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Article

The Impact of Smart Elderly Care Technology on Older Adults' Sense of Self-Control and Social Connectedness: An Empirical Analysis Based on the Empowerment Theory and Technology Acceptance Model

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Abstract

To explore the internal path through which smart elderly care technology influences older adults' sense of self-control and social connectedness, and to provide empirical evidence and theoretical support for optimizing the smart elderly care service system and enhancing older adults' psychological well-being, this study integrated the Empowerment Theory and the Technology Acceptance Model (TAM). A cluster sampling method was adopted to conduct a questionnaire survey among 1,031 older adults in communities in Jiangsu, Shandong and other provinces in China. A structural equation model was constructed, and Bootstrap method, multi-group analysis and other approaches were used to test the research hypotheses. The results showed that the use of smart elderly care technology significantly and positively improved older adults' sense of self-control through the empowerment effect ($\beta=0.382$, $p<0.01$) and technology acceptance ($\beta=0.415$, $p<0.01$), and significantly enhanced their social connectedness through the construction of social support networks ($\beta=0.363$, $p<0.01$). Empowerment played a partial mediating role between the use of smart elderly care technology and sense of self-control, with the mediating effect accounting for 38.2%. Technology acceptance exerted a partial mediating effect between the use of smart elderly care technology and social connectedness, with the mediating effect accounting for 40.1%. Technology acceptance also played a partial mediating role between empowerment and sense of self-control, and there was a significant interaction effect between empowerment and technology acceptance, which jointly and positively affected older adults' sense of self-control ($\beta=0.103$, $p<0.05$) and social connectedness ($\beta=0.087$, $p<0.05$). This study verified the chain mechanism of "technological empowerment—psychological acceptance—social integration" of smart elderly care technology. It is suggested to construct an optimized path for smart elderly care services with the core concepts of "digital inclusion" and "relational empowerment", and promote the in-depth integration of technological empowerment, humanistic care and traditional Chinese medicine health management.

Keywords: smart elderly care technology; sense of self-control; social connectedness; empowerment theory; technology acceptance model; digital inclusion; relational empowerment

1. Introduction

With the accelerating process of population aging in China, the trends of advanced aging and empty-nest aging have become increasingly prominent, and the traditional elderly care service model is facing multiple challenges such as resource shortages, uneven service provision and delayed response [1]. By the end of 2024, the population of aged 60 and above in China had reached 280 million, accounting for 19.8% of the total population, making the quality and efficiency of elderly care

services an important issue at the national strategic level [2]. Against this backdrop, smart elderly care, as an innovative form of the deep integration of information technology and traditional elderly care services, relies on modern technological means such as the Internet of Things, big data and artificial intelligence to provide real-time, convenient and personalized elderly care services for older adults, and has become an important support for addressing population aging [3]. The state has successively issued policy documents such as the *14th Five-Year Plan for the Development of National Undertakings for the Elderly and the Elderly Care Service System* and the *Action Plan for the Development of the Smart Health and Elderly Care Industry (2023-2025)*, which have provided a solid policy guarantee for the popularization and application of smart elderly care technology.

However, the phenomenon of “technological cold reception” is prevalent in the current practice of smart elderly care, and there is a significant gap between the functional iteration of smart elderly care technology and older adults’ actual user experience and psychological needs [4]. Most smart elderly care products overemphasize the development of instrumental functions while ignoring the in-depth impact of technology use on older adults’ psychosocial aspects. Older adults experience technological anxiety due to insufficient digital skills and age-inappropriate product design, and even a contradiction between “technological empowerment” and “psychological disempowerment” has emerged [5]. This contradiction reveals the core bottleneck in the development of smart elderly care: how to transform from “physiological indicator monitoring” to “holistic well-being improvement”, and make smart elderly care technology truly meet the psychological and social needs of older adults.

Existing studies have mostly focused on the technological realization, service models and industrial development of smart elderly care, but few have systematically explored the mechanism of technology use on older adults’ internal psychological experience. As a core indicator of older adults’ mental health, the sense of self-control directly affects their life satisfaction and psychological resilience [6]; social connectedness is a key factor in alleviating older adults’ loneliness and enhancing their sense of happiness [7]. As the core dimensions of older adults’ well-being, the correlation mechanism between these two factors and the use of smart elderly care technology has not been fully revealed. Based on this, this study integrated the Empowerment Theory [8] and the Technology Acceptance Model [9], conducted an empirical analysis of the impact path of smart elderly care technology on older adults’ sense of self-control and social connectedness through a large-sample questionnaire survey, tested the mediating and interaction effects of empowerment and technology acceptance, and explored the cross-group applicability of the model through multi-group analysis. It is expected to provide theoretical guidance and practical enlightenment for constructing a “warm, perceptible and acceptable” smart elderly care service model.

2. Theoretical Framework and Research Hypotheses

2.1. Definition of Core Concepts

2.1.1. Smart Elderly Care Technology

Smart elderly care technology is a product of the deep integration of modern information technologies such as the Internet of Things, big data, artificial intelligence and mobile communication with elderly care services [10]. It is a collection of intelligent service systems and technological applications built around the core needs of older adults in the whole life cycle, including health management, life care, spiritual comfort, social participation and safety protection. Its core characteristics are reflected in the precision of services, personalization of supply, high efficiency of response and full coverage of scenarios. Combining the daily use scenarios of older adults and the functional attributes of technology, this study divides it into three categories: first, health monitoring technology, represented by smart bracelets, remote blood pressure and blood glucose monitoring devices, and sleep monitors, which mainly realize real-time collection, abnormal early warning and data traceability of older adults’ physiological indicators; second, life assistance technology, including smart home, emergency call systems, smart navigation, voice assistants, etc., focusing on solving the life inconveniences caused by the decline of older adults’ physical functions and

improving their life autonomy; third, social support technology, including smart social platforms, video communication tools, online interest communities, etc., aiming to break the temporal and spatial social restrictions of older adults and build a social bridge integrating online and offline. The types of technology selected in this study are all application-oriented technologies that older adults can directly access and operate independently, excluding monitoring technologies only operated by elderly care institutions or family members in the background, which are more in line with older adults' subjective user experience and psychological perception.

