Empowering Autonomous Digital Learning for Older Adults

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ABSTRACT

The widespread adoption of smartphones has fundamentally transformed access to digital services, offering conveniences but also increased complexity. This presents a challenge for older adults unfamiliar with such rapid technological changes. My dissertation proposes support systems to help these individuals independently learn digital technologies. Initial research employed surveys and interviews to understand older adults' current digital interactions and barriers,taking digital banking as an illustrative case study. Based on their need for autonomous learning, we then developed an app that provides asynchronous social support with interactive tutorials and trial-and-error learning. Additionally, we are exploring how augmented reality (AR) can enrich the learning experiences of older adults. The forthcoming steps involve crafting an AI-powered assistant designed for empathetic, personalized interaction. Our objective is to forge an adaptable support system that uplifts older adults, bolstering their digital proficiency and bridging the technological divide to ensure a more inclusive future.

CCS CONCEPTS

• **Human-centered computing** → **Accessibility technologies**; **Empirical studies in HCI**; **Mixed / augmented reality**; *Ubiquitous and mobile computing systems and tools.*

KEYWORDS

older adults, learn, trial-and-error, digital technologies, AR, AI

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1 INTRODUCTION

Digital technologies have swiftly reshaped the contemporary landscape, making online platforms the primary means for accessing information and services. The digital shift is transformative, and numerous services have either been supplanted by or rendered exclusively accessible through digital domains. Among the most affected include essential services such as online educational courses from Coursera, edX, and Udacity [1–3], e-government offerings [44], and financial transactions through digital banking [15]. Although these digital modalities offer enhanced convenience, they can also present challenges for those who lack technical expertise. This barrier is especially pronounced among older adults. They are affected by a multitude of factors such as generational technology usage gaps [48], socioeconomic disparities in digital engagement—often referred to as the digital divide [9, 36] as well as natural age-related cognitive and physical declines [14, 32]. We first took digital banking, a rapidly evolving aspect of digital technology that impacts financial behaviors, as our case study to explore older adults' perspectives on the current digital technologies. We conducted a survey study of 155 older adults aged over 60 in 2021 in China, revealing that only 24.6% utilized ATMs and 19% engaged with digital banking platforms [23]. Notably, half were willing to endure extensive waits—over two hours—at physical banks, rather than trying alternative banking methods. Correlation analysis confirmed that age is a determinant of platform usage. Further qualitative insights were gained from in-depth interviews with 16 older adults and 7 banking employees, which illuminated the older adults' willingness to learn and utilize their experiences to solve issues independently, avoiding imposing on others for assistance [21]. This study corroborates previous research indicating a shift in older adults' learning preferences towards more flexible and independent methods, a need exacerbated by the generational cohabitation shift—with younger people less likely to reside with older adults—pointing to the necessity of asynchronous support [39]. Hence, attributes such as independence, flexibility, personalization, and asynchronous learning are vital for older adults when learning digital technologies.

Previous research has examined various independent support approaches, including instructional materials [6, 12, 28] and device help features [10, 38]. However, they tend to be rigid and not specifically tailored to older adults' requirements. Personalized assistance through remote social help, like video calls [39], although more tailored, demands considerable time and effort from helpers. While recent exploration of social support apps [31] allow for more nuanced communication of issues. However, these apps can become cumbersome when users are required to report problems frequently and switch between the help app and the targeted app. Particularly for complex tasks, users may have to wait for a response before proceeding with subsequent steps.

To address these gaps, my dissertation research aims to synergize the personalized nature of social help with the adaptable qualities of independent supports, reducing the learning curve and psychological load for older adults engaging with digital technologies. The following steps outline my research progression:

- We investigate the current practices and challenges of older adults using and learning digital technologies, taking digital banking as a case study [21, 23].
- We design and evaluate an interactive, app-independent service, named "Synapse". It can provides multi-modal feedback,

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voice assistance, and trial-and-error support in an overlay format, tailored to the learning needs of older adults [22].
- We then investigate the potential of Augmented Reality (AR) to bolster older adults' exploration and learning within feature-rich smartphone applications [24].
- We propose an innovative AI-empowered environment, design and implement a cognitive-adaptive supporting tool to facilitate effective trial-and-error learning methods.

