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Study on the "digital divide" in the continuous utilization of Internet medical services for older adults: Combination with PLS-SEM and fsQCA analysis approach

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Abstract

Background With the rapid digitalization of healthcare and an aging population, understanding the factors influencing older adults' sustained adoption of Internet medical services is critical. However, existing research often oversimplifies these factors by relying on linear models. This study integrates Partial Least Squares Structural Equation Modeling (PLS-SEM) and fuzzy-set Qualitative Comparative Analysis (fsQCA) to explore the complex pathways driving continued use.

Methods A survey of 1,920 older adults (60–75 years) in China assessed satisfaction, e-health literacy, self-efficacy, social support, social influence, social participation, and willingness to use Internet medical services. PLS-SEM examined the relationships between variables, while fsQCA identified multiple configurations leading to sustained use.

Results PLS-SEM identified satisfaction as the strongest predictor of sustained use ($\beta = 0.281$, $p < 0.001$), acting as both a direct determinant and a mediator for e-health literacy and social participation. Social influence ($\beta = 0.189$, $p < 0.001$) and social support ($\beta = 0.172$, $p < 0.001$) also contributed significantly. FsQCA revealed six distinct configurations, with satisfaction and e-health literacy as core conditions across most pathways.

Conclusions By integrating linear and configurational approaches, this study provides a nuanced understanding of older adults' digital healthcare behaviors. Enhancing satisfaction, digital literacy, and social engagement is key to fostering sustained adoption. Tailored interventions based on distinct configurations can maximize the effectiveness of digital health programs.

Implications This research bridges gaps in understanding complex behaviors and provides actionable insights for policymakers and healthcare providers, highlighting the critical role of digital literacy and social support.

Keywords Digital divide, Older adults, Internet medical services, PLS-SEM, Fuzzy-set qualitative comparative analysis (fsQCA)

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Background

With the continuous development of technology, networking and digitalization have become fundamental aspects of modern society, shaping a new social structure in which people utilize digital technology in a digital environment for various activities, including living, working, learning, and communication. Currently, over 962

million people worldwide, or approximately 13% of the global population, are aged 60 and above [29]. According to the Fifth China Urban and Rural Older Adults Living Conditions Sample Survey Basic Data Bulletin, released by the China Association of Older Adults, China's population aged 60 and above had reached 297 million by the end of 2023. The acceleration of digitalization has coincided with the growing trend of population aging.

As organ function declines with age, the prevalence of various diseases increases among older adults, leading to a rising demand for medical services. Consequently, they represent the most significant demographic in healthcare utilization. The 2018 Report on the Sixth National Health Services Statistical Survey [12] indicates that 59.1% of China's population aged 60 and above suffer from chronic diseases. Additionally, 23.8% have two or more chronic conditions, while 3.8% experience moderate-to-mild incapacitation. Although older adults constitute 17.9% of the total population, they account for 45.3% of all medical consultations in China. The widespread adoption of mobile health (mHealth), intelligent medical care, and other Internet-based healthcare technologies has significantly improved health outcomes across prevention, treatment, and rehabilitation. These advancements offer notable benefits in proactive health management and precision intervention strategies.

In the complex context of digitalization and an aging population, digital technologies inevitably pose challenges for older adults. Influenced by individual, technological, familial, social, and cultural factors, many older adults are either reluctant to adopt digital technology or lack the necessary conditions to use it. As a result, they are often considered disadvantaged in the digital era and have even labeled as "digital refugees" [16, 81]. Under such circumstances, the digital divide among older adults has garnered increasing attention from both society and academia. Addressing this divide and facilitating the integration of older adults into the digital society has become a pressing challenge in China's modernization of social governance. Most previous studies have relied on symmetry-based methods, such as multiple regression, structural equation modeling (SEM), and partial least squares (PLS) estimation. These traditional variance-based approaches focus on the "net effect" of predictors on an outcome variable, often overlooking potential asymmetric interactions between variables [15, 80].

However, the willingness of older adults to continue using Internet-based medical services is influenced by multiple interdependent factors, leading to complex causal relationships. Traditional regression methods have limitations in analyzing these combined effects [70]. The fuzzy-set qualitative comparative analysis (fsQCA) method, based on Boolean algebra, offers an alternative approach by considering that outcomes result from various combinations of conditions rather than a single determining factor [40]. In the real world, expected outcomes may be determined by a mixture of numerous antecedents rather than a single entity [56]. Consequently, researchers may need to identify multiple solutions tailored to different user groups, rather than relying on standard regression models to explain the majority of cases. Integrating PLS-SEM with fsQCA provides unique insights into model relationships that traditional methods may overlook. Specifically, fsQCA helps detect nonlinear patterns[52, 63] and unobserved heterogeneity within models [54, 64]. his method complements PLS-SEM-based latent class analysis, which has gained significant attention in recent years [9, 53, 61]. However, despite the increasing research on factors influencing the use of Internet-based medical services among older adults, previous studies have largely focused on linear relationships. To date, no research has combined PLS-SEM and fsQCA to examine the continued use of Internet medical services among older adults.

Building on the ternary interaction model of social cognitive theory, this study integrates the antecedent variables of self-efficacy, e-health literacy, social support, social participation, social influence, and satisfaction within a unified theoretical framework. By examining the causal associations among these factors, the study expands the application of social cognitive theory and deepens the understanding of the conditions influencing older adults' willingness to continue using Internet-based medical services. Furthermore, this study systematically analyzes the driving mechanisms behind older adults' sustained engagement with Internet medical services. Through fsQCA analysis, it reveals the complex interplay of antecedent conditions, complementing the findings of SEM.

By employing both PLS-SEM and fsQCA methods, this study identifies practical strategies for promoting the long-term adoption of Internet medical services among older adults. The findings emphasize the critical roles of e-health literacy, self-efficacy, social support, and satisfaction. Specifically, they highlight the necessity of tailored educational programs to enhance e-health skills and community-based initiatives, such as workshops, to foster confidence and trust. Strengthening self-efficacy through gradual exposure, a supportive environment, and robust social networks is essential for sustained participation. Moreover, satisfaction plays a mediating role between e-health literacy and social participation, underscoring the importance of user-centered service optimization, including personalized healthcare recommendations and responsive customer support. A holistic approach that integrates community resources, family

involvement, and policy initiatives is crucial to ensuring equitable access to Internet-based healthcare services. Such efforts will enhance health outcomes and improve the overall digital healthcare experience for older adults navigating the evolving Internet health landscape.

Theory and hypothesis

Research on internet medical services

Internet medical services are a new medical service model that leverages Internet technology to provide online consultations, remote diagnosis and treatment, electronic prescriptions, and health management [32]. Existing research on Internet medical services exhibits several key characteristics. First, studies have explored the development and optimization of these services, primarily from the perspective of service providers, including medical personnel, hospital administrators, and information technology specialists. These studies focus on building indicator systems to enhance the efficiency of Internet-based healthcare services [48, 85]. Second, research from the demand-side perspective has examined older adult patients in hospitals, chronic disease management, mobile technology adoption among older adults in community settings, and the integration of Internet services with elderly care. These studies primarily address individuals seeking medical care after diagnosis, those managing chronic diseases, and older adults requiring specialized care (N. [45, 60]).

This study specifically focuses on the utilization of Internet health services among older adults. While research on this topic remains limited, existing studies suggest that older adults have low awareness and utilization of these services [41, 49, 86]. However, findings on their willingness to adopt Internet medical services remain inconsistent, as older user groups exhibit diverse characteristics [49, 77, 83]. The factors influencing older adults' adoption of Internet medical services are multifaceted, encompassing variables such as age, geographic location, education level, family structure, frequency of medical visits, health status, and familiarity with electronic devices [19],D. [44, 79]. With the rapid expansion of Internet medical services and the increasing healthcare demands of the aging population, the number of older adults utilizing these services is expected to increase significantly [35]. This study analyzes the current state of Internet medical service utilization among older adults and the factors influencing their adoption. The findings will serve as a valuable reference for improving the acceptance and accessibility of Internet-based healthcare services for this demographic.

Theoretical foundation

Social cognitive theory (SCT), proposed by psychologist Bandura, emphasizes the role of individual cognitive factors in shaping human functioning. It introduces a ternary interaction model, where the environment, individual cognition, and individual behavior interact dynamically (Bandura, 2002). SCT explains human functioning through the principle of reciprocal determinism, asserting that cognitive factors, behaviors, and environmental influences continuously interact and shape one another [7]. Additionally, bidirectional causal relationships exist between any two of these factors (Fig. 1). Key cognitive factors include beliefs, emotions, and perceptions [66]. The cognitive-related variables often focus on self-efficacy, self-evaluation, and values [65]. Behavioral influences stem primarily from an individual's choice of activities, level of effort, and persistence—factors driven by intrinsic motivation, which, in turn, further influence motivation [23]. Environmental influences, on the other hand, arise from social constructs, organizational structures, and community activities [76]. Individuals adjust their self-expectations and behavioral choices by observing and comparing their environments.

