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RESEARCH ARTICLE

Digital divide among older adults and digital feedback in the family: A study from Nanjing, China

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ABSTRACT

Using questionnaire survey data conducted in Nanjing, China, this study investigates the impact of age on the digital divide among the elderly population and explores the moderating role of intergenerational communication. Through empirical analysis, it was found that increasing age significantly reduces the probability and duration of elderly people using the internet, but intergenerational communication can alleviate this negative impact to some extent. Specifically, increasing the frequency of contact with children promotes the acceptance and use of internet technology among the elderly, while the increase in meeting frequency significantly prolongs their internet usage time. This discovery emphasizes the important role of intergenerational interaction in promoting the digital integration of the elderly, providing a scientific basis for formulating relevant policy measures aimed at narrowing the digital divide among the elderly by enhancing the quality and depth of intergenerational communication.

Keywords: elderly people; digital gap; intergenerational communication; digital integration

1. Introduction

In Chinese society, the intensification of aging trend and the rapid development of information technology present a parallel phenomenon. Based on authoritative data from China's seventh national census, the number of elderly people aged 60 and above has exceeded 264 million, accounting for 18.7% of the country's total population[1]. This data deeply reflects the significant deepening of China's aging population. Accompanying this are a series of complex social issues, such as the widespread phenomenon of empty nest elderly, the increasing pressure on the elderly care system, and the reconsideration of child support responsibilities under traditional family structures, all of which pose severe challenges to the social structure and welfare system.

At the same time, the widespread popularity of smart devices such as smartphones and the deep integration of emerging media in daily life provide unprecedented opportunities for the elderly to access and integrate into the new generation of digital technologies. However, according to the 53rd Statistical Report on the Development of Internet in China released by the China Internet Network Information Center (CNNIC), although the number of Internet users in China has reached 1.092 billion and the Internet

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penetration rate has reached a new high of 77.5%, the proportion of elderly Internet users (aged 60 and above) is only 15.6%, about 170 million[2], which means that nearly 100 million elderly people still have no effective access to the Internet world, forming a significant digital divide.

Especially during the COVID-19 global pandemic, the widespread use of digital tools such as health codes, facial recognition, and online payments in the public domain was intended to improve social efficiency and convenience in people's lives, but unexpectedly became a major obstacle for the elderly to integrate into the digital society. The popularization of these technological "dividends" not only fails to fully benefit all members of society, but may also invisibly build a digital barrier, isolating the elderly group from the digital new ecology, exacerbating their sense of disconnection and marginalization from mainstream social activities[3]. Therefore, how to bridge this digital divide and ensure that all age groups, especially the elderly, can equally enjoy the convenience brought by digital development has become an important issue that urgently needs to be addressed in current society.

As the most closely connected and fundamental unit in the social network, the family plays a crucial role in the digital integration process of the elderly population[4]. Based on significant differences in the adoption and application of digital technology among different generations, the academic community has generally defined the younger and older generations as "digital natives" and "digital immigrants"[5], respectively. This classification profoundly reveals the significant gap in cognition, acceptance, and practical application ability between the two generations in the new media environment[6], especially in the fields of mobile phones, the Internet, social software, and online games. As an important driving force for social change, the potential value of media technology lies in strengthening emotional connections and relationship building within families. Intergenerational interaction within families, as a bridge connecting digital natives and digital immigrants, is seen as a key path to narrowing the digital generation gap and promoting intergenerational integration[7]. Bailey et al.'s research shows that intergenerational communication, interaction, and entertainment can not only effectively alleviate the intergenerational gap caused by digital technology, but also significantly enhance the emotional intimacy among family members, especially the deepening of parent-child relationships[8,9].

Therefore, from an academic perspective, promoting intergenerational digital feedback mechanisms within families is not only an inherent requirement for actively responding to the active aging strategy and promoting the comprehensive integration of the elderly into the digital society, but also a necessary way to accurately meet the digital needs of the elderly and achieve intergenerational harmonious coexistence. This process requires joint efforts from all sectors of society to promote the positive dissemination and sharing of digital technology within families through multidimensional strategies such as educational guidance, technological support, and cultural advocacy, in order to build a more inclusive and harmonious digital family ecosystem.

2. Research hypothesis

The digital divide, as a prominent social inequality phenomenon in the information age, encompasses a wide and complex range of connotations and manifestations. The Organization for Economic Cooperation and Development (OECD) defines the digital divide as a significant disparity in access to information and communication technology (ICT), internet usage opportunities, and their actual utilization among individuals, households, enterprises, and geographical regions across various socio-economic levels[10]. The International Telecommunication Union (ITU) has further expanded this concept, highlighting that the digital divide not only persists between nations, but also profoundly impacts groups within countries[11], depending on their

socioeconomic status, demographic characteristics (such as age, gender, income, race), and geographical locations (such as urban versus rural areas)[12].