2.1.2. Sense of Self-Control and Social Connectedness

Derived from Bandura's Social Learning Theory [11] and Self-Efficacy Theory [12], the sense of self-control is a comprehensive psychological perception of an individual's ability to control their own behaviors and life events, the degree of autonomous decision-making and the ability to predict outcomes. Specifically, it is reflected in older adults' sense of dominance in daily life, self-confidence in the face of life changes, and a sense of right to independently choose elderly care and life styles. It is a core evaluation index of older adults' mental health, and also a key variable affecting their life satisfaction, psychological resilience and subjective well-being. In the process of aging, older adults are prone to a weakening sense of self-control due to the decline of physical functions, withdrawal from social roles, changes in family structure and other factors, which in turn triggers negative emotions such as anxiety, depression and helplessness, and even leads to the loss of life initiative.

Social connectedness is an important concept in Social Capital Theory and Positive Psychology, referring to the emotional connections, interactive relationships, identity and sense of belonging established by individuals with others, groups, communities and society [13]. It is an important indicator to measure older adults' social adaptability, alleviate their loneliness and enhance their psychological well-being. Its core dimensions include family connectedness, friend connectedness and community connectedness, reflecting the frequency of daily interaction and emotional intimacy between older adults and their families, the depth of communication and interest resonance with peers, and the degree of participation, identity and integration in the community, respectively. The natural shrinkage of social circles due to aging, empty-nest and solitary living, and limited physical activity are prone to social isolation among older adults, and the lack of social connectedness will directly reduce their quality of life and even affect their physical health.

2.1.3. Empowerment and Technology Acceptance

Empowerment in this study [14] is a localized concept based on the scenario of smart elderly care technology empowerment, referring to the reconstruction of individual power and improvement of abilities of older adults through information acquisition, digital skill enhancement and participation in elderly care decision-making in the process of using smart elderly care technology. It is an important path to alleviate the "disempowerment" experience of older adults caused by "age-related vulnerability" and enhance their sense of self-control, specifically including three dimensions: first, resource acquisition empowerment, that is, technology breaks information asymmetry, enabling older adults to easily obtain resources such as health knowledge, elderly care services and policy benefits, and grasp the information initiative in elderly care life; second, decision-making participation empowerment, that is, older adults participate in the decision-making of their own health management and life care through technology, get rid of the state of "passively accepting services", and restore the dominant position in elderly care decision-making; third, capacity improvement empowerment, that is, older adults' digital skills, learning ability and problem-solving ability are improved in the process of technology use, thereby enhancing their self-efficacy and psychological self-confidence.

Based on the extended Unified Theory of Acceptance and Use of Technology (UTAUT) [15], technology acceptance refers to older adults' subjective willingness to accept, recognition of use and tendency of continuous use of smart elderly care technology, which is an important mediating variable connecting technology use behavior and psychosocial effects. It mainly includes four

dimensions: first, performance expectancy, that is, older adults' cognitive perception of the usefulness of smart elderly care technology in improving their quality of life and solving elderly care problems; second, effort expectancy, that is, older adults' evaluation of the difficulty of learning and using smart elderly care technology; third, social influence, that is, the degree of support and recognition perceived by older adults from external groups such as family, friends and communities for their use of smart elderly care technology; fourth, facilitating conditions, that is, the material conditions, technical support and learning resources actually owned by older adults for using smart elderly care technology. The four dimensions interact with each other and jointly determine older adults' acceptance and use behavior of smart elderly care technology.

2.2. Theoretical Foundation

2.2.1. Empowerment Theory

First proposed by the American scholar Solomon, the core viewpoint of the Empowerment Theory is that the vulnerable state of individuals does not stem from their own insufficient abilities, but from external factors such as uneven resource distribution, lack of environmental support and deprivation of rights. By providing individuals with resource support, capacity improvement and environmental empowerment, it is possible to enhance their control over their own lives and autonomous decision-making power, help them get rid of the "disempowerment" state and realize self-empowerment and development [16]. Initially applied in the field of social work, this theory has gradually expanded to many fields such as health management, elderly services and digital inclusion, and has become a core theory for studying the empowerment of vulnerable groups.

In the context of smart elderly care, the applicability of the Empowerment Theory is reflected in three levels: first, information empowerment, smart elderly care technology builds an all-round information acquisition platform for older adults, enabling them to independently obtain health monitoring data, elderly care service information, medical resource information, etc., breaking the pattern of information dominated by family members or institutions in traditional elderly care and realizing the redistribution of information rights; second, psychological empowerment, by learning and using smart elderly care technology, older adults improve their digital skills and problem-solving abilities, transforming from "unable to use and afraid to use" to "able to use and good at using", thereby enhancing their self-efficacy and self-confidence and alleviating the psychological anxiety caused by the digital divide; third, social empowerment, the online social platforms and community interaction channels built by smart elderly care technology provide older adults with opportunities for social participation, enabling them to reintegrate into the social network, restore social roles and enhance the right to social participation. This study focuses on the direct impact of information empowerment and psychological empowerment on older adults' sense of self-control, and explores their interaction with technology acceptance, providing theoretical support for explaining the psychological empowerment effect of smart elderly care technology.

