

The Effects of the Internet on Well-being Among Older Adults Ageing in Place:

The Roles of Subjective Income and Social Trust

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ABSTRACT: The rapid construction of electronic infrastructure in China has accelerated and promoted the application of the Internet, which improves the quality of life of older adults especially when they choose to age in place. However, it remains unclear how the Internet impacts the well-being of older adults, particularly in China. Based on China Family Panel Studies over the four periods of 2014, 2016, 2018, and 2020, panel models and mediation analysis were employed to explore the effects of two dimensions of the Internet, including internet perceptions (perceived importance of the Internet for information retrieval) and internet use, on the well-being of older adults in China. The results showed that (1) the internet perceptions of older adults significantly and positively predicted their subjective well-being; (2) the higher levels of older adults' internet perceptions were related to the higher degrees of their subjective income and social trust, which in turn promoted their subjective well-being; (3) older adults' internet use significantly improved their subjective well-being; (4) older netizens with lower levels of subjective income tended to have higher levels of subjective well-being, while social trust did not play a mediating role in the association between internet use and subjective well-being among China's older adults. The internet perceptions and internet use of older adults exhibited consistent positive effects on their well-being, but there are differences in their mediating mechanisms. Therefore, it is necessary to transform digital services into more age-friendly modules and optimise the internet environment for older adults.

KEYWORDS: subjective well-being, internet perceptions, internet use, subjective income, social trust.

Introduction

The ageing population is surging in China, and older adults' well-being deserves attention (Heo et al. 2015: 268; Hofer et al. 2019: 4426; Ollevier et al. 2020: 2). Internet construction has greatly improved in China, and this has influenced the lives of elderly people (Arthanat, Chang, and Wilcox 2020: 74; Li, Han, and Hu 2022: 910). However, the effects of the Internet on the well-being of older adults remain unclear. A number of studies have focused on the mixed impacts of internet use on the well-being of older adults

(Choi and DiNitto 2013: 2-3; Hong and Cho 2017: 856-7; Hunsaker and Hargittai 2018: 3937-8; Khalaila and Vitman-Schorr 2018: 479-80; Hofer et al. 2019: 4427-8; Duplaga 2021: 2). Nevertheless, the effects of the internet environment on older adults have been ignored in previous literature. Immersed in the circumstances of the Internet of Things (IoT) and widespread internet education in China, older adults are beginning to perceive the importance of internet use (Chattaraman, Kwon, and Gilbert 2012: 2; Li et al. 2016: 343-4; Arthanat 2021: 472).

Older adults in China prefer ageing in place (AIP), defined as “the ability to live in one’s own home or community safely, independently, and comfortably.”¹ Information technologies enable healthy older adults to age in place (Arthanat, Chang, and Wilcox 2020: 74; Ollevier et al. 2020: 2). The smart home environment brought about by the Internet represented by 5G networks is bound to bring many benefits to older adults at home (Arthanat, Chang, and Wilcox 2020: 74-5). Users can control smart home systems through smartphone applications, remote controls, or even voice interactions based on speech recognition technology (Choi, Thompson, and Demiris 2021: 16). These technical tools can make life easier for older adults. For example, voice commands allow older people to manipulate switches for doors, lights, and windows in smart homes (Arthanat 2021: 472). In addition, the detection of seniors’ activity data by smart home systems can identify and infer possible health events and enable timely interventions (Choi, Thompson, and Demiris 2021: 16). Despite the rapid development of the IoT, issues remain regarding the use and perceptions of these technologies by older adults. Up to now, few empirical studies have focused on the effects of internet environments on the well-being of older adults, especially in China, where the government is building strong cyberpower.

The digital divide refers to the gap between people who have access to the Internet and those who lack it (Friemel and Signer 2010: 145-6). Previous studies have generally used the indicator “internet use by older adults” as a criterium for bridging the digital divide (Hunsaker and Hargittai 2018: 3938, 3941-2; Aggarwal, Xiong, and Schroeder-Butterfill 2020: 2-4). However, older non-netizens may also have higher perceptions of the importance of the Internet in an evolving internet environment (Ollevier et al. 2020: 2). To what extent, in terms of internet perception or internet use, will the Internet contribute to older adults’ well-being? This identifies a gap in the literature, particularly given the prevalence of computer and mobile phone illiteracy among China’s older adults (Zhang 2022: 3). This study attempts to focus on two dimensions, including internet use and internet perceptions (i.e., the perceived importance of the Internet for information retrieval), in relation to well-being among China’s older adults. In order to clarify the impacts of the internet environment on older adults, we also explore the mediating role of subjective income and social trust in the aforementioned relations.

Literature reviews and theoretical hypothesis

Older adults’ internet perceptions and internet use

In the digital age, the Internet permeates all aspects of older adults’ lives (Aggarwal, Xiong, and Schroeder-Butterfill 2020: 1; Arthanat, Chang, and Wilcox 2020: 74). Older adults may perceive the importance of the Internet in their daily home life in internet-related environments, including video calls to their relatives or friends with the help of their children, voice recognition to regulate their smart home automation, wearing smart watches to test real-time heart rate, and emergency calls for help (Arthanat 2021: 472). In public places, older people enjoy public services from technology, including smart temperature measurement, electronic government, health care systems, and potentially driverless cars (Li, Han, and Hu 2022: 910-1). Little empirical evidence supports the impact of the network-building environment on older adults’ perceptions of the Internet. Real-

world data was utilised in this study to explore the effect of internet environments on older people’s lives.

Irrespective of whether older adults use the Internet in person or not, they can clearly perceive the impact of digital networks on their real life (Arthanat 2021: 472). In this case, older adults’ perceptions of the Internet become an important variable to measure their access to the Internet (Hunsaker and Hargittai 2018: 3945). Internet perceptions refer to the extent to which individuals perceive the importance of internet use (Wang et al. 2022: 3; Wu et al. 2023: 2). Perceptions do not always equal reality and even depend on social contexts (Chartrand, Maddux, and Lakin 2005: 334-5). In this vein, internet perceptions do not always equal internet use (Heimrath and Goulding 2001: 126; Žilionis 2008: 47). Digital disparities may create individual variations in internet perception in different regions. For instance, in areas with well-developed online networks, older adults can perceive the benefits brought by the Internet regardless of their autonomy of use (Arthanat 2021: 74-5; Choi, Thompson, and Demiris 2021: 16).

