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An empirical study on the alleviation of loneliness of the elderly by AI intelligent voice robot based on CAC model

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Abstract

With the intensification of population aging, the loneliness problem of the elderly has become a global focus. Loneliness not only seriously affects the physical and mental health of the elderly, but also accelerates the decline of their quality of life. As an emerging technology, AI intelligent voice robots have various functions such as health monitoring and interactive entertainment. Western countries have widely applied them to the care and companionship of the elderly and achieved initial results. Based on the CAC model (Cognition - Emotion - Intention Model), this paper takes the subjective cognition of the elderly as the independent variable, the emotional response of the elderly as the mediating variable, and uses social surveys as a means. Through empirical testing methods, it verifies that external variable factors such as loneliness trigger the elderly's internal needs for emotional companionship and health management, and further lead to their different degrees of media use of AI intelligent voice robots. The research findings are as follows: (1) The level of the elderly's cognition and emotional tendency can positively predict the degree of media use of AI intelligent voice robots by the elderly. (2) The loneliness of the elderly can positively predict the emotional tendency of the elderly. (3) The level of the elderly's cognition can positively predict the emotional tendency of the elderly, and there is a chain - mediating relationship between them. (4) The level of the elderly's cognition and emotional tendency play a complete mediating role in the model. (5) The gender of the elderly plays a moderating role in the above - mentioned chain - mediating relationship. This study attempts to provide an empirical theoretical basis for the effective alleviation of the elderly's loneliness by AI intelligent voice robots.

Keywords: elderly people; CAC model; AI intelligent voice robot; loneliness

1 INTRODUCTION

The 20th National Congress of the Communist Party of China clearly stated: “We must implement a proactive national strategy to address population aging and promote the realization of basic elderly care services for all seniors.” Currently, China is in a stage of deepening population aging. According to the latest data released by the National Bureau of Statistics, there are 310 million people aged 60 and over, and 220 million people aged 65 and over, accounting for 22.0% and 15.6% of the total population, respectively. The aging population in China is experiencing both “high growth” and “advanced age,” while the issues of “fewer children,” “loss of only children,” and “one old supporting another” are becoming increasingly prominent. The social isolation and mental health problems faced by the elderly, especially those who are empty-nesters or have lost their only child, urgently need to be addressed. In 2024, the General Office of the State Council issued the “Opinion on Developing the Silver Economy and Enhancing the Well-being of the Elderly,” which emphasizes “strengthening innovation in elderly products, promoting the application of intelligent nursing robots and home service robots, and advancing the integration of traditional elderly care services with barrier-free and age-friendly smart elderly care services.”The new form of intelligent service, “AI + Elder Care,” offers a fresh approach to alleviating the spiritual emptiness of elderly people living alone and enhancing their sense of happiness and emotional comfort. This study uses social survey data as a means and the CAC model as a perspective, aiming to explain through quantitative research methods: (1) What kind of elderly individuals are more likely to use AI voice robots? (2) How do AI voice robots alleviate the loneliness of the elderly? (3) How can the systematic use of AI voice robots by the elderly be regulated?

2 LITERATURE REVIEW

2.1 Psychological causes and behavioral characteristics of the elderly with loneliness

Loneliness, or the feeling of isolation or lack of companionship perceived by a social individual, generally refers to negative emotions caused by the absence of companionship or emotional support, or the isolation caused by the lack of a wider social network.Not only is it one of the most influential factors in measuring the quality of life of older people, it is also associated with higher rates of depression, self-harm and mortality.The «broad socialization theory» points out that individuals engage with mainstream social institutions significantly less frequently in adulthood compared to their teenage years. Family, workplace, and social networks become the primary venues for socialization in adulthood. As one enters old age, life events such as retirement, children leaving home to study or work, and the passing of relatives and friends occur one after another. The social roles of the elderly undergo significant changes; they are gradually marginalized in terms of division of labor and status within both family and society, leading to a further narrowing of their scope of socialization and interaction.At the same time, as the «use gap» and time deficit of digital products expand, the sense of disconnection between the elderly and society gradually intensifies. The values and spiritual dimensions of the silver-haired population are increasingly becoming «fragmented» and «decentralized.» They fail to find meaning in their own value or identity in the real world, which in turn gives rise to negative emotions such as loneliness, depression, burden, and anxiety, and can even lead to severe mental disorders.It is worth noting that compared with the elderly in urban areas, the elderly living alone in rural areas have smaller social networks and less emotional interaction, and have stronger spiritual support needs.The need for compensatory companionship and immediate pleasure is even stronger than the basic needs of physiology and medicine.

2.2 The path mechanism of AI technology to alleviate the loneliness of the elderly

Mental support, as a higher requirement for old-age care, is usually realized by filial piety in China. However, with the intervention of emerging technologies such as the Internet of Things and artificial intelligence, a diversified, multi-level, and multi-modal mental support system has been advocated and promoted. Scholars Liu Jianjun et al. (2022).By analyzing the research results of smart pension at home and abroad, it is pointed out that the construction of intelligent pension platform can effectively solve the feasibility of pension problems. On this basis, Cai Zhengru et al. (2023).The future application model of deep integration between smart elderly care and smart communities, smart hospitals, and smart cities is proposed. Unlike the domestic macro concept of elderly care that focuses on community construction and comprehensive protection, foreign scholars pay more attention to the individual interaction needs of the elderly, emphasizing that artificial intelligence (AI) technology can provide scalable and personalized emotional services in behavioral interventions.The specific application is shown in Table 1.