In the context of the elderly population, exploring the digital divide becomes particularly urgent. Traditionally, the digital divide primarily centered around the ownership of ICT equipment and internet access[13,14]. However, recent research trends indicate that the core of inequality has shifted towards the digital skill level of users. This shift underscores the pivotal role of user capabilities in determining their level of digital integration[15]. Existing studies reveal that older adults' utilization of social networks is closely tied to their accessibility to technological resources and socio-cultural backgrounds. This correlation not only underscores the importance of technological resources as a prerequisite for digital integration but also highlights the potential role of socio-cultural backgrounds in encouraging older adults to leverage internet technology to maintain and enhance their social status[16]. Furthermore, the causes of the digital divide among the elderly are attributed to a combination of two factors: individual factors (such as diminished digital skills and perceptual abilities) and social environmental factors (such as technological support and social network support)[17].

The socioeconomic status significantly impacts the digital divide within the elderly population. Elderly individuals who are uneducated and financially disadvantaged often encounter more severe digital exclusion, making it challenging for them to access and utilize technological resources, ultimately leading to their marginalization in the digital world[18]. Conversely, those with higher education levels or better economic conditions are better able to fully enjoy the conveniences brought by ICT[19]. This phenomenon not only exacerbates social inequality but also underscores the significance of policy intervention in fostering digital inclusivity. Notably, ICT technology demonstrates positive potential in mitigating geographical and social isolation among the elderly. Internet platforms, such as social media, offer older individuals novel ways to overcome physical barriers and maintain social connections, thereby helping to alleviate their sense of social isolation and enhancing their mental health[20]. However, the influence of intergenerational effects on the elderly's use of digital technology cannot be overlooked, as the elderly generally face a gap compared to younger individuals in learning how to use the internet.

Research hypothesis I: A digital divide exists among the elderly population, indicating that as individuals age, the proportion of those using the internet decreases.

When exploring the factors that promote Internet access and usage among the elderly, the significance of social support cannot be overlooked[21], and its influence differs based on socio-economic status. Individuals from high socio-economic backgrounds may be less reliant on external social support, whereas those from low socio-economic backgrounds encounter challenges in accessing effective support channels[22]. Notably, family support, as a crucial component of social support, significantly enhances the Internet participation of individuals from low socio-economic backgrounds, and is regarded as a key strategy to bridge the digital divide[23]. The intimate relationships and intergenerational interactions within the family play a pivotal role in facilitating the elderly to acquire Internet knowledge[24,25]. Face-to-face communication and imitative behaviors among family members, particularly the transmission of digital skills from children to parents[26], form the core mechanism of digital feedback[27]. This phenomenon not only boosts the elderly's initiative to learn Internet technology but also elevates their frequency and proficiency in Internet usage, thereby effectively narrowing the digital divide between generations.

The theory of cultural feedback, particularly the concepts of "post-literate culture" and "digital feedback", offers a theoretical framework for comprehending this phenomenon[28,29]. This theory posits that, in a rapidly evolving social environment, the younger generation emerges as the primary agents of

knowledge transmission to the older generation, owing to their swift adaptation and mastery of new technologies. This process manifests not only in the adoption, utilization, and dissemination of knowledge via new media but also profoundly impacts the cultural inheritance patterns within families[30]. Young people generally believe that their Internet application skills are higher than their parents[31]. Therefore, in the era of new media, cultural feedback is reflected in the transmission of digital capital from offspring to parents, a process known as digital feedback. The gap in adoption, use, and knowledge of new media between parents and children, known as the intergenerational digital divide, is an important reason for cultural feedback[32]. Meanwhile, feedback is also an effective way to narrow the digital divide[33]. Within the family, children often assume the role of "technology experts"[34]. They serve not only as a bridge for parents to acquire new technologies but also act as intermediaries in managing family media usage[35,36]. This "bottom-up technology transfer" model underscores the pivotal role of the younger generation in digital feedback[37]. By designing specialized intergenerational tutoring courses, as exemplified by Othelia Eun-Kyoung Lee's research, the digital skills of the elderly can be significantly enhanced, further attesting to the efficacy of digital feedback in mitigating the digital divide among the elderly[38].

Research hypothesis II: Intergenerational communication moderates the impact of bridging the digital divide among older adults.