Unlike internet perceptions primarily determined by the technological environment, Internet use among older adults mainly depends on demographic characteristics, and specifically, older people with urban household, higher incomes, higher education levels, lower age, and married status are more likely to use the Internet (Helsper 2010: 353; Hong and Cho 2017: 858; Hunsaker and Hargittai 2018: 3942). We found empirical evidence supporting the structural differences between internet perceptions and use among China’s older people. For example, rural older elderly (more than 75 years old) showed very weak or even no association between their internet perceptions and use (Evans 1996: 453).

Internet perceptions and well-being among older adults

Past research regarding the impact of older adults’ internet perceptions on well-being is still ambiguous. In particular, the gradual improvement of internet-related infrastructure in China has led to the integration of internet elements into the real environment around seniors (Gnangnon 2019: 346-7). It is necessary to examine the effects of older adults’ internet perceptions on their well-being in the context of a progressively improving internet environment in China. Technology brings convenience specifically, with digital assistants recognising the language of elderly owners for smart home operations such as switching lights on and off (Arthanat, Chang, and Wilcox 2020: 74-5). Internet-related tools such as smart wheelchairs, floor sweepers, and hearing aids can transform the instrumental activities of daily living (IADL) of ageing adults (Smrke, Plohl, and Imlakar 2022: 2). With the help of family and friends, seniors can watch internet TV, find health information, and talk to friends and family through the Internet (Ollevier et al. 2020: 2). Feeling the convenience brought by the Internet, the subjective well-being of older adults is likely to be enhanced. Given that, we developed the following hypothesis:

H1: The internet perceptions of older adults positively predict their subjective well-being.

Internet perceptions as a psychological variable may influence individuals’ judgments such as subjective income (Žilionis 2008: 49).

1. Center of Disease Control and Prevention, “Healthy Places Terminology,” 2009, <http://www.cdc.gov/healthyplaces/terminology.htm> (accessed on 9 August 2023).

Subjective income refers to individuals' self-assessment of their economic well-being (Cialani and Mortazavi 2020: 2). When older adults enjoy the benefits brought by the Internet, they may improve their socioeconomic status (Yoon et al. 2020: 106-7). Subjective income is an important dimension to measure social class, and may be positively correlated to perceived advantages from the Internet. Social comparison theory states that when individuals experience more upward social comparison, their sense of relative deprivation will increase (Pan and Zhao 2023: 3). For instance, people who score high in relative deprivation always compare themselves with reference targets judged to be better than themselves (e.g., by having more wealth or material goods), and in this context, they report lower degrees of income relative to their surrounding groups (Jestl, Moser, and Raggl 2022: 213). Relative deprivation is a form of social inequality, and is considered a negative determinant of well-being (Osborne and Sibley 2013: 997). Older people's feeling of relative deprivation may decrease if perceiving benefits from the Internet such as reduced information asymmetry, rather than blindly comparing themselves with surrounding groups in the physical environment (Helsper 2017: 223-4; Burraston, McCutcheon, and Watts 2018: 544). In addition, older adults with a stronger perception of the Internet may show a higher socioeconomic status, including higher levels of income and education, and have a superior living environment with more technological elements (Wu et al. 2023: 2). In this vein, older people with higher levels of internet perception are likely to report higher subjective income relative to the digitally disadvantaged group (Helsper 2017: 223). It has been confirmed that subjective income is a strong predictor of subjective well-being (Zhu et al. 2020: 4). Based on this, we hypothesise that:

H1a: The internet perceptions of older adults improve their subjective income, which in turn increases their subjective well-being.

Social trust, as an important social capital of social network building (Putnam 2000: 7-9; Zhu et al. 2020: 4-5), can measure the social climate of mutual trust and is likely to be predicted by internet perceptions. According to the cognitive appraisal theory, emotions originate from stimuli and are influenced by environmental events and cognitive processes (Folkman and Lazarus 1985: 152). Emotions are the product of interactions between humans and environments, leading to psychological and behavioural changes (Smith and Lazarus 1990: 614-6). People make responses when stimulated by the environment, and individuals' evaluations of things affect their emotions and behaviour toward these items (ibid.; Claffey and Brady 2019: 1061). Internet perception is a common perception in the internet age, and the Internet has significant impact on the lives of older adults, such as expanding their sociability (Wu et al. 2023: 2). Based on the cognitive appraisal theory, older people who have positive perceptions of the Internet are more likely to exhibit positive emotions and friendly behaviours toward others, which can increase their social trust and even subjective well-being (Gu, Kalibatseva, and Song 2021: 1021; Vuong et al. 2022: 1-2). The social circle of the elderly is expanding in the digital era, partly due to the expansion of social networks from online social media (Khalaila and Vitman-Schorr 2018: 487; Nam 2021: 4590-1). Previous studies point out

that higher levels of social capital are positively associated with subjective well-being, and social trust is viewed as a proxy for social capital (Yip et al. 2007: 36; Xu, Zhang, and Huang 2023: 2). Older people with higher levels of social trust may show higher degrees of subjective well-being (Zhu et al. 2020: 4). Social trust may mediate the relations between the perceived importance of internet use and subjective well-being among older adults. We attempted to utilise empirical evidence to test this claim. Given that, we developed the following hypothesis:

H1b: The internet perceptions of older adults enhance their social trust, which in turn promotes their subjective well-being.

Internet use and well-being among older adults

There is still controversy regarding the relation between autonomous internet use and well-being among older adults. Using timely communication technologies, older adults report higher levels of subjective well-being by contacting their friends, relatives, and children who are away from home (Silva, Delerue Matos, and Martinez-Pecino 2018: 694-5; Ang, Lim, and Malhotra 2021: 694-5). When experiencing social inequalities, older adults can access timely social support by using the Internet (Heo et al. 2015: 268; Nam 2021: 4591). Older adults at home can adopt smart devices to access health information, as seen especially during the Covid-19 epidemic, and they tend to report more beneficial health-related outcomes (Tavares 2020: 1-2). In this study, the sample was drawn from the whole of China for observing an increase in subjective well-being from older adults who have crossed "the first digital divide" (i.e., whether or not to use the Internet, Friemel and Signer 2010: 144). Based on this, we developed the following hypothesis:

H2: Internet use among older adults positively predicts their subjective well-being.