Table 1: AI cases used abroad to alleviate the loneliness of the elderly

Technology type	Path mechanism	Empirical effects (Singlehood rate drops)	typical case
Voice interaction robot	NLP dialogue, emotion recognition, memory recall	32% (3 months)	Romi robot
Smart speaker	Voice control, scene linkage, emergency call	19% (first week)	Amazon Alexa adaptation for the elderly
Virtual social platforms	Interest matching, intergenerational bridge, online event organization	28% (6 weeks intervention)	ChatForSenior System
Multimodal care robot	Facial recognition, tactile feedback, AR virtual companionship	41% (highly interactive group)	ElliQ Emotional Robot
Cognitive training system	Memory activation, nostalgia therapy, brain games	22% (MCI patients)	Recovery therapy AI module

As shown in the chart, current AI technologies used abroad to alleviate loneliness among the elderly can be roughly categorized into five types: voice interaction robots, smart speakers, virtual social platforms, multimodal companion robots, and cognitive training systems. These technologies achieve varying degrees of success in alleviating loneliness through mechanisms such as machine learning (ML) and reinforcement learning (RL). It is evident that among these five categories of AI technology applications for the elderly, the multimodal companion robot, exemplified by ElliQ, shows the greatest reduction in loneliness, at 41%, while the smart speaker, represented by Amazon Alexa, is the fastestThe first week showed a significant reduction in the loneliness of the elderly. Studies have shown that the proportion of human individuals›

perception of external information is 83%,11%,3.5%,1.5% and 1% respectively, and multi-sensory interaction can maximize the connection between individuals and the environment, strengthening the emotional experience of the elderly.However, with the decline of the physiological function of the elderly, the original most intuitive sensory reception mode is faced with the possibility of dullness and blindness, especially for those elderly people with poor vision, difficulty in typing, and poor judgment. They will increase their anxiety, frustration and loneliness in complex operations.At present, the introduction of personal voice assistant (PVA) devices or smart speakers such as Amazon Alexa provides a new opportunity for the intervention of loneliness in the elderly. PVA essentially refers to «the voice assistant presented in the smart speaker», which is responsible for the virtual labels such as daily life management assistant and chat interaction assistant for the elderly users.With their high degree of scene linkage and accessibility, they eliminate the physical operation problems of the elderly for external devices such as screens and keyboards. They only need simple voice commands to meet their needs to the greatest extent.

In addition to the above-mentioned ease of use, AI technology tools characterized by intelligent voice also show significant anthropomorphism, that is, the behavior representation of human entities that can be perceived by human individuals but are not human qualities and human intelligence.Although it cannot reach the interactive level of human beings, AI intelligence can achieve phonetic output and dynamic response with the help of natural language processing (NLP) technology and machine learning model, so as to meet the psychological needs of the elderly such as perceptual usefulness, fun and sociality.At the same time, previous studies have shown that individuals who are socially disconnected for a long time tend to form deeper dependence with non-human entities with more social contact characteristics, and considerate and empathetic anthropomorphic animals or AI robots are their trust objects.For example, «Very beautiful! It› s just a bit thin. It› s overcast outside, so it› s best to bring a coat.» «Xiao Li, Xiao Li, please play a segment of› Chao Yang Gou› .» «Xiao Li is my health assistant; I asked her how to plan the daily diet for people with high blood sugar, and Xiao Li immediately gave three suggestions.» Such rich human-machine dialogues demonstrate the great potential of AI intelligent voice technology in predicting, accompanying, and entertaining multiple scenarios to alleviate loneliness and enhance social perception among the elderly.

Based on previous empirical studies on AI intelligent voice technology and the elderly, most of the research topics explore how AI intelligent voice technology can alleviate the loneliness of the elderly, that is, how AI intelligent voice technology can provide companionship to the elderly.This paper starts from the usage intentions of elderly users to explore the impact of media literacy (cognition) and emotional mediation on the degree of media use among seniors. At the same time, it addresses issues such as dialect problems in rural areas of some regions in China, AI scenario integration, and AI ethics, proposing actionable suggestions for improving AI intelligent voice technology for older adults. Therefore, this paper puts forward the following hypotheses:

H1: The degree of loneliness of the elderly will positively predict the degree of media use of AI intelligent voice robots.

H2: The cognitive level of the elderly will positively predict the media use degree of AI intelligent voice robots for the elderly.

H3: The emotional tendency of the elderly will positively predict the degree of media use of AI intelligent voice robots for the elderly.

H4: Loneliness in the elderly will positively predict cognitive performance in the elderly.

H5: Loneliness in older adults positively predicts emotional tendencies in older adults.

H6: The cognitive degree of the elderly will positively predict the emotional tendency of the elderly.

H7: The gender of the elderly plays a moderating role in the above chain mediation.