2 BACKGROUND AND RELATED WORK

2.1 Older Adults Digital Learning Challenges and Preferences

Global aging is a growing trend that is affecting countries around the world. According to the United Nations, the number of people aged 60 and over is expected to double by 2050, reaching 2.1 billion [34]. This trend is particularly pronounced in developed countries, where the proportion of older adults in the population is already high. Research has shown that technology development can play a crucial role in improving the quality of life and well-being of older adults by providing access to healthcare, social connection, and education [13]. However, the evolving digital landscape presents challenges to older adults, accentuated by natural declines in both physical and cognitive abilities. Vision deterioration with age can hinder the ability to discern text on small screens, a challenge for older adults [14, 21]. Additionally, their typically wider click range may cause operational difficulties, particularly on cluttered interfaces [22, 29]. Consequently, there's a notable preference among this demographic for larger displays [38, 39]. This preference has inspired the application of augmented reality (AR) in our work, leveraging its capacity to provide an 'extended' visual interface. Cognitive decline in aging, such as memory issues or diminished concentration, can obstruct the digital learning process for older adults [17, 21]. They prefer clear, step-by-step instructions and find value in interactive tutorials and in-app guidance videos [28, 39]. Our initial studies [21, 23],which examined the shift from physical to digital services, revealed that older adults were familiar the business itself, but struggle with the technological transition, often fearing device damage—a concern that significantly influences their willingness to experiment [4, 12, 33]. Their digital explorations are deliberate, but there is a strong reluctance to commit errors that they perceive could have serious consequences [8, 21, 33]. Supportive measures that build confidence in a safety net can increase their willingness to engage in learning, aligning with findings that highlight a preference for autonomous learning approaches, such as trial-and-error [5, 39]. These findings motivated use to design *Synapse*, our third work [22].

2.2 Current Approaches to Supporting Older Adults Learning

Within the domain of assisting older adults in learning digital technologies, research has gravitated around two primary strategies: social help learning and independent learning. Traditional in-person social assistance, faced with accessibility challenges, has been complemented by remote methods, including video chats and apps such as Meerkat, which offer articulate assistance mechanisms [31].

In the landscape of independent learning, research efforts have predominantly encompassed three spheres: instructional materials, device-embedded help features, and the trial-and-error methodology. Instructional materials have been studied extensively. Comprehensive guidelines, articulated with lucid language and supplemented by visual aids such as screenshots, have been of particular interest. Technologies like Live View, which offers real-time UI illumination, and demonstrative videos serve as valuable assets in this realm [6, 12, 28]. Concerning device-oriented assistance, scholarly efforts have underscored the importance of personalized recommendations. The inclusion of relevant links, derived from a user's browsing history, ensures a guided experience, especially for older users who might have a limited technological backdrop [8]. Innovative tools, such as the tactile button presented by Conte et al. and TapTag by Pandya et al., facilitate guided exploration, making them invaluable in supporting independent learning endeavors [10, 38]. In the realm of trial-and-error, the emphasis has shifted to creating a supportive environment for older adults. Adopting designs that echo real-world analogs aids in minimizing cognitive strain, and crafting simulations rooted in daily scenarios bolsters cognitive engagement [19, 37]. Recognizing the trepidation older adults might face, provisions such as exploratory modes have been proposed, enabling users to experiment while safeguarding against irreversible changes [28]. My dissertation research built upon this progression and introduced *Synapse*. This platform not only facilitates demonstrations by experienced users but also fosters a safeguarded space for novices to explore, learn, and rectify errors, accentuating the essence of exploration in the learning process [22].

