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Impact of digital literacy on aging attitudes of the elderly from the perspective of social cognitive theory

Xiaodong Di^{1*} and Lijian Wang¹

Abstract

Background Under the background of digital economy, increasing awareness of active ageing through digital literacy is a realistic requirement to deal with deep aging. However, the lack of digital literacy and skills of the elderly seriously affects the ways and means of their participation in the digital society, and then produces negative aging attitudes such as loneliness, isolation and uselessness.

Methods We adopt stratified sampling to conduct a comprehensive social survey on the elderly care status of the elderly in six provinces including Henan, Hubei, Shaanxi, Gansu, Jiangsu and Shandong in July 2023, and use Ordinal Logistic Regression method to analysis the impact of digital literacy on aging attitudes.

Results The study finds that the improvement of digital literacy can significantly inhibit the aging attitude of the elderly. Further, mechanism analysis finds that the improvement of digital literacy has empowerment effect and energizing effect. In addition, compared with the urban, high-income and low-age elderly groups, the aging attitudes of rural, low-income and high-age elderly groups are relatively less dependent on digital literacy.

Conclusions The improvement of digital literacy can significantly inhibit the aging attitude of the elderly, so the government should optimize the balance and accessibility of digital resources and eliminate digital inequality among the elderly.

Keywords Digital literacy, Aging attitude, Social cognitive theory, Self-efficacy, Influence mechanism

Introduction

With the deep integration of digital technologies, improving the digital literacy and skills of the whole people has become a realistic requirement to accelerate the development of the digital economy. However, due to the decline of physical condition, cognitive function, social participation and other abilities, the elderly generally

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have problems such as low willingness to use digital resources, poor access to digital resources and lacking of digital security awareness [1, 2]. In the 53rd Statistical Report on the Development of the Internet in China, as of December 2023, the number of non-Internet users is 317 million, and the proportion of non-Internet users aged 60 and above in China is 39.8% of the total number of non-Internet users, that is, about 126 million elderly people cannot enjoy the social achievements of the digital economy due to lack of digital skills or limited digital resources. Therefore, it is urgent to enhance the digital literacy of the elderly and to ensure that they can share the achievements of digital development.

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The lack of digital literacy and skills of the elderly seriously affects the ways and means of their participation in the digital society, and then produces negative aging attitudes such as loneliness, isolation and uselessness [3]. The 14th Five-Year Plan for Healthy Aging in China points out that it is necessary to make full use of information technology means such as the Internet, the Internet of Things, and big data, which can improve the quality and efficiency of intelligent elderly care. However, the lack of digital literacy of the elderly not only hinders the embedding and development of intelligent elderly care, but also leads to a certain digital gap between the elderly and their families and society, resulting in a more pessimistic aging attitude [4, 5]. Therefore, how to improve the aging attitude of the elderly by enhancing their digital literacy has become an important issue for healthy aging.

At present, most studies on the factors affecting aging attitudes of the elderly focus on individual characteristics [6, 7], family support [8], and social network [9]. However, there are little research on the influence of digital literacy on aging attitude of the elderly, mainly focusing on the influence of digital product use on aging attitude. Urbina et al. analyzed the survey data and found that the use of smart phones could significantly weaken the negative aging attitude of the elderly, and there was heterogeneity among different elderly groups [10]. Based on the age-period-cohort model, Yu-Ting et al. found that Internet use had significant positive effects on both physical and mental health of empty-nesters [11]. Most of the existing literature studying on digital literacy of the elderly are limited to whether they use digital products or not, and have not considered the digital literacy level or digital skill level of the elderly, which is easy to cause hidden digital use inequality of the elderly, and then cover up the effective path to improve digital literacy of the elderly.

Therefore, in order to clarify the internal mechanism of the influence of digital literacy on aging attitudes of the elderly, this paper first builds an analytical framework of the influence of digital literacy on aging attitudes based on social cognitive theory. Then, using the social survey data of the elderly in 2023, this paper analyzes the direct impact of digital literacy on aging attitudes, the indirect impact of digital literacy on aging attitudes from the perspective of self-efficacy, and the heterogeneity of digital literacy on aging attitudes of different elderly groups. Finally, we put forward some effective ways to improve aging attitudes of the elderly from the aspects of popularizing digital literacy education for the elderly, optimizing the balance and accessibility of digital resources, and improving the suitability of digital products and services.

Theoretical hypothesis Social cognitive theory

Social cognitive theory is an important theory of social psychology put forward by Bandura in the 1970s, which reflects the ability of individuals to grasp their own behavior. It mainly includes two contents that one is cognitive ability, that is, the ability of individuals to recognize, learn and apply the external environment. The second is self-efficacy, that is, the one's subjective perception of having the ability to organize and carry out actions to achieve a certain goal [12]. In addition, the theory also emphasizes the interaction of individual, behavior and environment. At present, there are two viewpoints, namely, personal determinism and environmental determinism. Personal determinism holds that an individual's psychological beliefs, expectations and motivations will affect people's behaviors, and the results of behaviors will in turn affect individuals' subjective emotions. Environmental determinism holds that the external environment is the main factor affecting individual behavior, and in turn, the results of individual behavior will also change the environment.