3. Research design

3.1. Data source

This study rigorously adopted the questionnaire survey method as the main means of data collection, and its process strictly followed the norms of academic research. Firstly, the research team convened scholars and experts in relevant fields, and through multiple in-depth discussions and revisions, carefully designed a questionnaire content containing multidimensional indicators to ensure that the questionnaire can comprehensively and accurately cover various influencing factors of the digital divide among the elderly. Subsequently, the study was widely conducted within the city of Nanjing, covering various administrative regions and rural areas. A total of 1500 questionnaires were randomly distributed to adults aged 18 and above to ensure the diversity and representativeness of the sample.

During the data collection process, the research team strictly controlled the quality of questionnaire responses, and ultimately effectively collected 1237 questionnaires with a response rate of 82.5%, laying a solid data foundation for subsequent statistical analysis. Given that the core focus of this study is on the factors influencing the digital divide among the elderly, the research team rigorously screened the collected questionnaires, removing samples under the age of 60 to ensure the accuracy of the analysis subjects. Ultimately, 450 valid questionnaires were retained as the research sample. Although the sample size is limited, it is sufficient to support in-depth exploration of the factors influencing the digital divide among the elderly, and to a certain extent, ensure the reliability and effectiveness of the research conclusions.

3.2. Model design

To study the influencing factors of the digital divide among the elderly, this article designs the following model:

$$Y_m = a + bAge_m + cControl_m + \theta$$

Among them, Y is the dependent variable of this article, including whether the network is connected and the duration of network usage. Regarding the network access situation, "whether to use mobile devices and computers to access the internet" is used as a binary variable, with a value of 1 assigned to use the network,

otherwise it is 0. In terms of internet usage, the degree of internet usage is first measured by the amount of time spent online. "How much leisure time is spent online each week" is used as the ordinal variable, with a value of 0 indicating no internet usage; 1. Use the internet for less than 7 hours per week; 2. Use the internet for 7 to 14 hours per week; 3 means spending more than 14 hours online per week.

The explanatory variable of this article is age, aiming to explore whether there are significant differences in the access and use of the digital divide in the age dimension. In terms of controlling variables, they include education level, income level, ownership of housing provident fund, employment status, health level, etc., as shown in **Table 1**. The descriptive statistical results are shown in **Table 2**.

Table 1. Variable definition.

	Variable	**Variable Names**	**Variable Definition**
Explained Variable	Network access status	NAS	Using mobile devices and computers to access the internet, assign a value of 1; Conversely, it is 0
	Network usage time	NUT	The time spent online during leisure time each week is assigned a value of 0 if not online, 1 if spent less than 7 hours online per week, 2 if spent 7-14 hours online per week, and 3 if spent more than 14 hours online per week
Explanatory Variable	Age	Age	Age indicated in the questionnaire
Control Variable	Educational level	Education	Illiteracy=1, Semi Illiteracy=2, Primary School=3, Junior High School=4, High School and above=5
	Income	Income	Local evaluation of one's own income, very low=1, low=2, average=3, high=4, very high=5
	Is there a pension available	YLJ	Yes=1, No=0
	Whether to continue working after retirement	Work	No job=1, continue agricultural work=2, continue non-agricultural work=3
	Self-rated health	Health	Unhealthy=1, General=2, Healthy=3
	Total number of family members	Number	The number of family members filled in the questionnaire
	Degree of parent-child relationship	Relationship	Very close=1, not close=2, generally=3, close=4, very close=5
	Is there a caregiving relationship	Care	Yes=1, No=0

Table 2. Descriptive results

Variable	**Obs**	**Mean**	**Std.Dev.**	**Min**	**Max**
NAS	450	0.389	0.488	0	1
NUT	450	1.222	1.257	0	3
Age	450	68.027	6.258	60	83
Education	450	2.833	1.479	1	5
Income	450	2.882	1.402	1	5
YLJ	450	0.427	0.495	0	1
Work	450	1.949	0.825	1	3
Health	450	1.727	0.712	1	3
Number	450	3.464	1.480	1	6

