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A Study of the Interaction between User Psychology and Perceived Value of AI Voice Assistants from a Sustainability Perspective

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Abstract: With the development and innovation of artificial intelligence (AI) technology, users can regulate their social lives and personal emotions through continuous interaction with AI voice assistants or chatbots. Based on the value-based adoption model (VAM), this paper examines the differences between different psychological factors with respect to perceived value factors when using AI voice assistants. This study is of great significance to improving AI voice assistant services and provides an important reference point for deeper understanding of user perception and emotional response to AI voice assistants. The aim of this research is to examine whether the usefulness, enjoyment value, perceived emotional value, and functional value of an AI voice assistant vary according to the user's level of loneliness, resistance to innovation, and infringement of privacy. An online questionnaire created on the Questionnaire Star platform was used in this paper, and a three-way ANOVA was employed using SPSS 21.0 software. The findings suggest that the interaction effects of psychological factors such as loneliness, innovation resistance, and infringement of privacy differ in terms of perceived usefulness and enjoyment when using AI voice assistants, as well as in terms of perceived emotional and functional value. The results of this study provide a theoretical basis for the application and sustainable development of AI voice assistant technology by companies in different countries and regions. At the same time, this paper provides a valuable reference point for promoting urban economic sustainability in the context of digital technology.

Keywords: artificial intelligence (AI) voice assistant; value-based adoption model (VAM); loneliness; innovation resistance; infringement of privacy

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1. Introduction

An artificial Intelligence (AI) voice assistant is a social robot optimized for communication. Currently, AI voice assistant services are mainly based on speech recognition technology, also known as natural language recognition, which aims to convert the lexical content of human speech into computer-readable input. It allows the machine to understand human commands, understand and predict the user's needs based on the text, make relevant responses and actions, and output a reply text back to the user. In everyday life, it can provide weather forecasts, play music, chat, etc. There are also more useful functions such as setting alarms, reminding schedules, and controlling home devices. In addition to these common applications, AI voice assistants are playing an increasingly important role in healthcare, continuously improving the user experience and enabling sustainable socioeconomic development [1]. Users have begun to embrace virtual assistants such as chatbots as part of their daily lives and to communicate with them in a variety of ways [2]. The many attributes of AI voice assistants will, in the future, bring about the differentiation between

operators in the face of fierce competition in the intelligent speaker market, which will play an important role in the long-term strategic development of products and operators. If AI voice assistants are able to communicate effectively based on different user psychological changes according to the type of service, the communication effect will be greatly enhanced and will also bring enjoyment and resonance to the user experience [3]. So, it is particularly important to grasp the different psychoemotional states and cognitive levels of users when faced with new technologies to perceive the positive benefits of usefulness, pleasantness, and information generation, in addition to the emotional and functional value; whether or not perceptions of value are influenced by psychoemotional and cognitive factors is another issue that this study aims to explore.

Ko et al. (2005) proposed an intelligent interaction architecture by which to develop a compact robotic assistant which is operable with minimal control burden. On the other hand, the software and hardware technologies have now reached a maturation point where electronic assistants can acquire information from the user through camera images, as well as communicate with the user by means of natural voice language [4]. Reis et al. (2017) studied the use of intelligent personal assistants to strengthen the elderly's social bonds with a preliminary evaluation of Amazon Alexa, Google Assistant, Microsoft Cortana, and Apple Siri. In this context, a model for the adoption of electronic intelligent assistants for the elderly has been proposed [5]. Sohn et al. (2020) determined which models best explain user acceptance of AI-based intelligent products and which factors have the greatest impact in terms of purchase intention [6]. Phaosathianphan et al. (2020) aimed to the suitability of antecedent variables and IT processes for ultimately measuring and assessing feature values of an Intelligent Travel Assistant (ITA) related to the actual use of the Free Individual Traveler (FIT) [7]. Hasan et al. (2021) constructed a study to determine the influence of user trust, interaction, perceived risk, and novelty value on brand loyalty for AI-supported devices, and it was the first to propose a comprehensive model from both functional and social perspectives on continual usage intention of the smart speaker and online purchase intentions through AI assistants [8].

We not only need to understand intention of use and acceptance on a technical level; we also need to put social and personal psychological factors together as prior variables and observe, in depth, the intention of users to use AI voice assistants so as to develop a comprehensive understanding of AI voice assistants. In this research, the theoretical application is based on the VAM, which is a better model of user interpretation. The aim is to understand whether there are differences in the perceived usefulness and pleasantness of AI voice assistants in the interaction of three personal psychological factors: loneliness, resistance to innovation, and invasion of privacy. Secondly, whether there is an interaction between loneliness, resistance to innovation, and invasion of privacy in terms of the perceived emotional and functional value. Further, we analyze the factors and intermediate mechanisms that influence users' psychologically perceived value of AI voice assistants. The results of this study have important implications for expanding the use of AI voice system services and improving the marketing of AI voice assistant services. The findings also provide a reference value for producers and marketers of intelligent voice systems, pointing to the importance of communication methods and privacy protection for future AI voice assistants. It also provides practical implications for related industries, expanding research related to user-focused AI voice service technologies. In addition, this research will enable improvements in technologies related to AI voice assistants to ensure greater user awareness, enabling and value factors to better align with the goal of sustainable urban development and, ultimately, economic development, quality of life, and sustainability.

2. Theoretical Background

2.1. Value-Based Adoption Model (VAM)

The VAM is a new theoretical framework by which to explain technology acceptance [9]. The theory argues that people who respond to technology should be considered users who make decisions with perceived benefits and sacrifice. Perceived benefits are

based on a user's personal perception of the benefits they receive from using a product or service [10,11]. Perceived sacrifice refers to the cost factors that users must pay to use a product or service, which also includes psychological costs such as the time, effort, and dissatisfaction factors spent using the product [12]. The VAM focuses technology acceptance on maximizing personal value, assuming that perceived value is formed by comparing benefits and sacrifices [9]; that is, in order to measure technology acceptance behavior accurately and in a balanced manner, it is important to consider not only the positive aspects but also the costs incurred or sacrifice factors to be borne by accepting the technology. The positive aspects are reflected in the utilitarian benefits (e.g., usefulness, enjoyment), and the negative aspects are reflected in the perceived technicalities and costs (perceived fee). The perceived value of a new technology is recognized by users through perceived benefits and sacrifices, and this becomes an important variable in predicting the intention to accept the technology. In other words, the higher the utilitarian benefits of a new technology and the lower the sacrifice factors, the higher the perceived value and the higher the intention to accept the new technology. Improving users' cognition of favorable factors plays an important role in the perceived value and use of new technologies.

In daily life, AI voice assistants offer several conveniences to users and improve efficiency in dealing with problems. However, in order to provide more accurate services, a large amount of personal information may be collected and used. For example, the voice information they collect contains many cues that can be used to estimate an individual's emotional state, and because AI voice assistants are conversational, the devices receive private conversational content in addition to basic commands, which may likewise have a negative impact on the user's privacy, and there is a risk of invasion of privacy [13,14]. As a result, users may also experience varying degrees of anxiety during the use of AI voice assistants. Other research suggests that people who are more sensitive to the possibility of invasion of their privacy may be less willing to accept new products and services [15]. Korgaonkar and Wolin (1999) found that users' privacy concerns negatively impacted their use of e-commerce [16]. Hershel and Andrews (1997) found that many users were reluctant to purchase goods due to uncertainty about privacy and security in the transaction process [17]. The perceived level of privacy violations in the face of new technologies and products is also critical.