2.2.2. Technology Acceptance Model

Proposed by Davis in 1989, the core hypothesis of the Technology Acceptance Model (TAM) is that perceived usefulness and perceived ease of use are two key factors affecting users' technology acceptance. Perceived usefulness determines users' willingness to use technology, and perceived ease of use not only directly affects the willingness to use, but also indirectly affects it through perceived usefulness; the two jointly determine users' technology use behavior [17]. The traditional Technology Acceptance Model is mainly applied to young groups and work scenarios, and it is difficult to adapt to the physical and psychological characteristics of older adults and the scenario needs of elderly care services, with certain limitations.

Based on the traditional TAM model, combined with the characteristics of older adults and the scenario needs of smart elderly care, this study conducts localization and scenario-based expansion of it, and constructs a smart elderly care technology acceptance model suitable for older adults: first,

extend perceived usefulness to performance expectancy, not only focusing on the instrumental usefulness of technology, but also on the improvement effect of technology on older adults' quality of life, psychological well-being and social connectedness, which is more in line with the elderly care needs of older adults; second, extend perceived ease of use to effort expectancy, fully considering the characteristics of older adults' declining physical functions (such as poor eyesight and inflexible hands and feet) and insufficient digital skills, focusing on the difficulty of technology operation and learning costs; third, add the social influence dimension, considering that older adults' decision-making behavior is easily affected by external groups such as family, friends and communities, and external support and recognition can significantly improve their willingness to accept technology; fourth, add the facilitating conditions dimension, covering the material conditions (such as equipment and network), technical support (such as operation guidance and after-sales maintenance) and learning resources (such as training courses and operation manuals) for technology use, making up for the deficiency of the traditional TAM model in ignoring external environmental support. The extended Technology Acceptance Model is more in line with the technology use characteristics of older adults and can more comprehensively explain the acceptance mechanism of smart elderly care technology by older adults.

2.2.3. Theoretical Integration and Research Framework

This study organically integrates the Empowerment Theory and the extended Technology Acceptance Model, and constructs a research framework for the impact of smart elderly care technology on older adults' sense of self-control and social connectedness, aiming to make up for the insufficient explanatory power of a single theory and fully reveal the internal path of smart elderly care technology affecting older adults' psychosocial well-being.

In this research framework, the use of smart elderly care technology is the core independent variable, covering three dimensions of use frequency, use breadth and use depth, which is the prerequisite for triggering subsequent psychosocial effects; sense of self-control and social connectedness are the dependent variables, which are the core psychosocial well-being results brought by the use of smart elderly care technology and also the ultimate research objects of this study; empowerment and technology acceptance are the mediating variables, among which empowerment focuses on the ability empowerment and power reconstruction of older adults by smart elderly care technology, and technology acceptance focuses on older adults' subjective cognition and acceptance of smart elderly care technology. Both are direct results of the use of smart elderly care technology and important factors affecting older adults' sense of self-control and social connectedness; at the same time, empowerment and technology acceptance are not independent variables, and there is a significant interaction effect between them, which jointly affect the psychosocial effects of smart elderly care technology.

In addition, this study sets the demographic and sociological characteristics of older adults such as gender, age, education level, living status, number of chronic diseases and monthly income as control variables, and excludes their interference on the research results through statistical methods to ensure the scientificity and reliability of the research conclusions. This research framework clearly reveals the core transmission path of "technology use—empowerment/technology acceptance—psychosocial well-being", and at the same time pays attention to the direct effect, mediating effect and interaction effect between variables, laying a solid theoretical foundation for the subsequent derivation of research hypotheses and empirical tests.

2.3. Derivation of Research Hypotheses

2.3.1. Direct Effect of Smart Elderly Care Technology Use

The core value of smart elderly care technology lies in making up for the shortcomings of older adults' physical functions through technological empowerment, improving their life autonomy and social participation, and thus having a direct positive impact on their psychosocial well-being. From

the perspective of sense of self-control, health monitoring technology enables older adults to grasp their own health status in real time and realize autonomous decision-making in health management; life assistance technology solves the problems of older adults' life care and improves their control ability in daily life; social support technology enables older adults to independently expand their social circles and enhance their sense of dominance in social life. Various types of smart elderly care technology improve older adults' ability to independently control their lives from different dimensions, thereby strengthening their sense of self-control. Based on this, the following hypothesis is proposed:

H1. *The use of smart elderly care technology has a significant positive impact on older adults' sense of self-control.*

From the perspective of social connectedness, smart elderly care technology breaks the constraints of time and space and physical conditions, and builds diversified social channels for older adults. Video communication tools enable older adults to realize real-time interaction with family and friends, alleviating the loneliness caused by empty-nest and solitary living; smart social platforms and online interest communities enable older adults to meet like-minded friends and expand their social circles; community smart elderly care platforms enable older adults to participate in community activities and enhance their sense of community integration. At the same time, the use process of smart elderly care technology itself can become an interactive topic for older adults, promoting communication and interaction among them and further strengthening their social connectedness. Based on this, the following hypothesis is proposed:

H2. *The use of smart elderly care technology has a significant positive impact on older adults' social connectedness.*

2.3.2. Mediating Effect of Empowerment

Empowerment is an important transmission path between the use of smart elderly care technology and older adults' sense of self-control. Smart elderly care technology strengthens older adults' sense of self-control by realizing their resource acquisition empowerment, decision-making participation empowerment and capacity improvement empowerment, forming a mediating path of "technology use—empowerment—sense of self-control". On the one hand, smart elderly care technology provides older adults with rich resources such as health, elderly care and policies, breaks information asymmetry, realizes resource acquisition empowerment, enables older adults to independently make decisions about elderly care life and improve their ability to control life; on the other hand, in the process of using smart elderly care technology, older adults' digital skills and learning ability are improved, realizing capacity improvement empowerment, thereby enhancing their self-efficacy and self-confidence, alleviating the "disempowerment" experience and strengthening the sense of self-control. The use of smart elderly care technology itself cannot be directly transformed into older adults' sense of self-control, but needs to go through the mediating process of empowerment to realize the transformation from "technological empowerment" to "individual empowerment" and then to "psychological improvement". Based on this, the following hypothesis is proposed:

H3. *Empowerment plays a partial mediating role between the use of smart elderly care technology and older adults' sense of self-control.*

2.3.3. Mediating Effect of Technology Acceptance

Technology acceptance is an important transmission path between the use of smart elderly care technology and older adults' social connectedness. Older adults' acceptance of smart elderly care technology directly affects their technology use behavior and social interaction effect, forming a

mediating path of “technology use—technology acceptance—social connectedness”. The higher the technology acceptance, the stronger the older adults’ willingness to accept and recognition of using smart elderly care technology, and the more willing they are to take the initiative to use social support technology for social interaction; at the same time, a good technology acceptance experience can improve older adults’ satisfaction with technology use, making them more willing to continuously expand social channels and participate in social interaction through technology. On the contrary, if older adults have a low acceptance of smart elderly care technology, even if they use the technology passively, it is difficult to produce a positive social interaction experience and cannot effectively improve social connectedness. The improvement effect of smart elderly care technology on older adults’ social connectedness is highly dependent on older adults’ subjective acceptance and recognition of the technology. Based on this, the following hypothesis is proposed:

H4. *Technology acceptance plays a partial mediating role between the use of smart elderly care technology and older adults’ social connectedness.*

2.3.4. Chain Mediating Effect of Technology Acceptance

Empowerment can not only directly improve older adults’ sense of self-control, but also further strengthen it by improving their technology acceptance, forming a chain transmission path of “smart elderly care technology use—empowerment—technology acceptance—sense of self-control”, and technology acceptance plays a partial mediating role between empowerment and sense of self-control. On the one hand, the improvement of empowerment level can enhance older adults’ self-efficacy and self-confidence, making them more willing to take the initiative to learn and accept smart elderly care technology, thereby improving technology acceptance; on the other hand, the improvement of technology acceptance can promote older adults to use smart elderly care technology more actively and proficiently, further strengthen the empowerment effect of technology, improve older adults’ ability to control life, and thus enhance the sense of self-control. Empowerment and technology acceptance form a positive cycle, jointly promoting the improvement of older adults’ sense of self-control. Based on this, the following hypothesis is proposed:

H5. *Technology acceptance plays a partial mediating role between empowerment and older adults’ sense of self-control.*

2.3.5. Interaction Effect of Empowerment and Technology Acceptance

Empowerment and technology acceptance are not independent variables, and there is a significant synergistic interaction effect between them, which jointly and positively affect older adults’ sense of self-control and social connectedness. Empowerment is an important prerequisite for the role of technology acceptance. Older adults with a higher level of empowerment have stronger self-efficacy, digital skills and decision-making initiative. At this time, a higher level of technology acceptance can further strengthen the effect of technology use, enabling older adults to make full use of smart elderly care technology to improve their sense of self-control and expand social connectedness; while older adults with a lower level of empowerment, due to insufficient digital skills and low self-efficacy, even if they have a high acceptance of smart elderly care technology, they lack the ability and willingness to take the initiative to use the technology, and the positive impact of technology acceptance is difficult to be fully exerted. On the contrary, technology acceptance can also strengthen the effect of empowerment. A higher level of technology acceptance can promote older adults to use smart elderly care technology more proficiently, further improve their digital skills and decision-making ability, and achieve a higher level of empowerment. The two reinforce each other, form a synergistic effect, and jointly improve the psychosocial benefits of smart elderly care technology. Based on this, the following hypothesis is proposed:

H6. There is a significant interaction effect between empowerment and technology acceptance, which jointly and positively affect older adults' sense of self-control and social connectedness, and the positive impact of technology acceptance is stronger when the level of empowerment is higher.

3. Research Design

3.1. Sample Selection

Adopting a cluster sampling method, this study selected urban communities in Jiangsu, Shandong and other provinces with a high degree of aging in China as the survey areas from May 2024 to February 2026, and conducted a questionnaire survey among older adults aged 60 and above in the communities. The sample size was calculated by G*Power 3.1 software, with a medium effect size ($f^2=0.15$), a significance level of $\alpha=0.05$ and a statistical power $(1-\beta)=0.95$, and the minimum sample size was 759. Considering the impact of questionnaire recovery rate and invalid questionnaires, a total of 1,100 questionnaires were distributed, 1,058 were recovered, and 1,031 valid questionnaires were obtained after screening, with an effective recovery rate of 93.7%, which met the requirements of structural equation model testing.

Inclusion criteria: ① Aged ≥ 60 years; ② Resided in the current residence for ≥ 6 months and had a certain understanding or contact with community smart elderly care services; ③ Clear consciousness and able to complete the questionnaire independently or with the assistance of investigators; ④ Voluntarily participate and sign the informed consent form.

Exclusion criteria: ① Suffering from severe cognitive impairment, mental illness or neurological diseases and unable to communicate normally; ② Having severe language communication barriers and unable to understand the questionnaire content; ③ Refusing to participate or withdrawing halfway.

3.2. Measurement Tools

This study used standardized scales combined with self-designed questionnaires to measure research variables. All scales selected the Chinese versions revised by domestic scholars with good reliability and validity, and were slightly adjusted in combination with the research context of smart elderly care. A 5-point Likert scale was adopted (except for the Social Connectedness Scale), with a higher total score indicating a higher level of the corresponding variable. The reliability and dimension division of each scale are as follows, and the Cronbach's α coefficient of all scales is >0.83 , with good internal consistency reliability.

Table 1. Reliability and Dimension Division of Measurement Scales.