Care	450	0.464	0.499	0	1
Relationship	450	3.236	1.178	1	5

Table 2. *(Continued)*

4. Empirical strategy

4.1. Benchmark regression

This study aims to deeply analyze the impact of age factors on the digital divide phenomenon among the elderly population. By applying the least squares method to construct a regression analysis model, a systematic analysis was conducted on the correlation between the age of the respondents and their internet usage behavior, as shown in **Table 3**. Specifically, the preliminary regression results in column (1) of **Table 3** show a significant negative correlation between the age of respondents and whether they use the internet, which preliminarily confirms the hypothesis that as age increases, the tendency of the elderly population to adopt internet technology decreases. Subsequently, in column (2), the negative correlation remained significant by introducing the interviewee's personal situation variable as the control variable. On this basis, column (3) includes family characteristic variables to more comprehensively consider the influence of family environment on individual internet usage habits. However, even after controlling for these potential confounding factors, the negative impact of age on internet usage is still significant, clearly indicating that age is an important factor leading to a decline in internet usage among the elderly. In addition, columns (4) to (6) of **Table 3** focus on the impact of age on the duration of internet use in the leisure time of elderly people per week. By gradually incorporating personal and family characteristic variables, the significant negative effect of age variable is once again verified. This result indicates that as respondents age, their time spent on online activities during their free time also decreases, further highlighting the marginalization trend of the elderly population in the digital process. The above analysis is not only consistent with existing literature on the digital divide, but also deeply reflects the challenges faced by the elderly in the face of rapid digital change in society. The results of this study have a high degree of statistical robustness, providing empirical evidence for understanding how age differences exacerbate digital inequality among social groups. It also emphasizes the importance of developing targeted policies and measures to promote digital integration and social participation among the elderly population.

Table 3. Benchmark regression results

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	**NAS**			**NUT**		
Age	-0.020***	-0.021***	-0.009***	-0.042***	-0.048***	-0.037***
	(-6.198)	(-6.350)	(-2.773)	(-4.686)	(-5.302)	(-3.800)
Education		-0.020	-0.005		0.030	0.046
		(-1.305)	(-0.412)		(0.865)	(1.354)
Income		0.000	0.001		0.054	0.054
		(0.001)	(0.037)		(1.388)	(1.429)
YLJ		0.005	0.030		0.114	0.140
		(0.116)	(0.753)		(1.105)	(1.382)
Work		-0.046*	-0.064***		0.486***	0.472***
		(-1.703)	(-2.642)		(7.479)	(7.489)

Health		0.044	0.014		0.443***	0.408***
		(1.343)	(0.490)		(5.961)	(5.621)
Number			-0.153***			-0.159***
			(-12.917)			(-4.376)
Care			-0.107***			-0.007
			(-2.628)			(-0.066)
Relationship			0.013			0.043
			(0.749)			(0.982)
Constant	1.746***	1.896***	1.646***	4.096***	2.497***	2.158***
	(7.784)	(7.968)	(7.112)	(6.545)	(3.791)	(3.131)
Observations	450	450	450	450	450	450
R-squared	0.065	0.077	0.282	0.044	0.254	0.288

Note: *The robust t-statistic is shown in parentheses, where *, * *, and * * * represent significant at the 10%, 5%, and 1% statistical levels, respectively. Unless otherwise specified, the following table is characterized as such.*

Table 3. *(Continued)*

4.2. Heterogeneity analysis

In order to analyze the heterogeneous impact of age factors on the digital divide phenomenon among the elderly in more detail, this article further conducted a stratified analysis, focusing on the performance differences of different characteristic groups under the same indicator. Specifically, the results in columns (1) and (2) of **Table 4** indicate a significant negative relationship between age and internet usage probability in the elderly population with weaker digital cognitive abilities. This discovery profoundly reveals that digital technology, as an emerging field, poses significant challenges to the elderly population due to its rapid iteration and complexity. As people age, their memory and learning abilities decline, directly affecting their ability to accept and master digital technology, thereby reducing their probability of using the internet. Furthermore, the analysis of columns (3) and (4) in **Table 4** indicates a significant negative correlation between age and internet usage time in the elderly population with weak digital cognitive abilities. This means that as they age, even within their limited leisure time, these elderly people significantly reduce their time invested in online activities. This discovery not only reinforces that age is one of the important factors exacerbating the digital divide, but also highlights the crucial role of digital cognitive abilities in the online behavior of older adults.

Table 4. Heterogeneity analysis I

	(1)	**(2)**	**(3)**	**(4)**
	Digital cognitive ability			
	Good	**Bad**	**Good**	**Bad**
VARIABLES	**NAS**	**NAS**	**NUT**	**NUT**
Age	-0.012	-0.006*	-0.034*	-0.038**
	(-2.346)	(-1.553)	(-2.161)	(-3.051)
Education	0.037*	-0.045***	0.062	0.038

	(1.801)	(-2.626)	(1.112)	(0.874)
Income	0.010	-0.014	0.043	0.064
	(0.444)	(-0.777)	(0.706)	(1.297)
YLJ	0.009	0.060	0.136	0.133
	(0.149)	(1.154)	(0.845)	(0.996)
Work	-0.091**	-0.062*	0.452***	0.498***
	(-2.466)	(-1.867)	(4.458)	(5.790)
Health	0.004	0.034	0.433***	0.381***
	(0.091)	(0.844)	(3.897)	(3.800)
Number	-0.149***	-0.157***	-0.148***	-0.174***
	(-8.229)	(-9.948)	(-2.627)	(-3.480)
Care	-0.068	-0.150***	-0.063	0.047
	(-1.108)	(-2.711)	(-0.376)	(0.331)
Relationship	-0.005	0.031	0.054	0.032
	(-0.169)	(1.445)	(0.741)	(0.550)
Constant	1.819***	1.563***	1.893	2.353***
	(4.769)	(5.441)	(1.629)	(2.641)
Observations	200	250	200	250
R-squared	0.294	0.315	0.277	0.299