3 RESEARCH METHODS

3.1Model assumptions

The «Cognitive-Affective-Conative» (CAC) model was first proposed by social psychologist Martin Fishbein (1975), which emphasizes that people› s behavioral intention is the product of cognition (belief evaluation of behavioral results) and emotion (emotional tendency to behavior).In 1980, cognitive psychologist Ernest R. Hilgard et al. further systematized the model and clearly divided the behavioral decision-making process into three dynamic chains of cognition (Cognition), emotion (Affect) and intention (Conation). The term «CAC» was first proposed.On this basis, Walter Mischel et al. (1995) focused on the interaction between personality stability and situation, and proposed the concept of «cognitive-emotional processing» (CAPS), which provided a micro-psychological mechanism explanation for CAC model.So far, CAC model has been widely used in the comprehensive understanding of individual decision factors and behavioral motivation research, providing a theoretical basis for the design of behavioral intervention measures.

Based on the above theoretical model and micro-psychological mechanism trace, this study extracted the loneliness of the elderly (subjective cognitive variable), and integrated the external variables in the technical acceptance model (TechnologyAcceptanceModel, TEM) into the cognitive layer, and innovatively derived the following hypothetical mediation model (Figure 1) and the mechanism diagram (Figure 2).

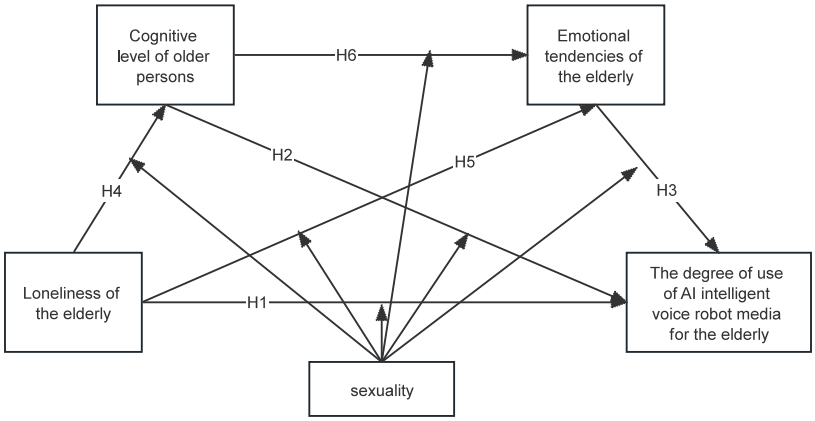

Figure 1 Hypothetical model of loneliness and AI intelligent voice robot for the elderly

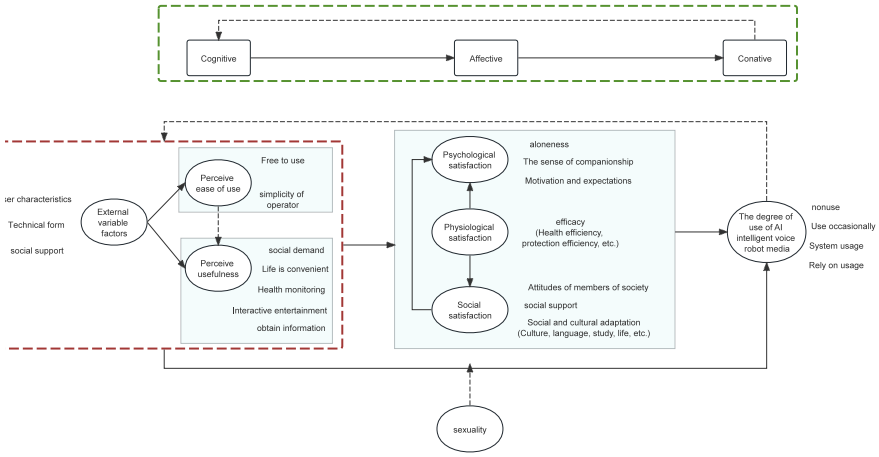

Figure 2 The mechanism of loneliness in the elderly and the role of AI intelligent voice robot

3.2Research subjects

This study primarily employs purposive sampling. Beijing, as the economic and political center of China, exhibits particularly pronounced urban differentiation and social isolation, with elderly individuals experiencing more intense feelings of loneliness. They also use AI intelligent voice robots more frequently, making them a typical subject for the study. The research conducted social surveys among elderly residents living alone in Haidian District, Chaoyang District, and surrounding towns and villages in Beijing. The sample meets two criteria: first, the elderly mainly live alone; second, they have purchased or used AI intelligent voice robots (smart speakers). Due to some respondents having visual impairments or reading difficulties, volunteers assisted the elderly in completing the questionnaire. A total of 400 questionnaires were distributed, with 307 valid responses collected, including 152 males and 155 females. The average age of the sample is 68.88 years (standard deviation 8.04 years).

Table 2 Descriptive analysis

Demographic variables (partial)		Number of persons (individuals)	proportion (%)
census register	town	179	58.3
	rural area	128	41.7
The state of the engagement	unmarried	46	15.0
	married	181	59.0
	dissociaton	30	9.8
	bereft of one's spouse	50	16.3
Educational level	primary school	33	10.7
	junior middle school	61	19.9
	senior middle school	58	18.9
	university	120	39.1
	postgraduate	35	11.4

According to the descriptive analysis in Table 2, from the perspective of household registration distribution, the distribution of elderly users is relatively balanced, with urban areas slightly higher than rural areas. Elderly users in towns may be more inclined to engage with and use new technologies like AI intelligent voice robots, while those in rural areas might lag behind. In terms of marital status, married seniors account for as high as 59.0%, suggesting that they are more likely to have companions in their daily lives and thus less likely to seek emotional support through AI intelligent voice robots compared to unmarried seniors, who are more likely to use them for social entertainment. The distribution of educational levels shows that elderly users with a college degree or higher make up 50.5% of the total, significantly higher than other educational groups. This indicates that highly educated elderly users are an important group for using AI intelligent voice robots, as they are more open to adopting new technologies.