Therefore, the utilitarian benefits included in the VAM may be perceived differently depending on individual attributes. Among the personal attributes, this study focuses on the perceived level of privacy invasion in the context of receiving precise services, as well as everyday life, personal psychological factors, loneliness, and resistance to innovation in the face of non-adoption of new technologies and innovative products.

Loneliness is a subjective and self-conscious feeling pertaining to the experience of isolation and alienation from others or society rather than an objective state. According to Robert Weiss, loneliness has two main aspects, namely, emotional loneliness and social loneliness. When individuals lack intimate relationships which they can fully trust, they feel empty, which leads to emotional loneliness; when individuals do not have a quality social network, it leads to social loneliness, which leads to a sense of not belonging [18]. People live in society and generally form various social relationships based on social needs. People feel lonely when a certain social need is not met or when there is a gap between the desire for social relationships and the actual level of what they actually have. Prolonged isolation or disconnection from others may lead lonely people to dismiss conventional ideas of contact with others and instead seek contact with non-human "agents" via their anthropomorphism [19]. Because anthropomorphic objects are often more reliable and accessible than humans, they may provide people with a sense of security and comfort and thus replace interpersonal relationships [20]. Users need to interact with humans in order to address feelings of loneliness, but they can also combat loneliness by interacting with anthropomorphic products. AI voice assistants also offer this possibility; that is, by conversing with the user, it senses the user's preferences, interests, and needs and provides a variety of customized services based on linked digital platform services. In turn, a sense

of bonding is formed through dialogue with the user during communication, which can alleviate the user's temporary isolation and become a substitute to help with emotional stability. Ultimately, people tend to gravitate towards material substitutes when they feel temporarily and socially isolated due to frustrated basic needs for social relationships; therefore, temporarily and socially isolated users will have a higher intention to accept AI voice assistants compared to non-lonely users.

2.2. Consumer Perceived Value

In recent years, value has been recognized as an important influencing factor from a user psychology perspective, with users exhibiting a range of different user behaviors based on their personal values. Sheth et al. (1991) pointed out the limitations of the existing value system and integrated all the values dealt with by economics, sociology, psychology, and marketing to form a multidimensional user value related to human consumption, namely, functional value, social value, emotional value, contextual value, and cognitive value [21].

Kim et al. (2021) developed a sustainable PropTech service model. Specifically, their model analyzes the user-oriented and service provider-oriented service elements to build a sustainable ecosystem. The results show that the user's intention to use services is influenced by service practicability in terms of user value [22]. Lee et al. (2011) examined the role of emotional and functional values in festival evaluation. At the same time, they investigated the relative contribution of emotional and functional values to satisfaction levels and behavioral intentions [23]. Desmet et al. (2001) study designing products with added emotional value: development and application of an approach for research through design. A design approach is introduced for designing products with added emotional value. It is argued that organizational buyers can be influenced by both rational and emotional brand values and that B2B brands can surmount functional capabilities to create an emotional connection with buyers [24,25]. According to prior research and based on the characteristics of AI voice assistants, this study will also examine user value in terms of both emotional and functional value. Emotional value refers to the utility that users perceive from the expression of a unique type of emotional experience or type of emotion in order to elicit a particular emotion or emotional state [26]; that is, the set of emotional reactions or feelings that users experience as a result of product use or consumption. Any product or brand that provides users with specific feelings, such as positive or negative emotions, psychological emotions, etc., is a product with emotional value. Functional value refers to the value derived from the expected quality of utility [27]. If users perceive that the performance and service quality of the product they purchase is the same or better than they expect, they will be satisfied with their purchase and will consume rationally and economically, which indicates high functional value. Most previous studies on perceived value have attempted to verify the causal relationship between customer satisfaction, service quality, and behavioral intention [27]. In this study, functional value can be described as the value obtained from the superiority of a firm's products and services and the reasonableness of its prices. Based on the extensive literature, it can be concluded that perceived value has important criteria for influencing user decisions, that it is influenced by user preference judgments and guides users' choices, and that perceived value is subject to the interaction of multiple factors. An illustration of the research framework for this study is shown in Figure 1.

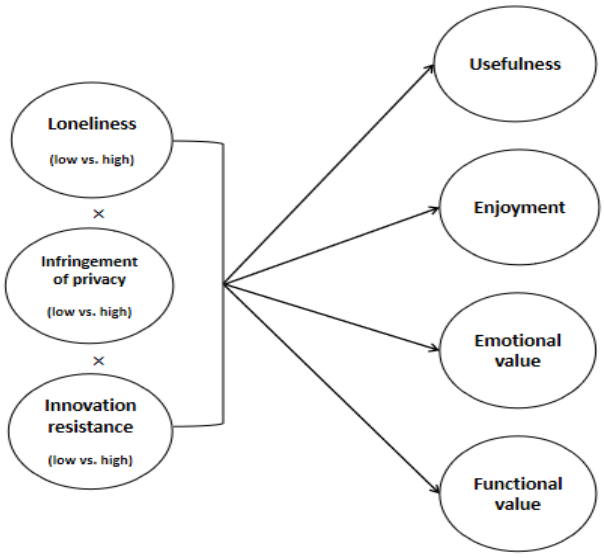

Figure 1. Conceptual proposed model.

Research Question 1: How does the perceived usefulness of intelligent voice assistants change depending on the interaction of users' psychological characteristics, loneliness, innovation resistance, and Infringement of privacy?

Research Question 2: How does the perceived enjoyment of intelligent voice assistants change depending on the interaction of users' psychological characteristics, loneliness, innovation resistance, and infringement of privacy?

Research Question 3: How does the emotional value of intelligent voice assistants change depending on the interaction of users' psychological characteristics, loneliness, innovation resistance, and infringement of privacy?

Research Question 4: How does the functional value of intelligent voice assistants change depending on the interaction of users' psychological characteristics, loneliness, innovation resistance, and infringement of privacy?

3. Materials and Methods

3.1. Participants

This study used an online questionnaire created by the Questionnaire Star platform. The respondents were of a wide age range, mainly between 18–39 years old, with some experience and basic understanding of AI voice assistants and a high level of internet access, which met the research needs of this study. Moreover, in a survey by PricewaterhouseCoopers (PWC), the adoption rate of voice assisted technology was high among 18–24 years old. However, the age group that uses AI voice assistants more frequently is 25–49 years old, 65% of whom are considered "heavy" users, sending voice commands to their device at least once a day. This is why we have put the age bracket at 18–39 years old. A total of 356 questionnaires were returned. If users filled out the questionnaires in a short period of time or did not show experience, they were not considered valid and were removed. A final total of 322 valid questionnaires were retained for this study, 161 for females and 161 for males. The operational definitions of the variables used in this study are as follows, and each item was measured using a 7-point Likert scale.