Table 4. *(Continued)*

From the analysis in **Table 5**, we can observe how differences in Chinese cognitive abilities moderate the impact of age on internet use and its duration. Specifically, for groups with weaker Chinese cognitive abilities, the likelihood and duration of their internet use show a significant downward trend with age. This discovery indicates that the insufficient Chinese cognitive ability, as a bridge between culture and technology, limits the participation of elderly people in the digital age, especially when facing emerging digital applications such as short video platforms and video communication tools. Their acceptance and comprehension abilities are limited, which exacerbates the network usage barriers caused by aging. On the contrary, in the group with strong Chinese cognitive ability, although the direct effect of age on internet use is negative, this effect has not reached a statistically significant level; Meanwhile, in terms of internet usage time, the influence of age has even turned positive, although equally insignificant. This shift may reflect that strong Chinese cognitive abilities help alleviate age-related cognitive decline, enabling this group to better adapt to and enjoy digital life.

Table 5. Heterogeneity analysis II

	(1)	**(2)**	**(3)**	**(4)**
	Chinese cognitive ability			
	Bad	**Good**	**Bad**	**Good**
VARIABLES	**NAS**	**NAS**	**NUT**	**NUT**
Age	-0.009***	-0.037	-0.036***	0.096
	(-2.636)	(-1.651)	(-3.724)	(1.667)

Education	-0.004	-0.039	0.043	0.106
	(-0.289)	(-0.606)	(1.235)	(0.742)
Income	-0.001	0.077	0.050	0.179
	(-0.035)	(0.784)	(1.292)	(0.831)
YLJ	0.033	-0.023	0.145	-1.476*
	(0.805)	(-0.096)	(1.407)	(-2.200)
Work	-0.062**	-0.205	0.449***	0.813
	(-2.509)	(-1.521)	(7.055)	(1.569)
Health	0.010	0.017	0.453***	-1.168*
	(0.330)	(0.122)	(6.168)	(-2.405)
Number	-0.152***	-0.083	-0.157***	-0.348
	(-12.562)	(-1.179)	(-4.248)	(-1.713)
Care	-0.100**	-0.410	-0.040	0.357
	(-2.368)	(-2.034)	(-0.373)	(0.644)
Relationship	0.013	0.065	0.041	-0.110
	(0.720)	(0.867)	(0.926)	(-0.512)
Constant	1.627***	3.604*	2.146***	-3.999
	(6.843)	(2.159)	(3.066)	(-1.074)
Observations	436	14	436	14
R-squared	0.269	0.893	0.290	0.883

Table 5. *(Continued)*

In order to further explore the differential role of age factors in the digital divide among the elderly population, this article subdivided the sample into two subgroups, urban and rural, based on the characteristics of the respondents' place of residence, and conducted comparative analysis. The results are summarized in **Table 6**. The analysis results show that although age has a negative impact on internet usage among urban residents, it has not reached statistical significance. This may reflect the relatively high internet penetration rate and digital literacy of urban residents, which weakens the direct impact of age differences on internet usage. In contrast, the negative relationship between age and internet usage among rural residents is significant at the 5% statistical level, revealing that the elderly population in rural areas is significantly constrained by their age due to relatively low living standards, limited internet exposure opportunities, and possible digital skills barriers, which significantly restrict their internet usage behavior.

Furthermore, in terms of internet usage time, there is a significant negative correlation between age and internet usage time among urban residents, indicating that even in urban environments with more opportunities for internet exposure, age still limits the amount of time elderly people spend engaging in online activities. For rural residents, although increasing age also tends to reduce their internet usage time, this effect has not reached statistical significance. This discovery may be attributed to the unique lifestyle of rural residents, who often need to invest a lot of time in agricultural activities such as farming, thereby compressing the leisure time available for online activities, making the effect of age on internet usage time less significant.