2.3 Potential of AR in Supporting Older Adults Learning

Augmented Reality (AR) technology extends interactions beyond the physical world, as Suzuki illustrates, overlaying enhanced virtual interfaces onto our reality [45]. Reipschläger et al.'s work further integrates virtual content intuitively into daily environments, suggesting benefits for older adults facing smartphone interface challenges [41, 42]. Studies on CAVE systems and extended smartphone interfaces support AR's potential to offer more accessible technology interactions for the elderly [11, 18, 25, 35]. AR's visual overlays can transform educational experiences, making learning immersive and user-friendly. This is supported by findings that demonstrate AR's role in simplifying complex ideas and enhancing collaborative efforts [26, 27]. With systems like InstruMentAR and AdapTutAR evidencing AR's versatility, there's a clear opportunity to apply AR in assisting older adults with smartphone app navigation, which motivates our fourth work [20, 30, 46].

3 RESEARCH QUESTIONS

My dissertation aims to enhance the learning process for older adults in the realm of digital technologies. The study is structured around a series of targeted research questions:

- RQ1: What are the current practices, challenges, and learning preferences of digital technologies among older adults [21, 23]?
- RQ2: How does the interactive tutorial influence older adults' self-directed learning of digital technologies [22]?

- RQ3: How does AR leveraging extended screen enhance older adults in learning digital technologies?
- RQ4: How to build cognitive-adaptive learning approach to support older adults by incorporating AI technologies [proposed]?

4 RESEARCH METHODS AND FINDINGS TO DATE

4.1 Survey and Interview on Current Practices, Challenges and Learning Preferences of Older Adults (RQ1)

Our prior work targeting banking, a shifting from physical to digital platforms, investigated current practices and challenges in banking experience and challenges through an online survey study with 155 older adults who are over 60 in China, which was published in DIS 2021 [23]. Our results show that older adults conduct banking transactions frequently. However, few do so using digital platforms (10.29% used mobile banking apps, 5.8% used virtual banks) despite long wait times in physical banks. Surprisingly half (50%) of the participants were willing to wait no matter how long it took (over 2 hours) rather than trying different banking platforms. The top reasons are about feeling unsafe, getting used to the habit, and usability issues, often getting lost. Nevertheless, they held positive attitudes through our 5-Likert-scale analysis. Moreover, we find age indeed has a significant influence on the adoption of digital platforms through correlation analysis. These findings indicate that during the shift from traditional physical services to digital ones, many of them still resisted the traditional methods, the older the less adoption of new ones, they encounter difficulties of getting lost when navigating the new platforms and worry about making mistakes, and unsafe without printed receipts.

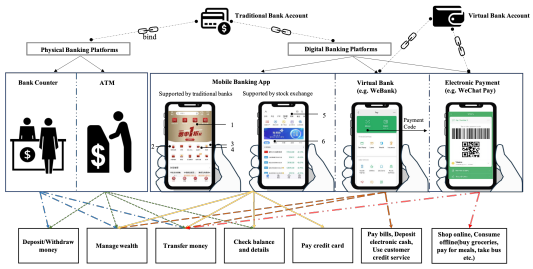

Figure 1: *Choices of banking platforms for different transactions.*

Built upon this quantitative study, we further conducted an in-depth interview study with 16 older adults and 7 bank employees to reveal their underlying motivation and need to learn, and specific challenges encountered, which was published in ASSETS 2022 [21]. Figure 1 shows their choices of banking platforms for different transactions. Our result indicates that almost all older adults came to the physical banks by themselves, and although they need and like in-person help, they feel bad about frequently asking for help get an impatience attitude, and worry about bothering others too much. These findings collaborate with previous work [39] that older adults actually want to be independent as much as possible. One of the motivation of them to learn is the self-confidence, that they believe that can learn it positively, but just encounter design issues not friendly to them, and suffer from the insufficient error recovery support and lack of feedback and confirmation, thus sometimes leading to the low perceived efficacy. This comprehensive understanding builds solid ground and reveals a future that prioritizes accessible and empowering technology for older adults.

