

"I Never Imagined Grandma Could Do So Well with Technology": Evolving Roles of Younger Family Members in Older Adults' Technology Learning and Use

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Older adults' technology learning is a long-term process, during which family members often play significant roles. Although much research has emphasized how family support is important, little research has dove into the evolution of family dynamics when older adults are learning to use new technology. Drawing on the results from a qualitative study that performed semi-structured interviews with 20 older adults and 18 younger adults in China, we unpack how family members were involved in technology learning over time. Our findings suggest that younger family members play transformative roles throughout older adults' learning stages, i.e., as influencers, supporters, protectors, and monitors. Younger family members' roles co-evolve with not only older adults' changing needs but also their perceptions of older adults' learning abilities and online behaviors. They may struggle to adjust their teaching strategies to accommodate older adults' needs and abilities during the process. They may also worry about older adults' online benefits and safety as many older adults become far more active online than anticipated. Challenges while teaching and tensions regarding protection may thus emerge during the support process. With these findings, we suggest that older adults' technology learning should be treated as a collaborative activity with family members rather than an activity they pursue alone. We also highlight older adults' technology learning as a recurrent, dynamic, and evolving process, and call attention to the unique culture of "*xiaoshun*" in China that acts as a buffer to the burdens and tensions found with family support.

CCS Concepts: • **Human-centered computing** → **Empirical studies in HCI**.

Additional Key Words and Phrases: older adults, technology learning, technology use, technology support, family, family support

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1 INTRODUCTION

Although there has been an increasing number of older adults starting to use new technologies (e.g., smartphones, tablets, e-books, etc.) [1, 58], older adults still need a wide range of support when learning and using technology [8]. This is especially true when new generations of technologies such as smartwatches become available and while older adults are beginning to use them [43]. Therefore, digital inclusion amongst the older population is still an important issue in HCI, including CSCW. In particular, understanding how older adults learn to use new technologies is of great interest to the CSCW community because it can inform future design of socio-technical systems for older adults (e.g., [12, 50, 59]).

Notably, family members often play significant roles in older adults' everyday technology use [19, 49]. Although the importance of family support has been highlighted in previous research, little attention has been paid to family dynamics (i.e., patterns of interactions among family members and factors that shape their interactions [22]). Prior work usually emphasized the general importance of family members as one of the major sources of support that older adults receive while using technology (e.g., [7, 19, 40, 49, 57]), or specific support family members provided to older adults, such as providing instructions (e.g., [34, 43]). There is sporadic evidence from older adults that family members may struggle to explain simple tasks [49] or disagree on the necessity of technology use with older adults [34], however the literature is lacking a holistic understanding of family dynamics based on perspectives from both sides. The perspectives from both is important because older and younger adults may have different perceptions of intergenerational communications [62].

Given this research gap, we sought to understand **how younger family members support older adults' technology learning over the long term**. Through addressing this question, we aim to unpack the roles of family members that may play through the course of learning. We conducted an interview-based study with 20 older adults and 18 younger adults in China. We focused on the relationship between older adults and their adult children or grandchildren, as adult children and grandchildren are usually the most essential family members when it comes to older adults' adoption and learning of new technologies [40, 49, 55, 64]. We operationalized "older adults" according to the current legal retirement age in China, i.e., 60 for men, 55 for female civil servants, and 50 for female workers [74]. We did not set age limits for younger family members. As for "technology", we encouraged participants to share all experiences they felt relevant.

Based on the interviews, we found that younger family members play the roles of influencers, supporters, protectors, and monitors in older adults' technology learning over time. These roles co-evolve with not only older adults' changing needs based on their learning stage, but also younger adults' adjustments to their perceptions of older adults' learning abilities and online behaviors. Younger adults usually start their support with a relatively low expectation towards older adults' technology use, but they may still struggle to adapt their teaching strategies according to older adults' cognitive abilities and digital literacy. In addition, many of these younger adults gradually find that older adults are far more active online than they anticipated. Some younger adults may then become monitors, trying to control older adults' technology use to ensure their online benefits and security. Besides these findings, we also highlight a culture of "xiaoshun" ("孝顺")¹ in China, which has influenced family support pattern. Under a culture of filial piety, younger adults in China may take it as their responsibilities to support and protect their older family members, while older

¹"xiaoshun" means filial piety in Chinese, which is regarded as a key virtue in traditional Chinese culture. "xiaoshuna" consists of respect, obedience, and care towards older family members [77].

Chinese adults may not have a strong preference for self-directed and independent learning as usually reported in North America and Western Europe (NAWE) [29, 34, 43, 45].

Taken together, the contributions of this work are:

- 1) An empirical understanding of evolving family dynamics in older adults' technology learning in the Chinese context. We highlight the emerging challenges and tensions during the support process. We also underline that, rather than being a uniform process, older adults' technology learning is a recurrent, dynamic, and evolving process that needs personalized support. This study also calls attention to a culture of filial piety as a buffer to the burdens and tensions in family support in China.
- 2) Design opportunities to facilitate older adults' technology learning. We suggest treating older adults' technology learning as a collaborative activity with family members rather than an individual activity that older adults pursue alone, especially in cultures practicing filial piety [77].

2 RELATED WORK

2.1 Older Adults' Learning and Use of New Technology

Although an increasing number of older adults have started to use new technologies (e.g., smartphones and social networking sites), the adoption rate of technology amongst older adults is still far less than younger adults [1, 58], especially with newer generations of technologies such as smartwatches and self-tracking devices [58]. Therefore, many researchers in HCI, including CSCW, have sought to understand the factors that influence older adults' technology adoption, challenges that older adults may meet during technology learning, and older adults' preferences toward technology learning, which can help them design better technologies for older adults.

Much of our understanding of older adults' technology adoption is based on research from Information Systems (IS). The technology acceptance model (TAM) and unified theory of acceptance and use of technology (UTAUT) are two dominant models that were used to interpret older adults' technology adoption behaviors [2, 35]. According to the TAM, the two most important attitudinal factors that can be used to explain the acceptance and usage of an information system are perceived usefulness (PU) and perceived ease of use (PEOU) [2]. UTAUT identified three direct determinants of intention of usage (i.e., performance expectancy, effort expectancy, and social influence), two direct determinants of usage behavior (i.e., behavioral intention and facilitating conditions), and incorporated four moderators variables (i.e., gender, age, experience, and voluntariness of use) [35]. Building on these two models, IS researchers found that PU, PEOU, and social influence are significantly correlated with older adults' intentions to adopt new technology [35]. In line with this has been the identification of several factors that may influence older adults' adoption of technology, such as usability, affordability, confidence, and so on [27].

Another line of research on older adults' technology use focused on older adults' technology learning. Research suggested that older adults show strong preferences toward independent learning, as opposed to interrupting family members or waiting long periods of time for customer service [21, 33]. Although many researchers then focused on designing better training materials for older adults (e.g., [5, 15, 65]), a recent study by Pang et al. found that older adults now lean toward self-paced learning and flexible learning methods and that they are less reliant on instruction manuals than before [43]. They also found that although older adults have become more comfortable executing basic tasks on mainstream technologies, challenges remain with the initial adoption and setup of newer generations of technologies (e.g., smartwatches) [43]. Similarly, based on an in-lab observational study with 10 children, 10 adults, and 10 older adults, Mahmud et al. found that older

adults spent a longer time exploring a feature-rich application and repeated sequences of failed selections, which may have caused frustration [36].

Although this literature generated a lot of findings to support older adults' technology use, prior research focused on older adults' adoption behaviors and early stages of learning (e.g., [36]) rather than older adults' technology learning and use in the long term. Even though some researchers have investigated older adults' long-term learning of new technologies, they focused on the overall situations where learning was occurring (e.g., [43]) rather than treating learning as an evolving process. Prior research has suggested that even with support from family, friends, and service providers, older adults may still disuse specific technologies after initial acceptance [26, 47]. For example, Piper et al. found that older adults had difficulties adapting to the evolving nature of new technologies because it requires ongoing learning to maintain skills [46]. Older adults who were online were also found to go offline due to aging-related changes such as declining eyesight [8]. These findings highlight the importance of using an evolving perspective to understand older adults' technology learning and use over the long term.

2.2 Roles of Younger Adults in Older Adults' Technology Use

Younger family members have been found to play a significant role while supporting older adults technology learning and use [34, 39, 49]. For example, family members were found to facilitate older adults' technology adoption by demonstrating the relevance and usefulness of certain technologies [34, 56]. They were also found to be important sources of instructions [43]. Many researchers found that technical support from grandchildren was one of the major sources of assistance that older adults received in technology use [7, 34, 43, 49]. Research on cybersecurity and privacy has also indicated that younger family members' support is important for older adults' technology use [9, 28]. The technology-rich younger generation was also found to enact guidance and provide technical support for older adults, becoming a self-appointed "family tech manager" [41].