Social cognitive theory is widely used in psychology, sociology and management research. This paper holds that digital literacy reflects the cognitive ability of the elderly to the digital living environment, and aging attitude reflects the individual characteristics and subjective emotions of the elderly, all of which belong to the conceptual category of social cognitive theory. It is precisely the triadic discussion about individuals, behavior and environment that social cognitive theory helps to explain the mechanism of digital literacy's influence on aging attitudes, which not only helps to expand the theoretical basis of geriatric psychology, but also helps to deepen the understanding and cognition of digital literacy of the elderly.

Digital literacy and aging attitude

The term digital literacy was first coined in 1994 by Israeli scholar Yoram Sheshet-Alkalai, who believed that digital literacy was the technical, cognitive and intellectual skills that individuals need to complete tasks or solve problems in a digital environment [13]. With the gradual improvement of the concept of digital literacy, in 2000, the European Union classified digital literacy into eight core literacies, including communication ability, scientific and technological literacy, civic literacy and so on. In order to further promote citizens' understanding and application of digital literacy, the EU has published several editions of the European Citizens' Digital Literacy Framework in 2013, 2016, 2017 and 2019. At present, the most representative is UNESCO's Global Framework for Digital Literacy, which defines digital literacy as people's ability to access, process, analyze, apply and evaluate information using digital tools in their work and life [14]. Therefore, according to the characteristics and living environment of the elderly, this paper defines the digital literacy of the elderly as the ability of the elderly to acquire, analyze and apply information through digital tools in their life, including three dimensions of digital cognitive literacy, digital skill literacy and digital security literacy.

Aging attitude refers to the subjective views of the elderly on changes such as aging, interpersonal pressure, health conditions, and life satisfaction, which can be divided into positive and negative attitudes. Positive aging attitudes refer to the positive views of aging due to healthy physical conditions and good interpersonal relationships and so on. Negative aging attitudes refer to the negative view of aging caused by the decline of physical functions and insufficient social participation during the aging process [15]. From the perspective of research content, the individual-level aging attitude mainly reflects the elderly's views on self-awareness and their own social value. The social-level aging attitude places more emphasis on the common health risks and limitations of participation in social activities among the elderly group. The aging attitude involved in this paper refers to the individual-level negative aging attitude. The main factors affecting aging attitudes of the elderly include age, gender, education level, marital status, economic status, family support, social support and so on [16, 17].

According to the social cognitive theory, external environmental factors affect people's behavior, and behavior and its results in turn affect individuals' emotional responses [18]. Digital literacy reflects the elderly's cognitive ability and ability to use digital tools. On the one hand, the improvement of digital cognitive ability is conducive to the elderly's integration into the digital society as soon as possible, can encourage the elderly to use digital thinking to understand, analyze and process digital information, can weaken the sense of social isolation caused by changes in care forms, entertainment products and consumption habits, and can eliminate intergenerational conflicts between the elderly and their families and society, which can improve the psychological mood and aging attitude of the elderly [19]. On the other hand, the improvement of digital use ability is conducive to the realization of self-care for the elderly, reducing their dependence on family and society, reshaping their self-confidence and sense of social value, promoting the re-employment and delayed retirement of the elderly, transforming the elderly from social burden to social wealth, and realizing healthy and active aging [20]. Therefore, we can put forward hypothesis 1 that the improvement of digital literacy can inhibit the negative aging attitudes for the elderly.

Digital literacy, self-efficacy and aging attitude

Self-efficacy is an important part of social cognitive theory, which emphasizes the adaptability of individual ability to environmental changes. Individuals with strong self-efficacy are more likely to adapt to environmental changes and cope with emergencies. Conversely, in the course of life, the more quickly individuals adapt to environmental changes and use new technologies to solve new problems, the greater the self-efficacy is [21]. Self-efficacy of the elderly refers to the adaptability of the elderly to the living environment and its changes as well as the degree of their control over uncertain events. It is mainly obtained from the following activities. The first is practical experience, that is, skills, knowledge and successful experience acquired by the elderly in the process of engaging in a certain production activity can enhance self-efficacy. The second is vicarious experience, that is, when the elderly see that individuals with similar social status, economic foundation, cognitive characteristics, educational experience and other characteristics achieve success in a certain life event, observers will feel that they can achieve the same success in the same situation, thus improving their self-efficacy. The third is social recognition, that is, when others think the elderly have the ability or advantage to handle an event, the self-efficacy of the elderly is enhanced.

The influence of digital literacy on the self-efficacy of the elderly is mainly reflected in the practical experience acquired by the elderly in the process of participating in digital activities, that is, the improvement of social ability, application ability and information acquisition ability in digital life enhances the self-efficacy of the elderly. It can be divided into two aspects. The first is the enhancement effect, that is, the influence of digital literacy on the adaptability of the elderly. With the wide application of digital products in life and production, convenient digital technologies such as online shopping, online chatting and online entertainment can fully meet most of the needs of the elderly in life care, emotional sustenance, entertainment and leisure, medical care and other aspects. Therefore, improving the digital literacy of the elderly can enhance their ability to adapt to the digital living environment, and then improve the self-efficacy of the elderly. The second is the empowerment effect, that is, the influence of digital literacy on the autonomy of the elderly. For the elderly with high digital literacy, they can independently obtain, evaluate and analyze information, make correct behavioral decisions, and get rid of dependence on family or society. Through digital applications, online shopping, online chat, online medical treatment, distance education and other activities, the elderly can independently meet the needs of life, thus enhancing self-efficacy.

