A study on Technology Acceptance Model of AI speakers among middle-aged people

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China has one of the fastest growing ageing populations in the world. Smart homes, as integrated systems powered by digital technology, have enormous potential in assisting future elderly and middle-aged individuals with household living. As the central control system of smart home, the acceptance of AI speakers among China's current middle-aged population who are about to enter the aging stage will significantly impact the future popularity of smart home. Based on Technology Acceptance Model, this study presented a hypothesis model by abstracting four factors through factor analysis. The results of the structural equation modeling revealed that user experience and gender made the factors have different levels of influence. Finally, based on the four path diagrams obtained from the analysis, design guidelines and strategies are proposed to aid the future popularization of smart home in China.

Keywords: middle-aged people; smart speaker; technology acceptance model

1 Introduction

1.1 Background of the study

China has already transitioned into an aging society, and the World Health Organization predicts that China's population over 60 years old will reach 35% in 2050, making it the most aging country in the world. According to a study by Guo (2010), 90% of China's elderly population chose home-based care.

Smart homes that incorporate IoT, big data processing technologies, etc. can solve the problems of home-based care and enable the elderly to live comfortably. Moreover, they can also contribute to the reduction of labor and time costs, while also offering a potential solution to mitigate labor shortages in eldercare services (Cai & Wang, 2006). However, the household penetration rate of smart home in China is still at a low level, and one likely reason derives from the gap between the functions and user's experience or expectations (Ji & Chan, 2020). Smart home product functions are becoming more diverse and complex, making it difficult for the general public to use them (Kashimura et al., 2001).

1.2 Purpose

This study focuses on AI speakers which play a role in voice interaction in the smart homes. The research aims to explore factors influencing people's usage of AI speakers and to elucidate the relationships among these factors. Finally, this study will contribute to smart home design by proposing strategies.

1.3 Previous studies

Kiyomiya and Xu (2017) found that 'perceived ease of use' and 'perceived usefulness,' traditionally important factors in the Technology Acceptance Model (TAM), are also significant predictors of consumers' acceptance intentions for smartphones. In addition, a comparison between Japan and China reveals that differences in social and cultural backgrounds have different effects on decision-making factors.

According to Okumura et al. (2015)'s study, the group with low intention to use information systems and services tends to gain a sense of security by experiencing ease of use, and tends to gain a sense of acceptance if the system is efficient and convenient. This research has found that people tend to feel more secure with technology that is easy to use rather than with technology that is safe and reliable.

According to Aoki (2015)'s study, a survey of homebound elderly persons and analysis using structural equation modeling revealed that mental health, social relations, self-esteem, actual age, and economic status were significantly related to subjective age among men. On the other hand, for women, mental health, social relationships, self-esteem, role, actual age, and economic status were significantly related to subjective age.

A study by Sakamaki et al. (2009) used the SD method to extract evaluation factors. Based on this, they clarified the relationship between the impression that Web design gives to users and the amount of information they remember through a structural equation modeling.

As described above, there have been many studies on technology acceptance targeting information systems and devices, but there have been few studies on technology acceptance of AI speakers. On the other hand, there have been many studies on understanding causal relationships through structural equation modeling, but the intention to use smart home products such as AI speakers has not yet been clarified.

2 About Technology Acceptance Model

2.1 Models related to technology acceptance

To understand the evolution of technology acceptance models and select the most appropriate one for this study, we reviewed existing models related to technology acceptance.