However, relatively little research has examined the family dynamics that occur during support. Family support is usually mentioned as one of the major themes in research on older adults' technology use (e.g., [7, 19]). It is also common for researchers to investigate the importance of family support with other factors such as PU and PEOU (e.g., [8, 40]). Even though much research has focused on family support in older adults' technology learning, it still tends to emphasize the general importance of family support to older adults in certain aspects, rather than unpacking family dynamics (e.g., [34, 49]). For example, Luijkx et al. detailed the digital devices that older adults adopted under the influence of family members (e.g., computers, electric bikes, mobile phones, and personal alarm), emphasizing the specific supports older adults received from family members, such as instructions and encouragement [34].

There is also sporadic evidence suggesting that tensions and challenges may exist during the support process. For example, sometimes older adults and their families disagree on the need for specific technologies, and younger adults have also been found to force their ideas on older adults [34]. Murthy et al. found some cases in which strict guidelines established by family members posed conflicts between older adults' safety and their agency [41]. Some older adults have also described frustrations with how support is given by certain family members and how they shied away from asking the same individuals for technical support later [45]. Xie also found that it is almost impossible for older Chinese adults to get technical support from younger adults, including their children, because younger adults tend to be impatient or regard teaching as boring and annoying [79]. However, there is still no holistic understanding of the family dynamics during support.

Additionally, this line of research has lacked the perspectives of younger adults. The perspective from younger adults is important because they may have different perceptions of intergenerational

communications with older adults. For example, Strom et al. found that although grandparents commonly described themselves as eager to learn from the youth, the youth reported grandparents unwilling to learn from them [62]. A recent mixed-method study on younger adults' assistance to older adults' mobile security suggested that younger adults are more willing to help older family members than other social groups with technology use, however the support they provided was often counter to older adults' preferences [39]. However, younger adults' support to older adults does not stop there; it also covers other important aspects of technology use (e.g., adoption [34]). Hence, this literature needs a more holistic understanding of family support to older adults' technology use based on perspective from both sides.

2.3 Older Adults' Technology Learning and Family Support in the Chinese Context

Although there is an abundance of research on older adults' new technology learning in HCI, most of this research was conducted in North America or Western European countries (e.g., [43, 47]). Research in China is still relatively limited. Many older adults in NAWA might have much experience in technology use because computers have become prevalent in workplaces in the 1980s in these places [33]. By contrast, many older Chinese adults may have only begun to use new technologies such as smartphones due to the recent trend of rapid digitalization in China [18, 23, 86]. For example, mobile payment systems have been extremely popular in China, so much so that buying an apple now requires a smartphone [18]. This rapid digitalization has required that older adults be able to access and use digital technology [16].

In China, family support may be more crucial for older adults' technology learning than it is in NAWA. Compared with NAWA, where nuclear families (i.e., husband, wife, and children [82]) tend to be the basic family unit, extended families (i.e., a family that extends beyond the nuclear family, including grandparents and other relatives [82]) are traditional forms of family in China [84]. Chinese people usually include grandchildren and grandparents when conceiving the unit of their family. For instance, while raising a grandchild is stigmatized in the U.S. [14], grandparents are major care providers for their grandchildren in China [66]. Family is also usually the primary source of support and care for older adults in China [80]. Filial piety is highly valued in China, and adult children are typically expected to fulfill the responsibilities of caring for their aging parents [80, 83]. In a mixed-method study based in Nanjing, China, Zhan et al. found that Chinese families, unlike families in NAWA, struggled to manage the cultural demands of elder care with other financial, caregiving, and emotional concerns; Chinese adult children even felt stigmatized when their parents moved to institutional care [83]. In Chile, another country that values filial piety, Gutierrez et al. found that younger family members take it as their responsibility to teach older adults how to use technology; Chilean older adults even perceive adoption of new communication technologies as unnecessary because their family members will fulfill their filial obligations through face-to-face encounters or using tools that have already been assimilated by older adults (e.g., telephone) [12]. Findings from this work imply the importance of a cultural perspective when understanding family support to older adults' technology use. As a study situated in China, our work can contribute to the understanding of older Chinese adults' technology learning and family members' roles in the process.

3 METHOD

The goal of our research is to understand the family dynamics when younger adults provide support to older adults' technology learning and use. We chose to use interview-based qualitative methods because qualitative methods are appropriate for understanding people's lived experience and uncovering the inner mechanism of a process [4]. We began our study with one-on-one interviews

with our participants, who were recruited from diverse sources. After that, we went through multiple rounds of data analysis until we came to an agreement on the final themes.

3.1 Participants and Recruitment

We used the current legal retirement age in China to define "older adults": 60 for men, 55 for female civil servants, and 50 for female workers [74]. We did not set age limits for younger family members. The inclusion criteria for the older adults were that they had to use technologies such as smartphones and smartwatches and had received technology support from their younger family members (i.e., adult children or grandchildren). The inclusion criteria for the younger adults were that they had older parents or grandparents who used technologies such as smartphones and smartwatches and provided technology support to their older parents or grandparents.

We recruited participants from four sources: (1) personal social networks (e.g., friends and relatives) of four authors who have lived in three different cities during the study (i.e., Shanghai, Chengdu, and Beijing), (2) older adults' online communities (e.g., a WeChat group established by older adults), (3) online communities (e.g., DouBan²), and (4) snowball sampling by family members who participated in the study [10]. We used four recruitment sources to try to increase the sample size and improve participant diversity. For example, we can reach people living in different cities in online communities. We recruited both older adults and younger adults and asked if their family members (i.e., adult children and grandchildren who provide supports or parents and grandparents they support) were willing to participate in the study.

Twenty older adults (gender: 12 female, 8 male; age: median = 70.5, average = 71.15, SD = 6.49) and eighteen younger adults (gender: 11 female, 7 male; age: median = 32.5, average = 34.27, SD = 9.41) were recruited to participate in the study at last. Demographic information about our participants are presented in Table 1 and 2. Since we did not set an age restriction to younger adults, we did not ask our older participants the age of their younger family member. There were nine groups of families, including one family which consisted of three people (Family H in Table 1). Although we offered to provide compensations, participants recruited from the authors' social networks were willing to participate in the study as volunteers. Because recruiting families was harder than individual younger participants, 200RMB was offered to all pairs of families and 25RMB was offered to individual participants. This study was approved by the Institutional Review Board (IRB) of City University of Hong Kong.

3.2 Semi-Structured Interviews

From July 2021 to August 2021, we conducted semi-structured interviews with our participants. All interviews were conducted one on one, with informed consent from all participants. Questions asked of older participants included how they started using technologies they mentioned, what support they received from their younger family members, and how they perceived that support. Questions for younger participants included how they chose technologies for older adults to use, how they supported their parents or grandparents in technology learning, and related feelings. Similar to [43], we did not restrict the conversation to a specific technology. Instead, we encouraged participants to share the experiences and feelings they felt relevant. Participants mainly talked about smartphones and digital applications (Appendix A), likely to the digitalization of China, which has made smartphones and some applications necessary in Chinese people's daily lives (e.g., WeChat [86], mobile payment [18], health QR code system [68]). The technologies that were mentioned by our participants are presented in Appendix C and D. We focused on specific situations they talked about and asked follow-up questions to build a contextualized and detailed understanding

²<https://www.douban.com/>

Family	Role	ID	Gender	Age	Location	Source	Interview Setting
A	Father	O1	M	65	Tier 1	Family	In-person
	Daughter	Y1	F	35	Tier 1	Personal	In-person
B	Mother	O2	F	74	Tier 1	Family	In-person
	Daughter	Y2	F	45	Tier 1	Personal	In-person
C	Father	O3	M	74	Tier 2	Family	WeChat call
	Daughter	Y3	F	44	Tier 1	Personal	In-person
D	Father	O4	M	81	Tier 1	Family	In-person
	Son	Y4	M	47	Tier 1	Personal	In-person
E	Grandfather	O14	M	88	Tier 3	Family	WeChat call
	Granddaughter	Y7	F	28	Sydney	Online	WeChat call
F	Mother	O15	F	66	Tier 1	Family	WeChat call
	Daughter	Y8	F	30	Tier 1	Online	WeChat call
G	Mother	O16	F	79	Tier 1	Family	WeChat call
	Daughter	Y14	F	52	Tier 1	Personal	WeChat call
H	Paternal grandmother	O17	F	72	Tier 3	Family	WeChat call
	Maternal grandmother	O18	F	71	Tier 3	Family	WeChat call
	Grandson	Y18	M	22	Tier 1	Personal	In-person
I	Grandfather	O20	M	68	Tier 2	Family	WeChat call
	Grandson	Y11	M	22	Tier 2	Online	WeChat call

Table 1. Demographic information about participants from the same family. China's unofficial hierarchical classification of cities [76] is used above. Tier 1 cities represent the most developed areas in China.

of participants' experiences. All participants were from Mainland China, so the interviews were conducted in Mandarin. The interviews were audio recorded after receiving participants' explicit permission. Notes were also taken during each interview.