As a digitally disadvantaged group, rural internet users have higher subjective income than internet non-users (Ma et al. 2020: 504). Similarly, we hypothesised that older non-netizens may report lower levels of subjective income, while the internet use of older adults can increase their subjective income. However, the Internet tends to display successful people, with whom upward social comparison by older internet users is detrimental to the subjective income of the latter (Schmuck et al. 2019: 2-3). The association between internet use and the subjective income of older people remains unclear in the existing theoretical knowledge. The preponderance of evidence indicates that internet use can enhance well-being in older adults (Heo et al. 2015: 268). Also, studies have shown the positive effects of subjective income on health-related outcomes (Tibesigwa, Visser, and Hodkinson 2016: 364; Zhu et al. 2020: 4). In this context, we empirically explored the possible mediation mechanism of subjective income in the relationship between internet use and well-being among older adults. The following hypothesis was developed:

H2a: Subjective income mediates the relationship between internet use and subjective well-being among older adults.

Internet use by older adults can expand their social networks, giving them more opportunities, space, and time for social trust

building (Cho 2014: 2813). Developed by internet use, expanded confidant networks (Silva, Delerue Matos, and Martinez-Pecino 2018: 695), perceived social support (Nam 2021: 4591), and increased social involvement (Liu, Pan, and Wu 2020: 2) are likely to promote older netizens' social trust and subjective well-being. Research also suggests the positive effects of social trust on well-being, especially for the older group (Nygqvist et al. 2013: 396). However, some studies have found inconsistent results that internet use significantly reduces the amount of time devoted to face-to-face contact with users' family members and confidants (Sabatini and Sarracino 2017: 457). Internet use displaces face-to-face communication with weaker online ties (Khalaila and Vitman-Schorr 2018: 480). Older netizens are exposed to more strangers and expand their social circle through the Internet, which possibly leads to decreased levels of social trust (ibid.: 488; Zheng, Wang, and Zhang 2023: 270). Controversy remains regarding the relationship between internet use, social trust, and subjective well-being, while social trust may mediate this positive association. For these reasons, we developed the following hypothesis:

H2b: Social trust plays a mediating role in the association between internet use and subjective well-being among older adults.

As perceptions are not equivalent to behaviours, the higher internet perceptions of older adults do not necessarily induce behaviour on the Internet (Žilionis 2008: 47-8; Chattaraman, Kwon, and Gilbert 2012: 2). This study examined two dimensions of internet savviness: namely, internet perceptions and internet use, and their effects on subjective well-being. We tested the correlation between internet perceptions and use among older people and its potential demographic differences. Baseline panel models were developed to investigate the direct effects of the Internet on subjective well-being among older adults. The exploration of mediating mechanisms of subjective income and social trust may help us to better understand the aforementioned relationships. To ensure reliable results, we conducted a robustness test with the substitution of the dependent variable for depressive symptoms. The framework of this study can be summarised in Figure 1.

Sociodemographic characteristics among older adults may affect their subjective well-being. As older adults' age increases, they may develop lower levels of subjective well-being (Lu, Kao, and Hsieh 2010: 627). Older people with partners report higher degrees of life satisfaction (Chipperfield and Havens 2001: 177). Agricultural rather than non-agricultural older adults report higher degrees of depressive symptoms, possibly due to sharp socioeconomic disparities, health systems, and social welfare (Li et al. 2016: 342-3). Education level among older adults may promote their life satisfaction (Zhou 2018: 27-8). There may be gender differences in health-related outcomes among older adults (Chipperfield and Havens 2001: 177). Income level may be a positive predictor of well-being in older people (Cialani and Mortazavi 2020: 2).

To ensure the robustness of the results, this study utilised depressive symptoms as an alternative variable with subjective well-being to measure health-related outcomes of older people ageing in place. Studies have found the association between internet adoption and depressive symptoms among Chinese older adults (Jing et al. 2023: 2). Subjective well-being was negatively correlated with depressive symptoms (Soósová et al. 2021: 708-9), and the two variables can accurately measure the health status of older people at home, particularly mental health (Chen and Zhang 2022: 1-2).

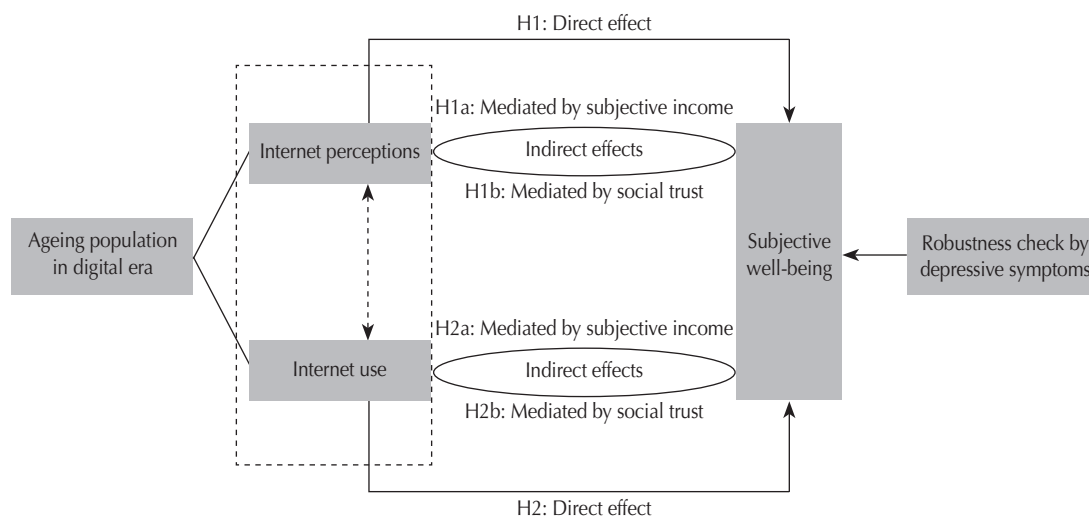
The present study used longitudinal data from 2014 to 2020 to explore the impact of older adults' internet perceptions and use on their subjective well-being and the possible mediation effects of subjective income and social trust on the aforementioned association (Figure 1). Older adults' internet perceptions reflect their levels of adaptation to internet environments such as the smart home, which is beneficial for their AIP. This study is able to provide theoretical references and empirical support for AIP.