According to the social cognitive theory, individual elements such as belief and motivation guide or control their behavioral choices, and in turn, behavior also affects the emotional response of the subject [22]. First of all, self-efficacy, as an internal driving force for individuals to explore the unknown, deal with crises and participate in social activities, can effectively eliminate the pessimism caused by the decline of physical energy, economic status and cognitive ability of the elderly. Secondly, self-efficacy can enhance the confidence of the elderly in participating in social activities. Good social network can help eliminate the loneliness and social isolation of the elderly, and reduce their pessimistic attitude toward aging. Finally, the self-efficacy can stimulate the social responsibility of the elderly. The elderly with a strong self-efficacy are more willing to seek social value through social participation, mutual assistance for the elderly, re-employment and other behaviors, so as to reduce the burden of family and social care, which is good for the mental health of the elderly. Therefore, we can put forward hypothesis 2 that digital literacy can inhibit negative aging attitudes of the elderly by improving their self-efficacy.

Methods

Data source

The research data in this paper comes from the comprehensive social survey of the elderly care status of the elderly in July 2023. The survey team consists of teachers, doctoral students, master's students and undergraduates from Xi'an Jiaotong University, all of whom have voluntarily applied for the study and have received certain professional training. This survey adopts stratified sampling, and selects six typical provinces with different aging degrees, namely Henan, Hubei, Shaanxi, Gansu, Jiangsu and Shandong, to investigate the living conditions of the elderly. The questionnaire contents includes personal characteristics, health status and digital literacy of the elderly. Through data cleaning and screening, 810 valid data related to this study are obtained. The data collection is close to the local actual situation, and the Cronbach's α value of data reliability is 0.71, which indicates that the measurement of digital literacy by each item is highly consistent.

Variable selection

Dependent variable

The dependent variable of this paper is aging attitude. Aging attitude is a complex psychological concept, and there is no clear measurement indicator yet. The current research is mainly measured by aging attitude scale [23], elderly people's sense of value and other indicators [24]. Considering personal characteristics and understanding ability of the elderly, this paper uses the question "I feel worthless because of my age" to measured aging attitude of the elderly, the higher the score is, the more pessimistic the attitude toward aging is.

Independent variable

Based on the digital literacy indicator system established by the Global Digital Literacy Framework, with reference to the definition of digital literacy of the elderly by Oh et al. [25], Zhang [1] and other scholars, this paper constructs a digital literacy index system from nine specific aspects including digital willingness, communication skills, life skills and digital security from three dimensions of digital cognitive literacy, digital skills literacy and digital security literacy of the elderly. In addition, in order to further ensure the rationality of the digital literacy index system, we invited 5 experts and some elderly people to conduct interviews, among them, two experts are scholars from Xi 'an Jiaotong University and Lanzhou University, and three experts are managers from different levels of the government. The elderly people surveyed were selected through random sampling in six provinces respectively. Finally we revised and supplemented the items, and finally obtained the digital literacy index system, as shown in Table 1.

The independent variable in this paper is the digital literacy constructed in Table 1. Therefore, how to scientifically empower is the key to building digital literacy index system. Based on the mainstream empowerment methods, this paper adopts the equal weight method to empower the benchmark regression, and calculates the digital literacy level of the elderly by summing up. In the robustness test, we use the weight method such as principal component analysis and entropy value method to measure the digital literacy level of the elderly, and to ensure the accuracy of the empirical results.

Control variable

Considering that individual characteristics have a great influence on aging attitude, referring to scholars' studies on the influential factors of aging attitude [26, 27], this paper chooses age, gender, education level, marital status, income level, urban and rural types as control variables to ensure that the results are not affected by the personal characteristics of the elderly.

Mediator variable

In order to examine the mechanism of enhancement effect and empowerment effect of digital literacy on aging attitudes, this paper selects the autonomous ability and adaptability of the elderly as the mediating variables.

The variables involved in this paper are shown in Table 2. The results of descriptive statistical analysis show that the standard deviation of most variables is close to 1, indicating that the data is concentrated near a central value and the sample has no outlier. The mean and

| Dimension | Indicator | Question | Options |
|----------------------------|---|---|--|
| Digital cognitive literacy | Digital Do you think it's important to know how to us Identity smartphone? (DI) | | (1)very not im- portant (2)not important (3) generally (4) important (5) very important |
| | Digital willingness (DW) | Are you willing to embrace digital products and services? | (1) Very reluctant (2) reluctant (3) Generally (4) willing (5) Very willing |
| Digital skills literacy | Communication skill (CS) | Your proficiency in chatting with others online. | (1) Not at all (2) Not very |
| | Entertainment skill (ES) | Your proficiency in watching videos or entertainment. | skilled (3) General |
| | Life skill (LS) | Your proficiency in shopping or spending online. | (4) More skilled |
| | Medical skill (MS) | Your proficiency in registering or making an appoint- ment with a doctor online. | (5) Very skilled |
| | Travel skill (TS) | Your proficiency in booking online. | |
| | Administrative skill (AS) | Your proficiency in using government applications online. | |
| Digital security literacy | Digital security (DS) | Have you received any training or education related to Internet fraud or telecommunications fraud? | (1) yes (2) no |