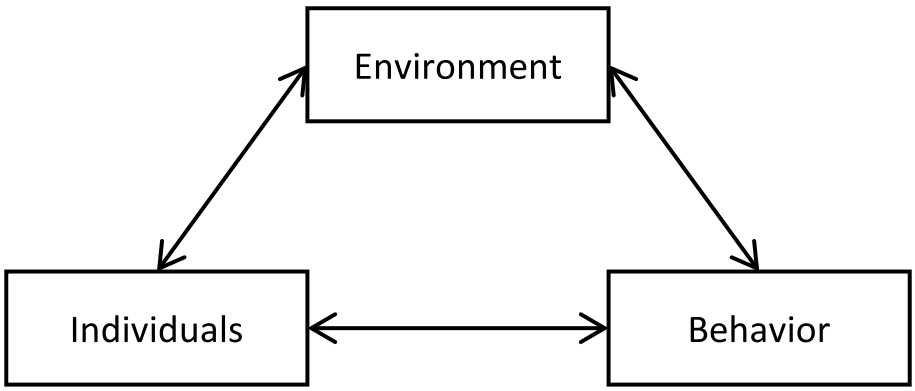

Fig. 1 Basic structure of the ternary interaction model

SCT is now widely used in research to understand and predict individual behavior in health-related contexts and the adoption of new technologies [31]. This theory provides a robust framework for understanding the factors influencing older adults' willingness to continue using Internet medical services. SCT emphasizes reciprocal determinism, where behavior, individuals (self-efficacy), and environmental factors (social support and social participation) dynamically interact to shape behavioral outcomes. Moreover, e-health literacy is a critical individual factor that enhances self-efficacy by equipping users with the skills to navigate digital medical services [58]. Self-efficacy, in turn, is a key determinant of behavioral persistence, enabling older adults to overcome technological barriers and maintain consistent use of Internet medical platforms [39]. Environmental factors (social participation and support) further reinforce the process by providing a supportive ecosystem fostering trust and engagement [17].

Hypothesis

Behavioral factors

Satisfaction and willingness to continue use Satisfaction is a key predictor of an individual's intention to continue using a service. Higher user satisfaction leads to stronger behavioral intent, particularly in digital platforms, where user experience plays a crucial role in continued engagement[55]. Extensive research has demonstrated that satisfaction significantly influences users' willingness to continue using various services across different contexts [4, 43, 84]. Xiong et al. [82] investigated the factors affecting the continued use of mobile government services, emphasizing perceived quality and value. Their findings revealed that information quality, system quality, service quality, perceived usefulness, perceived ease of use, and perceived interactivity positively influence users' willingness to continue using such services, mediated by satisfaction and trust. In the context of this study, older adults who experience higher satisfaction with Internet medical services are less likely to discontinue their use, thereby demonstrating a stronger willingness to continue using these platforms.

Hypothesis 1: Satisfaction positively affects older adults' continued use of Internet medical services.

Individual factors

Self-efficacy and e-health literacy Bandura defines self-efficacy as an individual's judgment of his or her ability to organize and execute the course of action required to accomplish a set behavioral goal [6]. The SCT views self-efficacy as a key factor influencing behavior change and persistence. For Internet medical services, self-efficacy influences older adults' ability to overcome technological barriers and actively engage with digital healthcare platforms. Higher self-efficacy enhances their confidence, increasing their willingness to continue using Internet medical services [22]. Similarly, e-health literacy plays a crucial role in shaping user experience and satisfaction. Higher e-health literacy enhances an individual's ability to understand and effectively use health-related information, thereby improving overall satisfaction [68]. Seçkin et al. [69] further validated the indirect effect of e-health literacy on satisfaction and the intention to continue using digital health services. Within the SCT framework, e-health literacy strengthens users' confidence and digital skills, leading to increased satisfaction and sustained engagement with Internet medical services.

Hypothesis 2: Self-efficacy positively affects older adults' continued use of Internet medical services.

Hypothesis 3: E-health literacy has a positive effect on satisfaction.

Hypothesis 4: E-health literacy positively affects older adults' continued use of Internet medical services.

Environment

Social environmental factors play an essential role in the use of Internet medical services by older adults [78]. SCT emphasizes the influence of environment on behavior, and social engagement provides a supportive environment for older adults to enhance their sense of belonging and trust in Internet health services. Increasing opportunities for interaction with others enhance older adults' satisfaction and willingness to continue using Internet health services [33].

Social support Support from family, friends, and community can help individuals overcome psychological [3] and practical barriers and increase trust and acceptance of new technologies. A supportive environment encourages behavioral persistence [46]. Social support, especially from family and friends, has been positively associated with the adoption and continued use of Internet medical services [67, 77].

Social influence Social influence refers to the impact of others' opinions or the prevailing social atmosphere [34]. It is a key determinant in the adoption of new technologies [74] and has been widely validated in studies on mobile health device utilization and the effectiveness of digital health services [1, 71].

Social participation It refers to both emotional and instrumental support that strengthens individuals' self-efficacy and enhances service satisfaction [11]. For older adults, engaging in social activities reduces feelings of

isolation and fosters a sense of belonging, both of which are crucial for increasing satisfaction with digital health tools [21]. Research suggests that social participation can indirectly influence behavioral intentions by improving satisfaction levels [5, 42]. By providing emotional and practical support, social participation fosters a supportive context that enhances satisfaction and promotes long-term engagement with digital health services [14]. Satisfaction, in turn, mediates the relationship between social participation and the intention to continue using these services.

Hypothesis 5: Social influence positively affects older adults' continued use of Internet medical services.

Hypothesis 6: Social support positively affects older adults' continued use of Internet medical services.

Hypothesis 7: Social participation has a positive effect on satisfaction.

Hypothesis 8: Social participation positively affects older adults' continued use of Internet medical services.

Hypothesis 9: Satisfaction is mediated by e-health literacy and social participation in older adults' continued use of Internet medical services.

The conceptual framework based on the SCT is illustrated in Fig. 2.

Methods

PLS-SEM

The two more common types of SEM are covariance-based SEM (CB-SEM) and principal component structure-based (PLS-SEM) [20]. CB-SEM is typically more theory-driven and is primarily used for validation analyses, making it suitable for testing well-established theoretical models. On the other hand, PLS-SEM is more appropriate for exploratory models, especially in situations where theory is less developed or where the model is intended to explore relationships between variables rather than confirm them. Although this study is theoretically grounded, no previous research has incorporated the specific variables into a single model. Therefore, this study is considered exploratory in nature. Reliability and correlational analyses were performed using STATA 18.0. PLS-SEM and the bootstrapping technique (re-sampling = 1,000) were adopted using Smart-PLS 4.

This study constructs a PLS-SEM model to examine older adults' willingness to continue using Internet medical services and identify the key influencing factors. The pathway model, based on the previously outlined hypotheses, is shown in Fig. 3.

Fuzzy-set qualitative comparative analysis(fsQCA)

Social phenomena and behaviors are complex and often arise from a combination of multiple causal variables. Analytical methods based on linear causality may not effectively capture the mechanisms behind certain phenomena or behaviors. To address this, Charles Ragin introduced Qualitative Comparative Analysis (QCA) in 1987, a case-study-oriented qualitative method [47]. QCA is grounded in the logic of set theory and Boolean algebra and focuses on configurational analysis. It compares the consistency and variability of multiple cases to identify the sufficient and necessary conditions for an outcome. This method reveals the asymmetrical relationships between dependent and independent variables and generates different combinations of conditions that lead to a particular outcome, providing a deeper understanding of the mechanisms underlying complex causal relationships. For example, Venkatesh et al. [75] used qualitative research to explore how information and communication technologies (ICTs) impact employee job satisfaction and performance, revealing the underlying contextual factors. Similarly,

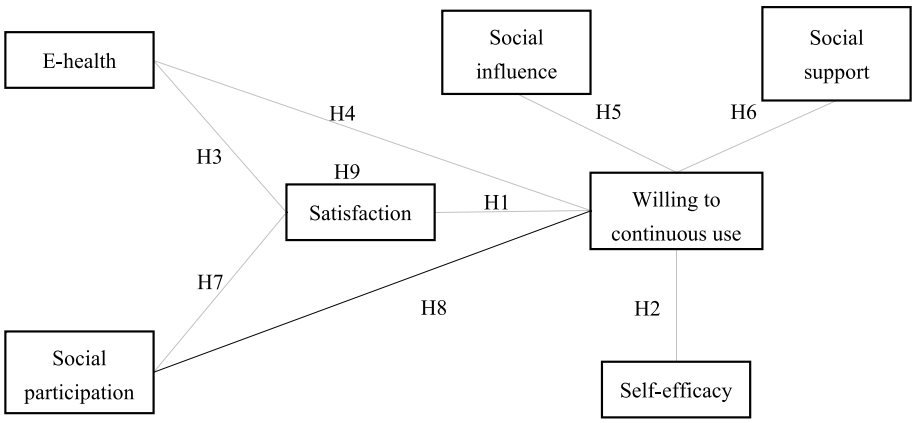

Fig. 2 Hypothetical model based on the social cognitive theory

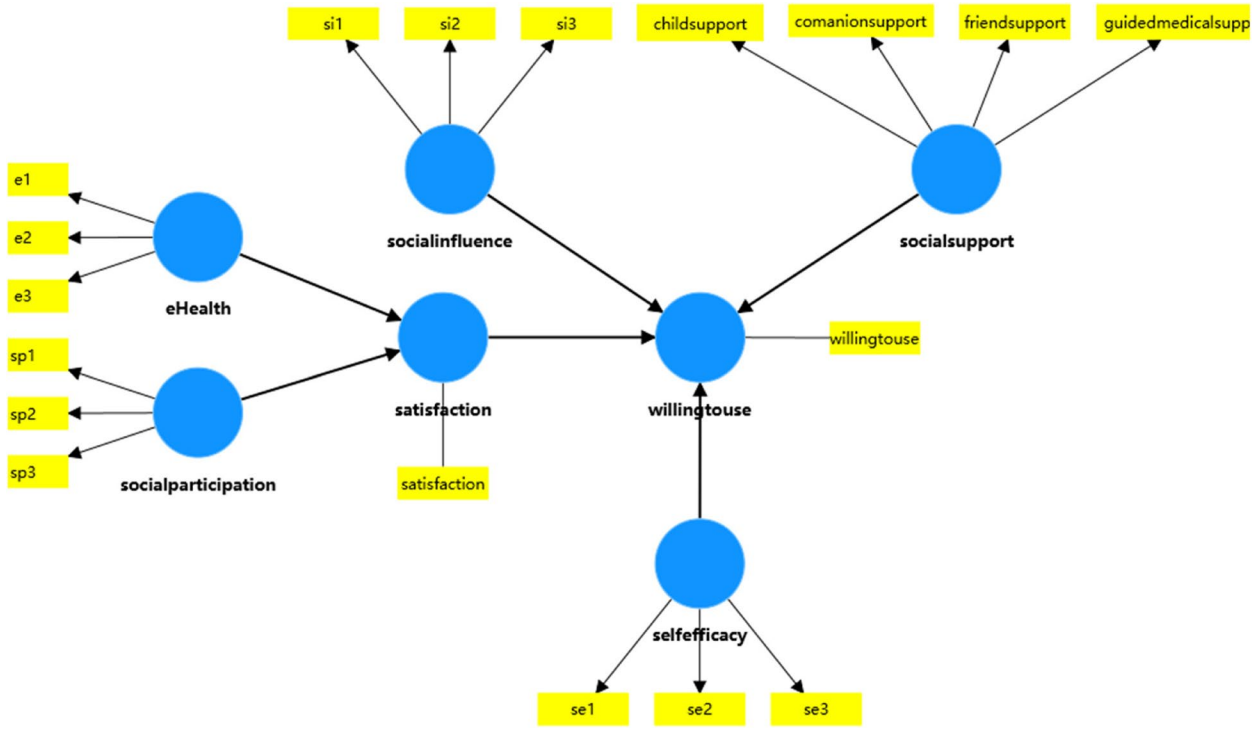

Fig. 3 PLS-SEM model of older adults' willingness to continue using Internet medical services