3.3 Data Analysis

To identify potential principal themes from the data, three researchers conducted a round of independent open coding [60], and discussed the resulting themes. The primary codes in the first round coding included: younger adults' choices of technologies for older adults, teaching strategies, imagined fears while teaching older adults, concerns about rumors spread online and financial issues, challenges in teaching, intergenerational trust, intergenerational communication during technology support, technology support from local communities, etc. We then went back to the data to conduct two additional rounds of focused coding [60], and a consensus on the themes was reached. All the quotes used in the paper were translated into English by the lead author and checked by the coauthors.

4 RESULTS

The themes that emerged highlighted several important findings about the roles of younger adults over the course of providing support to older adults while they were learning new technologies. We first summarize the technology support patterns that were used by participants and then identify

ID	Gender	Age	Location	Family member	Age of Family member	Source	Interview setting
O5	F	65	Tier 1	Son	N/A	Online	In-person
O6	F	77	Tier 1	Daughter		Online	In-person
O7	F	72	Tier 1	Son		Online	In-person
O8	F	70	Tier 1	Daughter		Online	In-person
O9	F	75	Tier 1	Two sons		Online	In-person
O10	F	65	Tier 1	Son		Online	In-person
O11	F	70	Tier 1	Son		Online	In-person
O12	M	64	Tier 1	Son		Online	In-person
O13	M	66	Tier 1	Son		Personal	In-person
O19	M	61	Tier 4	Son		Personal	WeChat call
Y5	F	42	Tier 1	Father	70	Personal	In-person
Y6	F	39	Tier 1	Father	66	Personal	In-person
Y9	F	25	Tier 1	Mother	62	Online	WeChat call
Y10	M	30	Tier 1	Mother	65	Online	WeChat call
Y12	F	23	Tier 1	Grandmother	82	Online	WeChat call
Y13	M	27	Tier 1	Father	60	Personal	In-person
Y15	M	26	Tier 1	Grandmother	76	Personal	WeChat call
Y16	F	45	Tier 3	Mother	71	Personal	WeChat call
Y17	M	35	New tier 1	Father	71	Personal	In-person

Table 2. Demographic information about participants who participated in the study individually without family members.

younger family members' roles and the key insights from each stage of older adults' technology learning and use.

4.1 Overview

The results indicated that there appear to be three major stages during older adults' technology learning processes (Figure 1): 1) adoption (i.e., deciding to use a new feature, application, or device), 2) onboarding (i.e., starting their initial use of a technology after deciding to use it), and 3) maintenance (i.e., the continuation of use of the technology [26, 51]). These stages may appear in a recurrent way, as older adults may discover new features, applications, or devices and go through the three stages again, often on a more micro level (e.g., a specific feature in an application that older adults have already assimilated). While there can be other stages with more nuances that can be conceptualized during technology use (e.g., pre-contemplation, contemplation, and preparation before action [7]), these stages may be elusive as technology use is a continuing process. Therefore, it should be noted that although we present this process based on three distinct stages, these stages do evolve.

Regarding family members, we found that they play the following roles throughout the learning processes of older adults:

- **Influencers:** influencing older adults to adopt and start to use new technologies;
- **Supporters:** assisting in older adults' technology use (e.g., fixing technical problems, providing instructions, and serving as proxy users);
- **Protectors:** protecting older adults from online threats;

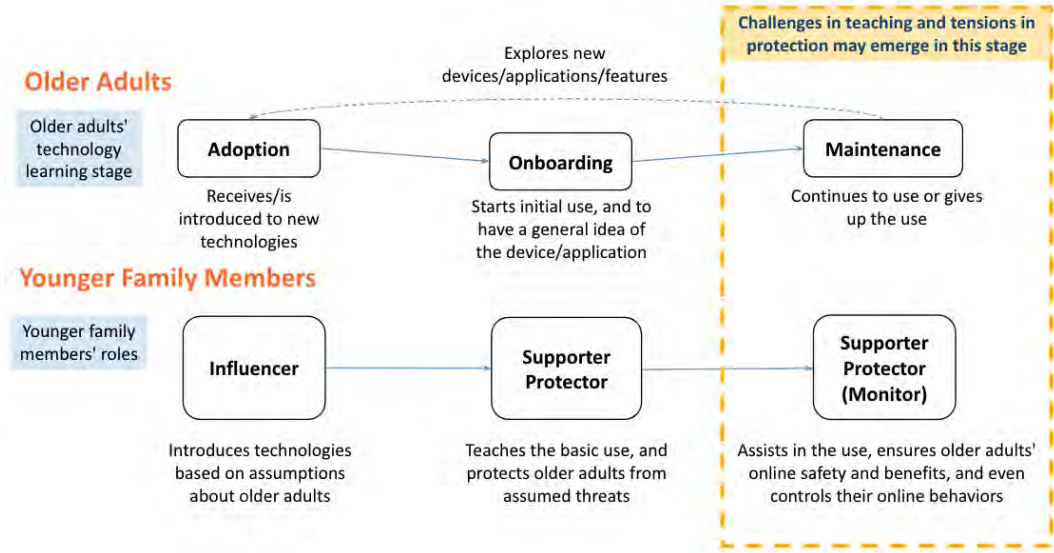


Fig. 1. Older adults' technology learning process over the long term and the evolving roles that younger family members play while providing support to their older family members.

- **Monitors:** regularly checking or controlling older adults' online behaviors.

It should be noted these roles are not separate but emphasize younger adults' different focus during support. For example, one may aim to protect older adults' online safety through assisting in money-related tasks.

As usually reported in prior research, younger adults play supportive roles (i.e., influencers [34], supporters [43], and protectors [41]) in older adults' technology use. Moreover, we found that their roles co-evolve not only with older adults' changing needs, but also as they make adjustments to their perceptions about older adults' learning abilities and online behaviors. Younger adults usually start their support with a low expectation about older adults' technology use and learning abilities. However, they may still need to adapt their teaching strategies due to older adults' forgetfulness [5] and digital illiteracy, which they may not be familiar with [79]. Besides, many younger individuals had no idea that their (grand)parents might be as active online as they are. They were surprised to find that older adults may explore new technologies (e.g., features, applications, and devices) that they had not introduced or even heard of. Younger adults then may be worried about the benefits of older adults' going online and their safety, which may lead them to take on the role of a monitor, controlling older adults' online behaviors. Details of each stage and family members' roles are presented in 4.2, 4.3, and 4.4.

4.1.1 Technology Support Pattern Shaped by "xiaoshun". Unlike the older adults who would avoid bothering their adult children or grandchildren in North America [29] and Western Europe [37], few older adults were reluctant to ask younger family members for help because they thought their adult children or grandchildren are "xiaoshun" (e.g., O6, O15, O16 and O20), though they still may have tried to relieve additional pressure on younger family members who were working or studying. For example, if their problems were not urgent, many older adults would write out a list of questions and ask them all at the same time (e.g., O14, O15, O20, Y10's mother, and Y12's grandmother). Take O15 as a typical case: "I don't feel I'm bothering my daughter. She's quite patient

and "xiaoshun" to me. But I know she's busy at work, so I wait for her to visit on the weekend and ask my questions then if there's no urgent problem." Because of "xiaoshun", many of younger adults also felt responsible for older adults' technology learning (e.g., Y5, Y7, Y8, and Y10). "As a daughter," said Y8, "I should care for my parents. I often pay attention to their needs and health conditions, including the difficulties they met in technology use."

The older adults often perceived family members as the most significant source of receiving technology support (all except O2, who was active with new technology and tech-savvy). As an extreme case, Y7 and her grandfather (i.e., O14) lived in different countries. However, O14 still often asked Y7 for technology support through WeChat³, as he perceives Y7 to be a technology expert and one of the closest people to him. Most of the older adults (except for O5 and O7) seldom turned to local communities and instead asked for help from family members. When asked why they did not turn to local communities, older adults reported that the technology support services were not well established (e.g., O4 and O14) and that asking family members was more convenient (e.g., O2 and O20). Interestingly, O8 thought it was inappropriate to ask questions related to privacy and finance to strangers to resolve difficulties related to the use of communication technologies and finance-related applications. She told us, "What if my money is lost? I know the volunteers are good guys and it is probably not their fault if similar cases happen, but you know, it will be embarrassing." This quote highlights the importance of family members in resolving sensitive issues related to privacy for older adults.