Methodology

Data

This paper utilised data from China Family Panel Studies (CFPS) across the four periods of 2014, 2016, 2018, and 2020. The Institute of Social Science Survey, Peking University, implements and releases

Figure 1. Research frame



Credit: author.

the CFPS, a longitudinal survey with two years per wave. Older adults aged above 60 were screened as the sample to participate in the current study. After removing missing values, we obtained four waves of 7,852 observations as Panel A and three waves of 8,013 observations as Panel B. The descriptive statistics of both panels are shown in Table 1.

Variables

(1) Dependent variables

Subjective well-being was measured by three items, including “How happy do you feel,” “How satisfied are you with your life,” and “How do you feel about your health” from the CFPS across the four periods of 2014, 2016, 2018, and 2020. A 10-point Likert scale was used to respond to the question about happiness, and items related to satisfaction with life and self-reported health were answered using a 5-point Likert. Health-related item scores were reverse scored. The sum of the three items was calculated to characterise subjective well-being. Higher scores mean higher degrees of subjective well-being among older adults.

Depressive symptoms were measured by the 8-item Centre for Epidemiological Studies Depression Scale (CES-D-8, Briggs et al. 2018: 124) from the CFPS across the three periods of 2016, 2018, and 2020. The 2016 wave of CFPS began collecting the CES-D-8 by asking respondents how often various feelings or behaviours have occurred in the past week ranging from 1: “rarely or none of the time, <1 day,” 2: “some or a little of the time, 1-2 days,” 3: “occasionally or a moderate amount of time, 3-4 days,” and 4: “most or all of the time, 5-7 days,” and the value range was 8 to 32. The items “I was happy” and “I enjoyed life” were reverse scored. Higher scores indicate greater depressive symptoms among older adults.

(2) Independent variables

Internet use was obtained from responses to the CFPS questions “Whether you use the Internet,” “Whether you use a mobile device to surf the Internet,” and “Whether you use the computer to surf the Internet,” and was recoded as “1: yes” and “0: no.” The data of CFPS across the three periods of 2016, 2018, and 2020 were measured separately for mobile device internet use and computer internet use, and the value was set to 1 whenever one of the situations was met.

Internet perceptions were obtained from responses to the CFPS question “How important is the Internet to your access to information” by referring to Wang et al. (2022). The question was scored on a 5-point Likert scale, with higher scores indicating older adults’ perceived greater importance of the Internet.

(3) Mediating variables

Subjective income was obtained from responses to the CFPS question “Your income related to other locals” and was rated on a 5-point Likert scale ranging from 1: “very low” to 5: “very high.” The higher scores indicate older adults’ higher relative income.

Social trust was measured by the two items “Trust in neighbours” and “Trust in strangers” from the CFPS. Trust in neighbours and strangers represents particularised trust and generalised trust, respectively, both of which constitute social trust (Putnam 2000:

7-10; Alesina and La Ferrara 2002: 209-10; Zheng, Wang, and Zhang 2023: 271-2). The items were rated on a 10-point Likert scale ranging from 1: “very distrusted” to 10: “very trusted.” The principal component analysis was utilised to extract the first common factor as the measurement of social trust with the variance contributions as 58.3% in the 2014 wave, 58.1% in the 2016 wave, 57.4% in the 2018 wave, and 57.1% in the 2020 wave. Higher scores indicate higher degrees of social trust among older adults.

(4) Control variables

Demographic variables included **age**; **hukou** 户口 recoded as 1: “agricultural household,” 0: “non-agricultural household”; **marital status** recoded as 1: “married,” 0: “other”; **gender** recorded as 1: “male,” 0: “female”; and **education** with higher scores representing higher levels of education. The above numerical variables were normalised separately according to each wave of the CFPS. **Income** was chosen as individuals’ current year household income, with its unit as RMB per year and the source as household finance dataset of CFPS. The logarithm of objective income was calculated to input the regression equations.

Modelling

We used panel models with fixed or random effects and panel data across four periods. Relative to cross-sectional data applied to similar studies, the panel data can mitigate omitted variable bias, improve the accuracy of estimation, and capture dynamic information. Additionally, robust standard errors were estimated to solve the potential heteroscedasticity problem. The baseline models were set as follows:

$$Y_{it} = \alpha_0 + \alpha_1 I_{it} + \chi_i + \varepsilon_{it} \quad (1)$$

$$Y_{it} = \alpha_0 + \alpha_1 I_{it} + \alpha_2 C_{it} + \chi_i + \varepsilon_{it} \quad (2)$$

In the formulas, i denotes individual and t denotes time period. Y_{it} characterises the subjective well-being of individual i in time period t , which can be subjective well-being and depressive symptoms. I_{it} characterises the internet use of individual i in time period t , which can be either perceived importance of the Internet or actual internet use. C_{it} denotes the control variables of individual i in time period t , including *age*, *hukou*, *marital status*, *education*, and *gender*. α_0 is the constant term, α_1 is the predictive coefficient of internet use on health-related outcomes, and α_2 is the predictive coefficient of the control variables. χ_i is the time fixed effects and/or province fixed effects. ε_{it} is the random disturbance term.

Following Baron and Kenny’s (1986: 1176) causal steps approach to testing for mediating effects, the regression equations for mediating analysis were set as follows:

$$M_{it} = \beta_0 + \beta_1 I_{it} + \Phi_i + \mu_{it} \quad (3)$$

$$Y_{it} = \gamma_0 + \gamma_1 I_{it} + \gamma_2 M_{it} + \theta_i + v_{it} \quad (4)$$

M_{it} represents the mediating variables of individual i in time period t , which can be subjective income and social trust. β_0 and γ_0 are constant terms. β_1 is the predictive coefficient of either internet perceptions or internet use on the mediating variables. γ_1 is the predictive coefficient of either internet perceptions or internet use on health-related outcomes. γ_2 is the predictive coefficient of the mediating variables on health-related outcomes. Φ_i and θ_i are time fixed effects. μ_{it} and v_{it} are random disturbance terms.