4.2 Interactive app-independent service with multi-modal feedback, voice assistant, trial and error support (RQ2)

Figure 2: The two modes of Synapse: basic mode (a1, a2), trial-and-error mode (b1-b5).

In response to the older adults' need for independent support when learning digital technologies, we built an app-independent mobile service, *Synapse*, for help-givers to create a multimodal interactive tutorial on a smartphone and for help-receivers (e.g., older adults) to receive interactive guidance with trial-and-error support when they work on the same task, which was published in IMWUT'22 [22]. As shown in Figure 2, in the Basic mode (a1, a2), *Synapse* highlights the target item with a red rectangle and plays the corresponding audio instructions recorded by a help-giver during the demonstration phase. In the Trial-and-Error mode, Synapse allows the user to freely explore the app. If they clicks a wrong item (b1), Synapse alerts them but still allows them to continue their exploration (b2). If they still could not complete the task or realized they made a mistake after a few trials, they could ask Synapse for help by saying, such as "can't find it" (b3). Synapse then returns to the last correct step with the corresponding audio instructions (b4). After they have completed the step correctly, Synapse provides positive multimodal feedback with both a textual prompt and an audio tone (b5). We then conducted a user study with 18 older adults to understand their performance and user experience of the two modes of Synapse (i.e., Basic and Trail-and-Error) compared to video tutorials. Our quantitative and qualitative results show that Synapse provided better support than the traditional video approach and enabled participants to feel more confident and motivated. Participants completed tasks faster after learning with both modes of Synapse compared to the video tutorial. They found both interactive support (e.g., being able to ask questions in natural language and multi-modal feedback) and trial-and-error support were helpful and enjoyable. Moreover, they were more confident in exploring the app with trial-and-error support. However, we found that some participants lost their patience after missing several steps during trial-and-error and kept intriguing the features that give hints and many reported that if they tried several times, they forget

which one has been tried before. This indicates the need for an extra screen to record their trial-and-error process, and offer other preview functions since they are found when exploring, they did more focus searches (click fewer links but more relevant ones) than younger adults [7]. Based on this investigation and observed users' behavior, we consider that leveraging AR's extensive screen may provide more effective support in their learning experience.

4.3 AR's opportunity for supporting older adults' independent learning (RQ3)

Figure 3: ***Innovative AR design to support autonomous learning***

To explore the AR's possibility of supporting older adults' learning, we conducted a two-phase study: (1) A workshop on investigating what challenges older adults face most when learning smartphones and where AR could be applied to offer support. (2) Technology probe-based participatory design sessions, which could help identify opportunities of emerging technology [40, 47] to brainstorm and develop an interactive AR support tool collaboratively. This work has been accepted for CHI'24 [24]. Our findings illuminate the multifaceted advantages of AR, notably in alleviating physical and cognitive strains, especially during tasks like multi-app navigation and the nuanced trial-and-error learning processes as Figure 3 shows. By deep-diving into the interactional experiences of older adults with AR, we derived specific design considerations that can shape the development of AR tools tailored to this demographic. However, participants felt that the price was too high for personal purchase, and were concerned about the heavyweight and discomfort after prolonged use. These findings provide insights for improving AR device's interactive design and other aspects to be more inclusive. Through the co-design process, we found that participants often needed extra information and expected the underlying explanations for the trial-and-error process. Moreover, they expressed a willingness of a dynamic companion assistant for different purposes, indicating they also need psychological support during different stages. We then consider leveraging LLM to provide sufficient knowledge and combine it with AIGC tools to generate suitable avatars to fulfill their psychological needs.