3.3Variable measurement

(1)Independent variables (cognitive level-external influence variables, subjective cognitive variables)

The social cognitive scale was used to measure the degree of individual subjective and objective cognition in the elderly. The scale was adapted from the UCLA Loneliness Scale (1978, UCLA Loneliness Scale), the Self-Efficacy Scale (1981, General Self-Efficacy Scale, GSES) and the Social Support Scale (1994, Social Support Rating Scale, SSRS),The original scale measures the number of family and friends that elderly individuals can meet, contact, discuss personal matters with, and seek help from, as well as the

objective support, subjective support, and utilization of such support by the elderly. This study integrates the original scale to measure the social cognition of the elderly from three dimensions: «self-perceived loneliness,» «technological mastery,» and «social support.» The measurement indicators include 60 items such as «I worry that no one will be interested in my topics» and «I can control household appliances through smart home devices (such as voice assistants)» and «You can obtain health information through AI smart speakers.» A 5-point rating scale is used (1= not at all, 5= very much), where higher scores indicate higher social cognition. In this study, the Cronbach› s α coefficient for the scale is.824.

(2)Dependent variable (intentional layer-behavior)

The AI intelligent voice robot usage scale was used to measure the media use of the elderly individuals. The scale was adapted from the Acceptance and Behavior Scale (2011, Acceptance and Action Questionnaire-II, AAQ-II).The original scale measures users ‹ psychological flexibility (Psychological Flexibility) and experiential avoidance (Experiential Avoidance) to explore the association between accepting internal experiences and value-oriented behaviors. Given that the survey targets elderly individuals, this study has made targeted extensions to the original scale. It measures and categorizes the degree of individual use of AI voice robots among the elderly from four dimensions: «never use,» «occasional use,» «systematic use,» and «reliant use.» The measurement indicators include 18 items such as «I avoid using AI robots because I am concerned about complex operations or errors,» «I only use the robot to answer video calls when my children remotely assist me,» «I habitually listen to news or stories read by the robot before bed,» and «I feel lonely or uneasy without a robot for company.» A 5-point rating scale is used (1= not at all, 5= very much), with higher scores indicating more positive emotional responses in the elderly. In this study, the Cronbach› s α coefficient of the scale is.861.

(3)Mediating variables (emotional layer-emotional response, emotional evaluation)

The emotional response and evaluation scale was used to measure the cognitive-based emotional tendency of the elderly individuals towards AI intelligent voice robots. The scale was adapted from the ATTARI-12 attitude scale (2024, Attitudes Toward AI and Robotics Index-12).The original scale comprehensively evaluates individuals ‹ cognitive, emotional, and behavioral attitudes toward artificial intelligence technology through a single-dimensional structure, covering the full spectrum of reactions from «resistance» to «enthusiasm.» This study extracted and modified the dimensions of the original scale, refining the original emotional dimension into three layers: «psychological satisfaction,» «physiological satisfaction,» and «social satisfaction.» These layers measure the emotional responses and evaluations of elderly individuals, including 18 items such as «video calls with distant family members via AI make me feel more secure,» «wearing health monitoring devices (like smart voice bands) helps me better understand my physical condition,» and «when chatting with elderly companionship robots, I feel they cannot replace real human interaction.» The scale uses a 5-point rating system (1= not at all, 5= very much), with higher scores indicating more positive emotional responses. In this study, the Cronbach› s α coefficient for the scale is.768.

This paper uses the macro plugin PROCESS developed by SPSS27.0 and Hayes for data analysis. Since the data were collected through self-reporting by participants and the study involves relationships between multiple variables, it is necessary to conduct exploratory factor analysis and common method bias testing. First, at the questionnaire design level, this study adopted methods such as anonymous surveys, reverse scoring, and screening for response time to clean and control the data; second, before data analysis, a Harman one-way ANOVA was used to test for common method bias. An unrotated exploratory factor analysis was performed on all items, and the results showed that the KMO sampling fit index of the scale was 0.97> 0.5, the Bartlett› s test of sphericity was significant at 0.00 <0.05, and there were three common factors with eigenvalues greater than 1, with the first common factor explaining only 35.7% of the total variance. This ratio is far below the 40% threshold commonly used in previous studies, indicating no significant common method bias in this study.