Table 1 Dimensions and measurement items of digital literacy index system

| Variable | | | Question | Mean | Median | Standard deviation |
|-------------------------|--------------------------------|---------------------------------|--|------|--------|--------------------|
| Dependent variable | Aging attitude (AT) | | l feel worthless because of my age (1)Strongly disagree (2)Disagree (3) Generally (4)Agree (5) Strongly agree | 2.27 | 2 | 1.05 |
| Independent variable | Digital literacy (DL) | | The index system of digital literacy of the elderly is obtained by weighting. | 2.61 | 2.56 | 0.73 |
| Control variable | Age (AG) | | (1)60–65 (2)65–70 (3)70–75 (4)75–80 (5)Above 80 | 2.45 | 2 | 1.22 |
| | Gender (GE) | | (1)Male (0)Female | 0.53 | 1 | 0.50 |
| | Marriage (MA) | | (1)Yes (0)Other | 0.81 | 1 | 0.39 |
| | Education (ED) | | (1)Elementary (2)Junior (3)High (4)Junior college (5) Bachelor | 2.21 | 2 | 1.10 |
| | Monthly income (MI) | | (1)Below 500 (2)500–1500 (3)1500–3000 (4)3000–5000 (5)Above 5000 | 3.31 | 3 | 1.28 |
| | Household registration (HR) | | (1)Urban (0)Rural | | 1 | 0.50 |
| Mediator variable | Self- Efficacy (SE) | Autono- mous ability (AA) | Can you do what you want on your own time? (1)Never (2)seldom (3)sometimes (4)often (5)usually | 4.12 | 4 | 0.86 |
| | | Adaptability (AB) | Can you adapt to changes in your living environment? (1)Not at all (2)a little (3)Generally (4)Largely (5)totally | 3.91 | 4 | 0.93 |

median values of digital literacy are 2.61 and 2.56, indicating that the digital literacy of the elderly is relatively low on the whole, and the sample is consistent with the actual situation of the elderly and has certain reliability.

Empirical model

Benchmark model

The paper takes digital literacy of the elderly as the independent variable, aging attitude as the dependent variable, personal characteristics and other factors as control variables, and builds the following empirical model.

$$Y = \alpha_1 DC + \alpha_2 X + \varepsilon \tag{1}$$

In Formula (1), Y denotes dependent variable, that is, aging attitude. DC denotes independent variable, that is, digital literacy. X denotes control variables. α denotes the regression coefficient, and ε denotes the error term.

Mediating effect model

In order to verify the influence mechanism of digital literacy on aging attitude of the elderly, this paper uses autonomous ability and adaptability to characterize selfefficacy of the elderly as mediator variables, and sets the following mediating effect model.

$$Y = \beta_1 S E + \beta_2 X + \varepsilon_1 \tag{2}$$

$$SE = \phi_1 DC + \phi_2 X + \varepsilon_2 \tag{3}$$

$$Y = \lambda_1 SE + \lambda_2 DC + \lambda_3 X + \varepsilon_3 \tag{4}$$

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In Formula, SE denotes mediator variables, that is, autonomous ability and adaptability. β , ϕ , λ denotes the regression coefficient.

Results and discussion

Benchmark regression

In order to verify the impact of digital literacy on aging attitudes, based on the formula (1) model, this paper uses Ordinal Logistic Regression method to analysis the impact, and the results are shown in Table 3.

In Table 3, most independent variables are significant at the level of 1%, and the log likelihood test is passed, indicating that the model is set reasonably and effectively, and the results had a certain stability. From the perspective of the sub-dimension of digital literacy, the regression coefficients of other variables are significantly negative except that the digital security indicator has no significant effect on the aging attitude, indicating that the improvement of digital cognition and digital skills will significantly inhibit the pessimistic aging attitude of the elderly. Hypothesis 1 passes the test. From the perspective of the comprehensive dimension of digital literacy, the influence of digital literacy on aging attitude is significantly negative, that is, every 1% increase in digital literacy, the occurrence rate of the elderly's aging attitude decreasing by at least one level increases by 90.60%. The results show that the improvement of digital cognition and digital skills can effectively reduce the pessimistic aging attitude of the elderly. This is mainly because in the context of the rapid development of digital information and technology, once a large amount of digital information exceeds the receptivity of the elderly, the elderly will appear abnormal symptoms such as confusion, frustration, and impaired judgment. Therefore, the