Mikalef & Pateli [50] combined PLS-SEM with fsQCA to analyze the relationship between dynamic IT-based coping mechanisms and firms' competitive capabilities, demonstrating how fsQCA enhances the results of PLS-SEM. Afonso et al. [2] also suggested that fsQCA (asymmetric analysis) provides more practical insights than symmetric methods like structural equation modeling (SEM) when exploring how motivation and involvement influence tourists' willingness to return to a wine region. Furthermore, Gligor & Bozkurt [28] showed that multivariate regression analyses could benefit from incorporating fsQCA to improve the explanatory power of findings in customer and brand interactions.

Since individual factors alone may not fully explain older adults' willingness to continuously use Internet medical services, and the combined effects of these factors may be necessary, we selected key factors from the PLS-SEM model for fsQCA analysis. This approach will help uncover the mechanisms behind the formation of older adults' willingness to engage with Internet medical services. Based on the results of the fsQCA configurations, we will propose an implementation program aimed at improving the use of Internet medical services among the elderly population.

Research design and participants

This study utilized a cross-sectional design, where participants were asked to complete a self-administered questionnaire that assessed e-health literacy, self-efficacy, social support, social influence, social participation, satisfaction, and willingness to continue using Internet medical services.

A restricted random sampling method was employed to select participants from three geographically diverse provinces: Beijing, Hunan, and Inner Mongolia, representing East, Central, and West China, respectively. Within each province, two cities were randomly chosen. In each city, three streets and three townships were randomly selected to ensure comprehensive geographical representation. A total of 18 townships (or streets) were included in the survey. The field survey was conducted from March to August 2023, targeting older adults aged 60–75. This sampling approach ensured a balanced geographical representation while maintaining randomness in participant selection.

Participants were required to meet the following inclusion criteria: aged between 60 and 75 years, permanent residents of the selected area, able to engage in everyday thinking, and with no history or family history of mental illness. Participation in the study was voluntary.

Individuals were excluded if they had psychiatric or psychological illnesses, suffered from major illnesses with severe conditions, or were unwilling to cooperate.

The study was approved by the Biomedical Ethics Committee of Peking University (No. IRB00001052-22147). All participants were informed that their participation was entirely voluntary and that they could refuse or withdraw at any time.

Quality control included uniform training of investigators before the survey; the field survey was conducted strictly according to the survey protocol. The cooperation of relevant local organizations and survey respondents was fully obtained. Self-designed questionnaires were used for data collection (Supplementary 1). For respondents with lower literacy, advanced age, or impaired hearing and vision, investigators assisted by reading the questions aloud and helping to complete the responses. A quality control team supervised the survey process and reviewed the completed questionnaires. All participants signed an informed consent form before participating in the study.

This study distributed a total of 2,038 questionnaires. After excluding those with issues related to age and response logic, 1,920 valid questionnaires were obtained, resulting in a validity rate of 94.2%.

Measures and instruments

All measurement scales were modified from reliable and valid existing scales.

Satisfaction

Participants were asked, "How would you rate your experience with Internet medical services?" The response scale ranged from 1 (very dissatisfied) to 10 (very satisfied).

Willingness to continue use

Participants were asked, "Are you willing to consider using Internet medical services during your next visit?" Responses were provided on a scale from 1 (very reluctant) to 10 (very willing).

Other variable measurement scales are presented in Table 1.

Results

Demographics of respondents

A total of 1,920 older adults aged 60–75 participated in this study, with an average age of 67.32 years (SD = 4.40). Table 2 summarizes the demographic characteristics of the participants. The sample was predominantly female (54.70%) and overwhelmingly of Han ethnicity (94.20%). More than half of the participants (51.80%) resided in urban areas. Regarding educational attainment, 14.20% were illiterate, 33.60% had completed primary school, 28.10% had reached middle school, and 24.10% had attained high school education or higher.

Regarding health conditions, 34.20% reported having no chronic diseases, while 41.10% had one chronic condition, and 24.70% reported two or more chronic diseases. Regarding living arrangements, 10.20% lived alone, 46.60% lived with one or two individuals, and 43.20% lived with three or more individuals. Most participants (87.00%) had good mobility, whereas 13.00% reported difficulties with walking.

For sensory and coordination abilities, vision was predominantly rated as poor (68.20%), with only 0.20% reporting good vision. Similarly, 76.80% rated their hand–eye coordination as poor, with only 0.20% reporting good coordination. These findings underscore the diverse demographic and health profiles of the older adult population sampled in this study, providing a strong foundation for understanding their engagement with Internet medical services. The overall utilization rate of Internet medical services among older adults was 37.8%,

Table 1 Summary of variable scales

Variables	Items	Choices	Score	Cronbach's Alpha	KMO	Explained Variance	References
E-health literacy	3	"Strongly inconsistent = 1" -"Strongly consistent = 5"	3–15	0.767	0.767	87.62%	(S.J. [30]) Custom design
Self-efficacy	3	"Strongly inconsistent = 1" -"Strongly consistent = 5"	3–15	0.912	0.751	85.06%	[13] Custom design
Social influence	4	"Strongly inconsistent = 1" -"Strongly consistent = 5"	3–15	0.809	0.765	63.74%	(A. [36]) Custom design
Social support	4	"Helpful = 1", 'Not helpful = 0","Impatient = −1"	−4—4	0.896	0.745	82.76%	(M. A. [37]) Custom design
Social participation	4	"Never = 1" -"Always = 5"	4–20	0.665	0.67	49.99%	[72] Custom design

Table 2 Demographic characteristics of participants (N = 1920)

Variable	Categories	Frequency	Percentage %
Age (mean, SD)		67.32 (4.40)	
Gender	Female	1051	54.70
Ethnic	Han	1808	94.20
Region	Urban	994	51.80
Education	Illiteracy	272	14.20
	Primary	646	33.60
	Middle	540	28.10
	High school and above	462	24.10
Number of chronic diseases	0	657	34.20
	1	788	41.10
	≥ 2	475	24.70
Cohabitation	Living alone	195	10.20
	Living with two	895	46.60
	Living with more than 3	830	43.20
Mobility	Fine	1670	87.00
	Problem with walking	250	13.00
Vision	Good	4	0.20
	General	607	31.60
	Poor	1309	68.20
Hand–eye coordination	Good	3	0.20
	General	443	23.10
	Poor	1474	76.80

Table 3 Descriptive statistics for core variables (N = 1920)

Variable	Mean	Standard Deviation	Minimum	Maximum
E-health	8.47	3.07	3	15
Self-efficacy	8.68	2.97	3	15
Social influence	9.26	2.85	3	15
Social participation	7.64	2.74	3	15
Social support	2.18	1.47	−4	4
Satisfaction	7.96	1.86	1	10
Willing to continuous use	6.35	2.70	1	10

Note: The satisfaction survey was conducted exclusively among older adults who had previously used Internet medical services, with a sample size of only 725

and 16.9% could independently utilize Internet medical services.

Descriptive statistics for variables

The descriptive results for all measures are presented in Table 3. The mean e-health literacy score was 8.47 (SD = 3.07), indicating a moderate level of e-health literacy among participants. Self-efficacy, reflecting confidence in using Internet medical services, had a mean score of 8.68 (SD = 2.97), suggesting a similar moderate capability. Social influence and social participation had mean scores of 9.26 (SD = 2.85) and 7.64 (SD = 2.74), respectively, indicating moderate to strong levels of perceived peer influence and community engagement.

Social support, measured on a scale ranging from −4 to 4, had a lower mean score of 2.18 (SD = 1.47), highlighting variability in participants' access to supportive relationships. Satisfaction with Internet medical services was assessed among a subset of 725 respondents with prior experience using such services, yielding a mean score of 7.96 (SD = 1.86), indicating relatively high satisfaction levels. The intention to continue using Internet medical services had a mean score of 6.35 (SD = 2.70), reflecting a moderately strong willingness to adopt these services.

These findings highlight the diversity in participants' e-health literacy, social contexts, and behavioral intentions, providing a foundation for further exploration of the factors influencing the sustained use of Internet medical services.

PLS-SEM

The model successfully met the criteria for composite reliability, discriminant validity, and average variance extracted (AVE). The factor loadings of all observed variables exceeded 0.7 and were statistically significant at the 0.05 level, confirming that the observed variables effectively represent their corresponding latent constructs [38]. Due to space limitations, the results of the

measurement model are provided in the Supplementary Material (Supplementary 2, Tables 1–3), while the structural model results are presented in the main text. All measurement instruments demonstrated strong reliability and validity. The path results for the PLS-SEM analysis are summarized in Table 4.

