Study on Acceptance of Social Robots by Aging Adults Living Alone

Na Chen, Xiaoyu Liu, and Yue Sun(✉)

Beijing University of Chemical Technology, Beijing 100029, China
chenn4@163.com, ytlxy@126.com, y_sun_kyu@outlook.com

Abstract. Social robots have become an important way to alleviate the impact of aging on society and families. This study aims to explore the influence of the living state of the elderly on robot acceptance. Based on Unified Theory of Acceptance and Use of Technology (UTAUT) questionnaire, this study conducted a questionnaire survey for the elderly. The results show that performance expectancy, social influence, facilitating conditions have significant positive effects on robot acceptance of the elderly. In addition, the gender of aging adults moderates the influence of performance expectancy on robot acceptance, the experience of using intelligent products for the elderly moderates the impact of social influence on robot acceptance, and the living state of the elderly moderates the significant influence of facilitating conditions on robot acceptance. Intelligent robots can improve the lives of aging adults living alone, and the higher the convenience of robots, the stronger the usage intention of aging adults living alone to use robots. The results of this study can help relevant researchers to better understand the psychological needs of the elderly, provide ideas for the design of robot products, and provide references for the establishment of social pension system.

Keywords: Aging adults living alone · Social robot · Acceptance · UTAUT

1 Introduction

The problem of aging in Chinese society is becoming increasingly prominent. The growth rate of the elderly population continues to rise rapidly, putting great pressure on social and family resources. Robots with artificial intelligence are an important way to alleviate the shortage on pension resources. With the increase of age, the daily activities of the elderly are restricted, and social activities change significantly, these have caused the elderly to lack sufficient family and social mental support and face serious mental health problems. This requires robots to provide both life help and some psychological comfort. Social robots can provide informal help and support for the elderly, including assessing and managing symptoms, using medication and providing personal care [1, 2]. Social robots improve the feasibility of home care [3], then reducing the cost of home care [4, 5]. Some intelligent robot products with simple accompanying function have already entered the market. For example, Paro, a seal-like robot from the institute of intelligent systems in Japan, offers solace to the elderly by responding to touch, hugging, remembering faces

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and learning to act in ways that produce favorable responses. Research proved that social robotics products can to some extent alleviate the elderly's loneliness, depression and other psychological problems, and improve their mental health. However, the existing research hasn't study enough on the acceptance of social robots in the elderly. Studying the acceptance of robots by the elderly can help society and families better understand the psychological needs of the elderly, provide ideas for the design of robot products, and provide reference for the establishment of a social pension system.

The UTAUT model is a technology acceptance model that has been widely adopted in recent years. Venkatesh et al. [6] integrated technology acceptance models such as Technology Acceptance Model (TAM), Theory of Reasoned Action (TRA), Theory of Planned Behavior (TPB), Social Cognitive Theory (SCT), aimed at exploring the influencing factors of user awareness, put forward Unified Theory of Acceptance and Use of Technology (UTAUT). The UTAUT model believes that behaviors and behavioral intentions are affected by performance expectancy, effort expectance, social influence, and facilitating conditions. At the same time, these effects are adjusted by four factors: gender, age, experience, and usage intention. Studies show that although it includes more factors at the expense of parsimony, the UTAUT model can account for as much as 70 percent of the usage intention. Among them, performance expectancy refers to the extent to which individuals believe that using the system can help them achieve job performance. effort expectance refers to the ease of using the system. social influence refers to the extent to which important social relationships influence the individual's use of the system. facilitating conditions refers to the extent to which the organization and infrastructure support the use of the system. More previous studies used the TAM to study the robot acceptance of the elderly, and less research used the UTAUT [7]. This study explores the acceptance of robots among elderly on the basis of the UTAUT.

Studies show that aging adults living alone without caregivers face more adverse physical and psychosocial health issues [8]. aging adults living alone face greater challenges in terms of physical, social, emotional and survival needs [9], They need more assistance in their daily activities, but have less access to services and comfort [10, 11]. aging adults living alone are more likely to feel lonely, frustrated, and unable to move [12]. Functional and cognitive impairments, chronic illnesses, reduced social relationships, and low levels of physical activity pose challenges to the lives of aging adults living alone [13–15]. Technology may provide them with some solutions. Therefore, this study included the living status of the elderly as a factor in the UTAUT model to explore the effect of the elderly's living status on their robot acceptance.