 Table 3
 Regression results of different dimensions of digital literacy affecting aging attitude

| Ŷ | AI | | | | | | | | | |
|----------------------|-----------|-----------|----------|-----------|-----------|-----------|-----------|-----------|----------|-----------|
| Independent variable | DI | DW | CS | ES | LS | MS | TS | AS | DS | DL |
| DL | -0.254*** | -0.313*** | -0.119** | -0.298*** | -0.196*** | -0.283*** | -0.192*** | -0.334*** | -0.014 | -0.645*** |
| | (0.000) | (0.000) | (0.032) | (0.000) | (0.000) | (0.000) | (0.002) | (0.000) | (0.916) | (0.000) |
| AG | 0.235*** | 0.216*** | 0.223*** | 0.175*** | 0.194*** | 0.229*** | 0.228*** | 0.215*** | 0.256*** | 0.150*** |
| | (0.000) | (0.000) | (0.000) | (0.002) | (0.001) | (0.000) | (0.000) | (0.000) | (0.000) | (0.001) |
| GE | -0.324** | -0.312** | -0.314** | -0.275** | -0.343** | -0.345** | -0.324** | -0.265** | -0.330** | -0.295** |
| | (0.015) | (0.019) | (0.019) | (0.040) | (0.010) | (0.010) | (0.015) | (0.049) | (0.013) | (0.028) |
| MA | -0.268 | -0.245 | -0.284 | -0.275 | -0.274 | -0.284 | -0.297* | -0.300* | -0.319* | -0.224 |
| | (0.123) | (0.160) | (0.102) | (0.113) | (0.113) | (0.101) | (0.086) | (0.081) | (0.065) | (0.197) |
| ED | -0.122* | -0.109 | -0.115* | -0.096 | -0.075 | -0.063 | -0.085 | -0.014 | -0.125* | -0.033 |
| | (0.072) | (0.108) | (0.090) | (0.157) | (0.278) | (0.360) | (0.215) | (0.842) | (0.064) | (0.631) |
| MI | 0.018 | 0.015 | 0.002 | -0.003 | 0.008 | 0.035 | 0.027 | 0.010 | 0.003 | 0.032 |
| | (0.767) | (0.798) | (0.977) | (0.960) | (0.894) | (0.561) | (0.661) | (0.873) | (0.955) | (0.591) |
| HR | 0.012 | 0.022 | 0.030 | 0.056 | 0.076 | 0.051 | 0.022 | 0.156 | 0.001 | 0.131 |
| | (0.937) | (0.884) | (0.842) | (0.713) | (0.617) | (0.737) | (0.884) | (0.309) | (0.993) | (0.392) |
| Log-l | -1090.99 | -1089.28 | -1096.56 | -1085.76 | -1092.01 | -1088.84 | -1094.11 | -1081.49 | -1098.87 | -1079.41 |
| LR | 58.35 | 61.77 | 47.21 | 68.81 | 56.31 | 62.66 | 52.11 | 77.36 | 42.6 | 81.51 |

Note: P-values are in parentheses. *** means significant at the 1% level, ** means significant at the 5% level, and * means significant at the 10% level

| variable | Aging attitude | | | | | | | |
|----------------|--|--------------------------|-----------------------------------|--|--|--|--|--|
| | Principal component analysis (1) | Entropy method (2) | Replac- ing variable (3) | | | | | |
| DL | -0.570*** | -0.642*** | - | | | | | |
| | (0.000) | (0.000) | 0.525*** (0.000) | | | | | |
| AG | 0.151*** | 0.148** | 0.133** | | | | | |
| | (0.009) | (0.011) | (0.028) | | | | | |
| GE | -0.297** | -0.292** | -0.268* | | | | | |
| | (0.027) | (0.029) | (0.053) | | | | | |
| MA | -0.227 | -0.220 | -0.168 | | | | | |
| | (0.191) | (0.205) | (0.344) | | | | | |
| ED | -0.031 | -0.037 | 0.191*** | | | | | |
| | (0.660) | (0.593) | (0.008) | | | | | |
| MI | 0.030 | 0.030 | -0.099 | | | | | |
| | (0.622) | (0.615) | (0.111) | | | | | |
| HR | 0.128 | 0.129 | -0.123 | | | | | |
| | (0.400) | (0.397) | (0.432) | | | | | |
| Log likelihood | -1078.00 | -1079.30 | -950.36 | | | | | |
| LR | 80.34 | 81.74 | 53.30 | | | | | |

 Table 4
 Regression results of robustness test

improvement of digital cognition and skills can effectively alleviate the elderly's pessimistic aging attitude. The research conclusion of Charness [28] and Wu et al. [29] also confirm this view. However, the digital security indicator is not significant, mainly because digital security reflects the elderly's prevention awareness of information leakage and economic fraud during the use of digital tools. Digital security has more impact on the consumption behavior, and has little impact on the elderly's digital social networking, digital entertainment and other activities, so the impact on aging attitude is not significant.

From the perspective of control variables, the impact of age on aging attitude is significantly positive, indicating that with the increase of age, the pessimistic aging attitude of the elderly is more serious. This is mainly because with the increase of age, the elderly's behavioral ability, cognitive function and social participation decline, so the aging attitude becomes more pessimistic. The impact of gender on aging attitude is significantly negative, indicating that the aging attitude of female elderly is more negative. This may be due to the fact that elderly women are more sensitive to changes in physical appearance and cognitive function, and are more likely to have bad emotions such as low self-esteem and depression, which will affect their aging attitude.