3.2. Variable Measurement

3.2.1. Loneliness

In this study, Loneliness refers to the psychological state in which individuals feel less satisfaction than expected in interpersonal relationships [28]. To measure chronic loneliness, 20 questions from Russell's revised UCLA Loneliness Scale Version 3 were used. For example: How often do you feel that you are "in tune" with the people around you?

How often do you feel alone? How often do you feel that you lack companionship? How often do you feel shy? etc.

3.2.2. Usefulness

In perceived usefulness, Rogers (1995) defined it as the total value perceived by a user using new technology [29], while Venkatesh (1999) defined it as the perceived usefulness of using technology to improve productivity [30]. Therefore, this study defines perceived usefulness as a significant perceived benefit factor for users using AI voice services [31]. To measure the usefulness, we used the following statements: using AI voice assistants can accomplish what I want to do faster; AI voice assistants can help me better accomplish what I need in life; using AI voice assistants can make it easier for me to complete the tasks I need to complete in my life; AI voice assistants will improve my work efficiency; AI voice assistants will be useful for real life, etc. [32].

3.2.3. Enjoyment

Davis et al. (1989) found that users who perceive any activity related to technology as personally enjoyable in itself are more likely than others to adopt and use technology more extensively [32], which has a significant impact on its acceptance. Yu (2022) defined enjoyment as daily lives and duties that process and sense of joy and gaiety, overall satisfaction, and expectations [33]. In this study, the enjoyment perception of AI voice service is an important benefit for users, which can be defined as a factor. In order to measure enjoyment, we used the following statements: AI voice assistants are fun to use; AI voice assistants feel good; when used, AI voice assistant equipment is very useful; AI voice assistant equipment brings me joy. A 7-point form of scale was used.

3.2.4. Infringement of Privacy

Information privacy refers to the right to have exclusive control over personal information, including the right to participate in the flow and use of personal information [34]. It can be seen as a state that does not compromise one's private life and does not disclose personal information at will. In this study, the following statements are used: I am worried that using AI voice assistants may expose my personal life; people who value their private lives should refrain from using AI voice assistants; in order to use AI voice assistants smoothly, I believe that one should give up their personal life to a certain extent; in order to better use AI voice assistants, I believe a certain level of information should be provided about me; if privacy is excessively emphasized, it is impossible to use AI voice assistants, etc. [15,35,36].

3.2.5. Innovation Resistance

All innovations generate resistance to change because they require users to change [37]. Zaltman and Wallendorf (1983) define innovation resistance as any behavior that tries to maintain the status quo in the face of pressure to change it [38]. User characteristics can influence innovation resistance; perceptions, motivations, personality, past experiences, and demographic variables all influence the degree of innovation resistance. Although there is variation in the definition of innovation resistance in research, one important characteristic of innovation resistance, i.e., the non-adoption of innovative products, is unanimously agreed upon [39]. In this study, measured indicators are as follows: I think AI voice assistants make people anxious; I would avoid using AI voice assistants; and I am hesitant to use AI voice assistants.

3.2.6. Emotional Value

Sweeney and Soutar (2001) defined emotional value as the utility derived from the feelings or emotional state that a product generates [26]. Sheth et al. (1991) defined emotional value as the emotional state generated by a choice and measurable in terms of feelings or sustained emotions in a specific situation [21]. We defined emotional value

as the utility derived from the feelings or emotional state that a product generates and measured it with statements such as the following: using an AI voice assistant is a very enjoyable experience; using an AI voice assistant is a very interesting thing; I really enjoy using an AI voice assistant, etc.

3.2.7. Functional Value

Functional value is the property of the product or service which performs a specific function [40]. In this study, functional value can be described as the value gained due to the superiority of the AI voice assistant service and the reasonableness of the price. In this study, it was measures with statements such as the following: using an AI voice assistant saves both time and effort; using an AI voice assistant can more effectively achieve my goals; using an AI voice assistant is more useful.

3.3. Procedure

This study was approved and reviewed by the Academic Research Ethics Committee of the Nanyang Institute of Technology. Written informed consent was obtained from the respondents prior to the study, and consent and approval were obtained from the participants in accordance with academic and ethical ethics.

3.4. Data Analysis

We used SPSS 21.0 software to perform descriptive statistics and correlation analysis of the variables. In this study, the reliability and validity of the variable measures needed to be examined in order to test the research questions posed. Skewness and kurtosis were also looked at in order to measure whether the data obtained had a normal distribution. The main method of analysis was the three-way ANOVA, was used to determine how the three different factors affect a number of response variables, exploring whether there is a statistically significant relationship between each factor and the response variable and also whether there is an interaction between the factors. In this study, the impact of the set variables on perceived benefits and perceived value in the context of the interaction was primarily tested. In previous studies, most of the underlying models have been tested on the basis of regression analysis or structural equations, finding more of a relationship between influence and the credibility of the VAM. However, in this study, a three-way ANOVA was used, which is unprecedented in other studies, It is an innovative way of looking at the variation in the dependent variables in response to the interaction of the independent variables.

4. Results

4.1. Descriptive Statistics

Of the 322 survey samples used, 161 were males, and 161 were females. We divided the age of users into five interval groups for testing (SD = 1.096). The data show that 72.1% of the sample are 18–39 years old, and 60.2% of the users are college students. The descriptive statistics of this study are summarized in Table 1.

To check the reliability and validity of the variables, we first conducted an exploratory factor analysis on the overall variables measured using SPSS statistical software. The initial factors were extracted using principal component analysis and then rotated using the maximum variance method in orthogonal rotation to retain factors with eigenvalues greater than or equal to 1 and factor loading greater than 0.7. The previous literature indicates that a Cronbach's alpha greater than 0.7 is good [9]. The results showed that the Cronbach's alpha values for each variable ranged from 0.854~0.976, all exceeding the acceptable level of 0.70, thus indicating a high level of internal consistency for statements measuring the same concept. To test the validity of the distinction between the constructs, a correlation coefficient analysis was conducted using SPSS, with the probability of significance assessed at the 0.05 and 0.01 levels and marked with an asterisk. Negative values between values

indicate the presence of negative factors in the antecedent variables that affect perceived value. The results of the descriptive statistics and correlation analysis are given in Table 2.

Table 1. Demographic profile of respondents (N = 322).

Measure		Frequency	Percent (%)
Gender	Male	161	50.0
	Female	161	50.0
Age (years)	Below 18 years old	2	0.6
	18–29 years old	113	35.1
	30–39 years old	119	37.0
	40–49 years old	52	16.1
	50–59 years old	22	6.8
	Above 60 years old	14	4.3
Academics	High school or below	13	4.0
	Technical school	65	20.2
	College student	194	60.2
	Graduate school or above	47	14.6
	Others	3	0.9
Income	Below 3000	31	9.6
	3000–5000	11	3.4
	5000–7000	89	27.6
	7000–10,000	115	35.7
	Above 10,000	76	23.6

Table 2. Correlations between variables.