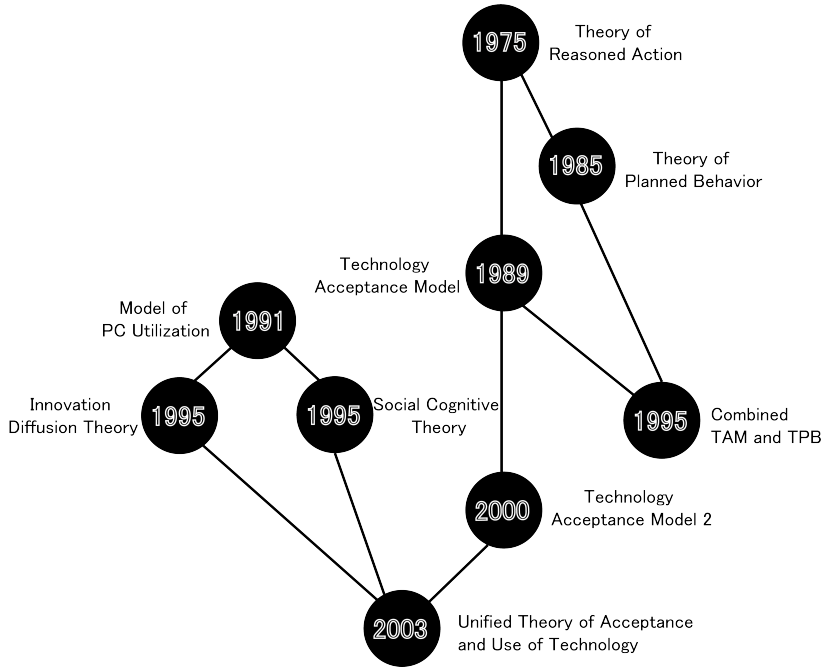

Figure 1. The developing of technology acceptance model

2.2 Characteristics of the Technology Acceptance Model

The Technology Acceptance Model (TAM), developed by Davis (1989) and shown in Figure 2, is known for its generality, as it can be applied to any information system and user, and its simplicity, as it explains usage behaviour with minimal factors.

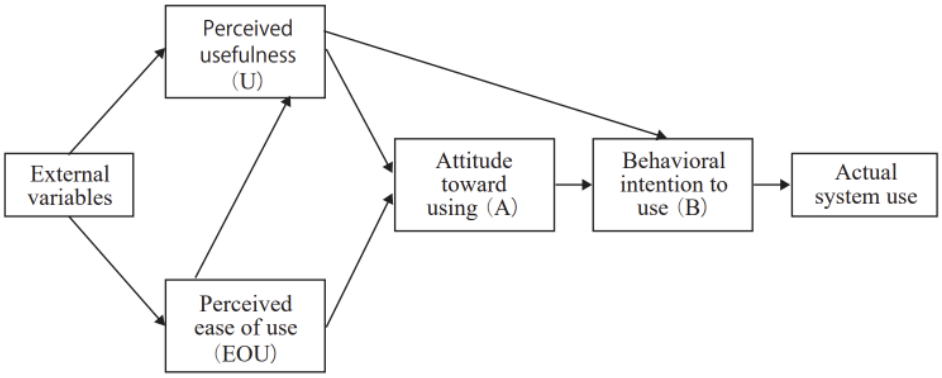

Figure 2. Technology Acceptance Model: Davis, Bagozzi, & Warshaw (1989).

Therefore, this study decided to use the Technology Acceptance Model.

2.3 Collection and organization of questionnaire questions

In order to analyze using the Technology Acceptance Model, this study collected and organized the questionnaire questions from the studies by Kiyomiya and Xu (2017), Okumura et al. (2015), Ministry of Internal Affairs and Communications (2009), Kawakatsu and Komiya (2011), Takada and Fujita (2013), Weng et al. (2018), Alfalah et al. (2020), and Matsuo et al. (2022). The questionnaire questions listed in the related studies were categorized into the five factors of "External variables," "Perceived usefulness," "Perceived ease of use," "Attitude toward using," and "Behavioural intention to use" which introduced in Davis et al.'s (1989) model.

3 Web survey among middle-aged Chinese

3.1 Outline of the survey

The survey aimed to target middle-aged people between the ages of 50 and 59 who are expected to become major users of smart homes in the near future. In addition, as consumer behaviour, income levels and infrastructure vary across China's cities, perceptions of smart products may also differ. For instance, Beijing, Shanghai, Shenzhen and Guangzhou, China's four first-tier cities, have the best urban business environments in the country, and have a higher concentration of middle-aged individuals working in finance, internet, and other high-paying careers. Individuals there tend to reside in high-rise apartments within communities. These characteristics lead us to believe that more reliable and valid data can be obtained by choosing residents of first-tier cities as survey respondents.