Robustness test

In order to enhance the robustness of the conclusion, this paper adopts the following three methods for testing.

Replacing the explained variable. In this paper, the question "As I get older, I feel that life has no direction" is used as a measure of aging attitude, and its mean, median

Table 5 Regression results of endogeneity test

| Variable | Stage one (D literacy) | igital | The second stage (aging attitude) | | |
|-----------------------------|---------------------------|--------|--------------------------------------|----------------|--|
| | Coefficient Pvalue | | Coefficient | <i>P</i> value | |
| Digital literacy | | | -0.504 | 0.010 | |
| Network access 0.578 0.000 | | | | | |
| Control variable Controlled | | | Controlled | | |
| Wald F 55.26 | | | 55.26 | | |
| Anderson LM | 51.85 | | 51.85 | | |
| Sargan | 0.331 | | | | |
| Hausman | P=0.023 | | | | |

and Standard deviation values are 2.01, 2 and 0.87 respectively, which indicates that there is no deviation value. As shown in Table 4 (3), the effect of digital literacy on aging attitude is still significantly negative.

Adjusting the weight. In this paper, the equal weight method is adopted to measure digital literacy in benchmark regression. Considering the subjectivity of equal weight method, we further adopt the entropy method to measure digital literacy. As shown in Table 4 (2), the regression coefficient is still significantly negative.

Principal component analysis. In order to reduce the correlation between digital literacy indicators, we further uses the principal component analysis method to assign weights to indicators. As shown in Table 4 (1), the regression coefficient is still significantly negative.

The above robustness test results are consistent and significantly negative, indicating that digital literacy has a certain negative impact on aging attitudes, and the benchmark regression results have strong robustness.

Endogeneity test

Although the benchmark regression in this paper controls the individual characteristics of the elderly, there are still unobserved missing variables. Considering that there may be a certain reverse causal relationship between the digital literacy and the aging attitude, the model may have endogeneity problems. Based on the reason, combined with the availability of questionnaire data, this paper selects "network access", that is, whether the house where the elderly live has network signals, as an instrumental variable [30]. On the one hand, whether the house has network signals reflects the basis of the digital life, which can directly reflect the digital literacy level of the elderly. On the other hand, whether the house has Internet signal does not directly affect the aging attitude of the elderly. Table 5 shows the hausman test and the regression results for the instrumental variables. The Pvalue of hausman test is 0.023, indicating the rejection of the null hypothesis and the existence of endogeneity problems. When other variables are controlled, the influence of digital literacy on aging attitude is still significant, with a coefficient of -0.504. At the same time, the underidentified null hypothesis and the null hypothesis of weak instrumental variables are rejected, indicating that the benchmark regression results are reliable, and digital literacy has an inhibitory effect on aging attitude.

Influence mechanism analysis

In order to further clarify the influence mechanism of digital literacy on aging attitude, this paper, from the perspectives of enhancement effect and empowerment effect, takes autonomous ability and adaptability as mediator variables respectively to represent self-efficacy, and discusses the influence path of digital literacy on aging attitude. The results are shown in Table 6.

In Table 6, the mediating effects of autonomous ability and adaptability on aging attitude are both significantly negative, and hypothesis 2 is verified through significance test. From the perspective of empowerment effect, when the autonomous ability of the elderly increases by 1%, the incidence rate of at least one level of reduction in aging attitude increases by 65.37%, indicating that the autonomous ability greatly affects the behavioral choices and emotional experiences of the elderly in the life process. Therefore, the improvement of digital literacy can effectively reduce the dependence of the elderly on family and society. The elderly can choose different types of elderly care services and activities by themselves, which can meet the needs of the elderly for self-esteem and independence, and restrain the negative aging attitude. From the perspective of enhancement effect, when the adaptability of the elderly increased by 1%, the incidence of aging attitude decreased by at least one level increased by 76.82%. This is mainly because the improvement of digital literacy means the improvement of the elderly's

Table 6 Regression results of mediating effect

ability to participate in the digital society and use digital products, which not only eliminates the gap between the elderly and the digital society, but also is conducive to the elderly to choose diversified contents and forms of elderly care services. Digital literacy can effectively meet the subjective initiative and social value needs of the elderly, and improve aging attitude, which is consistent with the research conclusion of Hasan [31] and Castilla [32].

Heterogeneity analysis

The above research results show that digital literacy can significantly inhibit aging attitudes. However, differences in individual characteristics, social characteristics and regional characteristics may directly affect the digital literacy level of the elderly, resulting in certain heterogeneity in aging attitudes of different elderly groups. Therefore, considering the particularity of the elderly group, this paper carries out heterogeneity analysis from three aspects of urban and rural attributes, income categories, age and gender.distribution. Among them, we classify the elderly with a monthly income of less than 3,000 as the low income group and sample size is 412, and those with a monthly income of more than 3,000 as the high income group and sample size is 400. Those under 75 years old are classified as the low age group and sample size is 455, and those over 75 years old are classified as the high age group and sample size is 357. Rural sample size is 388 and urban sample size is 424. Female sample size is 379 and male sample size is 433. The results are shown in Table 7.