4.1.2 Differing Degrees of Involvement. It is worth noting that younger adults may not always be involved in all stages of older adults' technology learning, which may depend on their perceptions of their parents or grandparents. If older adults were motivated to use new technologies, their family members may only be involved in the maintenance stage. These older adults were likely to know a lot about new technologies through their own exploration and social networks. Some older adults were even more familiar with new technologies than younger adults (e.g., Y3's father, Y5's parents, Y6's father and Y2's mother) because they saw the benefits and enjoyed using them. For example, technology has played an important role in O2's social life. When we asked O2 why she knew so many digital applications, she said, "My friends talk a lot about interesting applications and useful devices. We also share the links with each other." O2's daughter, Y2, told us her mother even recommended new technologies to her. Similarly, Y5 said, "I don't need to recommend technologies to my parents. They're using more of them than me."

Most participants, however, are not so active when learning new technology, although they may have been active in the use of a specific technology. In these cases, their younger family members were likely to engage with them during all stages. When older adults had no channels through which to learn about new technologies, younger adults were likely to give or recommend technologies to them (e.g., Y7, Y8, Y10, Y11, and Y12). Older adults generally followed younger adults' suggestions, as technology use was almost inevitable. If older adults were resistant to using devices or applications that were infrastructural or necessary for communication with family members, those members will put much more effort into persuading older adults to adopt them. For example, Y4's father, O4, was uninterested in new technology adoption and learning. Y4 told us he almost forced his father to use WeChat. Although his father accepted WeChat out of a need to communicate with colleagues, he was still resistant to learning how to use other technologies. O4 said he did not feel that learning to use such technologies was necessary, because he could "ask younger adults for help if he was alone outside". Y4 felt he could not do anything about this, although he was unhappy with his father's resistance.

³The most popular mobile application in China, with instant messaging as its core service but also integrating other services such as news subscriptions and money transfer [23, 75]; see Appendix B-1.



Fig. 2. (a) The smartphone used by one older participant. (b) Due to aging-related forgetfulness [5], some older adults wrote processes down on paper so they could refer to them later. (c) The smartwatch used by O1. (d) The intelligent voice assistant used by O6. (e) A screenshot of conversations in a family WeChat group in which older adults were active in reposting videos and articles. Younger participants often saw the posting of such information as the spreading of rumors.

4.2 Stage I: Adoption

Adoption is a significant stage in older adults' technology learning and use, as many older adults were resistant to new technologies even though they could access many digital devices and necessary resources such as the Internet [24]. Younger adults said they commonly gave new digital devices as gifts (e.g., Y1, Y8, Y10, Y11, and Y14), gave their disused devices (e.g., Y3, Y4, and Y13), or recommended new digital devices and applications to older adults (e.g., Y1, Y2, Y3, Y6, Y10, Y11, Y13, Y14, Y16, and Y17) either for practical purposes (e.g., communication with family members or better social integration, as smartphones are almost a necessity in China) or out of caring (e.g., health-related benefits). Older adults said they were usually happy to accept the technologies, as they perceived the devices or applications as necessary, useful or interesting, or perceived the technologies as a symbol of care.

4.2.1 Influencers: Introducing Technology to Older Adults Based on Assumptions about Aging. Younger adults often introduced technologies to older adults based on their own assumptions about aging. Appropriate technologies for older adults mentioned by younger adults generally featured functional benefits (e.g., improving health, facilitating communication). These choices

may reflect an assumed ideal of retired life – some younger adults said that older adults should live simple lives (e.g., Y8 and Y14), and almost all identified health and happiness as the main goals of older adults. Y8, a typical case, told us,

Health is most important in retirement life. Older adults had better enjoy a simple life. The simpler, the better. Older adults can use smartphones for shopping and watching online videos, but they don't have to use phones with too advanced functions. Older adults should have enough offline activities. A simple and healthy lifestyle is good for them.

Similar to Y8, other younger adults usually mentioned smartphones and health care devices as appropriate for older adults because these devices can help to foster an enjoyable retired life. They think older adults can use smartphones for fun and communication (e.g., Y8, Y11, and Y12), while health-related products can promote older adults' physical health (e.g., Y1, Y5, and Y11). Additionally, younger adults often mentioned that devices for older adults should be simple, as those participants generally held concerns about older adults' learning abilities (e.g., Y8, Y10, Y11, Y12, Y14, and Y18). Smartphones with accessible design (e.g., with physical buttons, large screen display, large fonts) and intelligent voice assistants were often mentioned as the most appropriate devices for older adults due to their ease of use (e.g., Y2, Y13, Y14, Y15, and Y18).

Although in most situations, younger adults' assumptions about older adults' technology needs might be true, sometimes they ignored factors important to older adults (e.g., self-conceptualization, sense of control, difficulty in speaking Mandarin). For example, many younger adults recommended or gave health-monitoring devices to older adults (e.g., Y1, Y8, Y11, Y13, and Y15), but older adults may not view themselves as aged enough to require health-related products (e.g., O14) or dislike being monitored (e.g., O12 and O4). In an extreme case, O12 told us he would not use most digital products given by his son because he "*did not want to be monitored by digital products such as a smartwatch*". He, however, did not tell his son the truth because he "*did not want to hurt his son's feelings*". Additionally, some devices perceived as simple by younger adults may not have been viewed similarly by older adults. Indeed, some older adults said they struggled to use voice assistants because they could not speak standard Mandarin well (e.g., O6 and O16). For O6, although the basic use of voice assistants (Figure 3d) was relatively easy, she noted that the assistants she used could not understand dialects in Shanghai. These cases imply that older adults' technology use is a holistic experience, not only related to aging-related factors that younger adults emphasized.

4.3 Stage II: Onboarding

Onboarding can be taken as a distinct stage in older adults' technology learning, as older adults usually face difficulty while setting up a new device [43, 61]. When older adults begin using a new device or application, it was often their younger family member who was in charge of teaching them how to use it properly, especially when the older adult was not tech-savvy. Based on their low expectation of older adults' learning abilities, they also helped to set up the device, downloading applications that they thought would be beneficial to older adults. As younger adults simplified the onset of technology use, older adults generally encountered few difficulties during onboarding. However, younger family members may still hold concerns about older adults' online safety and the benefits they get from using a technology.

4.3.1 Supporters: Teaching in the Context of Assumed Difficulties. Almost all younger adults said they had low expectations of older adults' learning abilities, and that they assumed that older adults would be intimidated by the difficulty of learning new technologies, except in families in which older adults actively used new technology. It was common for younger adults to only teach older adults basic skills (e.g., how to read online news and how to send messages using WeChat). For example, Y15 thought using a smartphone itself was good enough for older adults. With such

low expectations of older adults, some younger adults completed all the tasks they thought were complicated for older adults, especially complicated one-time tasks (e.g., setup and configuration), which was the case for O9's son, Y5, and O4's daughter. "If my mother buys new smartphones," said Y5, "I always do the setup and download all the applications she needs. All she has to do is using the phone I set up for her."

Such a simplification strategy worked well for older adults, as older adults may have only needed to complete the most basic task. As O4 told us: "My daughter told me that I can hail a car service with a smartphone. She has done almost all [configurations] for me and put money in my account...I just need to click the button to call a car." In this way, older adults may have relied on their adult children or grandchildren to do relatively complicated tasks (e.g., Y13's father, O4, O7, O10). O7 told us that she relied on her son to do her online shopping. She would tell her son what she wanted, and her son would buy the items for her.

Surprisingly, through teaching, some younger adults said they were surprised that it was easier to teach older adults than they imagined (e.g., Y10, Y11, and Y12). For example, Y12 only taught her grandmother to send voice messages rather than typing, because she assumed typing was too difficult for her. However, her grandmother actually preferred typing. As a former primary school teacher, Y12's grandmother enjoyed writing and preferred traditional ways of input. Y12 told us,

It was much easier than I had anticipated when I first began teaching her. I read online that many people said it was extremely difficult and painful to teach older adults how to use smartphones. However, it was not really that difficult. My grandmother is eager to learn, which was beyond my expectations, though it was still not as quick as I had hoped. I expected her to be unable to understand after one or two years, but she was able to use the smartphone after only two or three months.

In this way, the teaching experience may have contributed to the intergenerational understanding. The younger adults started to pay attention to individualistic characteristics of their (grand)parents.

4.3.2 Protectors: Creating a Safety Net for Older Adults. Downloading applications is a typical task that younger adults did for older adults to simplify their smartphone use (e.g., Y8, Y10, Y11, Y12, Y16, and Y18). Due to the same perceptions of aging found with the adoption stage (i.e., older adults should live simply, happily, and healthily), younger adults selected applications they regarded as simple, safe, and beneficial for older adults (e.g., necessary applications developed by major companies such as WeChat, major video streaming apps such as iQIYI⁴ and news reading apps from trustworthy sources) while avoiding those they perceived as complicated, unnecessary, or even negative for older adults. Although older adults would tell the family members about their needs, younger adults would still try to find applications they perceived as safe and beneficial for their older adults.