Therefore, in September 2022, this study conducted a Web survey of middle-aged people living in first-tier cities through a survey company called Questionnaire Star.

3.2 Survey content

The survey consisted of seven parts of questions: "Q1: Respondents' attributes such as age and gender," and "Q2: Experience in using various smart home products," are single choice questions. "Q3: Characteristics of AI speakers (external variables)," "Q4: Perceived usefulness," "Q5: Perceived ease of use," "Q6: Attitude toward use," and "Q7: Behavioural intention." are 5-point Likert scale questions.

Table 1. Questionnaire Details

No.	Item	No.	Item
Q1. Respondents		**Q4. Perceived usefulness**	
Q1-1	Gender	**Q4-1**	AI speaker has a very important role to play in my life
Q1-2	Age	**Q4-2**	My quality of life has improved if I use a AI speaker
Q1-3	Health (self-assessment)	**Q4-3**	The information available to AI speaker is helpful to me
Q1-4	Can you live on your own	**Q4-4**	Using the voice interaction feature of AI speaker, I can gather the information I need more quickly
Q1-5	People you live with		
Q1-6	Occupation	**Q4-5**	The range of things I'm able to do becomes much wider with AI speaker
Q1-7	Housing type	**Q4-6**	The efficiency is improved when using a AI speaker
Q1-8	Surrounding environment	**Q4-7**	AI speaker is more convenient than other tools
Q2. Experience in using various smart home products		**Q5. Perceived ease of use**	
Q2-1	Have you ever used smart appliances or smart-home	**Q5-1**	It's very easy to use AI speaker the way I want it
Q2-2	What type of product is it	**Q5-2**	Learning how to use AI speaker is easy for me
Q2-3	Have you ever used AI speaker	**Q5-3**	I don't need to constantly confirm the instructions and manuals
Q2-4	How receptive are you to smart-home	**Q5-4**	I rarely go wrong when using AI speaker
Q3. External variables		**Q5-5**	AI speaker is clear and easy to understand how to use it

Q3-1	Personal information will be leaked	**Q5-6**	The AI speaker links smoothly with other appliances or the home network
Q3-2	Fear of accidents caused by computer viruses	**Q5-7**	After the upgraded version, the AI speaker is just as easy to use as it was before
Q3-3	Fear of accidents caused by misuse		
Q3-4	Fear that AI speaker can't be trusted like people	**Q6. Attitude toward use**	
Q3-5	Looking forward to the products with more functions	**Q6-1**	I think AI speaker attracts me
Q3-6	Expect AI speakers to link to other products	**Q6-2**	I think it's wise to use the AI speaker
Q3-7	Looking forward to a more attractive look	**Q6-3**	I think there are many benefits to using AI speaker
Q3-8	I will be concerned about the price of AI speaker	**Q6-4**	I'm positive about the AI speaker
Q3-9	I will be concerned about the cost required for repair	**Q6-5**	I think using AI speaker is the future and trend
Q3-10	I will be concerned about the reasonableness of after-sales service costs	**Q7. Behavioural intention**	
Q3-11	I will be concerned about the responsiveness of AI speaker	**Q7-1**	I'll continue to use AI speaker even if there are other voice interaction products available
Q3-12	AI speaker won't be able to respond as flexibly as people do		
Q3-13	AI speaker can't effectively solve my problems	**Q7-2**	I'll continue to use AI speaker even if it is more expensive
Q3-14	I'm interested in innovative products	**Q7-3**	I'll continue to use AI speaker even if it is complicated to figure out how to use it
Q3-15	I enjoy using innovative products		
Q3-16	I would be influenced by brand image when choosing new products	**Q7-4**	I'm starting to plan for using AI speaker in the future
Q3-17	I would be influenced by product design when choosing a new product	**Q7-5**	I'll be using AI speaker in the future
Q3-18	AI speaker is very useful for me to connect with others	**Q7-6**	I'd like to use AI speaker right away
Q3-19	People around me are using AI speaker	**Q7-7**	I have a desire to recommend AI speaker to others
Q3-20	Family and friends had recommended me to use AI speaker	**Q7-8**	I would like to increase the frequency of using AI speaker in the future

3.3 Results of the survey

A total of 478 respondents participated in the web survey. Of these, four respondents who provided duplicate responses were excluded from the analysis. Additionally, 66 respondents who answered "60 years old or older" in "Q1: Age" were excluded from the analysis as they did not fall within the age range of middle-aged Chinese, the target group for this study.