In Table 7, under different samples of elderly people, the influence of digital literacy on aging attitude is significantly negative, which further proves that the influence of digital literacy on aging attitude is stable.

| Variable | AB | AT | AT | AA | AT | AT |
|----------|----------|-----------|-----------|----------|-----------|-----------|
| AA | | | | | -0.550*** | -0.503*** |
| | | | | | (0.000) | (0.000) |
| AB | | -0.643*** | -0.570*** | | | |
| | | (0.000) | (0.000) | | | |
| DL | 0.527*** | | -0.491*** | 0.728*** | | -0.568*** |
| | (0.000) | | (0.000) | (0.000) | | (0.000) |
| AG | 0.083 | 0.207*** | 0.133** | -0.126** | 0.280*** | 0.185*** |
| | (0.168) | (0.000) | (0.023) | (0.034) | (0.000) | (0.002) |
| GE | 0.224 | -0.280** | -0.260* | 0.212 | -0.285** | -0.261* |
| | (0.105) | (0.038) | (0.054) | (0.119) | (0.034) | (0.053) |
| MA | -0.242 | -0.207 | -0.143 | 0.272 | -0.347** | -0.258 |
| | (0.170) | (0.235) | (0.415) | (0.115) | (0.045) | (0.140) |
| ED | -0.027 | -0.121* | -0.052 | -0.097 | -0.109 | -0.028 |
| | (0.709) | (0.076) | (0.460) | (0.173) | (0.109) | (0.689) |
| MI | 0.075 | 0.016 | 0.035 | 0.022 | 0.024 | 0.047 |
| | (0.219) | (0.796) | (0.566) | (0.717) | (0.689) | (0.439) |
| HR | -0.238 | 0.052 | 0.144 | -0.038 | -0.055 | 0.066 |
| | (0.133) | (0.731) | (0.349) | (0.807) | (0.715) | (0.667) |
| Log-l | -934.19 | -1063.34 | -1052.54 | -994.76 | -1074.10 | -1059.26 |
| LR | 34.4 | 113.65 | 135.26 | 84.04 | 92.13 | 121.81 |

| Variable | Aging attitudes | | | | | | | | | | |
|----------|-----------------|-----------|------------|-------------|-----------|-----------|--------------|---------|--|--|--|
| | Rural | Urban | Low income | High income | Low age | High age | Male | Female | | | |
| DL | -0.459*** | -0.791*** | -0.471*** | -0.805*** | -0.878*** | -0.457*** | -0.690*** | -0.582* | | | |
| | (0.004) | (0.000) | (0.003) | (0.000) | (0.000) | (0.002) | (0.000) | (0.000) | | | |
| AG | 0.252*** | 0.093 | 0.178** | 0.122 | | | 0.136* | 0.178* | | | |
| | (0.004) | (0.236) | (0.039) | (0.131) | | | (0.085) | (0.042) | | | |
| MI | -0.015 | 0.096 | | | 0.072 | 0.017 | 0.095(0.236) | -0.042 | | | |
| | (0.860) | (0.272) | | | (0.385) | (0.842) | | (0.655) | | | |
| HR | | | -0.020 | 0.296 | 0.183 | 0.141 | -0.167 | 0.486** | | | |
| | | | (0.922) | (0.201) | (0.366) | (0.545) | (0.428) | (0.031) | | | |
| GE | -0.081 | -0.487*** | -0.407** | -0.165 | -0.264 | -0.276 | | | | | |
| | (0.680) | (0.009) | (0.031) | (0.394) | (0.139) | (0.177) | | | | | |
| MA | -0.592** | 0.095 | -0.532** | 0.159 | -0.177 | -0.322 | -0.252 | -0.165 | | | |
| | (0.019) | (0.696) | (0.022) | (0.555) | (0.527) | (0.145) | (0.328) | (0.494) | | | |
| ED | -0.026 | -0.044 | 0.016 | -0.063 | 0.069 | -0.135 | 0.041 | -0.121 | | | |
| | (0.827) | (0.613) | (0.893) | (0.464) | (0.463) | (0.198) | (0.654) | (0.269) | | | |
| Log-l | -513.03 | -560.87 | -554.13 | -517.43 | -576.72 | -499.93 | -557.62 | -516.33 | | | |
| LR | 37.53 | 54.63 | 39.49 | 51.21 | 40.16 | 23.19 | 41.79 | 40.40 | | | |

 Table 7
 Regression results of heterogeneity analysis

From the perspective of urban and rural attributes, the digital literacy of the urban elderly has a greater impact on aging attitude, mainly because in urban, elderly care, medical care, shopping, entertainment and other activities are more dependent on digital platforms, and the forms and products of elderly care services are mostly online services or online consumption. The improvement of digital literacy can effectively increase the adaptability and autonomous ability of the elderly and inhibit negative attitudes. The life of the elderly in rural areas is mainly based on mutual assistance in farming, chatting, playing cards, and family care and so on, and less dependent on digital tools. Moreover, the rural digital infrastructure is relatively imperfect, which also reduces the dependence of the elderly on digital products, so the impact is relatively small.