Variables	1	2	3	4	5	6	7	Cronbach's Alpha
LO	1							0.976
IPR	0.056	1						0.937
IR	−0.079	0.217 **	1					0.866
UF	0.113 *	−0.156 **	−0.223 **	1				0.902
EJ	0.050	−0.215 **	−0.211 **	0.417 **	1			0.887
EV	0.086	−0.139 *	−0.250 **	0.437 **	0.440 **	1		0.866
FV	0.087	−0.180 **	−0.192 **	0.469 **	0.449 **	0.470 **	1	0.854

** $p < 0.01$, ** Correlation is significant at the 0.01 level (2-tailed); * $p < 0.05$, * Correlation is significant at the 0.05 level (2-tailed); LO, Loneliness; IPR, Infringement of privacy; IR, Innovation resistance; UF, Usefulness; EJ, Enjoyment; EV, Emotional value; FV, Functional value. Cronbach's alpha: the reliability of internal consistency was evaluated with Cronbach's alpha coefficients. This value is calculated using the following equation: $\alpha = k/(k-1)*(1-\Sigma s^2/St^2)$.

4.2. Analysis Result

This study consists of a total of three independent variables and four dependent variables. The three independent variables are loneliness, invasion of privacy, and resistance to innovation. The four dependent variables are usefulness, enjoyment, emotional value, and functional value. Loneliness, innovation resistance, and infringement of privacy are the underlying variables that belong to the personal attribute level, and in particular, loneliness examines the psychological factors of the user. The inclusion of psychological factors in

the use of AI voice assistants is what makes this study different from previous studies, and the combination of innovation resistance factors and psychological factors caused by the user's own education level and other environmental factors in the application of new technologies may show different perceptions of favorable factors and value factors; at the same time, the degree of privacy infringement perceived by users during the use of AI voice assistants may also produce different perceptions of the above factors. Therefore, these three variables were set as independent variables. Moreover, according to the VAM, the addition of the favorable factors and value factors can provide a clearer understanding of the user's intention to accept and use the new technology. So, the usefulness and pleasantness of the favorable factors and the emotional and functional value of the value factors were set as dependent variables. In addition, the mean values of all independent variables are generally above the median of 4 points on a 7-point Likert scale. Therefore, in order to distinguish two groups for each independent variable for the purpose of verifying the research question, it is appropriate to use the mean value rather than the median value. Because the mean is often used for ordinal variables, it can be considered a good estimate for predicting subsequent data points. So, the groups were separated based on their respective mean values and used for post-recording analysis. This study was designed as a 2 × 2 × 2 by loneliness (low vs. high), infringement of privacy (low vs. high), and innovation resistance (low vs. high), according to the research questions.

To test RQ1, a three-way ANOVA was used to analyze the effect of the respective variables on the dependent variable and the interaction between the variables. For significance, our *p*-value from the test will need to be less than 0.05 to be significant at the 5% level. For the F-values that appear in the results, the greater the difference between groups, the greater the F-value and the greater the variability [3]. When usefulness was set as the dependent variable, the main effects were found for loneliness (F = 8.047, $p < 0.01$), infringement of privacy (F = 4.574, $p < 0.05$), and innovation resistance (F = 11.150, $p < 0.01$). Specifically, perceived usefulness was higher in the mean of the high group (M = 5.185); than the low group value (M = 4.703) in terms of loneliness; higher in the low group (M = 5.125) than in the high group (M = 4.762) for infringement of privacy; and higher in the low group (M = 5.227) than in the high group (M = 4.660) for innovation resistance.

For perceived usefulness, the interaction between loneliness and privacy relatedness resulted in a $p < 0.05$ level of significance (F = 5.651, $p = 0.018$). This suggests that loneliness and infringement of privacy relatedness combine to influence the dependent variable, usability. As shown in Figure 1, in a group with a high degree of loneliness, people with a high degree of infringement of privacy perceive the usefulness of AI voice assistants as higher. The results of the loneliness infringement of privacy analysis are given in Figure 2.

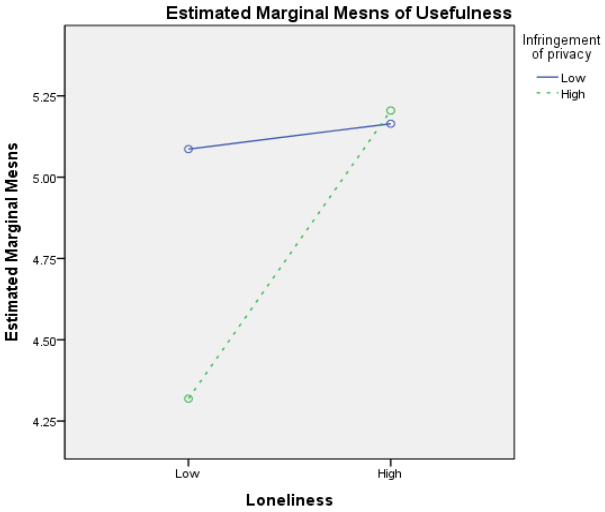

Figure 2. Loneliness infringement of privacy analysis.

On the other hand, the interaction between loneliness and innovation resistance resulted in a $p < 0.05$ level (F = 5.999, $p = 0.015$). This suggests that loneliness and innovation resistance combine to influence the dependent variable, perceived usefulness. As shown in Figure 3, those with higher levels of loneliness perceived the usefulness of AI voice assistants as higher than those with lower levels of innovation resistance. The results of the loneliness and innovation resistance analysis are given in Figure 3.

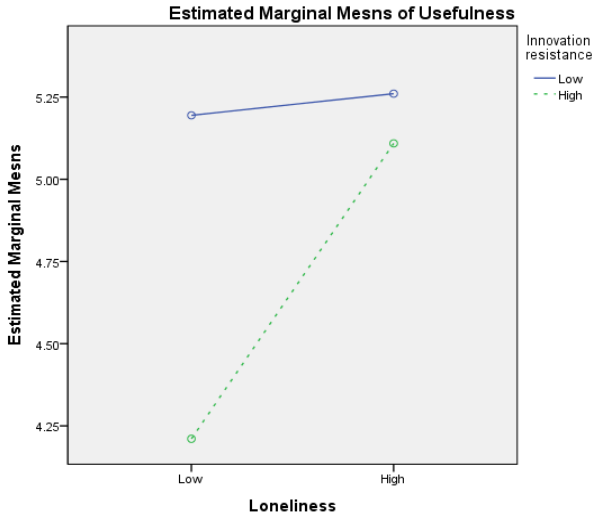

Figure 3. Loneliness innovation resistance analysis.

In addition, the interaction between the infringement of privacy and innovation resistance was significant at $p < 0.01$ (F = 16.115, $p = 0.000$). In Figure 4, the high infringement of privacy group perceived the usefulness of AI voice assistants as more than those with low innovation resistance. The results of the infringement of privacy and innovation resistance analysis are given in Figure 4.

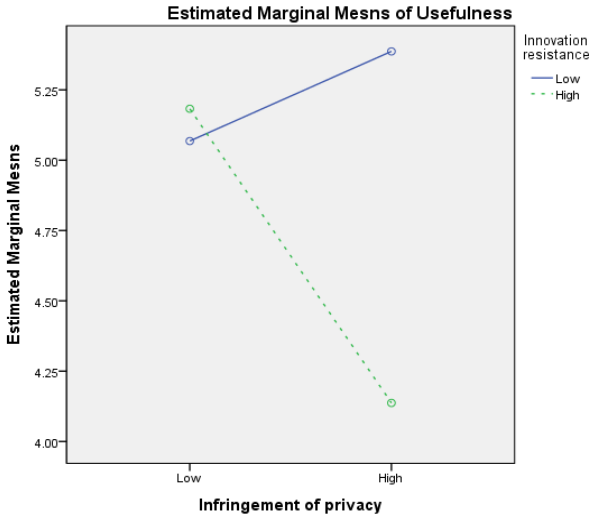

Figure 4. Infringement of privacy × Innovation resistance analysis.