Table 6. Heterogeneity analysis III

	(1)	**(2)**	**(3)**	**(4)**
	Urban	**Rural**	**Urban**	**Rural**
VARIABLES	**NAS**	**NAS**	**NUT**	**NUT**

Age	-0.006	-0.014**	-0.043***	-0.026
	(-1.469)	(-2.456)	(-3.699)	(-1.550)
Education	0.003	-0.023	0.078*	0.013
	(0.194)	(-1.096)	(1.841)	(0.230)
Income	0.006	-0.000	0.001	0.133**
	(0.317)	(-0.021)	(0.018)	(2.372)
YLJ	0.025	0.048	0.238*	0.035
	(0.494)	(0.744)	(1.839)	(0.213)
Work	-0.088***	-0.024	0.453***	0.524***
	(-2.860)	(-0.603)	(5.726)	(5.103)
Health	0.030	-0.020	0.422***	0.369***
	(0.798)	(-0.418)	(4.611)	(3.183)
Number	-0.146***	-0.161***	-0.108**	-0.231***
	(-8.917)	(-8.838)	(-2.274)	(-4.195)
Care	-0.087	-0.117*	0.089	-0.097
	(-1.574)	(-1.799)	(0.637)	(-0.581)
Relationship	0.031	-0.017	0.059	0.004
	(1.430)	(-0.596)	(1.075)	(0.051)
Constant	1.317***	2.117***	2.284***	1.801
	(4.447)	(5.578)	(2.617)	(1.542)
Observations	259	191	259	191
R-squared	0.257	0.315	0.269	0.327

Table 6. *(Continued)*

5. Further discussion

To investigate the potential impact of intergenerational communication on the internet usage behavior of the elderly, this article selected "frequency of contact with children" and "frequency of meeting with children" for comprehensive analysis. Specifically, the stepwise regression analysis from columns (1) to (3) of **Table 7** shows that age has a significant negative impact on whether elderly people use the internet, meaning that as they age, the proportion of elderly people who do not use the internet increases. However, after introducing the interaction term (age * contact_frequency) between "age" and "frequency of contact with children", the results in column (3) indicate that the coefficient of this interaction term is significantly positive, in contrast to the negative coefficient of the age main effect, reflecting the existence of a negative moderating effect. This discovery suggests that increasing the frequency of contact with children can effectively alleviate the inhibitory effect of aging on the internet usage behavior of the elderly, prompting more older adults to start using and adopting internet technology, thereby increasing the proportion of internet users in the elderly population.

Furthermore, the analysis in columns (4) to (6) of **Table 7** focuses on the impact of intergenerational communication on the internet usage time of the elderly. Although the results showed that the increase in frequency of contact with children did not have a statistically significant positive impact on the internet usage time of the elderly, this trend still suggests that intergenerational interaction may indirectly promote the elderly to invest more time in the internet by enhancing their awareness and interest in the value of the internet. Although the impact is not significant, this finding still has enlightening significance, suggesting that future research can further explore effective ways to enhance the quality and depth of intergenerational communication to promote internet use among the elderly.

Table 7. Further discussion (contact frequency)

VARIABLES	(1) NAS	(2) NAS	(3) NAS	(4) NUT	(5) NUT	(6) NUT
Age	-0.009***	-0.008**	-0.028***	-0.037***	-0.033***	-0.067**
	(-2.773)	(-2.470)	(-2.660)	(-3.803)	(-3.374)	(-2.473)
Contact frequency		0.043	-0.431*		0.222***	-0.626
		(1.468)	(-1.651)		(2.965)	(-0.942)
Age * contact_frequency			0.007*			0.012
			(1.869)			(1.287)
Education	-0.005	-0.007	-0.007	0.047	0.039	0.038
	(-0.412)	(-0.519)	(-0.569)	(1.384)	(1.175)	(1.136)
Income	0.001	0.001	0.002	0.052	0.055	0.056
	(0.037)	(0.085)	(0.112)	(1.366)	(1.481)	(1.506)
YLJ	0.030	0.030	0.026			
	(0.753)	(0.762)	(0.657)			
Work	-0.064***	-0.065***	-0.063***	0.468***	0.459***	0.463***
	(-2.642)	(-2.722)	(-2.640)	(7.448)	(7.289)	(7.378)
Health	0.014	0.014	0.016	0.409***	0.406***	0.410***
	(0.490)	(0.476)	(0.554)	(5.622)	(5.647)	(5.661)
Number	-0.153***	-0.151***	-0.152***	-0.156***	-0.150***	-0.152***
	(-12.917)	(-12.810)	(-12.950)	(-4.238)	(-4.078)	(-4.124)
Care	-0.107***	-0.092**	-0.093**	-0.010	0.067	0.065
	(-2.628)	(-2.146)	(-2.179)	(-0.096)	(0.611)	(0.595)
Relationship	0.013	0.011	0.012	0.045	0.037	0.038
	(0.749)	(0.655)	(0.703)	(1.031)	(0.850)	(0.878)
Constant	1.646***	1.465***	2.824***	2.209***	1.281*	3.708*
	(7.112)	(5.400)	(3.708)	(3.231)	(1.687)	(1.918)
Observations	450	450	450	450	450	450
R-squared	0.282	0.285	0.290	0.285	0.298	0.300