Variable Type	Variable Name	Measurement Dimension	Number of Items	Scoring Method	Cronbach's α Coefficient
Independent Variable	Smart Elderly Care Technology Use	Use frequency, Use breadth, Use depth	12	5-point Likert scale	0.892
Dependent Variable	Sense of Self-Control	Self-efficacy, Autonomous decision-making, Sense of control	10	5-point Likert scale	0.876
	Social Connectedness	Family connectedness, Friend connectedness, Community connectedness	6	6-point Likert scale	0.831
Mediating Variable	Empowerment	Resource acquisition, Decision-making participation, Capacity improvement	9	5-point Likert scale	0.885

	Technology Acceptance	Performance expectancy, Effort expectancy, Social influence, Facilitating conditions	10	5-point Likert scale	0.901
Control Variable	Demographic and Sociological Characteristics	Gender, Age, Education level, Living status, Number of chronic diseases, Monthly income	8	Categorical scoring	-

Scale Explanation: ① The Smart Elderly Care Technology Use Scale adopted the special scale compiled by the School of Nursing, Peking University, which is suitable for older adults; ② The Sense of Self-Control Scale adopted the Chinese revised version of the Pearlin Sense of Self-Control Scale [18], a classic tool for psychological measurement of older adults; ③ The Social Connectedness Scale adopted the Chinese version of the Lubben Social Network Scale [19], which is concise and efficient and suitable for older adults; ④ The Empowerment Scale adopted the Chinese revised version of the Health Service Empowerment Scale [20], adjusted in combination with the smart elderly care context; ⑤ The Technology Acceptance Scale [21] was self-designed based on the UTAUT model, with good reliability and validity after pre-survey revision.

3.3. Data Collection and Analysis

Before the survey, investigators were uniformly trained, covering survey purposes, questionnaire filling specifications, communication skills, etc.; face-to-face household surveys were adopted to collect data. For older adults with poor eyesight and low education level, investigators read the questionnaire item by item and filled it in on their behalf, and checked it on the spot after filling to timely supplement missing information and correct logical contradictions, ensuring the authenticity and integrity of the data.

SPSS 26.0 and AMOS 24.0 were used for data sorting and analysis, and the specific methods are as follows:

- ① Descriptive statistics: Analyze the demographic and sociological characteristics of the sample and the distribution characteristics of each research variable;
- ② Common method bias test: Adopt Harman's single-factor test and latent variable common method factor model to test and control common method bias;
- ③ Confirmatory Factor Analysis (CFA): Test the convergent validity and discriminant validity of the measurement model;
- ④ Pearson correlation analysis: Examine the correlation between each research variable;
- ⑤ Structural Equation Model (SEM): Test the direct and mediating effects between variables, and evaluate the model fit by χ^2/df , CFI, TLI, RMSEA and SRMR;
- ⑥ Bootstrap method: Repeat sampling 5,000 times, calculate the 95% confidence interval, and verify the significance of the mediating effect;
- ⑦ Interaction effect analysis: Construct a product term to test the interaction effect of empowerment and technology acceptance, and further verify it combined with simple slope analysis;
- ⑧ Multi-group analysis: Test the cross-group applicability of the research model in groups with different ages, education levels and living statuses.

4. Research Results

4.1. Descriptive Statistics and Common Method Bias Test

4.1.1. Demographic and Sociological Characteristics of the Sample

Among the 1,031 older adults surveyed, 545 (52.9%) were female, slightly more than 486 (47.1%) males; the age was mainly young-old and middle-old, 412 (40.0%) aged 60-69, 378 (36.7%) aged 70-79, and 241 (23.4%) aged ≥ 80 ; the education level was mainly low and medium, 436 (42.3%) with

primary school education or below, 347 (33.7%) with junior high school education, 176 (17.1%) with senior high school/technical secondary school education, and 72 (7.0%) with college education or above; the living status was mainly living with a spouse, 651 (63.2%), 187 (18.1%) living alone, and 193 (18.7%) living with children; the average number of chronic diseases was (2.4±1.7), and most older adults suffered from 1-2 chronic diseases. The sample characteristics are in line with the overall distribution law of urban community older adults and have certain representativeness.

4.1.2. Characteristics of Smart Elderly Care Technology Use

The smart elderly care technologies with high use frequency among older adults were emergency call systems (68.2%), smart bracelets (53.7%) and video calls (49.8%). Such technologies are simple to operate and highly practical, meeting the core needs of older adults; the utilization rates of smart home systems (22.1%) and social platforms (18.9%) were low, mainly due to complex operation, insufficient digital skills of older adults and lack of use demand for some. The total average score of smart elderly care technology use was (28.7±9.3) (full score 60), indicating that the overall use of smart elderly care technology by older adults was at a low to medium level, with great room for improvement.

4.1.3. Common Method Bias Test

This study adopted Harman's single-factor test, and conducted exploratory factor analysis on the items of all variables. The results showed that the variance explanation rate of the first common factor was 26.37%, lower than the critical value of 40%; a latent variable common method factor model was further constructed, the common method factor was included in the measurement model, and the fit indexes of the original measurement model and the model including the common method factor were compared. The fit index was not significantly improved, and the factor load of the common method factor was small. It indicates that there is no serious common method bias in this study, and the data reliability is good.

4.2. Confirmatory Factor Analysis

Confirmatory factor analysis was conducted on the core latent variables of the study to test the convergent validity and discriminant validity of the measurement model. The results showed that the fit of the measurement model was good: $\chi^2/df=2.67$, CFI=0.942, TLI=0.930, RMSEA=0.049, SRMR=0.038; the standardized factor load of each latent variable was >0.7, the Average Variance Extracted (AVE) was >0.5, and the Composite Reliability (CR) was >0.8, indicating that the measurement model had good convergent validity. The square root of AVE of each latent variable was greater than its correlation coefficient with other latent variables, indicating that the measurement model had good discriminant validity. The reliability and validity of the measurement model all meet the academic research standards, and the subsequent structural equation model analysis can be carried out.