Based on the UTAUT model, this study aims to explore the influence of the living state of the elderly on their robot acceptance, which will help to better understand the psychological needs of the elderly, provide ideas for social robot product design, and provide references for the establishment of social pension system.

2 Model and Hypotheses

Based on the UTAUT model, this study believes that the use of social robots by elderly can help them improve their quality of life, how easy it is for elderly to use robots, how social relationships around elderly affect their use of robots, and the infrastructure

required to use a robot will affect its robot acceptance. In addition, both gender and age of the elderly moderate the effects of performance expectancy, effort expectancy and social influence on robot acceptance. Therefore, this study proposes the following seven hypotheses. The model framework is shown in Fig. 1.

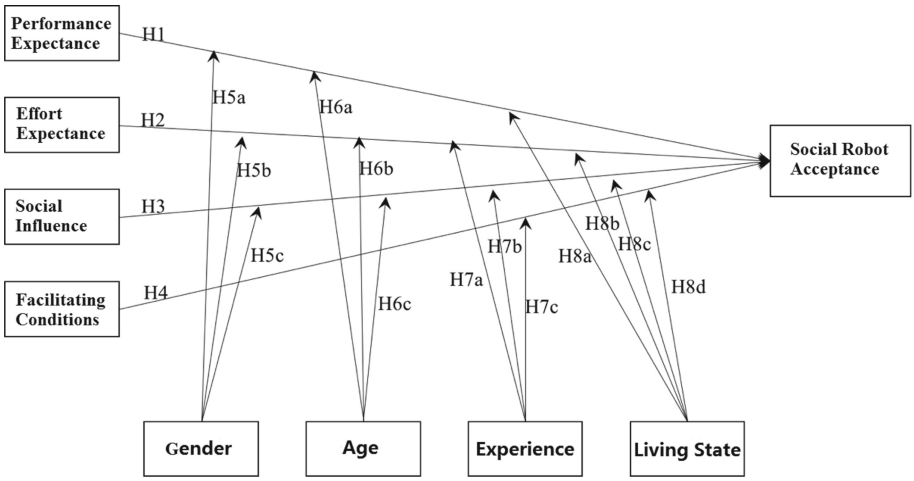

Fig. 1. Framework of the elderly's acceptance of social robots

H1: Performance expectancy has a significant effect on acceptance of social robots of the elderly.
H2: Effort expectance has a significant effect on acceptance of social robots of the elderly.
H3: Social influence has a significant effect on acceptance of social robots of the elderly.
H4: Facilitating conditions have a significant effect on acceptance of social robots of the elderly.
H5a: Gender moderates the effect of performance expectance on acceptance of the elderly.
H5b: Gender moderates the effect of effort expectance on acceptance of the elderly.
H5c: Gender moderates the effect of social influence on acceptance of the elderly.
H6a: Age moderates the effect of performance expectance on acceptance of the elderly.
H6b: Age moderates the effect of effort expectance on acceptance of the elderly.
H6c: Age moderates the effect of social influence on acceptance of the elderly.
H7a: Experience moderates the effect of effort expectance on acceptance of the elderly.
H7b: Experience moderates the effect of social influence on acceptance of the elderly.
H7c: Experience moderates the effect of facilitating conditions on acceptance of the elderly.

In addition, the living state of the elderly affects the social support they can get, and aging adults living alone receive less psychological comfort and life help, so the acceptance and expectation of using social robots may be different from that of non-solitary elderly people. Therefore, this study proposes the hypothesis that the living state

of the elderly moderates the effect of performance expectance, effort expectance, and social influence on robot acceptance.

H8a: Living state moderates the effect of performance expectance on acceptance of the elderly.
H8b: Living state moderates the effect of effort expectance on acceptance of the elderly.
H8c: Living state moderates the effect of social influence on acceptance of the elderly.
H8d: Living state moderates the effect of facilitating conditions on acceptance of the elderly.