4 EXPERIMENTAL ANALYSIS AND RESULTS

4.1Main effect test: Elderly people with loneliness use AI intelligent voice robot

Correlation analysis is a common method for exploring the mutual influence between two variables, such as the Pearson correlation coefficient r used in quantitative data calculations. The larger the r value between variables, the stronger their correlation. This study employed the bivariate correlation calculation model in SPSS27.0 to test the three influencing factors and hypotheses of elderly AI intelligent voice robots. The results of the correlation analysis are as follows (see Table 3):

Table 3 Correlation analysis results among variables

variable	M	SD	1	2	3	4	5
Loneliness of the elderly	3.12	.21	1				
Cognitive level of older persons	3.53	.46	.369**	1			
Emotional tendencies of the elderly	4.01	.40	.321**	.880**	1		
Use of AI intelligent voice robot for the elderly	4.00	.53	.383***	.901**	.875**	1	
sex			-.051	-.120*	-.129*	-.148**	1

Note: *p<. 05, **p<. 01, ***p<.001

According to the aforementioned correlation coefficients, there is a significant positive correlation between elderly loneliness, cognitive level, and emotional tendency of the elderly with their use behavior of AI intelligent voice robots. Moreover, there is also a significant positive correlation among these three variables. The model has a good fit for the data (R^2 =0.843), and the regression coefficients are highly significant. Elderly loneliness can positively predict elderly addiction to online micro-dramas (b=0.16, SE=0.063, p<0.001), thus fully supporting Hypothesis H1.In the entire research model, compared to other influencing variables, the correlation between elderly loneliness and the use of AI intelligent voice robots is stronger. The factor of elderly loneliness has a more significant positive predictive effect on the usage behavior of AI intelligent voice robots among the elderly. Therefore, emotional emptiness and entertainment needs are both based on this primary effect. However, it should be noted that the relationship between gender and the intensity of elderly loneliness is not significant.

4.2Test of intermediary effect: the influence of cognitive level and emotional tendency on AI intelligent voice robot for the elderly

During the research design phase, it is anticipated that the cognitive level and emotional tendency of elderly individuals will mediate the main effect of loneliness on their addiction to online micro-dramas. This study employs the SPSS27.0 macro plugin PROCESS Model 6 to conduct a multiple linear analysis of four factors: loneliness (independent variable), use of AI intelligent voice robots by the elderly (dependent variable), cognitive level (mediating variable 1), and emotional tendency (mediating variable 2). The aim is to explore whether there exists a chain mediation relationship among these three factors. The results of the chain mediation are as follows (see Table 4):

Table 4 Chain mediation model among variables

predictive variable	Model 1 (elderly AI intelligent voice robot)			Model 2 (cognitive level)			Model 3 (emotional tendency)		
	b	t	SE	b	t	SE	b	t	SE
Loneliness in older persons (Z)	0.16	2.45***	0.06	0.82	6.93***	0.12	-.01	0.90	0.06
Cognitive level of older persons (M1)	0.65	11.43***	0.57				0.77	30.13***	0.03
Emotional orientation of older persons (M2)	0.49	7.64***	0.06						
R^2		0.92***			0.37***			0.88***	
F		546.99***			47.99***			523.66***	

Note: *p<. 05, **p<. 01, ***p<.001

According to the PROCESS data test, after both cognitive levels and emotional tendencies of elderly individuals were entered into the regression equation, higher cognitive levels significantly positively predicted the degree of use of AI intelligent voice robots (b=0.65, SE=11.43, p<0.001); higher emotional tendencies significantly positively predicted the degree of use of AI intelligent voice robots (b=0.49, SE=7.64, p<0.001); loneliness significantly positively predicted cognitive levels in elderly individuals (b=0.82, SE=6.93, p<0.001), thus fully verifying Hypothesis H4; loneliness did not significantly positively predict emotional tendencies in elderly individuals (b=-0.01, SE=0.90, p>0.005), thus fully verifying that Hypothesis H5 is not valid. Additionally, higher cognitive levels significantly positively predicted emotional tendencies in elderly individuals (b=0.77, SE=30.13, p<0.001).

To further verify the mediating role of cognitive levels and emotional tendencies in the relationship between loneliness and the use of AI intelligent voice robots among the elderly. This study employed a 5000-bias-corrected percentile Bootstrap method to test the mediating effect. The results are as follows (see Table 5):

Table 5 Analysis of the mediating effect of mediators on loneliness and the use of AI intelligent voice robot in the elderly

Effect type		Effect value	BootSE	Bootstrap 95%CI		Relative effect ratio
				LLCI	ULCI	
gross effect		0.994	0.137	0.723	1.264	
direct effect		0.156	0.063	0.308	0.280	15.7%
indigo effect	Simple mediation effect of cognitive level	0.533	0.105	0.343	0.754	53.6%
	Simple mediating effect of emotional tendency	-0.004	0.026	-0.056	0.230	-0.3%
	Chain mediation effect	0.308	0.073	0.182	0.468	31.0%

Note: LLCI refers to the lower limit of the 95% confidence interval, and ULCI refers to the upper limit of the 95% confidence interval.

According to the data from the mediation effect table, the cognitive level of elderly individuals significantly mediates the relationship between their loneliness and the degree of use of AI intelligent voice robots (mediation effect = 0.533, SE = 0.105,95%CI= [0.343,0.754]). This mediation effect accounts for 53.6% of the total effect, thus Hypothesis H2 is supported: the cognitive level of elderly individuals not only positively predicts the degree of use of AI intelligent voice robots but also mediates the relationship between their loneliness and the degree of use of AI intelligent voice robots. The emotional tendency of elderly individuals does not significantly mediate the relationship between their loneliness and the degree of use of AI intelligent voice robots (mediation effect = -0.004, SE = 0.026,95%CI= [-0.056,0.230]), which accounts for-0.3% of the total effect, thus Hypothesis H3 is not supported: the emotional tendency of elderly individuals cannot positively predict the degree of use of AI intelligent voice robots and does not mediate the relationship between their loneliness and the degree of use of AI intelligent voice robots. Additionally, there is a significant chain mediation effect between the cognitive level and emotional tendency of elderly individuals (mediation effect = 0.308, SE = 0.073,95%CI= [0.182,0.468]), which accounts for 31% of the total effect, thus Hypothesis H6 is supported: the cognitive level of elderly individuals can not only positively predict their emotional tendency but also has a chain mediation relationship with it.