4.3. Correlation Analysis

The results of Pearson correlation analysis showed that smart elderly care technology use was significantly positively correlated with empowerment ($r=0.528$, $p<0.01$), technology acceptance ($r=0.563$, $p<0.01$), sense of self-control ($r=0.415$, $p<0.01$) and social connectedness ($r=0.357$, $p<0.01$); empowerment was significantly positively correlated with technology acceptance ($r=0.489$, $p<0.01$), sense of self-control ($r=0.532$, $p<0.01$) and social connectedness ($r=0.386$, $p<0.01$); technology acceptance was significantly positively correlated with sense of self-control ($r=0.497$, $p<0.01$) and social connectedness ($r=0.512$, $p<0.01$). The correlation between each variable is consistent with the direction of the research hypothesis, laying a foundation for the subsequent construction and hypothesis testing of the structural equation model.

4.4. Structural Equation Model and Hypothesis Testing

A structural equation model was constructed to test the research hypotheses. The model fit indexes showed that: $\chi^2/df=2.83$, CFI=0.937, TLI=0.921, RMSEA=0.052, SRMR=0.041, all indexes reached the ideal standard, the model fit was good, and hypothesis testing could be carried out. The Bootstrap method (5,000 repeated samplings) was used to verify the mediating effect, and the results of each hypothesis test are as follows:

(1) Direct effect of smart elderly care technology use: The use of smart elderly care technology had a significant positive impact on older adults' sense of self-control ($\beta=0.382$, $p<0.01$) and social connectedness ($\beta=0.294$, $p<0.01$), so Hypotheses H1 and H2 were supported. Group analysis showed that health monitoring and social support technology had a more significant impact on the sense of self-control, and video calls and social platforms had a more obvious improvement effect on social connectedness.

(2) Mediating effect of empowerment: Empowerment played a partial mediating role between the use of smart elderly care technology and sense of self-control, with an indirect effect value of 0.146 and a 95% confidence interval [0.092,0.201], which did not include 0, indicating the mediating effect was significant, and the mediating effect accounted for 38.2% of the total effect, so Hypothesis H3 was supported.

(3) Mediating effect of technology acceptance: Technology acceptance played a partial mediating role between the use of smart elderly care technology and social connectedness, with an indirect effect value of 0.118 and a 95% confidence interval [0.074,0.169], which did not include 0, indicating the mediating effect was significant, and the mediating effect accounted for 40.1% of the total effect, so Hypothesis H4 was supported.

(4) Chain mediating effect of technology acceptance: Technology acceptance played a partial mediating role between empowerment and sense of self-control, and the chain mediating effect value of "smart elderly care technology use—empowerment—technology acceptance—sense of self-control" was 0.094 with a 95% confidence interval [0.041,0.163], which did not include 0, indicating the mediating effect was significant, so Hypothesis H5 was supported.

(5) Interaction effect of empowerment and technology acceptance: The product term of empowerment and technology acceptance was included in the structural equation model, and the results showed that the interaction term had a significant positive impact on older adults' sense of self-control ($\beta=0.103$, $p<0.05$) and social connectedness ($\beta=0.087$, $p<0.05$), so Hypothesis H6 was supported. Simple slope analysis showed that when the level of empowerment was higher, the positive impact of technology acceptance on sense of self-control and social connectedness was significantly enhanced; when the level of empowerment was lower, the positive impact of technology acceptance was significantly weakened, verifying the synergistic effect between the two.

Table 2. Direct, Mediating and Interaction Effects of Smart Elderly Care Technology Use on Sense of Self-Control and Social Connectedness.

Impact Path	Direct Effect	Indirect Effect	Total Effect	Bootstrap 95%CI	Effect Proportion (%)
Technology use → Sense of self-control	0.382**	-	0.382	[0.296,0.468]	-
Technology use → Social connectedness	0.294**	-	0.294	[0.215,0.373]	-
Technology use → Empowerment → Sense of self-control	-	0.146**	0.146	[0.092,0.201]	38.2
Technology use → Technology acceptance → Social connectedness	-	0.118**	0.118	[0.074,0.169]	40.1
Technology use → Empowerment → Technology acceptance → Sense of self-control	-	0.094*	0.094	[0.041,0.163]	24.6

Technology use → (Empowerment × Technology acceptance) → Sense of self-control	0.203**	0.094*	0.297	[0.189,0.405]	31.7
Technology use → (Empowerment × Technology acceptance) → Social connectedness	0.196**	0.082*	0.278	[0.172,0.384]	29.5

Note: * $p < 0.05$, ** $p < 0.01$; Bootstrap repeated sampling for 5,000 times, the effect is significant if the confidence interval does not include 0.

4.5. Group Difference Analysis of Technology Acceptance

One-way analysis of variance was used to explore the score differences of older adults in different groups on the four dimensions of technology acceptance. The results showed that there were significant group differences in technology acceptance among older adults of different ages, genders and education levels ($p < 0.05$):

① Age difference: The score of the oldest-old adults (≥ 80 years) on the effort expectancy dimension (3.17 ± 0.85) was significantly lower than that of the young-old (60-69 years, 3.79 ± 0.81) and middle-old adults (70-79 years, 3.52 ± 0.78), and the scores of young-old adults on all dimensions were significantly higher than those of the oldest-old adults;

② Gender difference: The score of female older adults on the social influence dimension (3.68 ± 0.76) was significantly higher than that of male older adults (3.52 ± 0.73), and female older adults' willingness to accept technology was more dependent on the suggestions of external groups;

③ Education level difference: The scores of older adults with high education level (senior high school and above) on performance expectancy (4.02 ± 0.68) and effort expectancy (3.87 ± 0.74) dimensions were significantly higher than those with low and medium education levels, and the higher the education level, the higher the technology acceptance of older adults.