Therefore, the analysis was conducted using responses from 408 valid respondents. The valid response rate was 85%.

Table 2. Statistics of gender, age, and usage experience

	Have using experience	**No using experience**	**Total**
Male	118	70	188

	28.9%	17.2%	46.1%
Female	146 35.8%	74 18.1%	220 53.9%
Total	264 64.7%	144 35.3%	408 100%

4 Factor extraction and structuring

4.1 Factor extraction

To identify the factors of the questions in the "Q3 external variable", a factor analysis (main factor method, promax rotation) was conducted, and four factors were extracted based on the magnitude of the eigenvalues and the decay situation.

Table 3. Factor loadings for each factor

		Factor 1	Factor 2	Factor 3	Factor 4
Reliability	**Q3-2**	0.782	-0.119	-0.002	0.076
	Q3-3	0.768	-0.117	0.077	0.060
	Q3-1	0.751	-0.128	0.015	0.103
	Q3-4	0.711	-0.066	-0.023	-0.033
	Q3-13	0.641	0.081	0.144	-0.281
	Q3-12	0.574	0.059	0.180	-0.209
Innovativeness	**Q3-15**	-0.169	0.698	0.052	0.247
	Q3-11	-0.039	0.676	0.072	0.058
	Q3-7	-0.072	0.547	0.206	0.184
	Q3-6	-0.067	0.483	0.400	0.172
	Q3-5	-0.009	0.479	0.240	0.208
	Q3-17	-0.063	0.438	0.194	0.208
Economic	**Q3-8**	0.125	0.089	0.667	0.069
	Q3-9	0.117	0.130	0.562	0.005
	Q3-16	-0.001	0.394	0.457	0.144
	Q3-10	0.093	0.375	0.449	0.098
Relationship -building	**Q3-20**	0.025	0.265	0.079	0.717
	Q3-19	-0.096	0.344	0.007	0.538
	Q3-14	-0.054	0.243	0.254	0.391
	Q3-18	0.007	0.339	0.329	0.373
	Total	3.105	2.639	1.716	1.488
	% of Variance	15.526	13.196	8.580	7.439
	Cumulative %	15.526	28.722	37.302	44.741

There are many studies that reported that factor loadings should be greater than 0.5 for better results (Hulland, 1999; Truong & McColl, 2011). Also, the higher the load, the more relevant it is in defining the factor's dimensionality.

Therefore, Factor 1 was interpreted as a factor representing "Reliability" because it is related to the safety and trustworthiness of using AI speakers. In support of this, questions such as Q3-2, Q3-1, and Q3-3 all showed high loadings in this factor. This indicates that users consider problems such as whether the AI speaker can be infected with viruses like a computer, whether it can suddenly and unexpectedly malfunction, and whether it can expose one's personal information to the internet as most relevant to "Reliability".

Factor 2 was interpreted as "Innovativeness". Questions such as Q3-15, Q3-11 show high loadings in Factor 2. This can be explained by the fact that users' preferences for innovative products and their expectations of new AI speakers are rooted in the concern of "Innovativeness".

Factor 3 was interpreted as "Economic". Since Q3-8 and Q3-9 reach a loading of 0.5 or more in Factor 3, it can be assumed that Factor 3 is related to "Economic" like price of the AI speaker and the after-sales service fee.

Factor 4 was interpreted as "Relationship-building". Just like the high loadings demonstrated in Q3-20 and Q3-19, Factor 4 is considered to be related to social relationships like whether the people around me use and recommend me to use the smart speaker, so it is considered to be "Relationship-building".

Therefore, the external variables were considered to be captured by the four factors of "Reliability", "Innovativeness", "Economic", and "Relationship-building".

4.2 Structuring and analytical model

The factors that influence attitudes towards use are not independent of each other but are considered to be interrelated and influential. An analytical model was constructed based on the factors of the external variables extracted in the previous section and the factors listed in the Technology Acceptance Model. Structural equation modeling was conducted using AMOS.