Younger adults generally perceived applications with following characterizations as inappropriate for older adults: complicated procedures (e.g., online shopping apps), perceived negative content (e.g., KuaiShou⁵), or cheating in shopping or relationships (e.g., PinDuoDuo⁶ and apps used to make new friends). In this way, the younger generation tried to create a safety net for their older adults. For example, Y8 said she would not download KuaiShou for her mother, as she thought videos on KuaiShou were vulgar and older adults should only receive information from official sources. As Y8 said,

⁴A popular video streaming application in China; see Appendix B-7.

⁵A short video sharing mobile application with a particularly strong user base among users in countryside and rural areas [73]; see Appendix B-3.

⁶A popular application for online shopping in China; PinDuoDuo is well-known for affordable products that are often unbranded or white-labeled [63]; see Appendix B-4.

I won't tell my mother about KuaiShou, and she doesn't have any way of finding out about those kinds of new apps. I take care of everything she needs...Older adults don't have to know too much information; they don't need it. They can get what they need through trustworthy sources, like television, instead of reading online information.

Typically, younger adults carefully selected information-related applications for older adults (e.g., Y1, Y8, Y10, Y11) because they generally perceived older adults as vulnerable to misinformation and more likely to share rumors (e.g., Y2, Y5, Y8, Y9, Y10, Y11, Y12, and Y16; Figure 3e depicts a typical example). Nuances between rumors (i.e., circulating stories or reports of uncertain or doubtful truth) and misinformation (i.e., false or inaccurate information) caused great difficulties for younger family members. Many younger adults could not tell whether the information shared by older adults was misinformation or not. They were also unable to explain their rationale of information judgement, so it may have been hard for them to teach older adults how to evaluate the credibility of online information (e.g., Y7, Y9 and Y10). As Y10 said, *"To be honest, I feel it difficult to tell my mother a strict evaluation criteria of online information. It's hard to say with certainty which information is accurate and which is not."* Therefore, younger adults can only try their best to provide perceived trustworthy information sources for older adults.

Younger adults also tended to have assumed concerns about older adults' use of mobile payment and digital banking (e.g., Y1, Y2, Y5, and Y7); specifically, they feared older adults would be cheated out of their money. For example, Y1 did not download finance-related applications for her father, because she thought her father would not understand how they worked and thus might be cheated. Likewise, Y2 tried to instill a sense of caution in her mother before introducing her to smartphones:

I taught my mother a lot about online safety before she used smartphones. For example, I told her to put only a little money in online accounts so that she won't lose too much even if she's defrauded online.

Despite their concerns, many younger adults still supported older adults' use of information- and finance-related applications, as older adults might enjoy them (e.g., Y1, Y5, Y7, Y17, and Y18) and the use of some applications (e.g., mobile payment) was unavoidable (e.g., Y2).

4.4 Stage III: Maintenance

Support to maintain older adults' technology was significant as people have been found to disuse specific devices or applications even after initial adoption and use [26]. During this stage, younger family members continued to provide instructions if needed and often checked if older adults had difficulties with technology use. However, challenges emerged when teaching advanced use of technologies due to older adults' forgetfulness [5] and digital illiteracy. Contrary to many younger adults' expectations that older adults' online behaviors were limited, older adults may have started to discover new technologies, especially new features in applications and applications in smartphones, on their own. Older adults' free exploration of new technologies may have lead to younger family members' worries about older adults' online security, as younger family members often perceived older adults as vulnerable to online misinformation and malicious acts as mentioned above. Younger family members may thus have transformed from protectors into monitors to ensure older adults' online security (i.e., regularly checking or controlling older adults' online behaviors).

4.4.1 Supporters: Teaching Strategies that Need to Evolve. As older adults continued using technologies, their younger family members faced emerging challenges while teaching commonly due to older adults' forgetfulness [5] and their lack of digital literacy. Although the basic usage during onboarding became relatively simple with family support, older adults faced new difficulties as they continued to use a device or application.

Many older adults said they often forgot what younger family members had taught them (e.g., O2, O4, O7, O9, O10, and O15). As a result, older adults repeatedly asked the same questions. For example, O4 said,

Although I may have seemed to understand what my son was saying when he taught me, I actually didn't. He told me to exercise my brain [to improve memorizing skills], but I can't. My brain is not as sharp as when I was young. I am much more forgetful now, which younger adults may not understand.

By contrast, Y7 offered a successful example of addressing the challenges older adults faced regarding cognitive decline. She said she would write down a process and draw pictures on a piece of paper, which her grandfather could check later if he forgot the process (Figure 3b).

Another challenge younger adults often mentioned was the generation gap in digital literacy (e.g., Y7, Y13, and Y15). Many older adults were unfamiliar with concepts that younger adults took for granted, including technical terms (e.g., the word "menu"), design patterns (e.g., the common placement of buttons), and app-based mechanics (e.g., membership systems, separate passwords, voice assistants). As mentioned in the onboarding stage, younger adults tended to only teach older adults basic use of technology. Although such a strategy might work well for getting older adults to start using technologies, it might cause some trouble later on. O14 said he experienced numerous issues when he got a new device. He was required to enter a password, but he did not know what the word "password" referred to because his granddaughter had set up all his passwords for him. Meanwhile, O14's daughter, Y7, also told us it was difficult to teach O14 because he did not understand the inner mechanism of smartphones. For example, he did not understand he was using different applications on his smartphone and that he required separate passwords for each one. As far as O14 was concerned, he was just using his smartphone. Therefore, Y7 chose to keep a list of all his passwords. Y7, told us she did not realize her poor ability until she started teaching her grandfather to use technology. As she said,

For example, my grandfather cannot understand what home button is, and I need to work hard to explore a more childish way of teaching. As for the home button, I just told him the only button under the screen, which works for him.

Our participants' experiences implied that younger adults need to adapt their teaching strategies according to older adults' needs and preferences, which may require substantial effort.

4.4.2 Supporters Continued: Impatience while Teaching and Learning. Given the difficulties inherent in teaching, many younger adults became impatient even though they tried hard not to (e.g., Y15 and Y2). Some older adults might thus be unwilling to bother their family members anymore or feel embarrassed for asking for help (e.g., O2, O4, O5, and O7). For example, O7 described her son's teaching this way,

I will not ask my son for help. He teaches too fast and just tells me to click here or there. I can't remember what he says. If I ask him again, he'll say something like, "Older adults don't have to learn [to use technology]; [my teaching is meaningless because] you can't understand what I'm saying." At my age, how can I understand immediately?

Older adults complained that younger adults sometimes just repeated themselves and taught too fast, and they seemed to get impatient. Younger adults may also lose patience during explanations, instead choosing to resolve the problem for older adults and tell them that they do not need to understand (e.g., Y8, O4's son and Y10). Y8 said, "If my mother asked me about some complicated features and wouldn't understand even if I tried to explain, I'd just tell her that she doesn't have to learn about that". Some older adults then turned to local communities or their friends to ask for help (e.g. O2, O5, and O7). For these older adults, local communities seemed to serve as good

complements to their technology learning. O7 said younger adults in her community were all very nice. However, O4 told us it was hard to enroll in local technology training programs and younger adults in his local community also taught too fast so he was considering giving up learning how to use a smartphone.

Meanwhile, some younger adults said older adults' learning attitudes were important to successful learning outcomes (e.g., Y4, Y7, and Y8). They complained that older adults' impatience or resistance to learning would decrease their motivation to teach them. For example, Y4 said his father once angrily complained that his smartphone had frozen, which made Y4 uncomfortable. Similarly, although Y7 was willing to teach her grandfather, she was not as keen to teach her mother, who she said was bad-tempered and resistant to learning.

Finally, older adults may give up learning how to use specific technologies if they cannot see the possibility of success in learning (e.g., O4, O7, and O14), as they can still maintain most of their normal lives without learning to use technology. For example, many participants mentioned volunteers who offered help at public facilities (e.g., O1, O4, O10, and Y5). Generally younger adults said they respected older adults' decisions or felt they could do nothing to change their minds, even if they sometimes truly wanted older adults to use technology (e.g., Y4, Y8, Y11, and Y13).

4.4.3 From Protectors to Monitors: Adjustments to Younger Adults' Perceptions of Older Adults. Many younger adults said they were surprised to find that their parents or grandparents used features, applications, and devices that they did not teach them (e.g., Y1, Y3, Y8, Y9, and Y12). They assumed that older adults would only use the basic functions they taught. However, older adults may have learned about new applications and features through their social networks (e.g., friends and community). Many older adults also knew about new features and downloaded new applications needed for a public service (e.g., going to a bank or taking a bus). For example, Y8 and Y12 said that when they introduced smartphones to older adults, they assumed they would only use them for communication with family. However, they found that older adults had their own online social networks. As noted by Y12,

At first, we bought grandma a smartphone so she could communicate more easily with family. But I found she had her own WeChat group with friends in her aging care home. She can even read articles and repost them on WeChat. I found this quite interesting.