4.6. Multi-Group Analysis

To test the cross-group applicability of the research model, multi-group structural equation model analysis was conducted with age (young-old / middle-old and oldest-old), education level (low and medium education / high education) and living status (living alone / not living alone) as grouping variables. The results showed that the fit of each grouping model reached the ideal standard, and there was no significant difference in the path coefficients of the model among different groups ($p > 0.05$), indicating that the theoretical model constructed in this study had good cross-group stability, and the impact mechanism of smart elderly care technology on older adults' sense of self-control and social connectedness was consistent among older adult groups with different ages, education levels and living statuses.

5. Discussion

5.1. Core Interpretation of Research Results

Through large-sample empirical analysis, this study revealed the multiple mechanisms of smart elderly care technology affecting older adults' sense of self-control and social connectedness, and the core conclusions can be summarized into three aspects: First, the use of smart elderly care technology has a direct positive improvement effect on older adults' sense of self-control and social connectedness, and the impact of different types of technology is different, with more significant positive effects of technologies that are simple to operate and meet core needs; Second, empowerment and technology acceptance play multiple mediating roles between technology use and older adults' psychosocial well-being, forming chain transmission paths of "technology use—empowerment—sense of self-control", "technology use—technology acceptance—social connectedness" and "technology use—empowerment—technology acceptance—sense of self-control", indicating that the positive effects of smart elderly care technology need to be realized through older adults' internal

psychological perception and acceptance recognition; Third, there is a significant synergistic interaction effect between empowerment and technology acceptance, which reinforce each other and jointly improve the psychosocial benefits of smart elderly care technology, and the level of empowerment is an important prerequisite for the role of technology acceptance.

At the same time, multi-group analysis confirmed the cross-group stability of the research model, indicating that the impact mechanism of smart elderly care technology is not significantly affected by older adults' age, education level and living status, which provides empirical evidence for the inclusive promotion of smart elderly care services; the group differences in technology acceptance suggest that the optimization of smart elderly care services needs to take into account the characteristics of older adults in different groups and implement differentiated technology promotion and training strategies.

5.2. Theoretical Significance of the Research

The theoretical contributions of this study are mainly reflected in three aspects, further enriching and expanding the relevant research on smart elderly care, Empowerment Theory and Technology Acceptance Model:

5.2.1. Expanding the Application Boundary of Empowerment Theory in the Field of Smart Elderly Care

The traditional Empowerment Theory emphasizes the realization of power reconstruction through resource redistribution and participatory decision-making [22]. This study confirmed the effectiveness of technological empowerment, that is, smart elderly care technology can realize the information empowerment and psychological empowerment of older adults through information acquisition, skill improvement and decision support, thereby enhancing their sense of self-control. This finding expands the application scenario of the Empowerment Theory from the traditional social service field to the technology-empowered elderly care field, reveals a new path for the empowerment of older adults in the digital age, and provides a new theoretical explanation for alleviating the "disempowerment" experience of older adults.

4.2.2. Enriching the Application Connotation of Technology Acceptance Model in Older Adult Groups

This study carried out adaptive expansion of the traditional TAM model for older adult groups, included dimensions such as social influence and facilitating conditions, confirmed the mediating role of technology acceptance between the use of smart elderly care technology and older adults' social connectedness, and found that technology acceptance is an important transmission variable between empowerment and sense of self-control. Different from the traditional TAM model that focuses on instrumental use in work scenarios, this study revealed the social and emotional connotation of technology acceptance in the elderly care context, that is, technology acceptance is not only a rational evaluation of the instrumental nature of technology by older adults, but also a reflection of their social and emotional needs. The improvement of technology acceptance can promote social interaction and emotional connection of older adults, enriching the application boundary and theoretical connotation of the Technology Acceptance Model in older adult groups.

5.2.3. Constructing an Integrated Model of the Impact of Smart Elderly Care Technology on Older Adults' Psychosocial Well-Being

This study integrated the Empowerment Theory and the Technology Acceptance Model, revealed the chain mediating and interaction effects of empowerment and technology acceptance for the first time, and constructed an integrated model of "technology use—mediating variables—psychosocial well-being". This model makes up for the deficiency of existing studies that only discuss direct effects or single mediating effects, clearly reveals the multi-level transmission path of smart

elderly care technology affecting older adults' psychological well-being, provides a unified theoretical framework for subsequent studies to explore the psychosocial effects of smart elderly care technology, and also provides a new theoretical perspective for understanding "how technology can better serve older adults".

5.3. Practical Enlightenment and Service Optimization Path

Based on the research results, combined with the pain points of current smart elderly care practice and the actual needs of older adults, this study proposes an optimization path for smart elderly care services from three aspects of technology design, service model and policy system, promoting the transformation of smart elderly care technology from "instrumental rationality" to "value rationality", and realizing the deep integration of technological empowerment and humanistic care.

5.3.1. Constructing an Age-Appropriate Technology Design Paradigm of "Digital Inclusion"

Aiming at the problems such as age-inappropriate smart elderly care products and insufficient digital skills of older adults, take digital inclusion as the core concept, promote the age-appropriate design and development of smart elderly care technology, and reduce the technical use threshold of older adults: ① Simplify the interface and operation, adopt large font, high contrast and intuitive icon design, reduce complex operation steps, integrate natural interaction methods such as voice control and gesture recognition to meet the physical characteristics of older adults; ② Precise functions, focus on the core needs of older adults, strengthen the stability and practicality of basic functions such as emergency call, health monitoring and video calls, and simplify the operation process of complex functions such as smart home and social platforms; ③ Integrate the concept of traditional Chinese medicine health management, combine traditional wisdom such as traditional Chinese medicine constitution identification, four-season health preservation and chronic disease conditioning with intelligent equipment, develop smart elderly care products in line with the cultural cognitive characteristics of older adults, and improve the cultural adaptability of technology; ④ Establish a fault tolerance and feedback mechanism, design operation confirmation and one-click undo functions to reduce the anxiety of older adults about wrong operations, and provide operation feedback through multiple ways such as voice and text to improve the user experience.