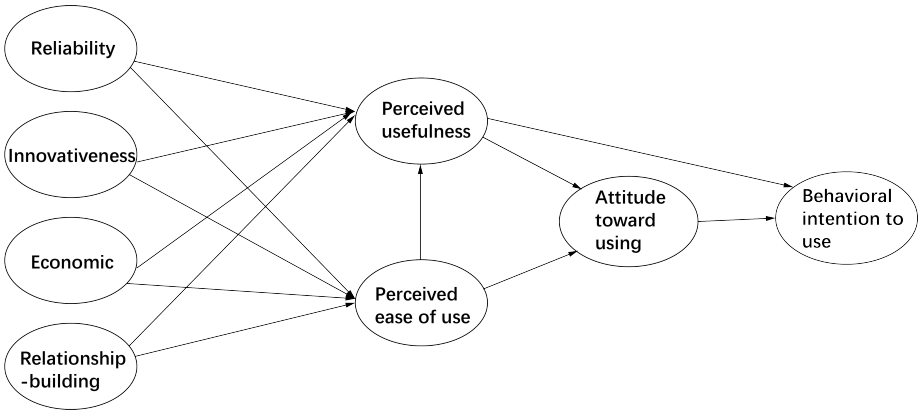

Figure 3. Hypothetical model of analysis

5 The relationship regarding technology acceptance

5.1 Relationship between technology acceptance and usage experience

The GFI (Goodness of Fit Index) of the models are all over 0.7, which means that the fits of models are at an average level (Kline, 2016). Comparing Figure 4 and Figure 5, we can see the relationship between technology acceptance and usage experience. (The path coefficients written for the former are for those with experience in using AI speakers and for the latter are for those without experience in using them.)

The "Relationship-building" factor (0.47=0.44×0.47+0.43×0.60) (0.52=0.57×0.85+0.25×0.17) has a high value of path coefficient and a significant positive impact regardless of whether the user has used AI speakers or not which means it can be seen as an important factor.

In the "Reliability" factor (-0.09=-0.20×0.47) (-0.12=-0.14×0.85), "Ease of use" is negatively affected regardless of whether the user has used the AI speaker before or not. In other words, the more the reliability of the AI speaker is valued, the lower the evaluation of "Ease of use" becomes.

For respondents who have experience using AI speakers, it is observed that they place more importance on requirements for "Innovativeness" (0.15=0.31×0.47) such as attractive appearance, diverse functions, etc. However, for users who have no experience using AI speakers, there is little interest in "Innovativeness." On the contrary, "Economic" (0.05=0.30×0.17) was seen as a important factor, with a significant difference. This indicates that the usage experience influences the factors that users consider most important.

Both "Usefulness" and "Ease of use" have a positive influence on "Attitude toward use" but the difference between "Usefulness" and "Ease of use" is more pronounced for the subjects who have no experience using AI speakers. For this group of respondents, perceived usefulness strongly influences their intention to use an AI speaker.