Direct effects

The results of the PLS-SEM analysis revealed several significant direct effects among the variables. Specifically:

(1) E-health literacy and satisfaction

E-health literacy had a significant positive effect on satisfaction ($\beta = 0.174$, $p < 0.001$), indicating that individuals with higher e-health literacy tend to experience greater satisfaction with Internet medical services.

(2) Satisfac2tion and willingness to continue using Internet medical services

Satisfaction had the most substantial direct effect on willingness to continue using Internet medical services ($\beta = 0.281$, $p < 0.001$). This finding highlights satisfaction as a critical determinant of behavioral intention in the digital healthcare domain.

(3) Self-efficacy and willingness to continue using Internet medical services

Self-efficacy exhibited a small but significant positive effect on willingness to use Internet medical services ($\beta = 0.058$, $p = 0.029$). This suggests that confidence in one's ability to navigate medical services modestly influences behavioral intentions.

(4) Social influence and willingness to continue using Internet medical services

Social influence significantly affected willingness to use ($\beta = 0.189$, $p < 0.001$), emphasizing the role of social norms and peer influence in shaping healthcare utilization behaviors.

(5) Social participation and satisfaction

Social participation was positively associated with satisfaction ($\beta = 0.074$, $p = 0.001$), suggesting that active social engagement contributes to an improved user experience with digital medical services.

(6) Social support and willingness to continue using Internet medical services

Table 4 Results of hypothesis testing

Hypothesis	Path	Coefficient (β)	Standard Error	T-Statistic	P-value	95% CI (2.5%, 97.5%)	Effect Type	Test results
H1	Satisfaction → Willingness to continuously use	0.281	0.019	14.438	< 0.001	(0.243, 0.319)	Direct	Support
H2	Self-efficacy → Willingness to continuously use	0.058	0.026	2.189	0.029	(0.007, 0.112)	Direct	Support
H3	E-health literacy → Satisfaction	0.174	0.024	7.389	< 0.001	(0.129, 0.221)	Direct	Support
H4	E-health literacy → Willingness to continuously use	0.049	0.008	6.306	< 0.001	(0.035,0.065)	Total	Support
H5	Social influence → Willingness to continuously use	0.189	0.026	7.217	< 0.001	(0.137, 0.240)	Direct	Support
H6	Social support → Willingness to continuously use	0.172	0.02	8.61	< 0.001	(0.129, 0.207)	Direct	Support
H7	Social participation → Satisfaction	0.074	0.023	3.229	0.001	(0.021, 0.126)	Direct	Support
H8	Social participation → Willingness to continuously use	0.021	0.007	3.136	0.002	(0.006,0.032)	Total	Support
H9	Social participation → Satisfaction → Willingness to continuously use	0.021	0.007	3.136	0.002	(0.010, 0.036)	Indirect	Support
H9	E-health literacy → Satisfaction → Willingness to continuously use	0.049	0.008	6.306	< 0.001	(0.034, 0.064)	Indirect	Support

Social support had a significant positive impact on willingness to use ($\beta = 0.172$, $p < 0.001$), highlighting the importance of support from family and friends in fostering greater engagement with digital healthcare platforms.

Indirect effects

The mediation analysis revealed two significant indirect effects:

(1) E-health literacy → Satisfaction → Willingness to continue using Internet medical services

E-health literacy indirectly influenced willingness to continue using Internet medical services via satisfaction ($\beta = 0.049$, $p < 0.001$). This suggests that individuals with higher e-health literacy tend to be more satisfied with digital healthcare services, which in turn enhances their intention to continue using them.

(2) Social participation → Satisfaction → Willingness to continue using Internet medical services

Social participation indirectly impacted willingness to continue using Internet medical services through satisfaction ($\beta = 0.021$, $p = 0.002$), indicating that active participation in social activities enhances satisfaction, which subsequently drives behavioral intention.

Total effects

The total effects analysis further highlighted the significant roles of e-health literacy ($\beta = 0.049$, $p < 0.001$) and social participation ($\beta = 0.021$, $p = 0.002$) on willingness to continue using Internet medical services, mediated through satisfaction. These results reinforce the central role of satisfaction as a mediator linking multiple antecedents to the intention to use Internet medical services.

fsQCA

Based on the results of the PLS-SEM model, factors such as e-health literacy, satisfaction, self-efficacy, social influence, social participation, and social support were found to positively impact older adults' willingness to continue using Internet medical services. However, the effect of individual factors may not be sufficient to consistently shape this willingness. Instead, a combination of factors may be necessary to effectively influence sustained usage. To further explore the formation mechanism of older adults' willingness to continuously use Internet medical services, a fuzzy-set qualitative comparative analysis (fsQCA) was conducted. This approach integrates findings from the PLS-SEM model, relevant literature, and the real-world context of Internet medical service adoption among older adults. The identified factors were selected as antecedent conditions for the fsQCA analysis, which aims to uncover configurations of conditions that drive continued usage. Additionally, the results provide insights for designing tailored implementation programs for older adults. The fsQCA analysis follows several key stages, including data calibration, necessity analysis, truth table construction, sufficiency analysis, and interpretation of solutions [57, 73]. Before conducting the analysis, data cleaning was performed, which involved handling missing values and outliers. Scatter plots were used to identify extreme values, and data points that fell outside a reasonable range were removed.

Calibration

The antecedent conditions and outcomes were transformed into fuzzy set membership values ranging from 0 to 1 through a data calibration process. First, three anchor points were identified to represent full affiliation, fuzzy affiliation, and no affiliation. Then, the values corresponding to the 95% quantile, 50% quantile, and 5% quantile of the data were selected as anchor points to calibrate the Likert scale-like data [10, 27]. The anchor point selection table is shown in Table 5. Finally, the anchor point values for each antecedent variable were input into the calibrate function in the fsQCA software to perform preliminary calibration of the data.

Necessity analysis

To identify the necessary antecedents for older adults' continued willingness to use Internet medical services, we conducted a necessity analysis using fsQCA software [59]. The assessment of necessity conditions relies on two critical indicators: consistency and coverage. These indicators must be interpreted together—high consistency

Table 5 Threshold of antecedent variables for calibration

Calibration	Satisfaction	Willing to use	e-health literacy	Self-efficacy	Social influence	Social support	Social participation
95%	10	10	15	15	15	4	14
50%	8	8	10	10	11	3	8
5%	5	3	3	3	6	1	4

and high coverage indicate that the presence of a condition is proportional to the presence of the outcome, signifying a highly important necessity condition. Conversely, high consistency but low coverage suggests that the condition is not a crucial necessity factor, as it does not sufficiently explain the outcome. Previous research has established that for a condition to be deemed necessary, its consistency must exceed 0.9, and its coverage must be greater than 0.5 (M. A. [37]).

The results showed that the consistency coefficients for the presence and absence of the six variables included in the analysis were below 0.9 (Table 6). The analysis results revealed that the consistency coefficients for the presence and absence of all six variables—e-health literacy, satisfaction, self-efficacy, social influence, social participation, and social support—were below the 0.9 thresholds (Table 6). This finding suggests that none of these factors independently serve as a necessary condition for older adults' willingness to continue using Internet medical services. Therefore, the study proceeded with an analysis of the combined effects of these conditions to explore the formation mechanisms of sustained Internet medical service usage among older adults.

Sufficient conditions analysis

Before conducting the configuration analysis, a truth table was constructed to classify and categorize sample cases into different combinations of conditions (configurations). In this study, six factors identified in the PLS-SEM model were selected as antecedent conditions, leading to a theoretical possibility of 2^6= 64 configurations [62]. The 725 sample cases were categorized and generalized into these 64 configurations (there were cases where there were no cases in some configurations) to obtain a truth table for the configuration analysis. According to Ragin's study, this threshold is recommended to be set at 0.75 [18]. As the application of fsQCA methodology in research develops, scholars gradually increase the consistency threshold to 0.8 to ensure the validity of conclusions [51]. Therefore, in this study, the consistency threshold was set to 0.8, and the case frequency threshold was set to 5.

Table 6 Necessary conditions for switching intention

Variable	Consistency	Coverage
satisfaction	0.876	0.809
~satisfaction	0.426	0.499
e-health literacy	0.742	0.760
~e-health literacy	0.578	0.603
selfefficacy	0.722	0.733
~selfefficacy	0.598	0.629
socialinflunce	0.690	0.746
~socialinflunce	0.630	0.623
socialsupport	0.653	0.661
~socialsupport	0.577	0.609
socialparticipation	0.665	0.688
~socialparticipation	0.632	0.652

Note: "~" indicates that the variable is absent

A Boolean technique based on counterfactual analysis was applied to simplify the truth table configurations logically. This process yielded three types of solutions: complex, simple, and intermediate. Conditions appearing in both the parsimonious and intermediate solutions were identified as core conditions, indicating a strong causal relationship with the outcome. Conditions that appear in the parsimonious and intermediate solutions are called core conditions, and conditions that appear only in the intermediate solutions are called auxiliary conditions [25].

The simple and intermediate solutions give rise to the notion of antecedents belonging to either core or peripheral [24, 27]. Core elements are causal conditions for which the evidence indicates a strong causal relationship with the outcome of interest, whereas peripheral elements exhibit weaker causal relationships and appear only in intermediate solutions. The intermediate solution is particularly valuable as it balances theoretical and empirical considerations, overcoming the limitations of both complex and parsimonious solutions. As a result, most studies rely on intermediate solutions to analyze how different configurations of antecedent conditions influence the outcome variable. Core conditions typically appear across multiple configurations, while peripheral conditions are present in only some configurations.

Coverage and consistency statistics were used to interpret the results of the fsQCA [57]. Coverage assesses how well each solution pathway and the overall solution explain the outcome, highlighting the empirical significance of each configuration. Consistency, on the other hand, measures whether a given configuration consistently leads to the same outcome across different cases. Configurations with consistency scores above 0.80 are considered sufficient, with prior studies suggesting that a minimum threshold of 0.75 is necessary to establish sufficiency.