From the perspective of income level, the digital literacy of high-income elderly people has a greater impact on the aging attitude, which may be due to the fact that high-income elderly people have higher requirements for the form and content of elderly care services, and pay more attention to the integration of digital technology and elderly care services. And the improvement of digital literacy of elderly people is conducive to the elderly to seek and use different levels of elderly care services. For low-income elderly people, digital economic activities have a certain economic threshold, and the lack of economic sources limits the elderly's use and dependence on digital products, so aging attitudes of the elderly are less affected by digital literacy.

From the perspective of age, the digital literacy of the younger elderly has a greater impact on the aging attitude, which is consistent with the research results of Győrffy et al. [33]. This is mainly due to the decline of physical function, cognitive ability and adaptive ability

with the aging of the elderly, which seriously hinders the elderly's use of digital products and digital services. Older people's needs are more health care and less dependent on digital life, so the older the age is, the smaller the effect of digital literacy on aging attitudes is.

From the perspective of gender, the digital literacy of elderly men has a greater impact on their aging attitudes. This might be because elderly men attach more importance to the use of digital products than elderly women, and the proficiency of digital skills directly affects the self-efficacy of the elderly. Furthermore, for elderly Chinese women, most of their time is spent taking care of grandchildren and managing family affairs, and their exposure to digital products is relatively low. Therefore, their digital literacy has a relatively small impact on their attitudes towards aging, which is consistent with the research conclusion of Getenet S et al. [34].

Conclusion and suggestion

Based on the social cognition theory, this paper analyzes the influence mechanism of digital literacy on aging attitudes using the social survey data of the elderly in 2023. The results show that the improvement of digital literacy can significantly inhibit the aging attitude of the elderly, indicating that the improvement of the digital cognition and digital skill of the elderly will significantly increase the opportunities to participate in digital activities, and help the elderly to build and share the economic achievements of the digital society. The mechanism analysis finds that the digital literacy has enhancement effect and empowerment effect on ageing attitudes, and can significantly strengthen the self-efficacy of the elderly and inhibit the negative aging attitude. In addition, in rural, low-income the elderly have a low dependence on digital literacy, indicating that due to the difficulties of digital resources and digital education, elderly people can obtain limited digital social benefits. According to the research conclusions, we put forward some suggestions.

Firstly, digital literacy education should be fully popularized to enhance the ability of the elderly to participate in digital society. The government should form a digital education network with the participation of multiple subjects such as society, community and family, and guide the elderly to participate in digital activities from the aspects of digital participation consciousness, participation forms and participation paths according to the needs of the elderly. Multiple subjects can improve the ability of the elderly to participate in digital activities by holding digital life lectures for the elderly, carrying out smart phone teaching courses, and popularizing digital security knowledge. In terms of educational content, we should pay attention to education in digital consumption, digital privacy, digital fraud and other aspects, and the elderly should be encouraged to actively participate in digital consumption, digital health care, digital entertainment and other activities.

Secondly, the government should optimize the balance and accessibility of digital resources and eliminate digital inequality among the elderly. The government should vigorously promote the sinking of digital resources, improve the coverage of internet resources and products, and ensure that vulnerable groups such as rural, lowincome and aging people can easily use digital products and services. For poor elderly groups, the government should increases subsidies for the construction of internet resources, reduce the cost of using digital products and services, and encourage the elderly to participate in digital activities and digital economy.

Thirdly, the government should introduce security standards, access standards and use standards for digital products, optimize the digital economic environment, eliminate digital security issues, and improve the coverage of digital economy. And elderly service enterprises should lower barrier for the elderly to use digital products, develop and design entertainment products or service content suitable for the elderly, and stimulate the enthusiasm of the elderly to participate in the digital economy. The government can establish an online mutual assistance platform for the elderly, weaken the digital inferiority, increase the digital life experience through mutual assistance.

Limitations

Although this paper conducts a comprehensive measurement of multiple aspects of digital literacy, it does not conduct a confirmatory factor analysis of different dimensions of digital literacy, and the measurement methods of digital literacy are relatively single. In terms of empirical analysis, considering the causal relationship between health condition and aging attitude, health condition is not included as a control variable. Further research on the relationship between health and aging attitude will be conducted in the future. In addition, this paper mainly conducts research from the perspective of the elderly's self-efficacy, so it did not study the differences in child support. Subsequent studies will focus on intergenerational support and child support.

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Author contributions

Xd D and Lj W participated in the design and conceptualization of the study. Lj W and Xd D reviewed literature. Xd D analyzed the data and interpreted the statistical results. Xd D drafted the manuscript. Lj W were involved in revising the manuscript critically. All of the authors have read, revised and approved the final manuscript.

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Data availability

The datasets used and/or analyzed in this study belong to our research team, and data does not involve any personal privacy information. The datasets are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The ethics approval for this study was given by the medical ethics committee of Health Science Center of Xi'an Jiaotong University (approval number 2018–1200). Participation in this study was voluntary, and informed consent was obtained digitally. By completing and submitting the survey, participants acknowledged that they had read the study information provided and consented to participate. No identifying information was collected to ensure participant anonymity and confidentiality. The paper data is in compliance with the Helsinki Declaration.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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