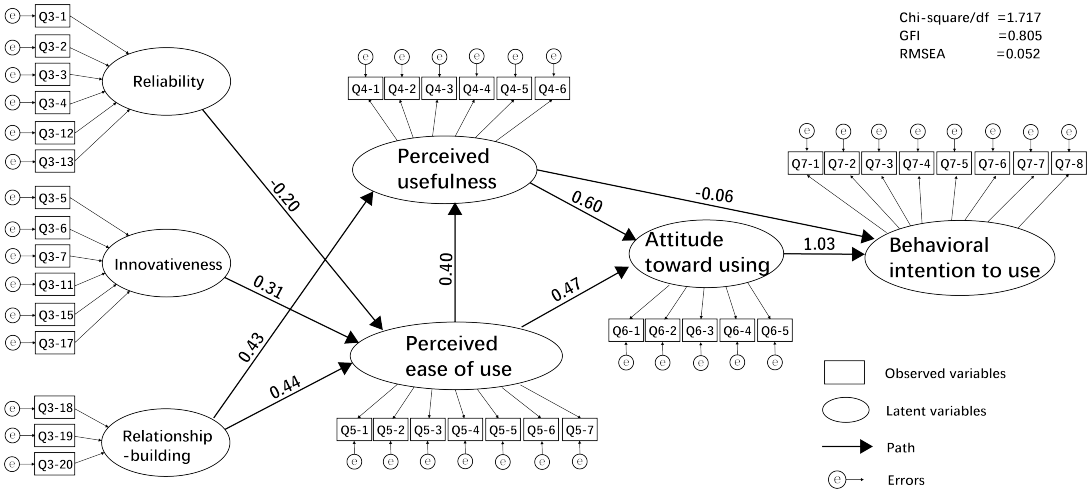

Figure 4. Path diagram (have using experience)

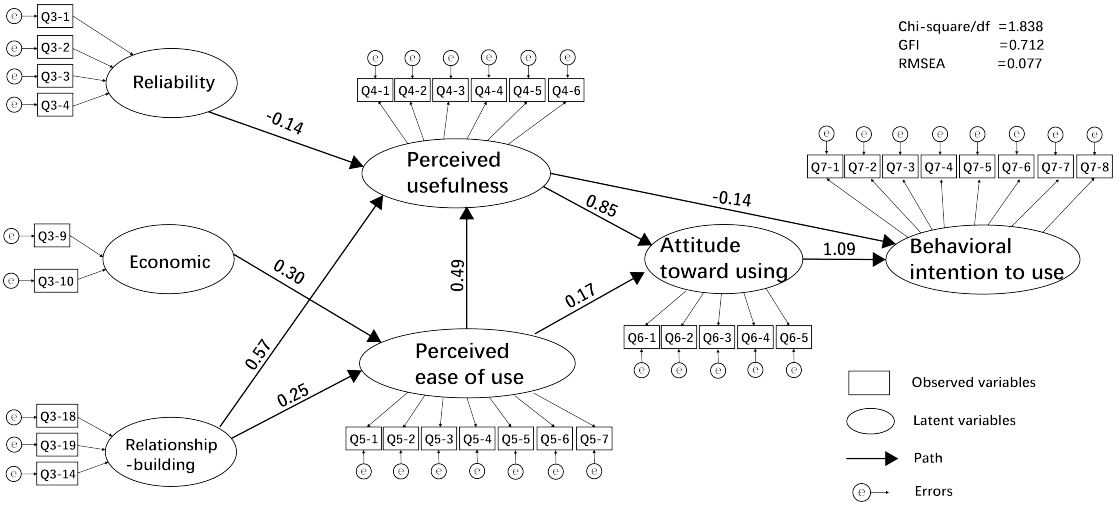

Figure 5. Path diagram (no using experience)

5.2 Relationship between technology acceptance and gender

As mentioned above, "Innovativeness" and "Economic" as external variables showed significant differences depending on whether the respondents had used the AI speakers before or not. Therefore, a structural equation modeling was conducted again, targeting only the 264 respondents (118 males and 146 females) who had used the technology, excluding the 144 respondents who had never used it. Comparing Figure 6 and Figure 7, we can see the relationship between technology acceptance and gender.

The influence of "Usefulness" on "Attitude toward use" was strong among men, and "Ease of use" had a certain degree of influence as well. "Relationship-building" (1.13=1.17×0.68+0.88×0.37) was significantly related to "Usefulness" and "Ease of use," and was found to be important for men. On the other hand, "Innovativeness" (-0.37=-0.55×0.68) and "Reliability" (-0.33=-0.35×0.68-0.25×0.37) had a negative impact, indicating that these two factors generate distrust of technology among men.

For women, "Usefulness" and "Ease of use" had the same level of influence on "Attitude toward use," and their prominence was relatively low. "Relationship-building" (0.32=0.61×0.53) showed a certain degree, although not as high as that of the men. On the other hand, "Innovativeness" (0.37=0.70×0.53) was ranked first, indicating a positive influence. This characteristic is unique to women and indicates that they have a strong interest in innovative products rather than men do.