Table 7 outlines six conditional configurations related to older adults' willingness to continue using Internet medical services, evaluating both coverage and consistency for each configuration. In this context, consistency is analogous to statistical significance, representing the probability that a given configuration leads to the intended outcome [8]. Prior research suggests that a minimum consistency threshold of 0.75 is required to establish sufficiency [26]. The results confirm that all six

Table 7 Configurations that lead to willingness to continuously use Internet medical services

Variance	Configuration 1: Independent Driver	Configuration 2: Confident Participant	Configuration 3: Family-Supported	Configuration 4: Socially Connected	Configuration 5: Balanced Support	Configuration 6: Community-Interactive
Satisfaction	●	●	●	●	●	●
E-health literacy	●	●	●	●		
Self-efficacy		○			○	○
Social influence	⊗				⊗	○
Social participation				○		○
Social support			○		○	
Consistency	0.904	0.900	0.908	0.904	0.919	0.917
Raw coverage	0.440	0.580	0.483	0.512	0.332	0.445
Unique coverage	0.440	0.580	0.483	0.512	0.332	0.445
Overall solution consistency	0.881					
Overall solution coverage	0.694					

Note: The black circles (●) and crossed-out circles (⊗) indicate the presence and absence or negation of a condition, respectively. In addition, The black circles (●) denote core conditions, hollow circles (○) denote peripheral conditions, and blank spaces indicate "do not care" conditions

configurations meet this criterion, indicating their adequacy as sufficient conditions for the continued use of Internet medical services. Coverage, on the other hand, reflects the explanatory strength of each configuration in accounting for the outcome. The overall coverage of 0.694 suggests that these configurations collectively capture the primary determinants of older adults' sustained engagement with digital healthcare services. Notably, Configuration 2 exhibits the highest coverage, implying that it provides the most substantial explanatory power in understanding the factors influencing the continued utilization of Internet medical services among older adults.

Results of fsQCA

(1) Core and peripheral conditions

Core conditions: Satisfaction and e-health literacy consistently appear across multiple configurations, underscoring their fundamental role in promoting the sustained use of Internet medical services among older adults.

Peripheral conditions: Self-efficacy, social support, social influence, and social participation act as contextual factors that influence continued usage under specific conditions.

(2) Configurations

1) Configuration 1: Independent driver configuration.

Solution expression: satisfaction * e-health literacy * ~ social influence.

This configuration highlights the crucial role of satisfaction and e-health literacy in sustaining older adults' use of Internet medical services while emphasizing the negative impact of social influence. Even when older adults are satisfied with these services and possess strong digital health literacy, negative social influences—such as skepticism or discouragement from peers—can pose significant barriers to continued use. Conversely, the absence of such external doubts fosters a more supportive environment, reinforcing the interplay between individual readiness and social context in digital health adoption.

Medical care providers and policymakers should develop tailored communication strategies to counter misinformation about Internet medical services. Targeted educational campaigns can address common misconceptions and highlight the benefits of digital health solutions. Training initiatives that enhance digital skills and confidence can empower older adults to engage with Internet medical platforms effectively. In rural communities, older adults who participate in personalized digital literacy programs tend to overcome skepticism and build confidence, leading to sustained engagement with Internet medical services.

2) Configuration 2: Confident participant configuration

Solution expression: satisfaction * e-health literacy * self-efficacy.

This configuration emphasizes that older adults with high satisfaction, strong e-health literacy, and a high level of self-efficacy are more likely to sustain their use

of Internet medical services. Self-efficacy, or the belief in one's ability to navigate digital health platforms, plays a crucial role in fostering confidence and reducing hesitation. When combined with positive service experiences and adequate digital skills, self-efficacy provides a strong foundation for long-term engagement with Internet medical services.

These findings highlight the need for targeted training programs to enhance self-efficacy among older adults. Such programs should focus on user-friendly interfaces, interactive tutorials, and real-life success stories to build confidence and reduce the perceived complexities of digital healthcare. For instance, a retired teacher with prior digital experience may independently engage with Internet medical services due to her confidence, demonstrating how self-efficacy can empower sustained usage.

Social participation shows varying effects on the willingness to continue using Internet medical services across different configurations. This variability can be attributed to the strength of individuals' social support networks. For example, in configurations with high levels of social support, social participation has a stronger positive impact on satisfaction, which in turn increases the willingness to continue using Internet medical services. However, in configurations with low social support, the impact of social participation may be less significant, as individuals may lack the emotional reinforcement needed to enhance their digital health engagement.

3) Configuration 3: Family-supported configuration

Solution expression: satisfaction * e-health literacy * social support.

This configuration highlights the critical role of family and peer support in sustaining older adults' use of Internet medical services. When high satisfaction and strong e-health literacy are reinforced by social support, older adults are more likely to continue engaging with digital healthcare platforms. Social support offers both emotional reassurance and practical assistance, helping users overcome technological challenges and build confidence in their digital health interactions.

The findings emphasize the importance of fostering family engagement in digital health interventions. Programs designed to educate and involve caregivers, such as tutorials and collaborative use sessions, can strengthen the role of family members in promoting sustained use of Internet medical services. For instance, older adults encouraged by their children may feel motivated to continue using Internet medical services, mainly when family members assist with scheduling online consultations or navigating complex healthcare systems. This synergy between individual readiness and familial support ensures emotional comfort and practical efficiency, driving long-term adoption of digital health solutions.

4) Configuration 4: Socially connected configuration

Solution expression: satisfaction * e-health literacy * social participation.

This configuration underscores the role of social participation in sustaining older adults' engagement with Internet medical services. When satisfaction and e-health literacy are coupled with active involvement in community activities or peer networks, older adults are more likely to continue using digital healthcare platforms. Social participation fosters knowledge exchange, reinforces positive perceptions, and enhances confidence in navigating online medical services.

The results suggest promoting community-based workshops and group activities focused on digital health education. These initiatives enhance technical skills and foster a supportive environment where individuals can exchange insights and motivate each other. For example, senior citizens attending digital health seminars often report increased confidence in using Internet medical services. The shared learning experience and peer encouragement foster a sense of belonging, reinforcing their intention to continue using these services daily.

5) Configuration 5: Balanced support configuration.

Solution expression: satisfaction * self-efficacy * ~social influence * social support.

This configuration reveals that older adults with high satisfaction and self-efficacy, reinforced by strong social support, can overcome the adverse effects of social influence to sustain their use of Internet medical services. Robust social networks provide emotional and practical assistance, while self-efficacy instills the confidence needed to navigate digital healthcare platforms. Together, these factors mitigate the impact of external skepticism or discouragement, creating a balanced support system for continued usage.

The findings highlight the importance of leveraging trusted community networks to amplify positive narratives surrounding Internet medical services. Community health initiatives could involve local leaders or volunteers in promoting digital health education, sharing success stories, and building trust among older adults. For example, community health volunteers can provide personalized guidance to older adults with solid digital confidence, helping them navigate healthcare systems without being influenced by external doubts. Such initiatives create a supportive ecosystem that fosters long-term engagement with Internet medical services.

6) Configuration 6: Community-interactive configuration.

Solution expression: satisfaction * self-efficacy * social influence * social participation.

This configuration underscores the combined influence of high satisfaction, strong self-efficacy, positive social influence, and active social participation in driving the sustained use of Internet medical services among older adults. A supportive social environment, reinforced by peer encouragement and community involvement, works synergistically with individual confidence to create a powerful motivation for continued usage. Positive social influence, such as endorsements from peers or local leaders, amplifies trust in these services. At the same time, active participation in community activities provides opportunities to learn and share experiences, further reinforcing adoption.

These findings suggest the need for media campaigns and community events that highlight success stories and encourage collective engagement. For instance, senior citizens participating in health clubs often become enthusiastic users of Internet medical services due to peer encouragement and exposure to targeted media campaigns. By leveraging community interactions and fostering a culture of mutual support, such initiatives create a dynamic and sustainable ecosystem for promoting digital health solutions.

The findings highlight the intricate interplay of individual and social factors in influencing older adults' continuous use of Internet medical services. While core variables such as satisfaction and e-health literacy are foundational, the contextual role of peripheral factors like self-efficacy, social participation, and social support cannot be overlooked. Notably, negative social influence presents a significant barrier, warranting strategies to mitigate its impact.

(3) Merge different configurations

The merger's logic was to categorize the six groupings into three types based on various drivers. Individual-driven factors, such as self-efficacy and satisfaction, constitute the independent motivation-based type, whereas social support factors, including family support and community support, define the social support type. The role of social participation and peer interaction constitute the community-driven type, which emphasizes the role of collective participation as a catalyst for sustained use.

Type I: Independent motivation-based grouping

This type focuses on the individual's internal motivations and readiness to engage with Internet medical services, with minimal dependence on external social factors. The Independent Motivation-Based Grouping pattern centers around two core conditions: satisfaction and e-health literacy. These factors suggest that when older adults are satisfied with their experience and possess adequate digital health skills, they are more likely to continue using Internet medical services, provided they are not influenced by negative social factors. The absence of negative social influence, such as skepticism or discouragement from others, ensures that these intrinsic factors can guide continued usage without external hindrances. The Confident Participation Grouping pattern builds on this by adding self-efficacy as a core condition, along with satisfaction and e-health literacy. In this configuration, older adults' belief in their own abilities (self-efficacy), combined with satisfaction and digital literacy, plays a crucial role in overcoming potential barriers. The individual's confidence in managing digital health services allows them to navigate challenges and continue their use despite any possible obstacles. Both groupings emphasize the role of intrinsic factors within the individual, such as satisfaction, e-health literacy, and self-efficacy, in driving sustained use.

Type II: Social support grouping pattern.

This type emphasizes the role of family and community support in facilitating sustained use of Internet medical services. The core conditions of the family-supportive grouping pattern include satisfaction, e-health literacy, and social support. In this grouping, families provide emotional comfort and practical help and especially play an important role in bridging the digital literacy gap. The core conditions of the balanced, supportive grouping pattern include satisfaction, self-efficacy, and social support, while the contextual factors include a lack of negative social influence (~social influence). A combination of strong social networks and self-efficacy effectively counteracts external skepticism and motivates older adults to continue using Internet medical services. This type highlights the critical role of family and social support in sustaining older adults' continued use of digital health services.