Finally, the interaction between loneliness, infringement of privacy, and innovation resistance is significant at $p < 0.05$ (F = 6.210, $p = 0.013$), indicating a three-way interaction between loneliness, infringement of privacy, and innovation resistance on the dependent variable, perceived usefulness. According to Figure 5, in the low innovation resistance state, if the loneliness level is high and the infringement of privacy is high, the perceived usefulness of AI voice service is higher. The high innovation resistance group thinks that AI voice service is more useful when the loneliness level is high, and the infringement

of privacy is low. The results of the loneliness, infringement of privacy, and innovation resistance analysis are given in Figure 5.

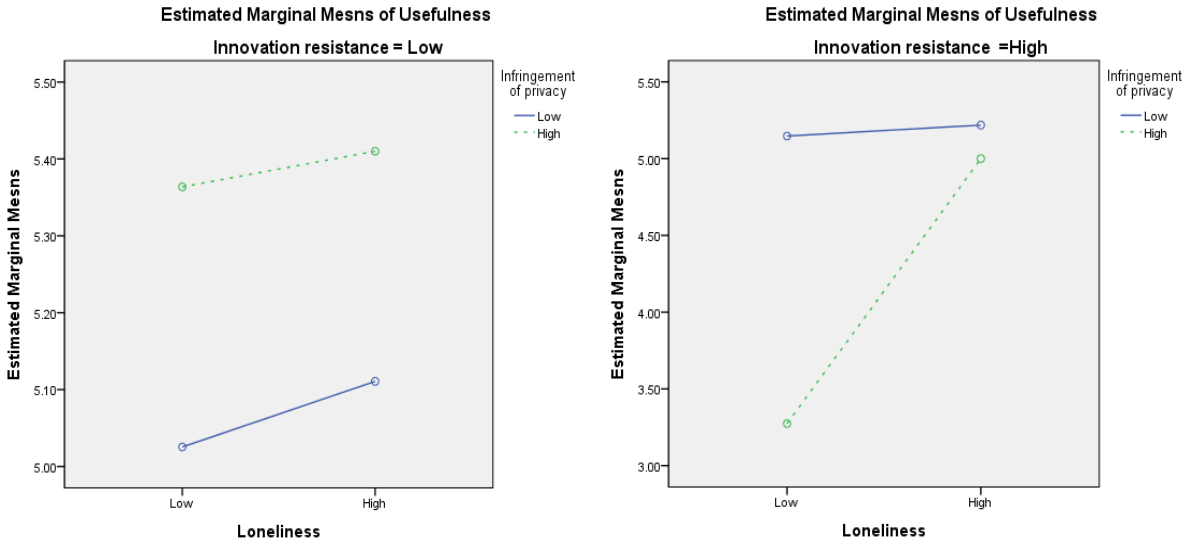

Figure 5. Loneliness infringement of privacy × Innovation resistance analysis.

With enjoyment as the dependent variable, we found the main effects for loneliness ($F = 5.793$, $p < 0.05$), infringement of Privacy ($F = 10.442$, $p < 0.01$), and innovation resistance ($F = 7.635$, $p < 0.01$). Specifically, perceived enjoyment was higher in the high group ($M = 5.039$) than in the low group ($M = 4.616$) for loneliness, higher in the low group ($M = 5.111$) than in the high group ($M = 4.544$) for privacy relatedness, and higher in the low group ($M = 5.070$) than in the high group ($M = 4.585$) for innovation resistance.

For perceived enjoyment, the interaction between loneliness and infringement of privacy relatedness resulted in a $p < 0.05$ level of significance ($F = 5.819$, $p = 0.016$). This suggests that loneliness and the infringement of privacy relatedness combine to influence the dependent variable enjoyment. As shown in Figure 6, people with a high level of loneliness and also a low level of perceived infringement of privacy have a high level of enjoyment of AI voice assistants. The results of the loneliness and infringement of privacy analysis are given in Figure 6.

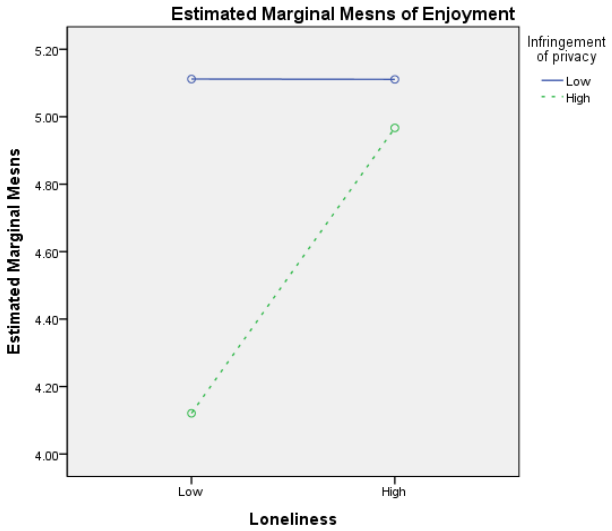

Figure 6. Loneliness infringement of privacy analysis.

On the other hand, the interaction between loneliness and innovation resistance was found to be significant at $p < 0.05$ ($F = 4.881$, $p = 0.028$). This suggests that loneliness and

innovation resistance combine to influence the dependent variable, playfulness. As shown in Figure 7, it was found that people with high levels of loneliness and also low levels of innovation resistance had a higher enjoyment of the AI voice assistants. The results of the loneliness and innovation resistance analysis are given in Figure 7.

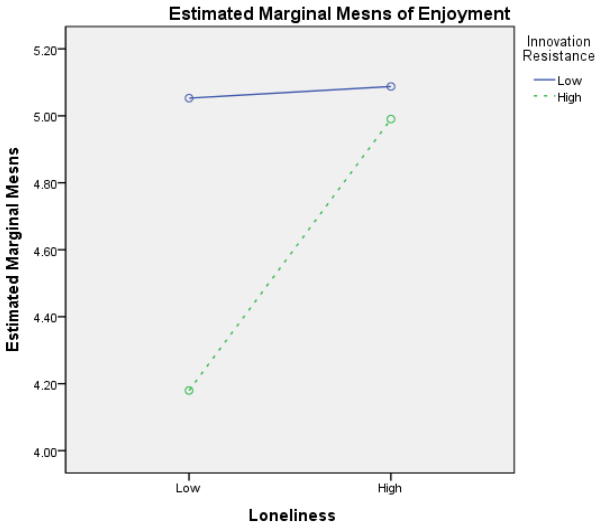

Figure 7. Loneliness innovation resistance analysis.

In addition, the interaction between the infringement of privacy and innovation resistance was significant at $p < 0.01$ (F = 7.918, $p = 0.005$). As shown in Figure 8, in the low infringement of privacy group, people with low innovation resistance perceived the enjoyment of AI voice assistance to be higher. The results of the infringement of privacy and innovation resistance analysis are given in Figure 8.