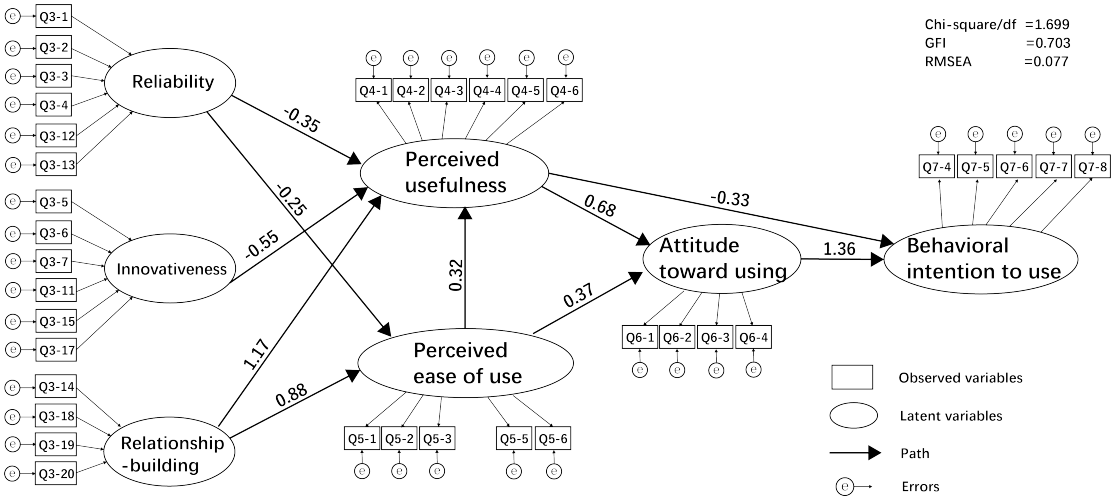

Figure 6. Path diagram (men)

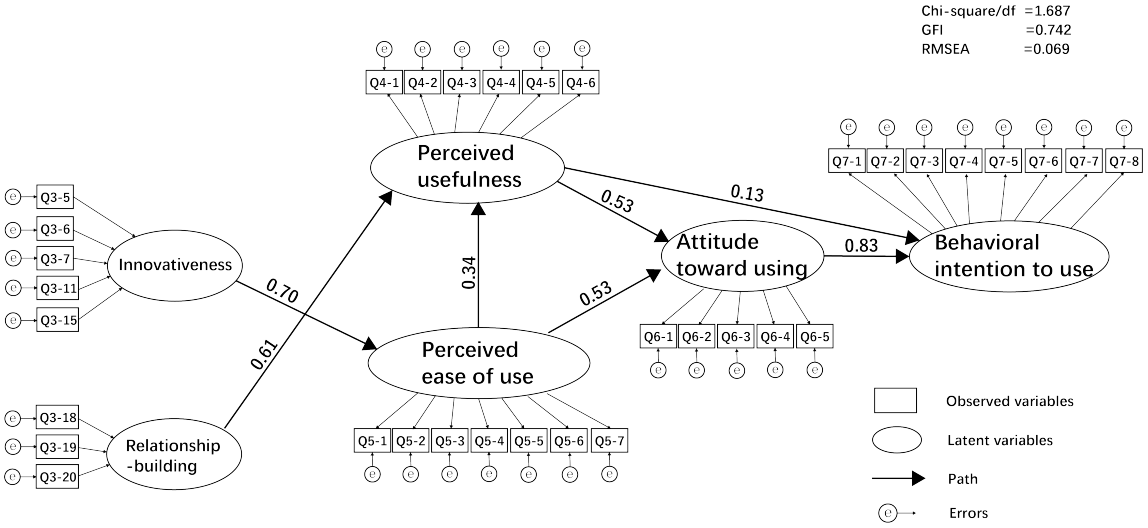

Figure 7. Path diagram (women).

5.3 Overall

According to the model analysis above, it was found that users with no experience of using AI speakers focus on the "Economic" (0.05), while users with experience of using AI speakers focus on the "Innovativeness" (0.15). The reason for this difference may be that users were concerned about the high cost and necessity of smart products when they did not own them. However, their concerns were resolved when they actually used them. On the other hand, attractive appearance and diverse functions are attracting the attention of users who are just starting to use AI speakers. In order to encourage these users to continue using AI speakers, it is considered necessary to upgrade the AI speakers′version regularly and devise linkage with other smart products.