Social support may play a more important role in groups with low levels of education, as these individuals may need more emotional support and assistance in learning and using Internet healthcare services. For older adult groups with low levels of education, increased social support and self-efficacy training can help overcome barriers to technology use.

For older adults with low education levels, social support and self-efficacy were found to be critical in driving their willingness to continue using Internet medical services. This group relies more on external encouragement

and confidence-building strategies. In contrast, for older adults living in rural areas, social participation played a central role in influencing their usage intentions. The close-knit nature of rural communities and peer-led activities enhanced trust in digital health services and supported continued usage.

Type III: Community-driven grouping

This type focuses on social engagement and community interaction as drivers of continued use. The core conditions of the socially connected grouping pattern are satisfaction, e-health literacy, and social engagement. Social engagement provides opportunities for learning and peer support, which increases confidence in digital health adoption. The core conditions of the community-interactive grouping pattern are satisfaction, self-efficacy, social influence, and social participation. A supportive community environment enhances social influence and promotes the continued use of Internet health services by older adults through collective interaction. This type emphasizes the critical role of community and social networks in promoting older adults' sustained use of Internet medical services.

In rural areas, older adult groups may be more reliant on a sense of community involvement and social network support, and therefore, enhanced social involvement can be effective in increasing their intent to continue using Internet medical services. For older adult groups in rural areas, enhanced community participation and family support can be used to increase their intent to use.

For older adults with low education levels, strategies should focus on enhancing social support and building self-efficacy through personalized guidance and confidence-building exercises. For rural populations, community-driven grouping that promotes social participation, such as neighborhood digital health workshops and peer support groups, may be more effective in fostering long-term engagement with Internet medical services.

Discussion

By applying SCT, his study enhances our understanding of how personal factors (such as e-health literacy and self-efficacy) and environmental factors (like social support, social participation, and social influence) interact to shape older adults' behavioral intentions regarding the continued use of Internet medical services. This application extends SCT, which has primarily focused on traditional health behaviors, into the realm of digital health behaviors, a largely underexplored area in prior research.

This study combines PLS-SEM and fsQCA to develop an analytical model that explains the causal conditions influencing older adults' willingness to maintain their use of Internet-based medical services. The findings identify six distinct configurations that drive sustained usage, underscoring the complexity of the factors that influence behavior. By analyzing these configurations, the study offers a systematic framework that not only enhances our understanding of how older adults adopt and continue using Internet medical services, but also provides actionable recommendations for health management interventions. These recommendations highlight the importance of considering multi-condition combinations to address the diverse needs of older adults.

The results indicate that satisfaction is the core factor influencing the sustained use of Internet medical services. This finding calls for user-centered service design, strongly emphasizing improving satisfaction to drive adoption and retention. The roles of e-health literacy and social participation are also critical, as they significantly impact user satisfaction. This suggests that interventions focused on improving e-health literacy and promoting social engagement can amplify these effects. In particular, fostering social support and leveraging community networks can enhance satisfaction, ensuring long-term service use.

Implication

Based on the results from both PLS-SEM and fsQCA, this study identifies several practical strategies that can help promote the long-term adoption of Internet medical services among older adults. These findings have important implications for both policy and practice.

The study emphasizes the importance of e-health literacy as a key factor in encouraging older adults to engage with Internet medical services. Simply providing information is not enough; older adults must be equipped with the skills to navigate these services independently. Tailored educational programs focused on Internet skills and easy-to-use service interfaces are critical to improving accessibility. Community-based initiatives such as e-health literacy workshops or online health tutorials can ensure that older adults are confident using digital tools. Also, fostering trust through initiatives like sharing success stories and targeted outreach can motivate those hesitant to embrace digital healthcare.

The study underscores the role of self-efficacy, which is an individual's confidence in their ability to use digital tools, as a crucial driver of continued use. Building self-efficacy and providing social support from family and community networks are integral components of encouraging long-term engagement. Gradual exposure and positive reinforcement can help build confidence. Resources like step-by-step guides, instructional videos, and personalized support can facilitate this process. In addition, social support from family and community networks plays a crucial role in sustaining engagement. Family

members can provide essential guidance and encouragement, while community-based programs such as peer-led seminars or family-involved health management activities create an environment that supports ongoing usage. Older adults more socially active and supported by robust networks are more likely to remain engaged with these services.

The study also highlights the critical role of satisfaction in driving the continued use of Internet medical services. Satisfaction mediates the relationship between e-health literacy and social participation, making it a key factor in ensuring ongoing adoption. A positive user experience is not limited to improving the interface or usability of digital platforms. Personalizing the service through customized healthcare recommendations, user-specific reminders, and responsive customer service is essential. Policymakers and healthcare providers must prioritize service optimization to ensure older adults receive the personalized, timely, and accessible care they need.

In summary, the findings suggest a holistic approach is necessary to promote sustained engagement with Internet medical services among older adults. Policies should integrate community resources, family support, and e-health literacy initiatives into a comprehensive framework. This approach will ensure equitable access to digital healthcare, accommodating the varying levels of digital skills, social participation, and health needs among older adults. By aligning these efforts, healthcare providers and policymakers can help older adults navigate the digital health landscape more effectively, ultimately improving their health outcomes and quality of life.

Limitation

(1) Sample diversity and generalizability

The sample used in this study, though diverse in terms of geographic regions within China, was limited in demographic variety, which may affect the generalizability of the findings. Future research should incorporate broader demographic and geographic samples to validate the identified configurations and ensure the applicability of the results across different older adult populations.

Although the sample used this study involved multiple regions, it was relatively homogeneous in terms of ethnicity and e-health literacy distribution. Most of the respondents were Han, and most had a moderate e-health literacy level, potentially limiting the generalizability of the findings across different groups, especially ethnic minorities and low e-health literacy groups. To address this, future research should incorporate a more diverse sample that includes a wider age range, a variety of ethnic groups, and a broader distribution of e-health literacy levels. Moreover, expanding the geographic scope to include both urban and rural areas, and adopting a multi-stage stratified random sampling method, could enhance the representativeness of the sample. This would allow the findings to be more applicable to older adults from various backgrounds, particularly ethnic minorities and those with lower e-health literacy.

(2) Cross-sectional design

The cross-sectional design of this study limits the ability to draw causal inferences about the relationships between variables. While PLS-SEM and fsQCA provide robust analytical frameworks, the study cannot fully explore how factors like satisfaction, e-health literacy, self-efficacy, and social support evolve over time and influence the sustained use of Internet medical services. Longitudinal studies would be essential to examine the dynamic changes in these factors and their long-term effects on older adults' continued engagement with digital health platforms.

(3) Measurement simplification

To accommodate older adult participants, simplified measurement tools were employed for variables such as e-health literacy and self-efficacy. While this approach enhanced response accuracy, it may have underrepresented nuanced aspects of these constructs. Future research could refine measurement instruments to capture a more comprehensive understanding of the factors influencing digital healthcare adoption.

Conclusion

This study provides valuable insights into the factors influencing older adults' sustained use of Internet medical services, revealing the complex and asymmetric relationships between antecedent conditions and behavioral intentions. By combining PLS-SEM and fsQCA, this research is the first to explore the daily use of these services among older adults, revealing that multiple, equally valid combinations of factors, such as e-health literacy, satisfaction, self-efficacy, social support, and social participation, can drive their willingness to engage with Internet medical services. The findings challenge traditional linear models, demonstrating that the presence or absence of the same antecedents can lead to different outcomes depending on how they interact, thus highlighting the need for a more nuanced, asymmetric approach to promoting Internet medical services for older adults.

In light of these findings, policymakers and healthcare providers should adopt a multi-faceted approach to enhance the adoption of digital health among older adults. Strategies should focus on improving e-health literacy, offering gradual exposure to technology to build self-efficacy, and leveraging social support networks, especially family and community, to help older adults navigate Internet medical services. Moreover, ensuring a high-quality user experience that is responsive, personalized, and easy to navigate will be critical in maintaining their engagement. Implementing these strategies will improve older adults' confidence and satisfaction with Internet medical services and contribute to better health outcomes, ensuring equitable access to digital healthcare for this vulnerable population.

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Authors' contributions
Wang Yu: Writing - original draft, conceptualization, methodology. Ji Ying: Writing - review and editing. Li Zhijing and Wang Kun: Data collection and sorting, Jiang Xue: Review and editing. Chang Chun: Conceptualization, methodology, and editing.

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Data availability
Data will be made available on request.