If β_1 and γ_2 are significant, it implies a mediating effect. Furthermore, if α_1 is insignificant, it implies a full mediation effect; otherwise, it is a partial mediation effect.

To ensure the robustness of the mediation tests, the Sobel test was used to observe whether the mediating path coefficients were significant. The Sobel statistic, Z , was calculated as follows:

$$Z = \beta_1 \gamma_2 / \sqrt{\beta_1^2 S_{\gamma_2}^2 + \gamma_2^2 S_{\beta_1}^2} \quad (5)$$

$S_{\gamma_2}^2$ and $S_{\beta_1}^2$ are the standard error of γ_2 and β_1 , respectively.

In order to observe the relative role that mediators played, a proportion of their mediating effect to the total effects was measured. The proportions of mediation effects, P , were calculated using the formula as follows:

$$P = \frac{\beta_1 \gamma_2}{\alpha_1} \quad (6)$$

Results

Descriptive statistics

The descriptive statistics were shown in Table 1. The CFPS began collecting internet information in 2014 and started to collect information on the CES-D-8 scale in 2016. Data across the four periods of 2014, 2016, 2018, and 2020 were used to construct Panel A, and data across the three periods of 2016, 2018, and 2020 were used to construct Panel B for the robustness check. On Panel A, the percentage of older netizens among the older adults has been climbing, from 5.90% in 2014, to 10.12% in 2016, to 15.82% in

2018, and finally to 19.53% in 2020. It is necessary to consider the effects of older adults' internet perceptions and actual internet use on their well-being. In addition, the reference groups of the dichotomous variables were individuals who chose the 0 level as their answers.

Associations between internet perceptions and use among older adults in China

Table 2 indicated the Pearson correlation coefficients between internet perceptions and use among older adults in various groups. The guide that Evans (1996: 453) suggests for the absolute value of r was utilised. The Pearson correlation coefficient of the full sample remained moderate ($r = 0.571$). However, the positive correlations were weak for the following groups: older elderly, agricultural groups, the illiterate, and older adults with lower levels of income ($r = 0.415$, $r = 0.375$, $r = 0.325$, and $r = 0.392$, respectively). Especially, agricultural seniors of higher ages reported a weaker positive correlation between their internet use and perceptions ($r = 0.230$). The gender and marital status differences in this relation were obscure. In addition, the correlation coefficients between internet use and perceptions among older adults gradually weaken over time ($r = 0.658$ in 2014, $r = 0.603$ in 2016, $r = 0.563$ in 2018, and $r = 0.493$ in 2020). In this context, the effects of Internet perceptions and use on subjective well-being among older people still remained unclear. It is necessary to separately consider the health-related outcome of internet perceptions and use.

Table 1. Descriptive statistics

	Panel A			Panel B		
	Mi			Mi		
	M±SD/% ¹	n	Max	M±SD/%	n	Max
Subjective well-being	14.53±3.04	3	20			
Depressive symptoms				13.33±4.37	8	32
Internet perceptions	1.63±1.22	1	5	1.76±1.31	1	5
Internet use (1 = yes, 0 = no)	12.84	0	1	15.44	0	1
Subjective income	2.90±1.14	1	5	2.96±1.17	1	5
Trust in neighbours	6.93±2.13	1	10	6.97±2.14	1	10
Trust in strangers	1.94±2.22	1	10	1.96±2.23	1	10
Age	68.03±5.06	60	93	67.91±5.11	60	93
Hukou (1 = agricultural household, 0 = non-agricultural household) ²	65.04	0	1	66.79	0	1
Marital status (1 = married, 0 = other) ²	88.05	0	1	87.86	0	1
Education ³	2.27±2.02	0	7	2.27±2.02	0	7
Gender (1 = male, 0 = female) ²	55.19	0	1	55.19	0	1
Number of provinces ⁴	25			25		
Time periods	4			3		
Observations	7,852			8,013		

Notes: 1. Means and standard deviations are reported for the numeric variables, and percentages are reported for the categorical variables.

2. The proportions of these variables coded as 1 were reported.

3. Following the items of the CFPS, education level was coded as "0: illiterate / semi-literate / those who have never attended school, 1: elementary school, 2: junior high school, 3: high school / technical secondary school / vocational high school, 4: junior college, 5: undergraduate, 6: master, 7: doctor."

4. Excluding Inner Mongolia, Tibet, Qinghai, Ningxia, Xinjiang, Hong Kong, and Macao.

Source: authors.

Table 2. Individual correlations between internet perceptions and use among older adults

	Variables and their levels	Obs.	Correlation coefficients
	All sample	7,864	0.571
Age	More than 75 ¹	885	0.415
	Less than 75 ¹	6,979	0.587
Hukou	Agricultural household	5,115	0.375
	Non-agricultural household	2,749	0.691
Older adults with age greater than 75 years old and agricultural household		502	0.230
Education	Illiterate	3,188	0.325
	Literate	4,676	0.626
Gender	Male	4,340	0.586
	Female	3,524	0.542
Married status	Married	6,924	0.573
	Other	940	0.546
Income	Less than 36,000 RMB per year ²	3,810	0.392
	More than 36,000 RMB per year ²	4,042	0.634
	2014	1,966	0.658
	2016	1,966	0.603
Wave	2018	1,966	0.563
	2020	1,966	0.493

Notes: 1. Younger elderly (between 60 and 74 years old) and older elderly (more than 75 years old) were grouped according to the criteria from the World Health Organisation.

2. The median income of 36,000 RMB per year was chosen to delineate income groups with high or low levels.

Source: authors.