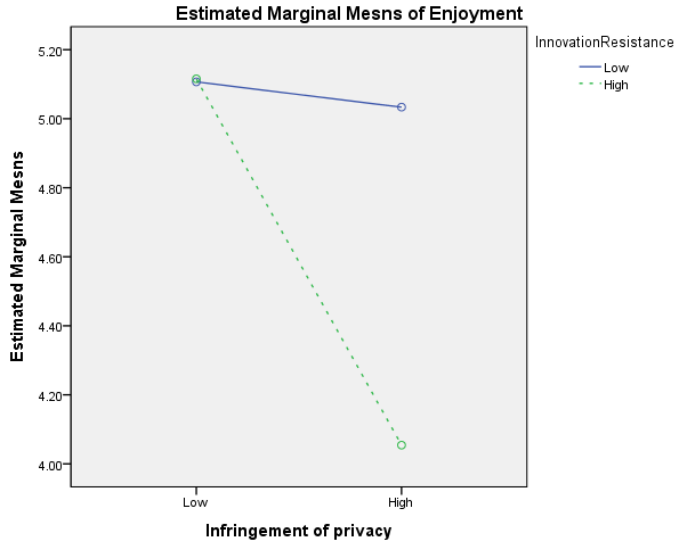

Figure 8. Infringement of privacy × Innovation resistance analysis.

With emotional value as the dependent variable, a main effect was found for innovation resistance (F = 23.131, $p < 0.01$). Specifically, innovation resistance is associated with a higher perceived emotional value in the low group (M = 5.204) than in the high group (M = 4.389). In terms of perceived emotional value, the interaction between loneliness and privacy-relatedness resulted in a $p < 0.05$ level of significance (F = 7.565, $p = 0.006$). This suggests that loneliness and privacy relatedness combine to influence the dependent variable, emotional value. As shown in Figure 9, in the group with a high degree of loneliness, people with a high degree of infringement of privacy perceived the emotional value of the

intelligent voice assistant to be higher. The results of the loneliness and infringement of privacy analysis are given in Figure 9.

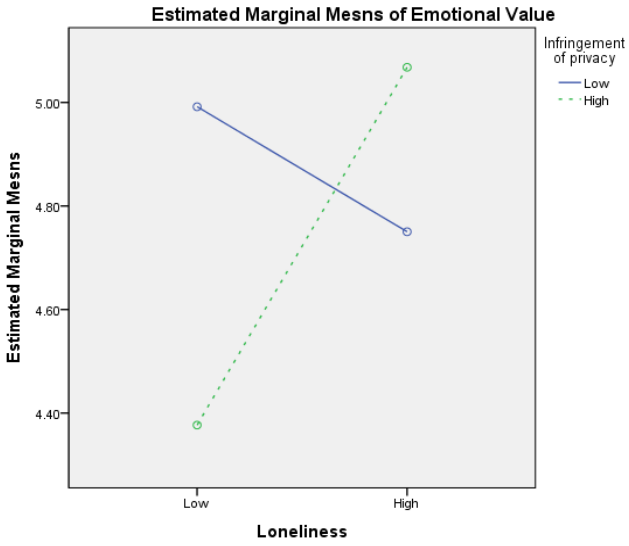

Figure 9. Loneliness infringement of privacy analysis.

In addition, the interaction between infringement of privacy and innovation resistance was found to be significant at $p < 0.01$ (F = 5.376, $p = 0.021$). As shown in Figure 10, the high infringement of privacy group perceived the emotional value of intelligent voice assistants to be higher than those with low innovation resistance. The results of the loneliness and infringement of privacy analysis are given in Figure 10.

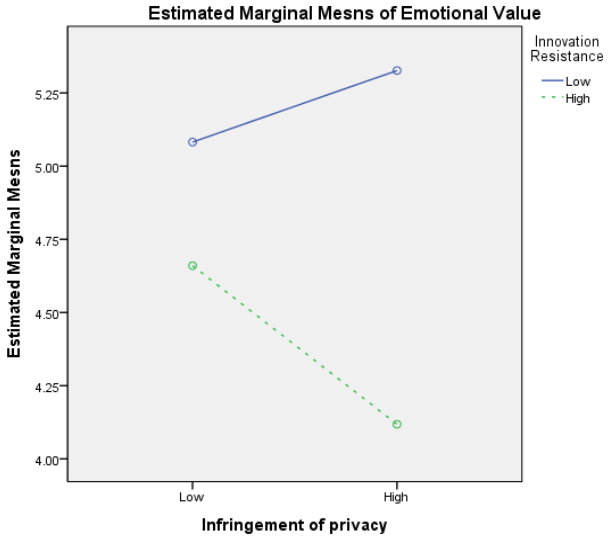

Figure 10. Infringement of privacy × Innovation resistance analysis.

Finally, the interaction between loneliness, infringement of privacy, and innovation resistance shows a result value at the $p < 0.05$ level (F = 15.352, $p = 0.000$), indicating that loneliness, infringement of privacy, and innovation resistance have a three-way interaction on the dependent variable, usefulness. According to Figure 11, in the low innovation resistance condition, the emotional value of intelligent voice assistants is perceived to be higher when the loneliness level is low and the infringement of privacy is high. In the high innovation resistance group, the emotional value of intelligent voice assistants is higher when the loneliness level is low and the infringement of privacy is low.

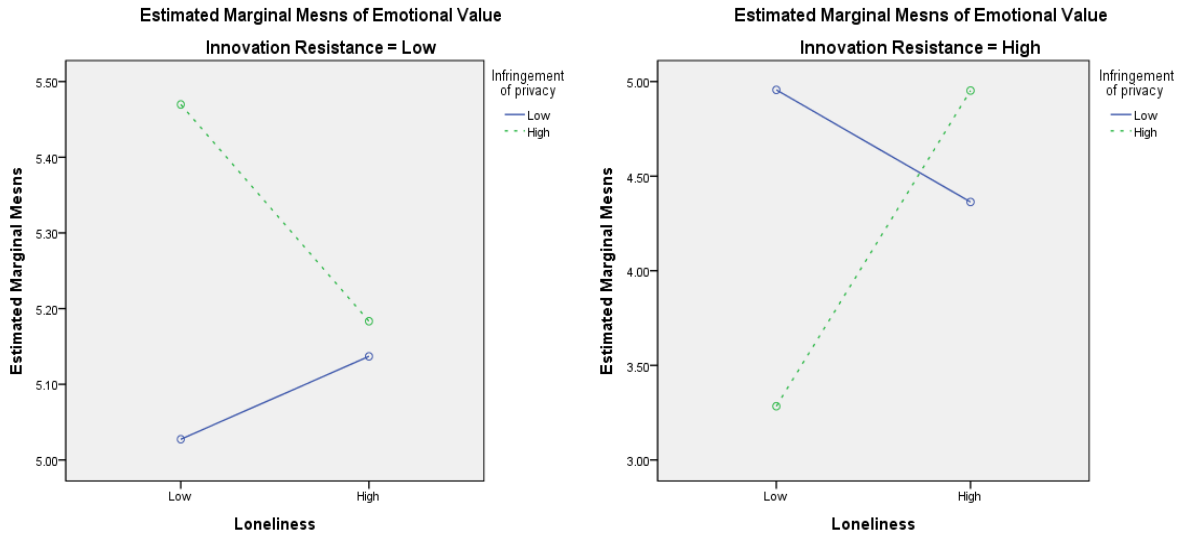

Figure 11. Loneliness infringement of privacy × Innovation resistance analysis.