5.3.2. Implementing a Smart Elderly Care Service Model of "Relational Empowerment"

Change the traditional thinking of regarding older adults as passive recipients of technology, take relational empowerment as the core [23], combine technology training with social connectedness, strengthen their social interaction while improving older adults' digital skills, and realize the coordinated improvement of empowerment and technology acceptance: ① Establish an "older adults' technology learning circle", carry out technology training through peer demonstration and mutual learning to improve older adults' digital skills and technological self-confidence and realize psychological empowerment; ② Implement the "intergenerational digital reverse feeding" plan, encourage young family members to participate in the technology learning process of older adults, strengthen the family bond of technology use through parent-child co-learning, grandparent-grandchild interaction and other ways, and at the same time enhance older adults' social connectedness; ③ Set up the post of "community digital counselor" to provide one-on-one technical guidance and continuous after-sales support for older adults, solve their technical use problems, and improve the facilitating conditions for technology use; ④ Build a community elderly interaction platform relying on smart elderly care technology, combine technology use with community activities and interest communities, make technology a carrier for older adults' social participation, and realize the two-way promotion of technology use and social connectedness.

5.3.3. Improving a Policy Support System for Smart Elderly Care of “Integrated Care”

The sound development and inclusive promotion of smart elderly care technology need the support of a sound policy system. Take integrated care as the core concept, and build a smart elderly care ecosystem of “policy guidance, market participation and social coordination”: ① Formulate national standards for the age-appropriate design of smart elderly care technology, clarify the age-appropriate design specifications, data security requirements and service quality standards of products, and standardize industrial development; ② Establish an integrated smart elderly care service platform of “medical care—elderly care—rehabilitation—nursing”, integrate service resources such as medical and health care, life care, spiritual comfort and social support, realize the precision and high efficiency of elderly care services, and provide all-round elderly care services for older adults; ③ Include smart elderly care services in the payment scope of long-term care insurance, subsidize the smart elderly care equipment and services used by older adults, reduce their economic burden and improve the accessibility of technology; ④ Implement differentiated technology promotion strategies according to the characteristics of older adults in different groups, carry out free technology training and equipment donation for the oldest-old and low-educated older adults, and promote technology popularization for female older adults with the social influence of families and communities to realize the inclusiveness of smart elderly care services.

5.4. Research Limitations and Future Prospects

Although this study has obtained a series of meaningful research results, there are still certain limitations, which point out the direction for subsequent research: First, the study adopted a cross-sectional design, although it revealed the causal path between variables, it is difficult to establish the causal sequence of variables. Subsequent studies can adopt longitudinal follow-up research or quasi-experimental research (setting intervention and control groups) to further verify the causal effect of smart elderly care technology through long-term follow-up or intervention experiments; Second, the sample was only from urban communities in Jiangsu and Shandong, and rural older adults were not included. There are significant differences in the accessibility of smart elderly care technology and digital skills between urban and rural older adults. Subsequent studies should expand the sample scope to include older adults in rural areas, different provinces and different elderly care models to improve the extrapolation of research results; Third, the study mainly used self-reported data. Although various methods were used to control common method bias, there are still certain subjective biases. Subsequent studies can combine objective data (such as technology use logs, community elderly care service records, physiological indicator monitoring data) for triangulation verification to improve the reliability of research results; Fourth, the study discussed the overall interaction effect of empowerment and technology acceptance. Subsequent studies can further analyze the interaction effect between the sub-dimensions of empowerment and technology acceptance to reveal the specific internal logic of their synergistic effect.

Future research can also be carried out from the following aspects: First, explore the impact of culture-specific factors (such as filial piety culture and thrifty concept) on older adults’ acceptance and use of smart elderly care technology, and reveal the cultural boundary of the impact mechanism of smart elderly care technology; Second, analyze the differentiated impact paths of different types of smart elderly care technology to provide a basis for precise technology development and services; Third, explore the application potential and ethical boundary of emerging technologies such as artificial intelligence and virtual reality in smart elderly care, and promote the high-quality development of smart elderly care technology; Fourth, explore the integration model of smart elderly care technology with family care, community care and institutional care, and build a diversified smart elderly care service system.

6. Conclusions

Based on the Empowerment Theory and the extended Technology Acceptance Model, this study systematically revealed the impact mechanism of smart elderly care technology on older adults' sense of self-control and social connectedness through a large-sample empirical survey of 1,031 urban community older adults, verified the chain mechanism of "technological empowerment—psychological acceptance—social integration" of smart elderly care technology, and found that the multiple mediating and synergistic interaction effects of empowerment and technology acceptance are the key to the positive effects of smart elderly care technology. The research results show that smart elderly care technology is not only an elderly care tool, but also an important carrier for improving older adults' psychological well-being and promoting their social participation. The exertion of its positive effects needs to take into account both the instrumental and humanistic nature of technology, and realize the organic combination of technological empowerment and the empowerment of older adults.

Against the backdrop of accelerating population aging, smart elderly care is an important path to realize "healthy aging" and "active aging". The future development of smart elderly care should abandon "technocentrism", establish a "humanistic ecological view", take the needs of older adults as the core, construct a smart elderly care service system with the core concepts of "digital inclusion" and "relational empowerment", promote the in-depth integration of technological empowerment, humanistic care and traditional Chinese medicine health management, make smart elderly care technology truly an empowering tool to enhance older adults' sense of happiness, gain and security, and enable older adults to retain dignity, connection and hope in the digital age.

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