As such, younger adults said they readjusted their perceptions of older adults' online behaviors. As Y1 told us,

I was truly surprised to find my father was shopping via live-streaming on DouYin, which even I had not heard of. I have always assumed that he only read online news on his smartphone. I didn't find this until he asked me how to return the items he ordered on DouYin. This really has given me a new perspective on my father. I felt like I had no control over him any more.

Y1's experience implies the tension between older adults' agency and younger adults' protection. Although some younger adults said they were happy to see older adults' exploration of new technologies (e.g., Y8 and Y9), many started to worry (e.g., Y1, Y2, Y5, Y8, Y15, and Y18) about issues like fraud, misinformation, and social communication. Some younger adults also worried about older adults' eyesight and other physical health impacts that could result from spending too much time online (e.g., Y5, Y8, Y15, and Y18). The assumed worries of younger adults may transition some protectors into monitors, leading them to regularly check or control older adults' online behaviors.

4.4.4 Monitors: Tensions Resulting from Family Members' Protection. Out of concern for older adults' online security, many younger adults tried to set restrictions on older adults' use of specific applications (e.g., Y1 told her father not to buy things of over 50RMB online, Y2 suggested binding

debit cards instead of credit cards for mobile payment applications, and Y5 told her father not to click links from unfamiliar sources). Others said they were not overly worried about older adults' technology use because they believed that older adults would be cautious in money-related contexts. In most cases, families could reach agreements on such restrictions, as older adults thought the restrictions were expressions of "xiaoshun".

However, sometimes older adults held conflicting opinions from younger adults. For example, while many younger adults thought the quality of products on PinDuoDuo were relatively low, they knew that many older adults were intrigued by the low prices. In addition, as mentioned in the adoption stage, much of the information older adults enjoyed reading was often what young participants perceived as rumors and may be misinformation. Meanwhile, many older adults said they think they have abilities to tell misinformation online (e.g., O4, O14, O15). Therefore, younger adults may have struggled to protect older adults from online misinformation. For example, Y2 said she put considerable effort into fact-checking for her father, which caused her stress: *"My father reposts a lot of articles to our (family) WeChat group. I need to check the validity of them every day. Sometimes, I even need to read research papers so that my father can trust me."*

Some younger adults said they had become monitors, regularly checking and controlling what applications older adults were using and who older adults were contacting online. Several younger adults said they checked their older adults' smartphone when they helped them solve specific problems (e.g., Y8, Y10, Y11). Y1 and Y8 checked their parents' phones and even deleted applications they perceived as inappropriate. Y1 told us this way,

I was surprised to see that my father had Alipay⁷ on his phone. I guessed it might have been downloaded when he went to his bank, and I immediately made a complaint against the bank. How can they fudge older adults for profits? I deleted Alipay and unbound his cards in WeChat Wallet. My father doesn't have a full understanding of these services, and he often didn't know what he did in the application.

Older adults may be unaware of such deletions, possibly because they were not sufficiently familiar with a device or application (e.g., Y10's mother, O20). However, such caring from younger adults caused some older adults' discomfort (e.g., O1 and O15). O1 felt uncomfortable with her daughter's control. He said he was not fearful of online fraud, as he believed he would not lose much even he was cheated. Y8's mother, O15, continued using PinDuoDuo for shopping regardless of Y8's disagreement. Unlike other participants, she said she initially viewed her daughter's reviewing of her phone as a privacy invasion and she even tried to hide her device. However, with her daughter's insistence, she came around to seeing that it was for the best. She said she now proffers her phone to her daughter for review: *"I told myself this is 'xiaoshun' from my daughter. Actually, I have nothing to hide on my phone. If she can help me identify misconduct online, that would be beneficial."* O8's experience illustrates how she self-regulated her perceptions of her daughter's control under the Chinese cultural context of "xiaoshun".

Most younger adults, however, said they did not control older adults' use of technology that much, as they respected their individual choices (e.g., Y2, Y5, Y8, Y15, and Y16) or thought a specific use of technology would not have negative consequences (e.g., Y3, Y5, Y8, Y12, Y10, and Y15). For example, Y7 told us that although she did not support her mother's shopping on PinDuoDuo, she would not interfere, as it did not result in significant financial losses. Many younger adults also mentioned that they believed older adults were wary of money-related actions (e.g., Y3, Y4, Y8, and Y12), which was evidenced by the suggestions in articles they read (e.g., Y9 and Y12). Many younger adults also mentioned that although using smartphones may have lead to negative outcomes (e.g.,

⁷A mobile and online payment application; see Appendix B-5.

misinformation, online fraud), they were among the best entertainment options for older adults who tend to stay at home and have nothing to do (e.g., Y6, Y8, Y12, and Y18).

5 DISCUSSION

Based on the perspectives from older and younger adults, this work contributes an empirical understanding of the evolving family dynamics in family support during older adults' technology learning along with the transformative roles that younger family members play (i.e., influencers, supporters, protectors, and monitors) in the Chinese context. We extend the existing literature by uncovering how challenges in teaching and tensions in protection may emerge from the support process over time. As suggested in this study, the roles of family members evolve not only based on older adults' changing needs, but also younger adults' adjustments of perceptions of older adults' learning abilities and online behaviors. Our younger adults tend to show unfamiliarity with older adults' learning abilities and online behaviors, which makes it challenging for them to adjust teaching strategies and establish trust towards older adults' technology use. Based on our findings, we suggest treating older adults' technology learning and use as a collaborative activity with family members. In this section, we also discuss how older adults' long-term technology learning should be considered as a recurrent, dynamic, and evolving process. We conclude this section by underlining the importance of cultural contexts in the design of socio-technical support systems for older adults.

5.1 Treating Older Adults' Technology Learning and Use as a Collaborative Activity

In contrast to treating technology learning as something older adults pursue alone, with family members as one external source that can be used by older adults (e.g., [34, 38, 43]), we suggest that older adults' technology learning should be considered as a collaborative activity with family members. That is, designers may not only consider how to help older adults acquire technical assistance when they encounter difficulties, but also how to form a long-term cooperative relationship between older adults and family members, with considerations of both younger and older adults. For populations outside of China, providing family support to older adults' technology learning is also important yet challenging (e.g., younger adults' impatience in teaching [38, 49], older adults' avoidance of being seen as a burden [37], disagreement on technology use [34]). Although nuclear families are dominant forms of families in NAWA [84], research suggested that younger adults in the U.S. are also more willing to provide technical assistance to their older relatives than other groups of people [39], and many did so out of a sense of obligation to people who they cared [48]. The main difference between older Chinese adults and those in NAWA may be that older adults in NAWA show stronger preferences toward independent learning [43], which we will elaborate on in 5.3. We provide design implications as follows.

5.1.1 Building Family Members' Awareness of Older Adults' Technology Use. We found that due to their unfamiliarity with older adults and ageism, younger family members may ignore some important needs of older adults (e.g., self-conceptualization) and underestimate older adults' learning abilities. Mendel et al. also found that there may exist a gap between older adults' expectations and family members' reactions when older adults receive support in cybersecurity issues [39]. Although many older adults expected to be guided to solve a problem, younger adults may just fix the problem without involving older adults. Echoing their findings, we also found that it may be challenging for younger adults to find a balance between teaching and fixing without involvement due to older adults' varying abilities and needs. While older adults experience many difficulties in technology learning, sometimes they were far more capable at learning than younger adults

expected. Therefore, building younger adults' awareness of older adults' abilities and needs is crucial to providing better support that aligns with older adults' needs.

Adding to this literature, we also found that younger Chinese adults may control older adults' online behaviors when they find older adults are far more active online than they anticipated. Murthy et al. similarly found that younger adults in India may enforce cybersecurity guidelines to older adults, because they perceive older adults as vulnerable to online threats and Indian families typically manage cybersecurity collectively [41]. Although controlling in technical support was rarely reported in other places, Chouhan et al. found that people in the U.S. also want to have oversight over their close family members (e.g., children, and older parents) for their online security [3]. In this study, although some younger adults became monitors, the majority of younger adults did not control older adults overtly if they believed technology use would not affect older adults' lives much. As such, building family members' awareness of older adults' technology use may also help to incrementally establish a trusting family relationship so that the imbalances in a family relationship may be avoided.