With functional value as the dependent variable, we found the main effects for loneliness (F = 7.401, $p < 0.01$), years of privacy (F = 5.752, $p < 0.05$), and innovation resistance (F = 7.816, $p < 0.01$). Specifically, the perceived functional value was higher in the high group (M = 5.032) than in the low group (M = 4.574) for loneliness; higher in the low group (M = 5.005) than in the high group (M = 4.601) for privacy relatedness; and higher in the low group (M = 5.038) than in the high group (M = 4.567) for innovation resistance.

For perceived functional value, the interaction between loneliness and privacy relatedness resulted in a $p < 0.05$ level of significance (F = 10.277, $p = 0.001$). This suggests that loneliness and privacy relatedness combine to influence the dependent variable, the functional value. As shown in Figure 12, in the group with a high degree of loneliness, people with a high degree of infringement of privacy perceived the functional value of intelligent voice assistants to be higher.

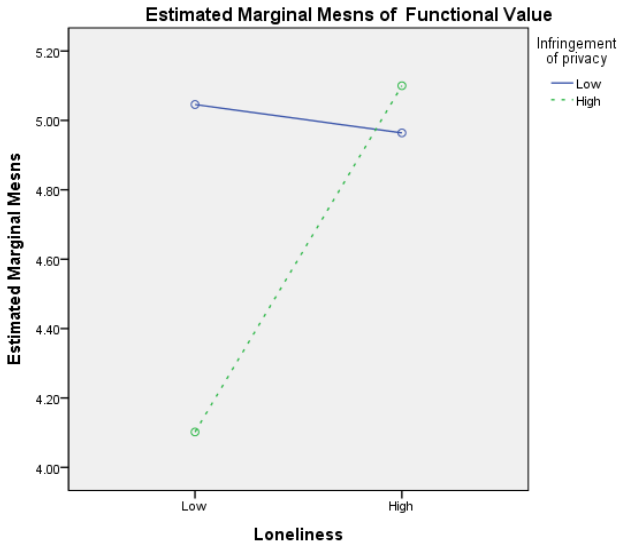

Figure 12. Loneliness × Infringement of privacy analysis.

In addition, the interaction between infringement of privacy and innovation resistance was significant at the $p < 0.01$ level (F = 9.800, $p = 0.001$). As shown in Figure 13, the high infringement of privacy group perceived the functional value of intelligent voice assistants to be higher than those with low innovation resistance.

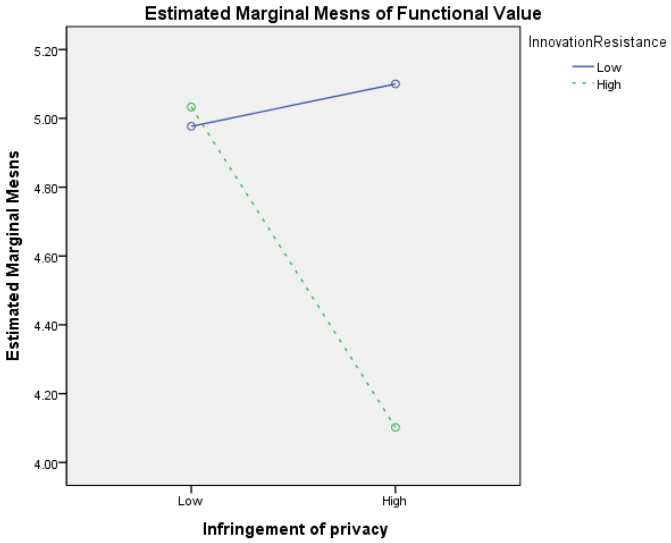

Figure 13. Innovation resistance × Infringement of privacy analysis.

5. Discussion

A survey of 322 users found that the interaction effect analysis showed the influence of different value combinations of multiple independent variables on perceived usefulness, perceived enjoyment, emotional value, and functional value. It provides a basis for exploring the benefit perception of individual cognitive combinations to AI voice assistants. At the same time, this has contributed to improved user experience, better quality of life, and sustainable development of digital cities. In particular, we found differences in the usefulness and enjoyment of AI voice assistants under the interaction of individual psychological factors, loneliness, innovation resistance, and privacy infringement (R.Q.1 and R.Q.2). Secondly, in value perception, emotional value perception, and functional value perception, loneliness, innovation resistance, and privacy infringement also have interactive relations (R.Q.3 and R.Q.4).

When usefulness was set as the dependent variable, the main effects were found for loneliness, infringement of privacy, and innovation resistance. In terms of perceived usefulness, the interaction between loneliness and infringement of privacy resulted in significance at the $p < 0.05$ level. This suggests that the combination of loneliness and privacy associations affects the dependent variables of usefulness. In a highly lonely group, even those with a higher perception of privacy intrusion rated the usefulness of AI voice assistants higher. While prior research suggests that people who are more sensitive to the possibility of invasion of their privacy may be less willing to accept new products and services, users seek to address feelings of isolation by interacting with anthropomorphic products to combat such emotions [36]. It is clear that AI voice assistants offer this possibility. On the other hand, loneliness and resistance to innovation jointly influence the dependent variable—perceived usefulness. In the cohort with higher loneliness, those with lower resistance to the innovation of AI voice services tended to find AI voice assistants more useful. Most of the non-adoption of a new technology as well as a new product is due to the perceived pressure to change, a state in which weak pressure perceptions somehow imply a willingness to try new products and technologies. This is why this group of users is more likely to be positive in their judgment of the usefulness of AI voice assistants due to their feelings of loneliness.

At the same time, groups with high levels of infringement of privacy and low resistance to innovation were more likely to perceive the usefulness of AI voice assistants. Finally, the interaction between loneliness, infringement of privacy, and innovation resistance was significant. In groups with low innovation resistance, the perceived usefulness of AI voice assistants was higher if the level of loneliness was high, and the perception of privacy infringement was high. In the high innovation resistance group, AI voice assistants were

perceived to be more useful in states with high levels of loneliness and low levels of privacy. This suggests that the personal innovation resistance variable is an important measure of users' perceived judgments, and that reducing users' concerns about AI voice assistants invading personal privacy can increase people's perceptions of usefulness as innovation resistance changes.

When enjoyment was set as the dependent variable, we found that groups with high loneliness and low perception of privacy invasion were more likely to perceive enjoyment of AI voice assistants. This differs somewhat from the perceived usefulness. Those with higher perceptions of privacy invasion in usefulness perceptions also give more positive ratings out of rational thought, but enjoyment perceptions are more stringent, and enjoyment can only be accentuated by overcoming loneliness in a secure perceived state where privacy is protected. On the other hand, people with high loneliness and low resistance to innovation perceive AI voice assistants as more enjoyable. In addition, in the low infringement of privacy perception group, people with low innovation resistance perceived higher enjoyment of AI voice assistants. The risks perceived from resistance to innovation can be real or non-real risks. When we are faced with a brand new product, we may first be wary and want to make sure that the product is safe enough before we are willing to use it. So, for a new technology or product to survive in a competitive marketplace, it is not enough that it is newer, has improved functionality, and adds one or two selling points; it must be able to withstand both existing user habits and perceived risks.