3 Methodology

3.1 Participants

In this study, seven communities and senior universities in Beijing were selected to distributed questionnaires. A total of 492 questionnaires were distributed and 386 questionnaires were collected, including 274 valid questionnaires, with an effective recovery rate of 55.69%. Among the valid questionnaires, 146 are male, accounting for 53.28%, and 128 are female, accounting for 46.72%. The age range is 63 to 85 years, with an average age of 69.69 years. Living state includes 81 people living alone, accounting for 29.56%, and the remaining 193 people living with a partner or other family members, accounting for 70.44%.

3.2 Questionnaire Design

The questionnaire in this study contains three parts: demography related questions (moderator variables), acceptance influencing factors, and acceptance questions. the demographics section includes four factors, which measure participants' gender, age, living state, and experience with intelligent products. experience was measured by Likert 5-point scale (1 = inexperienced, 5 = experienced). The results show that the experience of these participants in using intelligent products is 1.92, which is relatively low.

The McColl and Nejat [16] scale was appropriately modified to obtain the acceptance factors scale and acceptance scale. The acceptance factor section contains four sub-scales, which are performance expectance, effort expectance, social influence, and facilitating conditions. The acceptance section includes a sub-scale, that is, usage intention. Each of these sub-scales contains three items. Therefore, this study questionnaire modifies some items to better fit the research context. For the performance expectance sub-scale, this study selects three typical use scenarios to measure whether older people think that social robots can play a role in these situations. These scenarios include companionship and care (i.e. tea and chat), and management of daily matters (i.e. reminding you to take medicine, etc.) and supporting remote collaboration (i.e. getting in touch with people and medical staff). For the social influence sub-scale, the study measures the effects of children, brand promotion, and national policies on the elderly. These items are measured by a Likert 5-point scale (1 = strongly disagree, 5 = strongly agree).

4 Data Analysis

4.1 Reliability and Validity Analysis

The factor load of each item in the sub-scale is greater than 0.665, indicating that the items in the measure scale all reflect the same construct. Cronbach's Alpha is 0.668, which indicates that the questionnaire of this study has high reliability, and the items of each subscale can be combined into the same factor for subsequent analysis. The KMO value of each subscale is greater than 0.585, and the scale has good structural validity. The CR value of each subscale is greater than 0.821, and the scale has good construction reliability. The square root of the AVE value of each subscale is greater than its correlation coefficient, and the scale has high convergence validity. Cronbach's Alpha, CR and AVE values of the subscales are shown in Table 1.

Table 1. Reliability and validity analysis results of the questionnaire.

Factor	M	SD	Cronbach's Alpha	CR	AVE	AVE square root
Usage intention	2.51	0.77	0.777	0.871	0.692	0.83
Performance expectance	2.36	0.37	0.692	0.828	0.620	0.79
Effort expectance	2.42	0.63	0.720	0.843	0.642	0.80
Social influence	2.61	0.59	0.668	0.821	0.608	0.78
Facilitating conditions	2.62	0.63	0.763	0.864	0.679	0.82
Gender	0.53	0.50				
Age	69.60	3.17				
Experience	1.92	0.83				
Living state	0.30	0.46				

According to the correlation analysis, in addition to the non-significant correlation between the effort expectance and the usage intention ($p > 0.05$), there is a correlation between the other variables, and the correlation coefficients are less than 0.6 (the highest is 0.233), It can be considered that the collinearity degree of the data is within the acceptable range in this paper. At the same time, the square root of AVE of each variable is greater than the correlation coefficient between the variables, indicating that there is a good discriminative validity between the variables. correlation coefficients between variables are shown in Table 2.

4.2 Model Test

Perform a regression test on the variables. The test results are shown in Table 3. In model 1, the effort expectance is not significant, therefore, H2 is not verified. Remove effort expectance from the model. According to the results of model 2 and model 3, there is a positive correlation between performance expectance, social influence, facilitating

Table 2. Correlation coefficient matrix.