Given the above considerations, we suggest that designers consider older adults' technology learning and use as a long-term cooperative activity with family members, where collaborative technologies can play a significant role. Considering the influence of family members as both facilitators and regulators, designers may need to consider younger family members as an important stakeholder when designing technologies for older adults. For example, family tracking (e.g., [30]) and family accounts (e.g., [6]) can be used to facilitate information exchange in terms of older adults' technology use. With older adults' permission, designers can add in-built tracking features in applications with options (e.g., irregular, and ephemeral sharing), to enable older adults to share their online behavioral data (e.g., frequency and use time of specific applications or features) and preferences toward learning (e.g., fixing without involvement, and instructions). This data may help younger adults quickly adjust their perceptions of older adults' technology use, provide timely support with informed decisions, and remove unnecessary concerns.

5.1.2 Helping Younger Adults Develop Individualized Teaching Strategies and Maintain Motivations During Teaching. Our findings support that younger adults' impatience and frustration during teaching are among the main challenges when they provide technical support to older adults [38, 49, 79]. Nevertheless, patience alone is insufficient if younger adults only repeat their words. As noted in 5.1.1, younger adults need to adjust their teaching tactics to accommodate older adults' changing needs. Therefore, we suggest designers consider ways (e.g., in-built videos or tips) to increase younger adults' knowledge about older adults' learning characteristics (e.g., adults prefer learning by doing [25]) so that they can provide better support that aligns with older adults' needs in different contexts. Researchers usually suggested creating in-built tools to facilitate family members' technical support to older adults in specific tasks (e.g., providing explanations in understandable language to older adults (e.g., [39])). However, such a strategy may be unadaptable to older adults' changing abilities and needs, as well as constantly evolving technologies. We also suggest designers consider ways to sustain older adults' learning motivations, which, according to our findings, is also significant to younger adults' teaching practices. For example, developers can maintain a user log for older adults and enable failure tracking so that younger adults can identify where older adults got lost instead of relying on older adults' explanation. With this user log, older adults can refer to correct usage in past contexts, thereby facilitating their practice and increasing their motivations to learn [17, 32].

5.1.3 Fostering Collaboration Among Different Sources of Support. The findings further suggest the potential of fostering collaboration between family members and external sources (e.g., local community and volunteer) to facilitate older adults' technology learning. Researchers often

reported that older adults would turn to community services for in-person technology support [46, 57]. However, as suggested by Piper et al., travelling to community centers is often difficult for older adults due to age-related physical challenges such as limited mobility [46]. The constantly evolving nature of technology may also make older adults hard to receive timely support from local communities [46]. Therefore, we suggest that designers create communication tools to build relationships between younger family members and local communities so that they can share challenges and experiences related to older adults' technology learning and provide continuing support to older adults. One way would be to establish a group chat in existing communication tools such as WeChat. Although in this study it is not common for older adults to turn to local communities for technology support, our findings suggest that local communities have the potential to serve as useful complements to family support, especially when family members cannot provide effective support or they are remote. Our participants also received much supports from volunteers when they were using public services. Collaboration among these different sources may encourage older adults to communicate their needs in terms of technology learning, so they can get support more efficiently.

5.2 Rethinking Older Adults' Technology Learning as a Recurrent, Dynamic, and Evolving Process

The findings also highlight how older adults' technology learning is recurrent, dynamic and evolving over the long term. Over time, older adults can discover new technologies in nuanced contexts, e.g., new applications in smartphones or new features within applications, or migrate their old applications to new smartphones. These scenarios imply that older adults will continue going through the three stages of technology learning in a recurrent way, even if they are using only one device or application. Researchers and designers may thus need to consider the nuances in older adults' technology learning in a more fine-grained way (i.e., device-, application- and feature-based) from an evolving perspective, rather than treating the process uniformly (e.g., [43]). For example, Li et al. found that even though older adults are frustrated in learning to use communication services in WeChat for a long time, they may become motivated to overcome the difficulties after the adoption of social tracking services in WeChat [30].

Given the infrastructuralization of technologies [18, 85, 86], we expect that such recurrences of technology learning will become more prevalent in the future, as older adults may use a wider range of devices and applications, and change devices more frequently than before. Mainstream applications and sites (e.g., WeChat, DouYin, Facebook, and Google) will also continue to integrate several services into one application (e.g., communication, mobile payment, online shopping, news reading) [85, 86] and evolve with frequent updates [46]. Although the integration of services may pose new challenges to older adults' technology learning due to difficulties in keeping up with the evolving nature of technology [47], it may also present opportunities to lower the bar and even increase older adults' motivations to adopt new technologies with prior experience in one specific application. For example, older adults may be more willing to adopt tracking services in WeChat than tracking devices because they have established social networks in WeChat with its social network services [11]. Future work can explore older adults' use of integrated systems such as WeChat and Facebook.

Taking an evolving perspective, we found that older adults may be discouraged from, or even stop, learning to use specific technologies due to ineffective support, even if they have desires for learning, because they may feel embarrassed and stop asking questions. Therefore, researchers need to pay continuing and timely attention to older adults' technology learning, focusing on factors that can sustain or interrupt long-term learning processes. Moreover, we found that older adults' demands while learning technology vary at each stage. For instance, while researchers

often emphasized challenges in early stages of older adults' technology learning (e.g., [36, 43]), older adults in this study did not meet significant challenges during the onboarding stage probably because family members simplified the start of technology learning for older adults (e.g., only teaching basic use, helping to finish one-time complicated tasks, only downloading applications that were easy to use). However, simplifying the start of learning can increase the difficulty when one needs to use advanced features later. Therefore, when older adults use technology later, the focus of support may need to shift from demonstrating technology use to increasing digital literacy (e.g., introducing common designs of applications). This implies that researchers and family members need to provide customized and stage-based support and consider how interventions in different stages may influence older adults' long-term learning outcomes.

5.3 Reflecting on Family Support in Chinese Cultural and Socioeconomic Contexts

Our findings suggest that the role of family support in older adults' technology learning is culturally embedded. The family support pattern uncovered here was largely shaped by a culture of "*xiaoshun*" in China. "*Shun*" ("顺"), which is normally understood in the sense of obedience in modern Chinese, is an important component of "*xiaoshun*" [77]. That is, "*xiaoshun*" usually represents an authoritative hierarchical parent-child relationship, rather than an equal and reciprocal relationship centered around care between two individuals [81]. As a result, the authority of older adults has long been associated with Chinese culture [69], while Western Europeans are more accustomed to the independence of younger and older family members [53].

Influenced by such a culture of "*xiaoshun*", older Chinese adults may be more comfortable asking for help from younger family members than those in NAWA, not only because they see younger adults as technology experts, but also because they treat it as an expression of "*xiaoshun*". Older adults in this study did not have strong preferences for self-directed and independent learning and may not see asking for help from younger family members as a burden, contrary to what is usually reported in NAWA [29, 34, 37, 43, 45]. Meanwhile, many younger adults felt that it is their responsibility to teach older adults and protect them from possible threats, thus paying particular attention to older adults' everyday technology use and providing support proactively. The intentions to protect older adults may then lead to paternalism (i.e., making all the decisions for the people they are responsible for). However, while paternalism may negatively impact older adults' agency as argued by Murthy et al. [41], older adults in this study tended to show an understanding of their younger family members and perceived their protections as beneficial rather than disempowering, although the protection sometimes did lead to discomfort. This way, the culture of "*xiaoshun*" may play as a buffer to the burdens and tensions in family support.

It should be noted that the influence of culture is generative and dynamic. As argued by Irani et al., culture is "a system of interpretive signification through which the world intersubjectively meaningful" rather than "a static denomination" [20]. For instance, in this study, the cultural context of "*xiaoshun*" is taking effect along with the socioeconomic context in China, which is characterized by a recent rapid digitalization trend, especially in major cities [18, 23, 86]. Interestingly, in a study conducted in Shanghai in 2004, Xie found that it was nearly impossible for older Chinese adults to receive technical support from younger adults, including their children, because younger adults tend to consider teaching to be boring and annoying [79]. In the meantime, Gutierrez et al. found that culture of filial piety can be a barrier to older adults' technology adoption [12, 13]. They reported that in Latin America, where people also value filial piety, few older adults consider themselves as active users of social media or comfortable with smartphone use [13], probably because their family members fulfilled their filial obligations through older adults' familiar ways (e.g., face-to-face communications and telephone) [12]. The differences between these previous findings and our findings may imply the intersectional effect of cultural and socioeconomic contexts.

Due to the inevitability of new technologies in China nowadays, as well as immaturity of technical training programs [42, 67], younger family members in China may be expected to take on the majority of the duty for teaching elder family members, especially for older adults who are not active in learning new technology.