4.3Test of moderated mediation: gender differences in the use of AI intelligent voice robots by the elderly

During the research design phase, this study considered that gender factors might influence elderly users› behavior and play a moderating role in the interaction of various variables. The study used the SPSS27.0 macro plugin PROCESS model 92 to test the aforementioned hypotheses, and all data were standardized before regression analysis. The results of the moderated mediation model analysis are as follows (see Table 6):

Table 6 Analysis of mediation model

	Y				M1				M2			
	β	SE	t price	p price	β	SE	t price	p price	β	SE	t price	p price
Z	0.129	0.206	0.624	0.533	-0.079	0.392	-0.253	0.840	0.175	0.182	0.962	0.001**
sex:	-0.067	0.433	-0.155	0.877	-1.864	0.745	-2.504	0.013*	-0.224	0.341	-0.657	0.512
Z* sex:	0.016	0.128	0.122	0.903	0.567	0.238	2.384	0.018*	-0.132	0.113	-1.162	0.245
M1	0.604	0.172	3.517	0.005**					0.494	0.085	5.809	0.000***
M1* Gender:	0.030	0.118	0.258	0.797					0.174	0.052	3.362	0.009**
M2	0.524	0.199	2.633	0.009**								
M2* Gender:	-0.030	0.132	-0.228	0.820								
sample capacity	307				307				307			

Note: *p<.05, **p<.01, ***p<.001; Z (independent variable): loneliness of the elderly; Y (dependent variable): use of AI intelligent voice robot by the elderly; M1 (mediating variable 1): cognitive level of the elderly; M2 (mediating variable 2): emotional tendency of the elderly

According to the data in the regression analysis table, when both cognitive level and emotional tendency of elderly individuals are entered into the regression equation, loneliness does not significantly predict cognitive level or AI intelligent voice robot usage among the elderly. However, cognitive level and emotional tendency can both significantly predict AI intelligent voice robot usage among the elderly. When gender is included in the model, however, cognitive level and emotional tendency do not positively predict AI intelligent voice robot usage under the moderating effect of gender (b=0.030, SE=0.118, p=0.797; b=-0.030, SE=0.132, p=-0.228), indicating that gender has no significant impact on the relationship between cognitive level, emotional tendency, and AI intelligent voice robot usage among the elderly. In contrast, gender significantly moderates the positive relationship between loneliness and cognitive level, as well as cognitive level and emotional tendency (b=0.567, SE=0.238, p<0.05; b=0.174, SE=0.052, p<0.01). However, there are no significant gender differences in other paths within the model, thus partially supporting Hypothesis H7 from our research design phase.

4.4Path analysis between multiple variables

This paper presents the validation results of the relationships between variables using path analysis. Based on descriptive analyses, exploratory factor analysis, confirmatory factor analysis, and linear regression analysis of the three variables—loneliness, cognitive level, and emotional tendency—in elderly individuals, significant coefficient relationships are organized in the figures. The path relationships are then corrected and refined based on the original hypothesis model. The resulting path relationship model is as follows (see Figure 3):

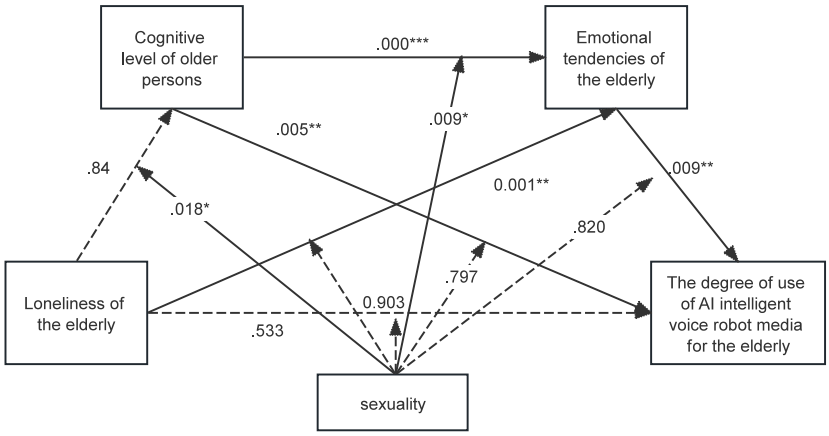

Figure 3 Path model of loneliness and AI intelligent voice robot for the elderly

According to the coefficient relationships in the path analysis table, it is evident that the cognitive level and emotional tendency of elderly individuals play a significant positive predictive role in the relationship between their loneliness and the use of AI intelligent voice robots. Among these, gender has a significant positive moderating effect on the relationship between the degree of loneliness and cognitive level, as well as between cognitive level and emotional tendency. However, there are no significant gender differences in other paths. When both cognitive level and emotional tendency are included in the model, the degree of loneliness does not significantly predict the use of AI intelligent voice robots. In this case, cognitive level and emotional tendency fully mediate the relationship between loneliness and the use of AI intelligent voice robots. This is the most important finding in the path analysis of this study and is consistent with the initial mechanism diagram of this study.