Baseline panel model results

According to Formula 1 and Formula 2, taking subjective well-being as the dependent variable, the results of the panel model with robust standard errors were calculated as shown in Table 3. To find the most appropriate model fit, we used the Hausman test to compare the model results of random effects with fixed effects. The Hausman test results for Model 6 were not significant, indicating that the model with random effects can be applied to Model 6. The estimated provincial fixed effects show that regional disparities may exist among different provinces.²

Older adults' internet perceptions significantly positively predicted subjective well-being ($\beta = 0.047$, $p < 0.001$ in Model 1, $\beta = 0.043$, $p = 0.0003$ in Model 2). This predictive relation did not hold when adding mediating variables such as subjective income and social trust ($\beta = 0.017$, $p = 0.138$ in Model 3). When adding the control variables such as education, gender, and objective income, this predictive relation still did not hold ($\beta = 0.018$, $p = 0.051$ in Model 4). H1 was therefore partially verified.

Internet use among older adults significantly negatively predicted subjective well-being ($\beta = 0.077$, $p = 0.010$ in Model 5). When adding controlling variables such as age, marital status, and hukou, the predictive relation of internet use to subjective well-being becomes insignificant ($\beta = 0.018$, $p = 0.607$ in Model 6). When adding mediating variables such as subjective income and social trust, this predictive relation did not hold ($\beta = 0.001$, $p = 0.976$ in Model 7). When added control variables such as education and gender, the predictive relation still did not hold ($\beta = 0.013$, $p = 0.355$ in Model 8). H2 was therefore partially validated.

Table 3. Panel model results with subjective well-being as dependent variables

Dependence variables: Subjective well-being								
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Internet perception	0.047*** (0.012)	0.043*** (0.012)	0.017 (0.012)	0.018 (0.011)				
Internet use					0.077* (0.033)	0.018 (0.034)	0.001 (0.034)	0.013 (0.035)
Age		0.103*** (0.013)	0.071** (0.012)	0.077*** (0.012)		0.131*** (0.013)	0.069*** (0.012)	0.075*** (0.012)
Marital status		0.246* (0.035)	0.206*** (0.033)	0.210*** (0.033)		0.133** (0.044)	0.207*** (0.033)	0.210*** (0.033)
Hukou		-0.076** (0.026)	-0.085*** (0.023)	-0.077*** (0.027)		-0.062 (0.033)	-0.092*** (0.024)	-0.080*** (0.027)
Social trust			0.159*** (0.010)	0.159*** (0.010)			0.160*** (0.010)	0.160*** (0.010)
Subjective income			0.281*** (0.011)	0.275*** (0.011)			0.282*** (0.011)	0.276*** (0.011)
Education				-0.015* (0.006)				-0.014* (0.006)
Gender				0.038 (0.022)				0.038 (0.022)
ln(Income)				0.074*** (0.008)				0.074*** (0.008)
Constant						-0.079 (0.049)		
Random effect	No	No	No	No	No	Yes	No	No
Province fixed effects	No	No	No	Yes	Yes	No	No	No
Time fixed effects	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Observations	7,852	7,852	7,852	7,675	7,852	7,852	7,852	7,675
F statistics	16.313**	32.848***	196.678***	50.418***	6.770**	108.048***	196.256***	50.327***

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Values reported in parentheses were the standard errors.
Source: authors.

2. Readers can request the analysis of provincial differences from the corresponding author, due to space limitations.

Table 4. Results of mediation models with internet perceptions as the independent variable

	Subjective well-being	Subjective income	Social trust	Subjective well-being
Internet perceptions	0.047*** (0.012)	0.054*** (0.011)	0.055*** (0.012)	0.022* (0.011)
Subjective income				0.287*** (0.011)
Social trust				0.161*** (0.010)
Random effect	No	No	No	No
Time-fixed effects	Yes	Yes	Yes	Yes
Observations	7,852	7,852	7,852	7,852
F statistics	16.313***	23.848***	20.354***	361.851***

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Source: authors.

Test results for mediating effects

According to Formula 3 and Formula 4, the mediation models for the panel with fixed or random effects were calculated. Time fixed effects were considered. The results of the mediation models with subjective well-being as the dependent variable are shown in Figure 2. The path coefficients were reported on lines with arrows. Based on Formula 5, Sobel tests were utilised to explore the robustness of the mediating pathways.

Older adults' higher levels of internet perception were significantly associated with higher degrees of subjective income and social trust, which in turn predicted higher levels of subjective well-being (Table 4). Subjective income and social trust were the significant full parallel mediators of the relationship between internet perceptions and subjective well-being ($Z = 4.824$, $p < 0.001$ in the model with subjective income as the mediator, and $Z = 4.408$, $p < 0.001$ in the model with social trust as the mediator). Formula 6 was utilised to calculate the proportions of mediation effects, and the effects of subjective income and social trust were 33.0% and 18.9%, respectively. H1a and H1b were verified.

The meditation model results with internet use as the independent variable are shown in Table 5. Older netizens' higher subjective well-being was suppressed by their lower subjective income ($Z = -2.916$, $p = 0.003$, MacKinnon, Krull, and Lockwood 2000: 175-7), but not mediated by their social trust ($Z = -0.626$, $p = 0.950$). The suppression effect of subjective income accounted for 36.3% of the total effect of

Table 5. Results of mediation models with internet use as the independent variable

	Subjective well-being	Subjective income	Social trust	Subjective well-being
Internet use	0.077* (0.033)	-0.097*** (0.033)	-0.057 (0.036)	0.042 (0.032)
Subjective income				0.288*** (0.011)
Social trust				0.162*** (0.010)
Random effect	No	No	No	No
Time-fixed effects	Yes	Yes	Yes	Yes
Observations	7,852	7,852	7,852	7,852
F statistics	5.291**	8.757***	2.467	369.907***