Furthermore, in order to comprehensively evaluate the specific impact of different forms of communication (i.e. meeting frequency) in intergenerational interaction on the internet usage behavior of the elderly, this article conducted an in-depth analysis of the moderating effect of "meeting frequency with children" on age factors in internet usage behavior. The results are summarized in **Table 8**. The analysis results show that the frequency of meeting between the elderly and their children does not have a significant moderating effect on the binary decision of whether to use the internet, indicating that the number of meetings alone may not be sufficient to directly change the initial adoption decision of the elderly towards internet use.

However, when exploring the ordered variable of internet usage time, the frequency of meeting between the elderly and their children showed a significant negative moderating effect. Specifically, as the frequency of face-to-face meetings increases, the internet usage time of elderly people also extends. This discovery reveals the unique role of face-to-face communication in promoting the depth of elderly people's online use: on the one hand, frequent face-to-face interactions may allow elderly people to more intuitively feel their children's active state in cyberspace, thereby stimulating their curiosity and exploration of the online world; on the other hand, children may effectively enhance the elderly's online skills and self-efficacy through practical demonstrations, experience sharing, and other means during the meeting process, thereby encouraging them to invest more time in online activities.

In summary, this study found that the frequency of meeting with children has a negative moderating effect on the internet usage time of the elderly. This not only enriches our understanding of the role of

intergenerational communication in alleviating the digital divide, but also provides a new perspective for designing intervention measures to promote the integration of the elderly into the internet, emphasizing the importance of high-quality, face-to-face intergenerational interaction in enhancing the elderly's internet usage ability and interests.

Table 8. Further discussion (meeting frequency)

	(1)	(2)	(3)	(4)
VARIABLES	**NAS**	**NAS**	**NUT**	**NUT**
Age	-0.008**	-0.009***	-0.033***	-0.037***
	(-2.470)	(-2.652)	(-3.365)	(-3.783)
Meeting frequency	0.043	0.033	0.223***	0.170**
	(1.468)	(1.062)	(2.943)	(2.187)
Age * meeting frequency		0.001		0.003***
		(1.366)		(2.813)
Education	-0.007	-0.007	0.039	0.038
	(-0.519)	(-0.528)	(1.146)	(1.139)
Income	0.001	0.002	0.058	0.060
	(0.085)	(0.117)	(1.545)	(1.617)
YLJ	0.030	0.028	0.141	0.129
	(0.762)	(0.701)	(1.398)	(1.283)
Work	-0.065***	-0.070***	0.462***	0.440***
	(-2.722)	(-2.884)	(7.331)	(7.008)
Health	0.014	0.013	0.406***	0.400***
	(0.476)	(0.438)	(5.644)	(5.611)
Number	-0.151***	-0.149***	-0.153***	-0.142***
	(-12.810)	(-12.305)	(-4.213)	(-3.894)
Care	-0.092**	-0.089**	0.071	0.087
	(-2.146)	(-2.064)	(0.639)	(0.780)
Relationship	0.011	0.011	0.034	0.033
	(0.655)	(0.632)	(0.796)	(0.766)
Constant	1.465***	1.475***	1.227	1.280*
	(5.400)	(5.373)	(1.599)	(1.686)
Observations	450	450	450	450
R-squared	0.285	0.288	0.301	0.313

6. Conclusion

Chinese society has entered a stage of deep aging, and at the same time, the leapfrog development of digital technology has injected strong impetus into economic and social development, but it has also exacerbated the significant gap in digital usage among the elderly population. This study focuses on the significant differences between the elderly and the younger generation in terms of network access convenience, digital application capabilities, and overall digital literacy, revealing the phenomenon of digital exclusion faced by the elderly population. This issue has important academic and social value. To systematically explore the multidimensional influencing factors of the digital divide among the elderly, this study selected Nanjing, China as a representative research area. Through a carefully designed questionnaire distribution, collection, and strict screening process, 450 effective research samples were ultimately established. The data analysis results show that age is one of the core factors restricting elderly people from

deepening their digital lives. Specifically, as age increases, the frequency and duration of elderly people's use of the internet show a downward trend. In addition, this influence effect shows significant differences in different dimensions, including individuals' digital cognitive ability, Chinese cognitive ability, and residential characteristics. Further in-depth analysis reveals that intergenerational communication and interaction play a crucial role in alleviating the digital divide among the elderly. Specifically, elderly people who maintain frequent contact with younger generations such as their children show more significant progress in improving their digital literacy and enhancing their ability to use the internet. This phenomenon not only reveals the positive role of intergenerational support within families in the digital integration of the elderly, but also provides important insights for formulating policy measures aimed at narrowing the digital divide.