4.5Research deficiency and prospect

This study, while building on the CAC model, conducted a detailed quantitative analysis of elderly people› s addiction to online micro-dramas (intentional level-behavior) from three variables: loneliness (cognitive level-subjective cognitive variable), cognitive levels (cognitive level-external influence variable), and emotional tendencies (emotional level). However, it still has several shortcomings: (1) The total number of samples collected is relatively small, or there may be issues with representativeness; (2) The analysis of demographic characteristics in the study is limited, including factors such as educational level, place of household registration, and income level, which could all influence the use and consumption of AI intelligent voice robots by the elderly. Presenting data purely in numerical form does not adequately reflect the subjective attitudes of individual elderly users when interacting with robots. Future research can further conduct in-depth interviews and group discussions based on existing data analysis to qualitatively study the psychological usage of elderly users and better interpret the mechanisms illustrated in the text.

In light of the shortcomings in the aforementioned studies, future research will continue to strive for standardization and interdisciplinary approaches. By designing standardized questionnaire questions and improving sample collection and cleaning, we aim to enhance quantification efficiency and conclusion accuracy. With an interdisciplinary perspective, we will address psychological issues among the elderly, striving to provide theoretical and empirical evidence for the improvement of public governance mechanisms for loneliness in older adults.

5 RESEARCH IMPLICATIONS AND MEASURES

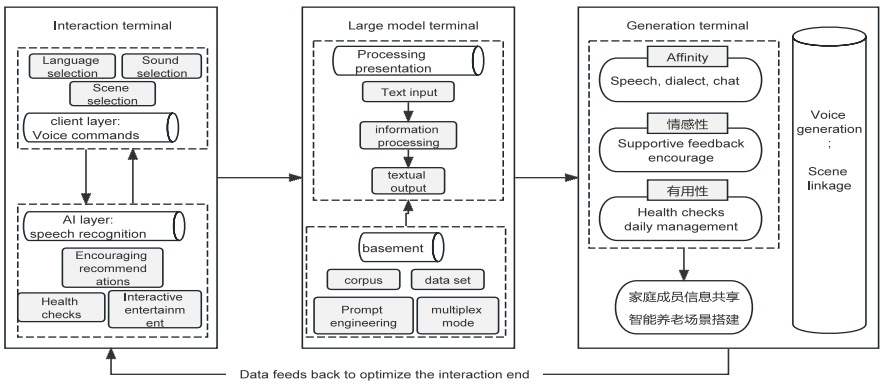

Figure 4 Schematic diagram of the operation of AI intelligent voice robot for aging

Through the quantitative analysis and path analysis of three variables—loneliness, cognitive level, and emotional tendency—with the varying degrees of AI intelligent voice robot usage among the elderly, it can be concluded that the behavior of using AI intelligent voice robots is not solely caused by individual loneliness but is directly influenced and reinforced by cognitive level and emotional tendency. Additionally, gender plays a significant moderating role in the effect pathway. Therefore, how to develop an AI intelligent voice robot with low cognitive barriers and high emotional engagement for the elderly, helping them integrate into the digital age and overcome loneliness, has become a challenge in current technological governance. This paper adheres to the principle of integrating and utilizing existing mature models and technologies, aiming to create an intelligent terminal with «Vue+Node.js+Python» as the technical framework and «interaction end-large model end-generation end» as the technical path, as shown in Figure 4.

5.1 Customized interaction: interactive mode is built to take into account both emotion and simplicity

In response to the characteristic of mixed dialects in China, this study simulates the creation of an AI intelligent voice robot suitable for the elderly. The aim is to integrate dialect voiceprint cloning technology and a cultural symbol database to build an interactive system with a sense of regional identity. Specifically, the AI intelligent voice robot receives voice commands from elderly users, converts text content into speech signals using Text-to-Speech (Text To Sound, TTS) technology, and then processes them through advanced speech-driven models such as Mel Frequency Contour Synthesis Network (Mel-Generative Adversarial Network, Mel-GAN) and the VADER sentiment analysis library, Further simulation and recognition of dialect voice lines and emotional fluctuations in speech signals, dynamically converting Mandarin phonetic models into dialect voiceprints such as Sichuanese and Cantonese. Based on the fuzzy matching engine of the Edit Distance Algorithm (Levenshtein Distance), dynamic emotional adjustments are made to the duration of pauses and tone of voice in elderly users› dialect speech. For example, when elderly users issue vague commands like «turn on...,» the AI intelligent voice robot will run the aforementioned processing procedure to complete commands such as «turn on the TV,» addressing interaction barriers caused by non-standard Mandarin. As mentioned above, cognitive deficiencies and sensory decline in the elderly can significantly affect their willingness and emotional inclination towards media use. From the perspective of emotional availability of media products, age-friendly AI voice robots should adhere to an «audience-centric» approach. Considering the comprehensive decline in vision and hearing among the elderly, they should optimize interface design to meet sensory needs, using large fonts and high-contrast colors, simplifying layout for easier visual reading, and adding voice functions and usage prompts to enhance auditory experience.At the same time, tactile vibration activation, UWB positioning and millimeter wave radar monitoring, active recommendation of personalized content and other functions are designed to reduce the cognitive threshold of elderly users and improve their use experience.