Women seem to regard "Innovativeness" (0.37) as the primary factor that improves their attitude towards using AI speakers. Based on this fact, innovative designs for women are required. However, "Innovativeness" (-0.37) has a negative impact on men. Although we did not conduct a deeper investigation and analysis of this difference in this study, we believe that different preferences of gender should be considered in future designs. For men, "Usefulness" (0.68) was more strongly

associated with the attitude toward use than "Ease of use" (0.37). Women place the same importance on both (0.53).

"Relationship-building" is strongly linked to attitude towards use in all results and is an important factor in improving the acceptance of technology. This may be due to the fact that middle-aged people seek online communication, one of the important functions in AI speakers, non-face-to-face means of interaction due to the influence of COVID-19. On the other hand, not only family interactions but also social influences, such as recommendations from close friends, may have led middle-aged people to start using AI speakers.

All the results showed that "Reliability" factor has a negative impact to the intention to use, regardless of whether the user has used AI speakers before or not, showing a clear different trend from other factors. It is believed that the current products do not address concerns about reliability. Therefore, it is important to prevent accidents and manage personal information to improve the reliability of AI speakers. This will also become one of the issues that must be studied in the age of AI.

Overall, "Economic" was not strongly related to "Usefulness." This may be due to the fact that the survey was limited to only a few cities in China, and the economic level of the region is about the same. In future studies, it would be desirable to consider regional differences and conduct research covering a wider range of regions.

6 Conclusion

6.1 Summary of this study

In this study, we explored the acceptance of AI speaker technology among middle-aged people living in a first-tier city in China.

Based on the quantitative analysis of this study, we have proposed some design point of view.

User	Need	Insight
Middle-aged Chinese people with AI speakers	Make friends and increase social presence	Provide friend formation service such as a special-interest online community
	The process of using AI speakers in which personal information and property are guaranteed	To remind the user when starting a video or audio recording
Middle-aged Chinese people who have not used a AI speaker	Lower prices and after-sales service costs	Combine China's market characteristics like online merchandising, shopping carnival, etc. to lower the purchase price
Middle-aged Chinese people who are using AI speakers	Attractive appearance and diverse functions	Upgrade appearance regularly and devise linkage with other smart products
Middle-aged Chinese men who are using AI speakers	To be helpful and of high value to their lives	Add wealth management, personal education and other functions
Middle-aged Chinese women who are using AI speakers	Creative services and functions	Provide voice-interactive services based on the physical and psychological characteristics of menopausal women

Figure 8. Design point of view.

The results showed that the factors considered important by users differed depending on whether they had used AI speakers before and on their gender. For all middle-aged Chinese people,

"Relationship- building" is the most important factor influencing the intention to use which suggest that we should pay more attention to the " Relationship- building " brought by AI speakers in future design. Since the most important reason for middle-aged and elderly people in China to use the Internet is to make friends (Sun et al., 2020), it is feasible and effective to provide a friend formation service on AI speakers.

On the other hand, "Reliability" had a negative impact, indicating that more reliable AI speakers are desired in order to eliminate distrust of technology. This suggests that we need to be able to inform the user when the smart speaker is performing an audio and video recording function, rather than doing it without the user realizing it.

For all the middle-aged Chinese people who have no experience in using AI speakers, price is the most concerned factor. Therefore, the promotional activities such as the Double 11 shopping carnival (Shiau et al., 2022) will lower the price and at the same time arouse the desire of Chinese consumers to buy.

Finally, the impact of "Innovativeness" tended to vary by gender, suggesting that the difference of gender needs to be given different consideration. For men, they pay more attention to whether the AI speakers can help them and be valuable to their life, so functions such as wealth management and personal education should be paid attention to. For women, they value the creative interactive experience of AI speakers, so it makes sense to offer them voice-interactive services for solving menopausal worries.

The discussion above will help future researchers to study smart home products and provide some referable ideas for the design and marketing of smart home products.

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