In summary, this study reveals the complex causes of the digital divide among the elderly in the context of China's aging society through empirical data analysis, and emphasizes the key role of intergenerational communication in alleviating this problem. Future research can further explore more diversified intervention strategies to promote more comprehensive and equal participation of the elderly in the digital society, and achieve harmonious coexistence between aging and digitalization.

6.1. Policy implications

In addressing the persistent digital divide among the elderly population, a multifaceted and comprehensive policy framework is imperative, encompassing institutional design at the governmental level, reinforcement of family support systems, and enhancement of community education services. This holistic approach aims to ensure seamless integration of seniors into the information society, without hindrance.

6.1.1. Governmental level

The government must assume a proactive leadership role by instituting targeted policies that forge a robust institutional and social infrastructure to bridge the digital divide. These policies should prioritize the aging-friendly adaptation of core internet sectors, encompassing government services, community services, news media, social communication platforms, and e-commerce, thereby facilitating barrier-free digital engagement for the elderly. Furthermore, the integration of diverse resources to establish an elderly-centric intelligent technology learning platform is vital. This platform should embody a deep understanding of the communication patterns and learning preferences of older adults, offering tailored functionalities and emphasizing outreach to economically disadvantaged regions. Curriculum design should cater to regional nuances and individual interests, fostering digital literacy among seniors. Lastly, to accommodate marginalized segments, mandatory retention of manual service channels in public facilities like hospitals, banks, and transportation hubs is essential, safeguarding the elderly's security and confidence amidst digital transformation.

6.1.2. Family level

Fostering intergenerational digital mentorship constitutes a cornerstone in this endeavor. This necessitates nurturing a modern filial piety culture that encourages children and other family members to actively engage in the digital education of elders, fostering a supportive and loving environment. The emphasis should extend beyond mere frequency of interaction to depth and breadth, ensuring efficacy in skill transfer. Such initiatives not only facilitate familial bonding and alleviate loneliness, but also forge new avenues for intergenerational connection, strengthening parent-child relationships.

6.1.3. Community level

As the epicenter of elderly daily life, communities must emerge as the primary hub for digital skills training. Communities must marshal resources, including community workers, volunteers, and other stakeholders, to deliver regular and sustained digital literacy programs tailored to seniors. Creating a conducive learning and practice environment is crucial for boosting technological self-efficacy among the elderly. Additionally, broadening the scope of digital mentorship providers, such as caregivers, neighbors, and nursing home social workers, can enrich the diversity and accessibility of feedback mechanisms. Encouraging youth to innovate in their contributions to this cause further propels collective efforts, fostering a societal ecosystem that embraces and supports the digital inclusion of the elderly.

6.2. Limitations and further research

In the process of exploring the path to alleviate the digital divide among the elderly, although this study strives to be comprehensive and in-depth, there are still inevitably certain limitations and shortcomings, which are reflected in the following aspects: firstly, limitations in research methods. This study mainly relies on the questionnaire survey method to collect data. Although this method has the advantage of wide coverage, it is relatively weak in delving into the inner experiences of the respondents and understanding their behavioral patterns in detail. The lack of in-depth interviews as a supplement limits a profound understanding of the complex psychological changes and individual differences in the process of digital integration among the elderly. Therefore, future research should consider combining questionnaire surveys with in-depth interviews to obtain richer and more detailed research data, and enhance the comprehensiveness and depth of the study. The singularity of data indicators. When evaluating the effect of digital feedback for the elderly, this study mainly depends on two quantitative indicators: Internet access and network use time. Although this assessment method is intuitive and easy to implement, it does not fully reflect the multi-dimensional improvement of the elderly's Internet application ability. In particular, it failed to directly quantify the improvement of the elderly's actual participation and sense of gain in Internet life, that is, the direct embodiment of the effect of "agency feedback". In view of this, follow-up research should expand the coverage of data indicators, including but not limited to the diversity, activity, satisfaction and social interaction of elderly Internet applications, to build a more comprehensive and scientific evaluation system and accurately measure the actual effect of digital feedback.

In summary, this study has certain limitations in methodology and data indicator selection. Future research needs to integrate diversified research methods and improve the data indicator system to further enhance the scientific and rigorous nature of the study, providing more solid theoretical and practical support for effectively alleviating the digital divide among the elderly.

Conflict of interest

The authors declare no conflict of interest.

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