5.2 Real-time processing: the real-time update of the corpus is aligned with the dynamic nature of the large model

The large model serves as the «central brain» for processing user input speech and output, heavily relying on backend foundations such as corpora and prompt engineering. In this study, an AI intelligent voice robot adapted for elderly use was developed by deploying Vue 3 on the frontend and Node.js on the backend, adopting a «federated learning model» and «edge-cloud collaboration» information processing architecture to achieve real-time self-data updates and dynamic alignment at the large model end.The federated learning model, where multiple entities share resources through crowdsourced information uploads, works as follows: on one hand, AI-powered voice robots automatically collect 100,000 daily dialect conversations from elderly users anonymously and upload them in real-time to regional nodes via WebSocket long connections. On the other hand, elderly users can fully leverage their initiative by providing feedback on product strengths and weaknesses, social needs, community news, and more through voice or text to the cloud or platform. Meanwhile, enterprises and governments inject shared materials such as the «Guidelines for the Management of Chronic Diseases in Chinese Seniors,» disease guidelines from the National Health Commission, and policy databases from the Ministry of Civil Affairs into the general LLaMA3 model using online storage technologies like Vue 3, to enhance the accuracy of information provided to seniors.Under such a sharing mechanism, elderly users are not only consumers of content, but also creators and guardians of the Internet environment, thus establishing links between «user-platform» and «user-user» in deeper participation and interaction.Form a multi-dimensional collaborative governance model system of «government-enterprise-user».Of course, for elderly users, the processing mechanism of large models also exhibits the characteristic of «edge-cloud collaboration.» When individual elderly users are within the range of an AI intelligent voice robot and their commands are relatively simple, the edge-end mechanism of the large

model will be triggered. For scenarios involving dialect recognition, health coordination, or life warnings for elderly users within or across regions, the large model will activate the regional/cloud information processing path to synchronize the physical condition of the elderly with the scene to communities, nursing homes, and their children. Ninety-five percent of daily interactions are completed locally, ensuring core functions such as fall alerts can still be executed even in a disconnected network environment, prioritizing the safety and well-being of the elderly.

5.3 Scenario-based linkage: construction of multi-modal intelligent home care platform

As can be seen from the above, multimodal AI robots have the best effect on reducing the loneliness of the elderly, who are more likely and efficient to accept and understand the presentation of multimodal information. Mode refers to the symbolic form of speech, which is defined by communication as the smallest unit of display media, such as text, pictures, audio, etc.Multimodality refers to the combination of different modes, which integrates a single mode symbol such as text, audio or picture into the same video or digital product to achieve the effect of multi-sensory coexistence of hearing and vision. The AI intelligent voice robot for aging adaptation simulated in this study adopts Tornado+HomeAssistant middleware, Compatible with over 200 mainstream brands on the market, aiming to create a multi-modal intelligent home care platform centered around AI smart voice functions and coordinated use of branded devices. For example, when elderly users give voice commands like «sleep,» the AI smart voice robot will automatically close Xiaomi curtains (MQTT protocol) and adjust Gree air conditioners based on indoor temperature (Modbus protocol). It will also activate the Huawei wristband to monitor the user› s sleep (BLE protocol), achieving cross-platform integration of tactile, visual, and other multimodal smart home care services. In addition to content creation that is both engaging and useful, the AI smart voice robot has specifically set an emotional function with a daily interaction threshold of 4 hours. This means that after more than 4 hours of daily interaction between elderly users and the AI smart voice robot, the robot will forcibly initiate video calls with family members, preventing social isolation due to technological dependence and strengthening intergenerational ties among children.

6 CONCLUSION

As the digitalization process continues to force its way in, the elderly are compelled to accelerate their integration into media-saturated living spaces. They break away from their previous social habits and build «emotional utopias» and «smart nursing homes» centered around AI voice robots, aiming to bridge the emotional gaps caused by cold feedback in real-life interactions due to kinship, geographical, and social connections. However, they may not realize that such actions are inadvertently entangling them with algorithmic technology and self-deception-based emotional compensation. Ultimately, the online practices of the elderly community urgently need «human warmth.» Governments and communities should actively organize community activities to increase the social participation of the elderly, breaking down isolation at the «social connection» level. Family members need to take on the role of «guides,» using digital support and «warm communication» to help the elderly update their digital thinking and reshape their social interaction methods, reinforcing their emotional attachment at the «kinship» level. Corporate platforms must act as «gatekeepers» in content production, distribution, and experience, guiding the elderly through correct value orientations and user-friendly application models to enhance their AI usage experience, overcoming loneliness and fatigue at the «geographical connection» level. New media products are never a shackle that deprives the elderly of physical health and emotional cognition; rather, they are powerful tools for alleviating the loneliness of the elderly. This requires proactive management and improvement from multiple sectors of society, transforming the «digital divide» into a «digital bond,» allowing the elderly to enjoy the digital intelligence era.

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Abbreviations: AI: Artificial Intelligence; QOL: Quality of Life; SUS: System Usability Scale

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