Given findings from this work, we suggest designers pay particular attention to the roles of family members when designing technical support system for older adults in China and similar cultures featured by filial piety and familism (e.g., Latin America [12, 13], East Asia [54], South Asia [52], and Southeast Asia [31]), rather than emphasizing supporting independent learning in NAWA (e.g., [43]). On the other hand, culture is an intersubjective system rather than a static denomination as noted above [20]. Therefore, we call for future research on family members' involvement in older adults' technology learning and use in these places.

5.4 Limitations

This study has a few limitations. First, we relied on self-reported data and as the research topic was related to family issues, participants may not have disclosed their true feelings out of social respect for their family (e.g., how they feel about their family members). Observation-based field studies can reveal a more holistic understanding of family support in older adults' technology learning. Second, most of the participants were from the most developed areas of China. Therefore, we do not claim to generalize all of our findings and implications to all Chinese families. For example, compared with older adults in urban cities, those in less developed areas may face more difficulties in technology learning and their children may also live in a context of digital inequality [78]. Future research can explore the technology support patterns in less developed areas in China. Third, only one of our participants was over 85. The oldest-old group (i.e., over 85) may have much more difficulties in technology learning due to their physical and cognitive declines [47]. Future research could explore the technology support pattern among this group of older adults. Fourth, since all members of our research team are of Chinese origin, the statements related to non-Chinese culture in this study are based on prior literature and may be biased. Nuances in culture may exist in different countries. Future work should be conducted for verification.

6 CONCLUSION

This research conducted a qualitative interview study to understand how younger family members support older adults' technology learning with 20 older adults and 18 younger adults in China, including 9 families. The findings suggest that younger family members' roles co-evolve with older adults' changing needs in technology learning, and that they often adjust their perceptions of older adults' learning abilities and online behaviors as they provide support. Based on these findings, we suggest that older adults' technology learning be treated as a collaborative activity with family members, and that older adults need continued and evolving care while learning new technology. We also emphasize Chinese cultural and socioeconomic as two important contexts to understand family support patterns in China.

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A TECHNOLOGIES MENTIONED BY THE PARTICIPANTS

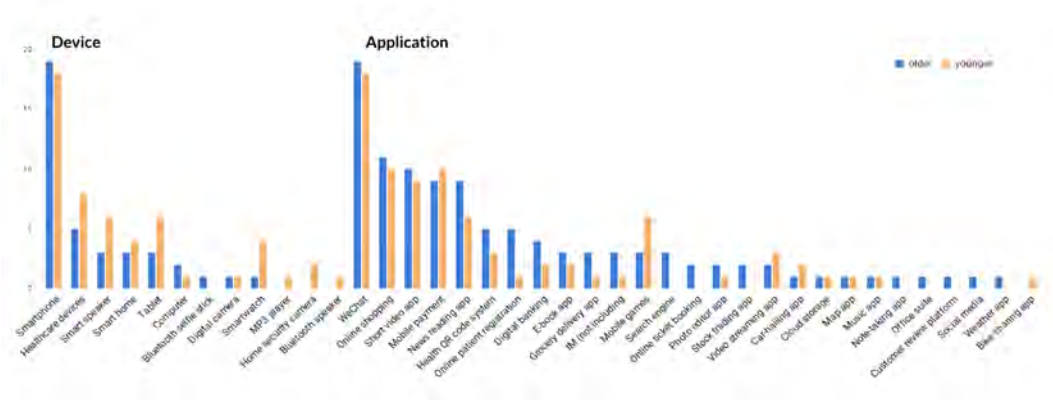


Fig. 3. Distribution of technologies mentioned by participants. Most technologies were mobile devices and applications.

B TECHNOLOGIES SPECIFIC TO THE CHINESE CONTEXT

ID	Technology	Type	Introduction
1	WeChat ("微信")	Digital Application	a multi-purpose instant messaging, social media and mobile payment application [75]
2	DouYin ("抖音")	Digital Application	a short video sharing mobile application; the Chinese version of TikTok [71]
3	KuaiShou ("快手")	Digital Application	a short video sharing mobile application with a particularly strong user base among users in country-side and rural areas [73]
4	PinDuoDuo ("拼多多")	Digital Application	a popular online shopping application well-known for affordable products that are often unbranded or white-labeled [63]
5	Alipay ("支付宝")	Digital Application	a mobile and online payment application [70]
6	Health QR code system ("健康码")	Digital Application	QR code based travel tracking systems developed during the COVID-19 that dictates whether people should be quarantined or allowed into public spaces [44]
7	iQIYI ("爱奇艺")	Digital Application	a Chinese online video platform similar to Netflix [72]

C TECHNOLOGIES MENTIONED BY THE OLDER PARTICIPANTS

ID	Technologies Mentioned
O1	smartphone, mobile payment, digital banking, online patient registration, WeChat, online shopping, news reading app
O2	smartphone, online shopping, digital banking, mobile payment, short video app, online patient registration, health QR code system, healthcare devices, news reading app, WeChat, photo edit app, online ticket booking, grocery delivery app, review platform, Bluetooth selfie stick, smart home devices, stock trading app
O3	smartphone, online shopping, mobile payment, digital banking, intelligent voice assistant, online patient registration, WeChat, news reading app, search engine
O4	mobile payment, smartphone, smart home devices, online patient registration, news reading app, health QR code system
O5	smartphone, online shopping, photo edit app, WeChat, mobile payment, ride-hailing app, mobile games, WeChat, health QR code system, news reading app
O6	smartphone, WeChat, online shopping, short video app, intelligent voice assistant, card games on computer (seldom), healthcare devices
O7	short video app, mobile payment, smartphone, WeChat, healthcare devices
O8	online shopping, smartphone, e-book reading app, mobile games, news reading app, cloud storage, IMs, social media, tablet, WeChat
O9	online shopping, mobile payment, smartphone, short video app, online patient registration, WeChat, stock trading app, e-book listening app, news reading app, mobile games, grocery delivery app
O10	smartphone, mobile payment, online shopping, short video app, WeChat, online ticket booking
O11	smartphone, online shopping, mobile payment, smartwatch, tablet, WeChat, music app, search engine, news reading app, weather app, note-taking app, map app, short video app, iQIYI, e-book reading app, digital banking, office suite, laptop, IM, search engine
O12	smartphone, online shopping, WeChat, digital camera, healthcare devices
O13	smartphone, WeChat
O14	smartphone, WeChat, iPad, health QR code system
O15	smartphone, WeChat, online shopping, iPad, smart instant pot, video streaming app
O16	smartphone, WeChat, intelligent voice assistant, healthcare devices
O17	WeChat, grocery delivery app, short video app, smartphone
O18	WeChat, short video app, smartphone, health QR code system
O19	short video app, WeChat, smartphone
O20	smartphone, WeChat, news reading app, short video app, health QR code system

D TECHNOLOGIES MENTIONED BY THE YOUNGER PARTICIPANTS

ID	Technologies Mentioned
Y1	short video app, digital banking, smartphone, smartwatch, intelligent voice assistant, online shopping, mobile payment, news reading app, tablet, smart home devices, healthcare devices, WeChat
Y2	smartphone, WeChat, online shopping, mobile payment, mobile games, photo edit app
Y3	smartphone, mobile payment, intelligent voice assistant, online shopping, WeChat, tablet
Y4	smartphone, WeChat, mobile payment, news reading app
Y5	mobile payment, WeChat, smartphone, intelligent voice assistant, health QR code system, online patient registration, iPad, healthcare devices, bike sharing app, digital camera, ride-hailing app
Y6	WeChat, mobile payment, short video app, smartphone, healthcare devices
Y7	WeChat, iPad, smartphone, healthcare devices, music app, MP3 player, home security camera, mobile games, news reading app
Y8	smartphone, WeChat, online shopping, iPad, short video app, intelligent instant pot, iQIYI, ride-hailing app
Y9	IM, mobile payment, mobile games
Y10	WeChat, smartphone, online shopping, mobile games, health QR code system, mobile payment
Y11	smartphone, online shopping, short video app, WeChat, news reading app, mobile games, video streaming app, map app
Y12	smartphone, news reading app, smartwatch, intelligent voice assistant, short video app, e-book reading app, WeChat, healthcare devices
Y13	smartphone, WeChat, online shopping, grocery delivery app, healthcare devices, mobile games
Y14	smartphone, intelligent voice assistant, smartwatch, short video app, online shopping, video streaming app, cloud storage, news reading app, WeChat
Y15	WeChat, home security camera, intelligent voice assistant, mobile payment, digital banking, smart home devices, online shopping, smartphone
Y16	computer, WeChat, short video app, smart home devices, e-book reading app, Bluetooth speaker, health QR code system, healthcare devices, smartphone
Y17	WeChat, online shopping, mobile payment, short video app, smartphone, health QR code system
Y18	WeChat, short video app, mobile payment, healthcare devices, smartphone
	WeChat, short video app, smartwatch, smartphone, tablet

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