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

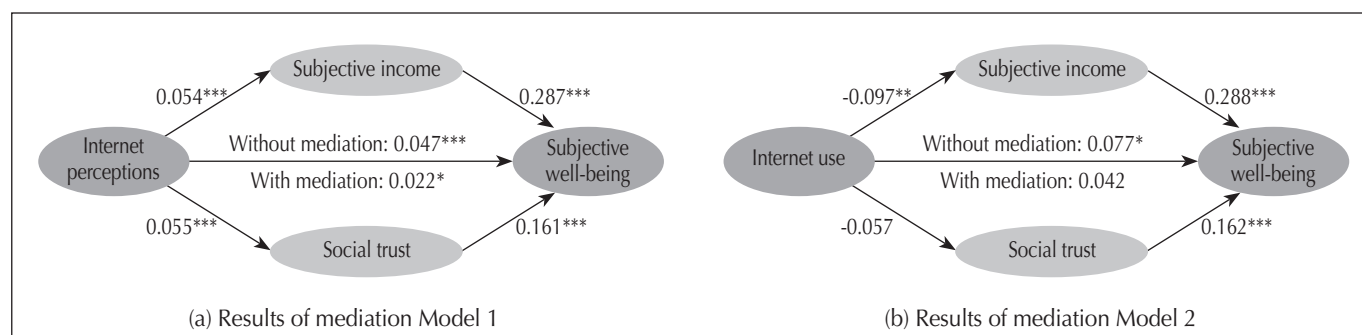
Source: authors.

seniors' internet use predicting their subjective well-being. Neither H2a nor H2b was verified.

Robustness check

Table 6 showed the robustness check results of panel models with depressive symptoms as the dependent variables. The robust standard errors were estimated, and Hausman tests were used to ensure random or fixed effects of the models. There is a significant direct effect of older adults' internet perceptions on their depressive symptoms ($\beta = -0.058$, $p < 0.001$ in Model 9). When adding controls, this effect became insignificant ($ps > 0.05$ in Model 10, Model 11, and Model 12). H1 was moderately validated. Older adults' internet use was a significant negative predictor of depressive symptoms ($ps < 0.001$ in Model 13-15 and $p < 0.05$ in Model 16). H2 was validated.

Table 7, Table 8, and Figure 3 reported results of the mediating roles that subjective income and social trust play in the association between internet perceptions and depressive symptoms among older adults. Subjective income and social trust were significant partially parallel mediators of the relationship between internet perceptions and depressive symptoms ($Z = -4.777$, $p < 0.001$ in the model with subjective income as the mediator, and $Z = -5.132$, $p < 0.001$ in the model with social trust as the mediator). The proportions of mediation effects from subjective income and social trust were 12.8% and 13.5%, respectively. Empirical results for H1a and H1b remained robust.

Figure 2. Results of mediation models

Notes: The number of observations for both mediation models was 7,852; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Credit: author.

We explored the mediation mechanism of the relationship between internet use and depressive symptoms, but found that this association was suppressed by subjective income ($Z = 3.309, p < 0.001$; see Table 7 and Figure 3(a) for more details – MacKinnon, Krull, and Lockwood 2000: 175-7). It enlarged the absolute value of the coefficient of the negative correlation between internet use and depressive symptoms among older adults when subjective

income was considered as a mediator in the mediation model. The suppression effect from subjective income accounted for 4.4% of the total effect of internet use on depressive symptoms among older adults. Social trust did not play a mediating role in the association between internet use and depressive symptoms among older adults ($Z = 0.599, p = 0.549$). Neither H2a or H2b was validated.

Table 6. Panel model results with subjective well-being as dependent variables

Dependence variables: Depressive symptoms								
	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15	Model 16
Internet perceptions	-0.058*** (0.011)	0.007 (0.010)	-0.005 (0.011)	0.009 (0.011)				
Internet use					-0.313*** (0.031)	-0.153*** (0.033)	-0.168*** (0.032)	-0.073* (0.033)
Age		0.002 (0.014)	-0.027* (0.012)	-0.028* (0.012)		-0.048*** (0.012)	-0.034*** (0.012)	-0.033*** (0.012)
Marital status		-0.282*** (0.042)	-0.362*** (0.033)	-0.274*** (0.034)		-0.379*** (0.034)	-0.359*** (0.033)	-0.273*** (0.034)
Hukou		0.319*** (0.030)	0.362*** (0.023)	0.157*** (0.028)		0.321*** (0.025)	0.316*** (0.025)	0.141*** (0.028)
Social trust			-0.108*** (0.010)	-0.092*** (0.010)			-0.108*** (0.010)	-0.092*** (0.010)
Subjective income			-0.123*** (0.011)	-0.121*** (0.011)			-0.125*** (0.011)	-0.121*** (0.011)
Education				-0.037*** (0.006)				-0.033*** (0.006)
Gender				-0.231*** (0.023)				-0.230*** (0.023)
ln(Income)				-0.091*** (0.008)				-0.090*** (0.008)
Constant		0.035 (0.045)						
Random effect	No	Yes	No	No	No	No	No	No
Province-fixed effect	No	No	No	Yes	No	No	No	Yes
Time-fixed effects	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8,013	8,013	8,013	7,808	8,013	8,013	8,013	7,808
F statistics	25.772***	159.957***	112.849***	37.857***	102.490***	103.868***	117.622***	38.005***

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Source: authors.

Table 7. Robustness results of mediation models with internet perceptions as the independent variable

	Depressive symptoms	Subjective income	Social trust	Depressive symptoms
Internet perceptions	-0.058*** (0.011)	0.059*** (0.011)	0.072*** (0.012)	-0.042*** (0.011)
Subjective income				-0.126*** (0.012)
Social trust				-0.109*** (0.011)
Random effect	No	No	No	No
Time-fixed effects	Yes	Yes	Yes	Yes
Observations	8,010	8,010	8,010	8,010
F statistics	25.661***	29.268***	36.385***	98.059***

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

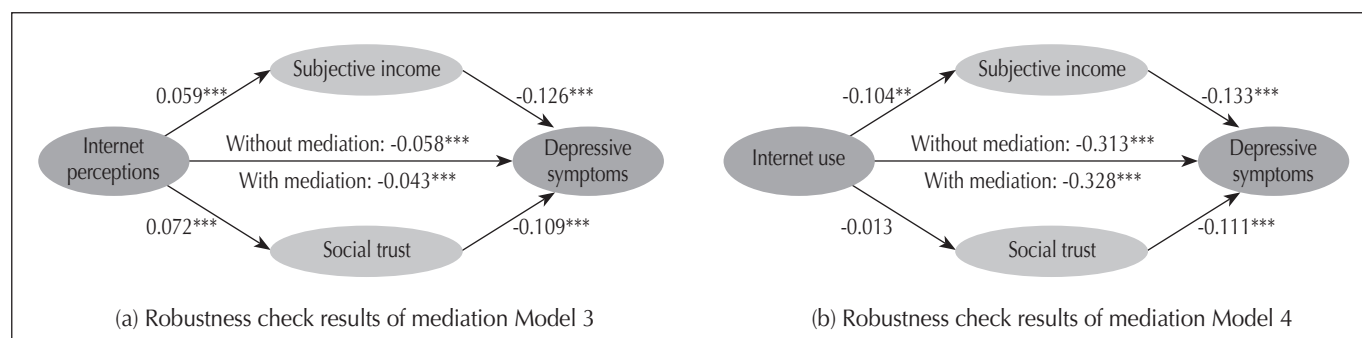
Source: authors.

