119-6_22
53. Lattanzio, F., Abbatecola, A.M., Bevilacqua, R., Chiatti, C., Corsonello, A., Rossi, L., Bustacchini, S., Bernabei, R.: Advanced technology care innovation for older people in Italy: necessity and opportunity to promote health and wellbeing. J. Am. Med. Dir. Assoc. **15**(7), 457–466 (2014). https://doi.org/10.1016/j.jamda.2014.04.003
54. Beer, J., Prakash, A., Smarr, C., Chen, T., Hawkins, K., Nguyen, H., Rogers, W.: Older users' acceptance of an assistive robot: attitudinal changes following brief exposure. Gerontechnology **16**(1), 21–36 (2017)
55. Giuliani, M.V., Scopelliti, M., Fornara, F.: Elderly people at home: technological help in everyday activities. In: IEEE International Workshop on Robot and Human Interactive Communication. ROMAN 2005, pp. 365–370. IEEE (2005)
56. Turja, T., Van Aerschot, L., Särkikoski, T., Oksanen, A.: Finnish healthcare professionals' attitudes towards robots: reflections on a population sample. Nurs. Open **5**, 300–309 (2018)
57. Hall, A.K., Backonja, U., Painter, I., Cakmak, M., Sung, M., Lau, T., Thompson, H.J., Demiris, G.: Acceptance and perceived usefulness of robots to assist with activities of daily living and healthcare tasks. Assist. Technol. **31**(3), 133–140 (2017). https://doi.org/10.1080/10400435.2017.1396565
58. Mitzner, T.L., Chen, T.L., Kemp, C.C., Rogers, W.A.: Identifying the potential for robotics to assist older adults in different living environments. Int. J. Soc. Robot. **6**(2), 213–227 (2014). https://doi.org/10.1007/s12369-013-0218-7
59. Rantanen, T., Lehto, P., Vuorinen, P., Coco, K.: The adoption of care robots in home care—a survey on the attitudes of Finnish home care personnel. J. Clin. Nurs. **27**(9–10), 1846–1859 (2018)
60. Dinet, J., Vivian, R.: Perception and attitudes towards anthropomorphic robots in France: validation of an assessment scale. Psychol. Fr. **60**(2), 173–189 (2015). https://doi.org/10.1016/j.psfr.2015.05.002
61. Tay, B., Jung, Y.B., Park, T.: When stereotypes meet robots: the double-edge sword of robot gender and personality in human–robot interaction. Comput. Hum. Behav. **38**, 75–84 (2014). https://doi.org/10.1016/j.chb.2014.05.014
62. Paperno, N., Rupp, M.A., Parkhurst, E.L., Maboudou-Tchao, E.M., Smither, J.A., Bricout, J., Behal, A.: Age and gender differences in performance for operating a robotic manipulator. IEEE Trans. Hum. Mach. Syst. **49**(2), 137–149 (2019). https://doi.org/10.1109/thms.2019.2890855
63. Lee, W.H., Lin, C.W., Shih, K.H.: A technology acceptance model for the perception of restaurant service robots for trust, interactivity, and output quality. Int. J. Mob. Commun. **16**(4), 361–376 (2018). https://doi.org/10.1504/ijmc.2018.092666
64. Beer, J.M., Prakash, A., Smarr, C.-A., Mitzner, T.L., Kemp, C.C., Rogers, W.A.: Commanding your robot older adults' preferences for methods of robot control. In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting, vol. 1, pp. 1263–1267. SAGE Publications Sage CA, Los Angeles (2012)