5 EXPECTED NEXT STEPS

5.1 Cognitive adaptive supporting mechanism to support older adults to learn digital technologies(RQ4)

Built upon my previous work, I realized older adults' diversity and they had their own personalized learning strategies due to different cognitive abilities. In my next work, I will explore more in psychology aspects to create a mapping from the cognitive ability to supporting mechanism. One of the component will be a dynamic companion assistant among older adults, including the integration of Large Language Models (LLMs) [16] for effective knowledge transfer and the utilization of Artificial Intelligence Generated Content (AIGC) [43] tools to craft dynamic avatars. I will design a testing game to quantify their cognitive ability and classified it into low, medium, and high level. According to their different cognitive ability, the dynamic companion assistant will change to adapt to their specific level. Another component will be the dynamic algorithm of better supporting older adults to conduct trial-and-error. For different cognitive ability older adults, the timing to provide support, the complexity of the support format may vary. I will initially develop a straightforward algorithm and iterate the algorithm according to the possible key challenges and insights from a pilot study. Moreover, a critical examination will be conducted to evaluate how this method fares against non-cognitive adaptive support mechanisms, including a comparative study designed to elucidate the strengths and weaknesses of this AI-mediated methodology.

6 ANTICIPATED CONTRIBUTIONS

The accelerated development of emerging technologies is poised to further exacerbate the existing digital divide. My dissertation aims to enrich our understanding of older adults' interactions with and learning processes regarding digital technologies. It seeks to provide novel insights that could mitigate the learning curve, thereby furnishing substantial support to enhance their learning experiences. It will contribute to the design of innovative independent support and the strategic use of AR to empower self-directed learning. Moreover, the development of an AI-enhanced, empathetic assistant marks a stride toward more personalized and psychologically attuned user support. The synthesis of these elements is expected to set new standards for user-centric technology education, and establish a benchmark for compassionate technology design that can be extended to diverse user groups. We anticipate project outcomes in two key areas: (1) contributions to knowledge about how to design digital technologies (e.g., interactions, navigation) friendly for older adults; (2) practical and innovative tools to support older adults in more independent and flexible learning. These methodologies are also applicable to other domains of work where involving older adults to make the world more inclusive.

7 DISSERTATION STATUS AND LONG TERM GOALS

I am currently a third-year Ph.D. candidate in Academy Interdisciplinary Studies advised by Dr. Mingming Fan and Dr. Huamin Qu from the Hong Kong University of Science and Technology. I successfully passed the PhD Qualifying Examination (PQE). I aim to complete the proposed research projects and dissertation defense before Spring 2025. Upon graduation, I intend to seek research positions in academy to further explore how to enable active aging including healthcare and learning in the digital era.

REFERENCES

[1] 2021. Coursera. https://www.coursera.org/. Accessed: 2023-09-07.

[2] 2021. edX. https://www.edx.org/. Accessed: 2023-09-07.

[3] 2021. Udacity. https://www.udacity.com/. Accessed: 2023-09-07.

[4] Keith Atkinson, Jaclyn Barnes, Judith Albee, Peter Anttila, Judith Haataja, Kanak Nanavati, Kelly Steelman, and Charles Wallace. 2016. Breaking Barriers to Digital Literacy: An Intergenerational Social-Cognitive Approach. In *Proceedings of the 18th International ACM SIGACCESS Conference on Computers and Accessibility*. ACM, Reno Nevada USA, 239–244. https://doi.org/10.1145/2982142.2982183

[5] Yvonne Barnard, Mike D Bradley, Frances Hodgson, and Ashley D Lloyd. 2013. Learning to use new technologies by older adults: Perceived difficulties, experimentation behaviour and usability. *Computers in human behavior* 29, 4 (2013), 1715–1724.

[6] Jeanie Beh, Sonja Pedell, and Wendy Doube. 2015. Where is the "I" in iPad?: The Role of Interest in Older Adults' Learning of Mobile Touch Screen Technologies. In *Proceedings of the Annual Meeting of the Australian Special Interest Group for Computer Human Interaction*. ACM, Parkville VIC Australia, 437–445. https://doi.org/10.1145/2838739.2838776

[7] * Jessie Chin and Wai-Tat Fu. 2012. Age differences in exploratory learning from a health information website. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, Austin Texas USA, 3031–3040. https://doi.org/10.1145/2207676.2208715

[8] Jessie Chin and Wai-Tat Fu. 2012. Age differences in exploratory learning from a health information website. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, Austin Texas USA, 3031–3040. https://doi.org/10.1145/2207676.2208715

[9] Jyoti Choudrie, Chike Obuekwe Junior, Brad McKenna, and Shahper Richter. 2018. Understanding and conceptualising the adoption, use and diffusion of mobile banking in older adults: A research agenda and conceptual framework. *Journal of Business Research* 88 (2018), 449–465.