Factor	Performance expectance	Effort expectance	Social influence	Facilitating conditions	Gender	Age	Experience	Usage intention
Effort expectance	0.193**							
Social influence	0.163**	0.094						
Facilitating conditions	0.164**	0.130*	0.105					
Gender	0.120*	−0.011	−0.010	0.067				
Age	−0.105	−0.046	−0.096	0.072	0.022			
Experience	0.009	−0.209**	−0.048	0.016	0.055	0.086		
Living state	−0.056	−0.034	0.116	0.037	−0.019	−0.024	0.046	
Usage intention	0.198**	0.048	0.233**	0.196**	−0.060	−0.004	0.172**	0.502**

conditions and the elderly's acceptance of social robots ($\beta = 0.108, p < 0.05$; $\beta = 0.149, p < 0.01$; $\beta = 0.117, p < 0.05$). H1, H3, H4 are verified. The regression coefficient between performance expectance and gender is −0.074, which is significant at the 0.05 level. H5 is partially verified. The regression coefficient of social influence and experience is −0.101, which is significant at the level of 0.01. H7 is partially verified. The regression coefficient of facilitating conditions and living state is −0.133, which is significant at the level of 0.001. H8 is partially verified.

Table 3. Regression analysis results (standardize coefficients).

Variable		Robot acceptance		
		Model 1	Model 2	Model 3
Independent	Performance expectance	0.111*	0.108*	0.174***
	Effort expectance	−0.014	–	–
	Social influence	0.150**	0.149**	0.049
	Facilitating conditions	0.119**	0.117*	0.046
Moderator	Gender			−0.065*
	Age			−0.005
	Experience			0.129***
	Living state			0.440***
Moderator effect	Performance expectance × gender			−0.074*
	Performance expectance × age			0.057
	Performance expectance × living state			0.031
	Social influence × gender			0.022
	Social influence × age			−0.027
	Social influence × experience			−0.101**
	Social influence × living state			−0.004
	Facilitating conditions × experience			−0.017
	Facilitating conditions × living state			−0.133***
	R2	0.103	0.103	0.575
	Adjusted R2	0.090	0.093	0.548
	F	7.753***	10.340***	21.906***

In order to more intuitively describe the moderating effects of gender, experience and living state on the acceptance of the elderly, this paper draws interactive graphs between variables to illustrate. It can be seen from Fig. 2 that the slope of the solid line (male elderly) is greater than that of the dashed line (female elderly). Gender has a significant moderating effect between performance expectance and elderly acceptance. For male and female elderly, the higher the performance expectance, the higher their acceptance of robots (male: $t = 2.221$, $p = 0.028$; female: $t = 5.709$, $p < 0.001$), but the female

elderly's acceptance is more affected. It can be seen from Fig. 3 that the slope of the dashed line (low intelligent device experience) is greater than that of the solid line (high smart device experience), and there is a significant moderating effect between the social influence and the acceptance of the elderly. For the elderly with less experience in using intelligent devices, the higher the experience, the higher the acceptance of the robot ($t = 2.350$, $p = 0.021$). For the elderly with more experience in using intelligent devices, experience has no significant effect on their acceptance ($t = -1.520$, $p = 0.137$). It can be seen from Fig. 4 that the slope of the solid line (non-solitary living) is negative, and the slope of the dashed line (solitary living) is positive. There is a significant moderating effect between the facilitating conditions and the acceptance of the elderly. For solitary elderly people, the higher the facilitating conditions, the higher their acceptance of the robot. For non-solitary elderly people, the lower the facilitating conditions, the higher their acceptance of robots.

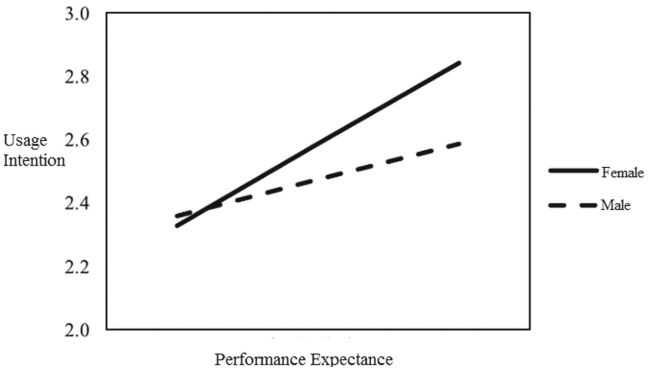

Fig. 2. The moderating effect of gender between performance expectance and usage intention.