Declarations

Ethics approval and consent to participate
The study was approved by the Biomedical Ethics Committee of Peking University, Beijing, China (Ethics Approval Number IRB00001052-22147). The study adhered to the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Admassu W, Gorems K. Analyzing health service employees' intention to use e-health systems in southwest ethiopia: using UTAUT-2 model. BMC Health Serv Res. 2024;24(1):1136. https://doi.org/10.1186/s12913-024-11567-y.
2. Afonso C, Silva GM, Gonçalves HM, Duarte M. The role of motivations and involvement in wine tourists' intention to return: SEM and fsQCA findings. J Bus Res. 2018;89:313–21. https://doi.org/10.1016/j.jbusres.2017.11.042.
3. Ahr PR. Support systems and community mental health: lectures on concept development. Psychiatric Services. 1974;25(10):682-a-683. https://doi.org/10.1176/ps.25.10.682-a.
4. Alruwaie M, El-Haddadeh R, Weerakkody V. Citizens' continuous use of eGovernment services: the role of self-efficacy, outcome expectations and satisfaction. Gov Inf Q. 2020;37(3): 101485. https://doi.org/10.1016/j.giq.2020.101485.
5. Andervazh L, Ghorbanpour MZ. Enhancing the participation intention and improving customer satisfaction in the banking industry by utilizing social media technology due to the mediating role of value perceived by customers. J Innov Sustain RISUS. 2024;15(1):47–61. https://doi.org/10.23925/2179-3565.2023v15i1p47-61.
6. Bandura A. Self-efficacy mechanism in human agency. Am Psychol. 1982;37(2):122–47. https://doi.org/10.1037/0003-066X.37.2.122.
7. Bandura A. Organisational applications of social cognitive theory. Aust J Manag. 1988;13(2):275–302. https://doi.org/10.1177/031289628801300210.
8. Baumgartner M, Ambühl M. Optimizing consistency and coverage in configurational causal modeling. Sociological Methods & Research. 2023;52(3):1288–320. https://doi.org/10.1177/0049124121995554.
9. Becker JM, Rai A, Ringle CM, Völckner F. Discovering unobserved heterogeneity in structural equation models to avert validity threats. MIS Quarterly. 2013;37(3):665–94.
10. Bhattacharya P. What is ragin's indirect method of calibration? Int J Soc Res Methodol. 2023;26(6):825–31. https://doi.org/10.1080/13645579.2022.2110732.
11. Canedo-García A, García-Sánchez J-N. Exploring the instrumental and emotional supports for sustainability and social participation. Sustainability. 2022;14(16): 10377. https://doi.org/10.3390/su141610377.
12. Center for Health Statistics and Information, National Health Commission. National Health Services Survey Report of China in 2018(First edition). Beijing: People´s Medical Publishing House; 2021.
13. Chen K, Chan AHS. Gerontechnology acceptance by elderly hong kong Chinese: a senior technology acceptance model (STAM). Ergonomics. 2014;57(5):635–52. https://doi.org/10.1080/00140139.2014.895855.
14. Choi E, Han K-M, Chang J, Lee YJ, Choi KW, Han C, Ham B-J. Social participation and depressive symptoms in community-dwelling older adults: emotional social support as a mediator. J Psychiatr Res. 2021;137:589–96. https://doi.org/10.1016/j.jpsychires.2020.10.043.
15. Chuah SH-W, Aw EC-X, Yee D. Unveiling the complexity of consumers' intention to use service robots: an fsQCA approach. Comput Hum Behav. 2021;123: 106870. https://doi.org/10.1016/j.chb.2021.106870.
16. Combes B. (2009, January 1). Digital natives or digital refugees? Why we have failed gen Y? *Preparing Pupils and Students for the Future - School Libraries in the Picture*. International Association of School Librarianship Conference Proceedings, Abano Therme, Italy.
17. Conner M, Norman P. Predicting and changing health behaviour: research and practice with social cognition models. London: McGraw-Hill Education (UK); 2015.
18. Cooper B, Glaesser J. Exploring the robustness of set theoretic findings from a large n fsQCA: an illustration from the sociology of education. Int J Soc Res Methodol. 2016;19(4):445–59. https://doi.org/10.1080/13645579.2015.1033799.
19. Crouch E, Gordon NP. Prevalence and factors influencing use of internet and electronic health resources by middle-aged and older adults in a US health plan population: cross-sectional survey study. JMIR Aging. 2019;2(1): e11451. https://doi.org/10.2196/11451.
20. Dash G, Paul J. CB-SEM vs PLS-SEM methods for research in social sciences and technology forecasting. Technol Forecast Soc Chang. 2021;173: 121092. https://doi.org/10.1016/j.techfore.2021.121092.
21. Dawson-Townsend K. Social participation patterns and their associations with health and well-being for older adults. SSM - Population Health. 2019;8: 100424. https://doi.org/10.1016/j.ssmph.2019.100424.
22. De Veer AJE, Peeters JM, Brabers AE, Schellevis FG, Rademakers JJJ, Francke AL. Determinants of the intention to use e-health by community

dwelling older people. BMC Health Serv Res. 2015;15(1):103. https://doi.org/10.1186/s12913-015-0765-8.
23. Deci EL. Intrinsic motivation and self-determination☆. In: Reference module in neuroscience and biobehavioral psychology. Elsevier; 2017. p. B9780128093245056133. https://doi.org/10.1016/B978-0-12-809324-5.05613-3.
24. Ding H. Qualitative comparative analysis: search target, reflection on the top-down approach, and introduction of the bottom-up approach. Int J Qual Methods. 2023;22: 16094069231182634. https://doi.org/10.1177/16094069231182634.
25. Dușa A. Critical tension: sufficiency and parsimony in QCA. Sociological Methods & Research. 2022;51(2):541–65. https://doi.org/10.1177/0049124119882456.
26. Fainshmidt S, Witt MA, Aguilera RV, Verbeke A. The contributions of qualitative comparative analysis (QCA) to international business research. J Int Bus Stud. 2020;51(4):455–66. https://doi.org/10.1057/s41267-020-00313-1.
27. Fiss PC. Building better causal theories: a fuzzy set approach to typologies in organization research. Acad Manag J. 2011;54(2):393–420. https://doi.org/10.5465/amj.2011.60263120.
28. Gligor D, Bozkurt S. FsQCA versus regression: the context of customer engagement. J Retail Consum Serv. 2020;52: 101929. https://doi.org/10.1016/j.jretconser.2019.101929.
29. Gu Y-H, Bai J-B, Chen X-L, Wu W-W, Liu X-X, Tan X-D. Healthy aging: a bibliometric analysis of the literature. Exp Gerontol. 2019;116:93–105. https://doi.org/10.1016/j.exger.2018.11.014.
30. Guo SJ, Yu XM, Sun YY, Nie D, Li XM, Wang L. Adaptation and evaluation of Chinese version of eHEALS and its usage among senior high school students. Chinese Journal of Health Education. 2013;29(2):106–8, 123. https://doi.org/10.16168/j.cnki.issn.1002-9982.2013.02.019.
31. Hagger MS, Gucciardi DF, Chatzisarantis NLD. On nomological validity and auxiliary assumptions: the importance of simultaneously testing effects in social cognitive theories applied to health behavior and some guidelines. Front Psychol. 2017;8: 1933. https://doi.org/10.3389/fpsyg.2017.01933.
32. Han Y, Lie RK, Guo R. The internet hospital as a telehealth model in China: systematic search and content analysis. J Med Internet Res. 2020;22(7):e17995. https://doi.org/10.2196/17995.
33. Heo J, Chun S, Lee S, Lee KH, Kim J. Internet use and well-being in older adults. Cyberpsychol Behav Soc Netw. 2015;18(5):268–72. https://doi.org/10.1089/cyber.2014.0549.
34. Hertel G, Niedner S, Herrmann S. Motivation of software developers in open source projects: an internet-based survey of contributors to the linux kernel. Res Policy. 2003;32(7):1159–77. https://doi.org/10.1016/S0048-7333(03)00047-7.
35. Hong YA, Cho J. Has the digital health divide widened? Trends of health-related internet use among older adults from 2003 to 2011. The Journals of Gerontology Series B: Psychological Sciences and Social Sciences. 2016;gbw100: gbw100. https://doi.org/10.1093/geronb/gbw100.
36. Hossain A, Quaresma R, Rahman H. Investigating factors influencing the physicians' adoption of electronic health record (EHR) in healthcare system of bangladesh: an empirical study. Int J Inf Manage. 2019;44:76–87. https://doi.org/10.1016/j.ijinfomgt.2018.09.016.
37. Hossain MA, Quaddus M, Warren M, Akter S, Pappas I. Are you a cyber-bully on social media? Exploring the personality traits using a fuzzy-set configurational approach. Int J Inf Manage. 2022;66: 102537. https://doi.org/10.1016/j.ijinfomgt.2022.102537.
38. Hair JF, Risher JJ, Sarstedt M, Ringle CM. When to use and how to report the results of PLS-SEM. Eur Bus Rev. 2019;31(1):2–24. https://doi.org/10.1108/EBR-11-2018-0203.
39. Jokisch MR, Schmidt LI, Doh M. Acceptance of digital health services among older adults: findings on perceived usefulness, self-efficacy, privacy concerns, ICT knowledge, and support seeking. Front Public Health. 2022;10: 1073756. https://doi.org/10.3389/fpubh.2022.1073756.
40. Kallmuenzer A, Kraus S, Peters M, Steiner J, Cheng C-F. Entrepreneurship in tourism firms: a mixed-methods analysis of performance driver configurations. Tour Manage. 2019;74:319–30. https://doi.org/10.1016/j.tourman.2019.04.002.
41. Laukka E, Lakoma S, Harjumaa M, Hiltunen S, Härkönen H, Jansson M, Leskelä R-L, Martikainen S, Pennanen P, Verho A, Torkki P. Older adults' preferences in the utilization of digital health and social services: a qualitative analysis of responses to open-ended questions. BMC Health Serv Res. 2024;24(1):1184. https://doi.org/10.1186/s12913-024-11564-1.
42. Levasseur M, Richard L, Gauvin L, Raymond É. Inventory and analysis of definitions of social participation found in the aging literature: proposed taxonomy of social activities. Soc Sci Med. 2010;71(12):2141–9. https://doi.org/10.1016/j.socscimed.2010.09.041.
43. Li Y, Shang H. Service quality, perceived value, and citizens' continuous-use intention regarding e-government: Empirical evidence from China. Information & Management. 2020;57(3): 103197. https://doi.org/10.1016/j.im.2019.103197.
44. Liu D, Yamashita T, Burston B, Keene J. The disparities in accessing online health information and health care utilization among older Americans. Innovation in Aging. 2020;4(Supplement_1):316–7. https://doi.org/10.1093/geroni/igaa057.1013.
45. Liu N, Wang Y, Li Z. Internet use, physical activity and depressive symptoms in older adults: a cross-lagged panel analysis. J Affect Disord. 2024;350:937–45. https://doi.org/10.1016/j.jad.2024.01.201.
46. Luijkx K, Peek S, Wouters E. "grandma, you should do it—It's cool" older adults and the role of family members in their acceptance of technology. Int J Environ Res Public Health. 2015;12(12):15470–85. https://doi.org/10.3390/ijerph121214999.
47. Marx A, Rihoux B, Ragin C. The origins, development, and application of qualitative comparative analysis: the first 25 years. Eur Polit Sci Rev. 2014;6(1):115–42. https://doi.org/10.1017/S1755773912000318.
48. Meng F, Qing D, Zhang Y, Wang X. Physical and internet medical system: service quality and management mode analysis. Comput Ind Eng. 2024;197: 110539. https://doi.org/10.1016/j.cie.2024.110539.
49. Merkel S, Hess M. The use of internet-based health and care services by elderly people in europe and the importance of the country context: multilevel study. JMIR Aging. 2020;3(1): e15491. https://doi.org/10.2196/15491.
50. Mikalef P, Pateli A. Information technology-enabled dynamic capabilities and their indirect effect on competitive performance: findings from PLS-SEM and fsQCA. J Bus Res. 2017;70:1–16. https://doi.org/10.1016/j.jbusres.2016.09.004.
51. Oana I-E, Schneider CQ. A robustness test protocol for applied QCA: theory and R software application. Sociological Methods & Research. 2024;53(1):57–88. https://doi.org/10.1177/00491241211036158.
52. Olya HGT. Towards advancing theory and methods on tourism development from residents' perspectives: developing a framework on the pathway to impact. J Sustain Tour. 2023;31(2):329–49. https://doi.org/10.1080/09669582.2020.1843046.
53. Olya HGT, Al-ansi A. Risk assessment of halal products and services: implication for tourism industry. Tour Manage. 2018;65:279–91. https://doi.org/10.1016/j.tourman.2017.10.015.
54. Olya HGT, Gavilyan Y. Configurational models to predict residents' support for tourism development. J Travel Res. 2017;56(7):893–912. https://doi.org/10.1177/0047287516667850.
55. Pang S, Bao P, Hao W, Kim J, Gu W. Knowledge sharing platforms: an empirical study of the factors affecting continued use intention. Sustainability. 2020;12(6): 2341. https://doi.org/10.3390/su12062341.
56. Pappas IO, Giannakos MN, Sampson DG. Fuzzy set analysis as a means to understand users of 21st-century learning systems: the case of mobile learning and reflections on learning analytics research. Comput Hum Behav. 2019;92:646–59. https://doi.org/10.1016/j.chb.2017.10.010.
57. Pappas IO, Woodside AG. Fuzzy-set qualitative comparative analysis (fsQCA): guidelines for research practice in information systems and marketing. Int J Inf Manage. 2021;58: 102310. https://doi.org/10.1016/j.ijinfomgt.2021.102310.
58. Park C. Electronic health literacy as a source of self-efficacy among community-dwelling older adults. Clinical Gerontologist. 2024;1–10:1. https://doi.org/10.1080/07317115.2024.2373894.
59. Ragin CC, Drass KA, Davey S. Fuzzy-set/qualitative comparative analysis 2.0. Arizona: Department of Sociology, University of Arizona. 2006;23(6);1949–55.
60. Rheu MM, Jang Y, Peng W. Enhancing healthy behaviors through virtual self: a systematic review of health interventions using avatars. Games for Health Journal. 2020;9(2):85–94. https://doi.org/10.1089/g4h.2018.0134.
61. Ringle CM, Sarstedt M, Schlittgen R. Genetic algorithm segmentation in partial least squares structural equation modeling. OR Spectrum. 2014;36(1):251–76. https://doi.org/10.1007/s00291-013-0320-0.