In terms of perceived emotional value, we found a main effect of innovation resistance. Specifically, the perceived emotional value was higher in the low innovation resistance group than in the high group. Meanwhile, the interaction between loneliness and infringement of privacy reached a significant level. This suggests that loneliness and perceived infringement of privacy interacted together to influence the emotional value of the dependent variable. In the high-loneliness group, the emotional value derived from the AI voice assistants was perceived even though the perceived level of privacy invasion was higher.

Furthermore, the interaction between infringement of privacy and resistance to innovation was significant. Groups with high perceived levels of infringement of privacy were able to generate higher emotional value when resistance to innovation was lower. This also shows how targeting people with higher levels of loneliness can reduce the level of innovation resistance of the using group, and enhanced privacy protection can have a significant effect on enhancing emotional value. Finally, the ternary interaction between loneliness, infringement of privacy, and innovation resistance presented also indicated that the emotional value of AI voice assistants was perceived to be higher when the level of loneliness was low, and the level of privacy invasion was high under the low innovation resistance conditions. In the high innovation resistance group, the emotional value of AI voice assistants was higher when the level of loneliness was lower, and the level of privacy invasion was lower. This again validates the presence of innovation resistance as an important factor influencing user value perceptions. Some users' resistance to innovative products is not because the physical functions of innovative products do not have comparative advantages but because the values related to the use of products are inconsistent with the existing traditions and norms of society, which leads to users' resistance to the products. Therefore, when launching innovative products, AI voice assistant companies should consider whether there are social traditions and norms related to the use of their products and how to effectively minimize such differences. For the risks that exist in products or services, strengthening the description of product privacy policies and clarifying the retention period of personal information can reduce and avoid some of the risks. At the same time, providing personalized services and adding product benefits such as graphical interfaces and visual knowledge graphs that are searchable, editable, and easy to understand can effectively reduce user resistance.

Using functional values as dependent variables, we found that loneliness, infringement of privacy, and resistance to innovation were the main influencing factors. In terms of loneliness, the perceived functional value was higher in the high-loneliness group than in

the low group; in terms of perceived infringement of privacy, the low group was higher than the high group; and in terms of resistance to innovation, the low group was similarly higher than the high group. At the same time, the interaction between loneliness and perceived infringement of privacy reached a significant level. This suggests that in the high-loneliness group, there was a general bias towards more positive judgments of the functional value of AI voice assistants, even though they perceived the possibility of privacy invasion. Furthermore, an interaction between the infringement of privacy and resistance to innovation was also found, with groups with high perceptions of privacy invasion also having higher perceptions of functional value when they had lower resistance to innovation.

6. Conclusions

This study applies the VAM to analyze the perceived benefits and value factors affecting AI voice assistants. Among the user psychological factors, the interaction between the loneliness of use and innovation resistance, as well as the perceived level of infringement of privacy, are featured in this study and are the first of their kind. In this study, the theoretical application is based on the VAM, which is a better explanatory model for users. This study identifies differences in the perceived usefulness and pleasantness of AI voice assistants in response to the interplay of three personal psychological factors: loneliness, resistance to innovation, and infringement of privacy. Secondly, there was also an interaction between loneliness, resistance to innovation, and infringement of privacy in terms of perceived emotional and functional value. Further, we analyzed the factors and intermediate mechanisms that influence users' psychological perceived value of AI voice assistants.

As technology continues to develop and advance, AI voice assistants have become one of today's hot topics, with increasing applications in healthcare, education, finance, and other fields. This paper also innovatively explores the sustainable development of AI voice assistants in information technology and system updates, industry, and other areas. In addition, this study combines AI voice assistants with VAM to expand the application space and boundaries of the theory. The results of this study are important for expanding the use of AI voice system services and improving the scale of marketing, as well as providing insights into the perceptions and emotions of AI voice assistant users. The findings also provide informative value to manufacturers of intelligent voice systems, pointing to the importance of communication style and privacy protection for future AI voice assistants.

The results of this study take full account of the psychological aspects of the user and promote the future use and development of AI voice assistants in the healthcare industry. In particular, they continue to play a unique role in regulating users' emotional and psychological problems. From a practical daily life perspective, it is necessary to differentiate between the frequency of daily use by users, to reduce the psychological resistance of first-time users of AI voice assistants, and to increase the level of perceived usefulness and pleasure—for example, by constantly updating the system to improve the quality and intensity of dialogue content responses, and increasing the proportion of emotional support that AI voice assistants provide in multiple modes. We need deeper interactions to generate psychological experiences, rather than simply influencing user behavior through general dialogue. Certainly, this research will lead to improvements in the technology associated with AI voice assistants. During the development and updating of technologies and systems, developers need to be aware that the perceived intensity of potential risks during use can affect the perception of value. For example, personal privacy issues, security breaches, etc. When using AI voice assistants, privacy protection should be enhanced during the system setup process, and appropriate legal and regulatory mechanisms should be established to ensure a safer and more secure application of AI voice assistant recognition technology. When providing services related to AI voice assistants, especially in the advertising process, relevant information can also be included to demonstrate that it can indeed alleviate the burden of cost or invasion of personal privacy concerns of users.

At the same time, when considered from an industry perspective, ensuring that digital technologies are sustainable and that users are better aware of the benefits and value factors will better align with the goal of sustainable urban development and, ultimately, economic development, quality of life, and sustainability. In conclusion, AI voice assistants are a very promising and practical innovative technology which provides us with a more convenient and effective way of living. As technology continues to advance, we believe that AI voice assistants will bring us even more surprises and convenience. Moreover, the development of AI voice assistants also requires our continuous investment and innovation, applying natural language processing technology to more areas, making human-AI interaction smoother and more natural, and improving security and privacy protection.

7. Limitations and Future Research

This study also has some limitations. First, considering that the survey samples are from China, the scope of the research samples and the extensibility of the research results are limited. By further comparing the differences in user experience value perception of AI voice assistants in different countries, the scope and breadth of the research can be expanded in the future. Secondly, with the continuous development of technology and updates to the system, AI voice assistants can be further studied in mental health and other medical fields. In particular, the degree of satisfaction in terms of information provision and improvement of mood can be included in future studies as factors affecting users' use. On the other hand, as discussed in this study, value perception has multiple dimensions, and different psychological emotions and personal attributes will affect the value perception system. Future studies can explore the sub-dimensions of value perception and the influence of different influencing factors on user behavior, which is also very meaningful. To date, research on AI voice assistants has been relatively underdeveloped and has focused on the technical aspects of the user. Much of this has been based on the experiences of those who have already used AI voice assistants, meaning that most of the research has been about capturing users' intent to use them. The AI voice assistant market is becoming increasingly competitive, and the next research direction will be to understand the perceived value of AI voice assistants as well as the usage intent of users who are not yet using AI voice assistants. This is necessary in order to expand the market and achieve sustainable growth.

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