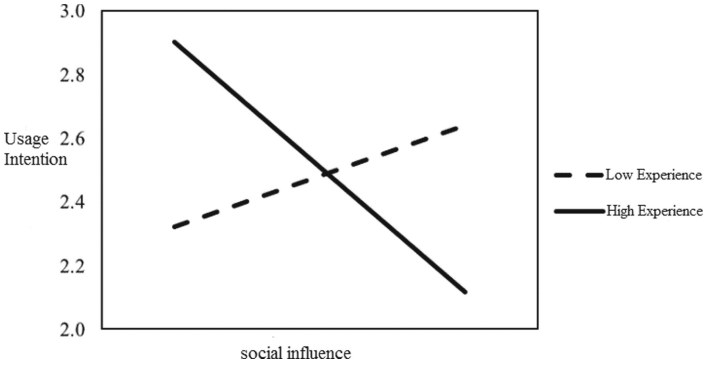

Fig. 3. The moderating effect of experience between social influence and usage intention.

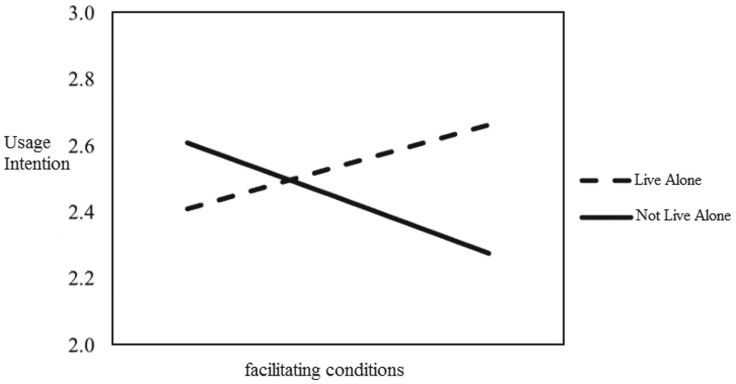

Fig. 4. The moderating effect of living state between facilitating conditions and usage intention.

The hypothesis verification status of this study can be summarized as shown in Table 4.

Table 4. Hypothesis verification.

Number	Hypothesis	Verification
H1	Performance expectancy has a significant effect on acceptance of social robots of the elderly	Verified
H2	Effort expectance has a significant effect on acceptance of social robots of the elderly	Unverified
H3	Social influence has a significant effect on acceptance of social robots of the elderly	Verified
H4	Facilitating conditions have a significant effect on acceptance of social robots of the elderly	Verified
H5a	Gender moderates the effect of performance expectance on acceptance of the elderly	Verified
H5b	Gender moderates the effect of effort expectance on acceptance of the elderly	Unverified
H5c	Gender moderates the effect of social influence on acceptance of the elderly	Unverified
H6a	Age moderates the effect of performance expectance on acceptance of the elderly	Unverified
H6b	Age moderates the effect of effort expectance on acceptance of the elderly	Unverified
H6c	Age moderates the effect of social influence on acceptance of the elderly	Unverified

(*continued*)

Table 4. (*continued*)

Number	Hypothesis	Verification
H7a	Experience moderates the effect of effort expectance on acceptance of the elderly	Unverified
H7b	Experience moderates the effect of social influence on acceptance of the elderly	Verified
H7c	Experience moderates the effect of facilitating conditions on acceptance of the elderly	Unverified
H8a	Living state moderates the effect of performance expectance on acceptance of the elderly	Unverified
H8b	Living state moderates the effect of effort expectance on acceptance of the elderly	Unverified
H8c	Living state moderates the effect of social influence on acceptance of the elderly	Unverified
H8d	Living state moderates the effect of facilitating conditions on acceptance of the elderly	Verified

5 Result and Discussion

This study explores the impact of the living state of the elderly on their robot acceptance. The results show that the living state moderates the impact of facilitating conditions on the acceptance of the elderly, and the standardization coefficient of the living state is very high.

Further illustrates that the impact of facilitating conditions on the acceptance have bigger difference between solitary people and non- solitary people. Robots can help the elderly live better independently [17]. For aging adults living alone and not living alone, there may be differences in the impact of facilitating conditions on their lives. For aging adults living alone, the better the facilitating conditions, the better the maintenance of the robot can be guaranteed, and the more likely it is to use an intelligent robot. For aging adults who are not living alone, the better the facilitating conditions, the more life support they receive from the outside world, and the less their motivation for using intelligent robots.