Table 8. Robustness results of mediation models with internet use as the independent variable

	Depressive symptoms	Subjective income	Social trust	Depressive symptoms
Internet use	-0.313*** (0.031)	-0.104*** (0.030)	-0.013 (0.035)	-0.328*** (0.030)
Subjective income				-0.133*** (0.012)
Social trust				-0.111*** (0.011)
Random effect	No	No	Yes	No
Time-fixed effects	Yes	Yes	Yes	Yes
Observations	8,010	8,010	8,010	8,010
F statistics	102.364***	12.090***	0.353	133.352***

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Source: authors.

Figure 3. Robustness check of results for mediation models

Note: The number of observations of mediation for both Model 3 and Model 4 was 8,013; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Credit: author.

Discussion

Internet perceptions do not always equate with internet use (Heimrath and Goulding 2001: 120-1; Žilionis 2008: 47). Our empirical evidence found demographic differences in the association between internet perceptions and use among older people. For instance, agricultural household seniors older than 75 years old showed a very weak linkage between their internet perceptions and adoption (Evans 1996: 453). The Pearson correlation analysis using CFPS data across the four periods of 2014, 2016, 2018, and 2020 showed that the correlation coefficients of internet perceptions and internet use among older adults became smaller over time. As technology advances, internet perceptions in line with internet use seem increasingly unrelated, as regards older adults. It is credible to use these two dimensions to portray the impacts of the Internet on older adults.

This study has found that older adults' internet perceptions and use played an enhancing role in their subjective well-being. However, some of these roles disappeared when regression equations were added with demographic characteristics and mediating variables such as subjective income and social trust. Higher levels of subjective well-being reported among older netizens disappeared when the regression equations introduced mediating variables such as subjective income and social trust, and similar results were found in previous studies (Duplaga 2021: 9). In a well-developed internet environment, the subjective well-being of older adults is implicit and may increase from their perceptions of smart technologies such as smart home devices, IoT, and robots (Arthanat 2021: 472; Choi, Thompson, and Demiris 2021: 16). This assumption may be verified, based on the significant mediating roles played by subjective attitudes such as subjective income and social trust in the aforementioned association. Additionally, older adults' sociodemographic characteristics such as marital status and educational level may be stronger factors influencing their well-being (Ang, Lim, and Malhotra 2021: 694-5).

We found a robust mitigating effect of internet perceptions and use among older adults on their depressive symptoms. Subjective income played a significant mediating role in the association between internet perceptions and depressive symptoms, but a suppressing role in the correlation between internet use and depressive symptoms among older adults. It is necessary to create

an age-friendly online environment for older netizens; for instance, internet platforms can use intelligent recommendation algorithms to filter out photographs or short videos depicting materialism and money orientation (Yu et al. 2022: 2).

This study has confirmed positive age differences in beneficial health-related outcomes among older people, possibly because older adults who can live to an older age have a more optimistic mindset that enhances their well-being and resists depression. Older adults with a spouse reported higher levels of well-being relative to other marital statuses such as unmarried, widowed, and divorced, implying that the companionship of a partner is an important safeguard for older adults' mental health. Agricultural older adults were at higher risk of depression than non-agricultural older adults, possibly due to socioeconomic backwardness, poor rural health systems, and poor internet access (Jing et al. 2023: 3-4). Higher education levels among older adults reduced their subjective well-being, possibly because older people with higher literacy levels tend to perceive the value of the Internet, but the complexity of information from the Internet likely hinders their aspirations for a better life. Male older adults reported higher degrees of health-related outcomes than female older adults, evidence of which is found in many countries, indicating that female older people are exposed to more social structural risks, poorer health, and more disability (Zunzunegui et al. 2007: 199). High income levels, represented by an abundance of social resources, can enhance subjective well-being in seniors (Tibesigwa, Visser, and Hodgkinson 2016: 364).

There are still some shortcomings in this paper. First, this study used internet perceptions and internet use to measure the digital literacy of older adults, while the rise of internet penetration requires taking note of the impact of different types of internet use on healthy ageing: for example, the effects on the lives of older adults from social media use, short video watching, online shopping, and even video gaming. Second, apart from the dependent variables, which were adopted from multiple items or scales, most of the remaining variables were single items, which were weak measures. Follow-up studies can adopt scales to measure internet access and skills in older adults. Despite the limitations, this study found that subjective income and social trust affected the health-related outcomes of older adults in the digital era.

Conclusion

Healthy ageing in place in the digital era deserves attention. Based on data from CFPS over four periods, panel models were conducted to examine the effects of internet perceptions and internet use on the subjective well-being of older adults. Parallel mediation models employing subjective income and social trust as mediating variables were utilised. The results showed that (1) older adults' internet perceptions and authentic internet use significantly positively predicted their subjective well-being; (2) subjective income and social trust played a significant partial parallel mediating role in the relation between older adults' internet perceptions and their subjective well-being; subjective income played a suppressing role in the relationship between older adults' internet use and their subjective well-being. Social trust did not play a mediating role in the

relationship between internet use and subjective well-being among China's older adults. Older adults' internet perceptions and internet use exhibited consistent significant positive effects on their subjective well-being. These effects were mediated or suppressed by subjective income, but there remained different results with social trust as a mediating variable. In particular, older adults' internet perceptions rather than internet use positively predicted subjective income and social trust, which in turn improved their subjective well-being.

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