62. Rutten R. Uncertainty, possibility, and causal power in QCA. Sociological Methods & Research. 2023;52(4):1707–36. https://doi.org/10.1177/00491241211031268.
63. Sarstedt M, Hair JF, Nitzl C, Ringle CM, Howard MC. Beyond a tandem analysis of SEM and PROCESS: use of PLS-SEM for mediation analyses! Int J Mark Res. 2020;62(3):288–99. https://doi.org/10.1177/1470785320915686.
64. Schlittgen R, Ringle CM, Sarstedt M, Becker J-M. Segmentation of PLS path models by iterative reweighted regressions. J Bus Res. 2016;69(10):4583–92. https://doi.org/10.1016/j.jbusres.2016.04.009.
65. Schunk DH, DiBenedetto MK. Motivation and social cognitive theory. Contemp Educ Psychol. 2020;60: 101832. https://doi.org/10.1016/j.cedpsych.2019.101832.
66. Schunk DH, Usher EL. Social cognitive theory and motivation. In: Ryan RM, editor. The Oxford handbook of human motivation. 1st ed. Oxford University Press; 2012. pp. 13–27. https://doi.org/10.1093/oxfordhb/9780195399820.013.0002.
67. Schwei RJ, Hetzel S, Kim K, Mahoney J, DeYoung K, Frumer J, Lanzafame RP, Madlof J, Simpson A, Zambrano-Morales E, Jacobs EA. Peer-to-peer support and changes in health and well-being in older adults over time. JAMA Netw Open. 2021;4(6): e2112441. https://doi.org/10.1001/jamanetworkopen.2021.12441.
68. Seçkin G, Hughes S, Yeatts D, Degreve T. Digital pathways to positive health perceptions: does age moderate the relationship between medical satisfaction and positive health perceptions among middle-aged and older internet users? Innov Aging. 2019;3(1). https://doi.org/10.1093/geroni/igy039.
69. Seçkin G, Hughes S, Yeatts D, Degreve T. Digital pathways to positive health perceptions: Does age moderate the relationship between medical satisfaction and positive health perceptions among middle-aged and older internet users? Innov Aging. 2019;3(1). https://doi.org/10.1093/geroni/igy039.
70. Slinker BK, Glantz SA. Multiple linear regression: accounting for multiple simultaneous determinants of a continuous dependent variable. Circulation. 2008;117(13):1732–7. https://doi.org/10.1161/CIRCULATIONAHA.106.654376.
71. Szinay D, Perski O, Jones A, Chadborn T, Brown J, Naughton F. Influences on the uptake of health and well-being apps and curated app portals: think-aloud and interview study. JMIR Mhealth Uhealth. 2021;9(4): e27173. https://doi.org/10.2196/27173.
72. The China health and retirement longitudinal study (CHARLS). Retrieved January 7, 2025, from http://charls.pku.edu.cn/en/index.htm.
73. University of Bamberg, Mattke, J., Maier, C., University of Bamberg, Weitzel, T., University of Bamberg, E. Gerow, J., Department of Economics & Business, Virginia Military Institute, B. Thatcher, J., & Temple University. (2022). Qualitative comparative analysis (QCA) in information systems research: Status quo, guidelines, and future directions. *Communications of the Association for Information Systems*, *50*, 208–240. https://doi.org/10.17705/1CAIS.05008
74. Venkatesh M, Davis, & Davis. User acceptance of information technology: toward a unified view. MIS Q. 2003;27(3):425. https://doi.org/10.2307/30036540.
75. Venkatesh V, Bala H, Sykes TA. Impacts of information and communication technology implementations on employees' jobs in service organizations in India: a multi-method longitudinal field study. Prod Oper Manag. 2010;19(5):591–613. https://doi.org/10.1111/j.1937-5956.2010.01148.x.
76. Videras J, Owen AL, Conover E, Wu S. The influence of social relationships on pro-environment behaviors. J Environ Econ Manag. 2012;63(1):35–50. https://doi.org/10.1016/j.jeem.2011.07.006.
77. Wang N, Zhou S, Liu Z, Han Y. Perceptions and satisfaction with the use of digital medical services in urban older adults of China: mixed methods study. J Med Internet Res. 2024;26: e48654. https://doi.org/10.2196/48654.
78. Weaver JB, Thompson NJ, Weaver SS, Hopkins GL. Healthcare non-adherence decisions and internet health information. Comput Hum Behav. 2009;25(6):1373–80. https://doi.org/10.1016/j.chb.2009.05.011.
79. Wilson J, Heinsch M, Betts D, Booth D, Kay-Lambkin F. Barriers and facilitators to the use of e-health by older adults: a scoping review. BMC Public Health. 2021;21(1):1556. https://doi.org/10.1186/s12889-021-11623-w.
80. Woodside AG. Embracing the complexity turn in management research for modeling multiple realities. In: Woodside AG, editor. The complexity turn. Springer International Publishing; 2017. p. 1–19. https://doi.org/10.1007/978-3-319-47028-3_1.
81. Xie, L., Yang, H., Lin, X., Ti, S., Wu, Y., Zhang, S., Zhang, S., & Zhou, W. (2021). Does the internet use improve the mental health of Chinese older adults? *Frontiers in Public Health*, *9*. https://doi.org/10.3389/fpubh.2021.673368
82. Xiong L, Wang H, Wang C. Predicting mobile government service continuance: a two-stage structural equation modeling-artificial neural network approach. Gov Inf Q. 2022;39(1): 101654. https://doi.org/10.1016/j.giq.2021.101654.
83. Xue Z, Liu C. The effect of internet use on the health of middle-aged and older adults: evidences from China general social survey. BMC Public Health. 2024;24(1):2949. https://doi.org/10.1186/s12889-024-20313-2.
84. Yang Z, Zhou Q, Chiu DKW, Wang Y. Exploring the factors influencing continuous usage intention of academic social network sites. Online Inf Rev. 2022;46(7):1225–41. https://doi.org/10.1108/OIR-01-2021-0015.
85. Zhang X, Wei X, Zhang T, Tan Y, Xu D, Ordóñez De Pablos P. How platform-based internet hospital innovation affects doctors' active stress coping efforts: the conservation of resource theory perspective. Technovation. 2023;121: 102556. https://doi.org/10.1016/j.technovation.2022.102556.
86. Zhou Y, Bai Y, Wang J. The impact of internet use on health among older adults in China: a nationally representative study. BMC Public Health. 2024;24(1):1065. https://doi.org/10.1186/s12889-024-18269-4.

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