This study did not find a significant effect of effort expectance on the acceptance of the elderly, which is somewhat different from previous studies [18, 19]. This difference may be due to the influence of the technology acceptance model over time. Although UTAUT is powerful and robust, technology acceptance may fluctuate over time [20–22]. The influence of certain factors in the technology acceptance model is different before the technology is implemented (when the technology is not used) and after the technology is implemented (when the user has used and experienced the technology) [23, 24]. The conclusion of this study is significant for the current stage when intelligent robots have not entered the consumer goods market. However, when intelligent products are widely used by the elderly, the conclusion of this study needs to be further discussed and adjusted. In addition, Although the questionnaire in this research emphasizes intelligent

robot products, the elderly still has very little experience in using intelligent products, which may make it difficult for the elderly to imagine what kind of effort is required to use the robot, causing the effect of effort expectance on acceptance is not significant.

Based on the UTAUT model, the results of this study show that performance expectance, social influence and facilitating conditions have significant effect on the acceptance of the elderly. However, there are also literatures argue that the acceptance model ignores the basic determinants [25–27]. Such as specific biophysical factors associated with aging (e.g., cognitive and physical decline), and psychosocial factors (e.g., social isolation, fear of disease, etc.) [28]. In addition, the cost (price) of technology is also ignored in many studies [28]. Therefore, more research is needed to better understand the acceptance of the elderly. Based on the acceptance model, another paper explores the impact of robot prices on the acceptance of the elderly.

The results of this study showed that gender moderates the influence of performance expectance on the acceptance of the elderly, and that for female elderly, performance expectance have a greater impact on acceptance, and that female elderly are more acceptable, which is somewhat different from the previous research results. More previous studies have shown that men are more receptive and willing to use robots [29, 30]. However, the subjects of these studies were non-elderly, while the subjects of this study were elderly Chinese. Therefore, for different age groups, the influence of user gender on the acceptance of intelligent robot products may be different, which needs further exploration.

6 Conclusion

The application of intelligent robots to alleviate the increasingly severe problem of aging in Chinese society has become a hot topic in industry and academia, and the acceptance of the elderly is a fundamental issue in the development of the intelligent robot industry. This study uses an acceptance study method and uses a questionnaire to explore the acceptance of robots of the elderly in China. The results of data analysis show that performance expectance, social influence and convenience have significant positive effects on acceptance, while effort expectations have no significant effects on acceptance.

This study explores the effects of performance expectance, effort expectance, social influence, and facilitating conditions on the acceptance of the elderly, and explores the moderate effects of gender, age, experience with intelligent products, and living state. A total of 386 valid questionnaires were collected. The results of data analysis show that performance expectance, social influence and facilitating conditions have significant positive effects on acceptance, while effort expectance have no significant effects on acceptance. In addition, the gender of aging adults moderates the influence of performance expectancy on robot acceptance, the experience of using intelligent products for the elderly moderates the impact of social influence on robot acceptance, and the living state of the elderly moderates the significant influence of facilitating conditions on robot acceptance.

The results of this study show that the living state of the elderly affects their robot acceptance. Intelligent robots can improve the lives of the elderly living alone, and the

higher the facilitating conditions of the robot, the stronger the willingness of the elderly living alone to use the robot.

In addition, elderly women have a higher acceptance of robots, and their acceptance of robots to improve their lives is more significantly affected than that of elderly men. Experience with intelligent products will increase the acceptance of older people. Therefore, this study suggests that intelligent robot products and functions should be developed more specifically for the lifestyle and psychological state of the elderly living alone, so as to provide more convenient service conditions and environment and improve the quality of life and mental health of the elderly living alone. In addition, different intelligent robot services are provided for female and male senior citizens to provide them with differentiated services. This study also recommends that older people should be provided with a wider range of easy-to-understand recommendations for intelligent products to improve their understanding and acceptance.

The results of this study can help relevant researchers to better understand the psychological needs of the elderly, provide ideas for the design of robot products, and provide references for the establishment of social pension system.

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