[10] Sho Conte and Cosmin Munteanu. 2019. Help!: I'm Stuck, and there's no F1 Key on My Tablet!. In *Proceedings of the 21st International Conference on Human-Computer Interaction with Mobile Devices and Services*. ACM, Taipei Taiwan, 1–11. https://doi.org/10.1145/3338286.3340121

[11] Carolina Cruz-Neira, Daniel J Sandin, Thomas A DeFanti, Robert V Kenyon, and John C Hart. 1992. The CAVE: audio visual experience automatic virtual environment. *Commun. ACM* 35, 6 (1992), 64–73.

[12] Elizabeth V. Cyarto, Frances Batchelor, Steven Baker, and Briony Dow. 2016. Active ageing with avatars: a virtual exercise class for older adults. In *Proceedings of the 28th Australian Conference on Computer-Human Interaction - OzCHI '16*. ACM Press, Launceston, Tasmania, Australia, 302–309. https://doi.org/10.1145/3010915.3010944

[13] S.J. Czaja, W.R. Boot, N. Charness, and W.A. Rogers. 2019. *Designing for Older Adults: Principles and Creative Human Factors Approaches, Third Edition* (3rd ed.). CRC Press. https://doi.org/10.1201/b22189

[14] Sara J Czaja, Neil Charness, Arthur D Fisk, Christopher Hertzog, Sankaran N Nair, Wendy A Rogers, and Joseph Sharit. 2006. Factors predicting the use of technology: Findings from the Center for Research and Education on Aging and Technology Enhancement (CREATE). *Psychology and Aging* 21, 2 (2006), 333–352. https://doi.org/10.1037/0882-7974.21.2.333

[15] EY. 2020. Global FinTech Adoption Index 2019. https://assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/banking-and-capital-markets/ey-global-fintech-adoption-index.pdf. Accessed: 2023-09-07.

[16] Ian J. Goodfellow, Jean Pouget-Abadie, Mehdi Mirza, Bing Xu, David Warde-Farley, Sherjil Ozair, Aaron Courville, and Yoshua Bengio. 2014. Generative Adversarial Nets. *Advances in neural information processing systems* 27 (2014).

[17] Philip J. Guo. 2017. Older Adults Learning Computer Programming: Motivations, Frustrations, and Design Opportunities. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. ACM, Denver Colorado USA, 7070–7083. https://doi.org/10.1145/3025453.3025945

[18] Jeremy Hartmann, Aakar Gupta, and Daniel Vogel. 2020. Extend, push, pull: smartphone mediated interaction in spatial augmented reality via intuitive mode switching. In *Proceedings of the 2020 ACM Symposium on Spatial User Interaction*. 1–10.

[19] * Nic Hollinworth and Faustina Hwang. 2010. Relating computer tasks to existing knowledge to improve accessibility for older adults. In *Proceedings of the 12th international ACM SIGACCESS conference on Computers and accessibility*. ACM, Orlando Florida USA, 147–154. https://doi.org/10.1145/1878803.1878830

[20] Gaoping Huang, Xun Qian, Tianyi Wang, Fagun Patel, Maitreya Sreeram, Yuanzhi Cao, Karthik Ramani, and Alexander J Quinn. 2021. Adaptutar: An adaptive tutoring system for machine tasks in augmented reality. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. 1–15.

[21] Xiaofu Jin and Mingming Fan. 2022. "I Used To Carry A Wallet, Now I Just Need To Carry My Phone": Understanding Current Banking Practices and Challenges Among Older Adults in China. In *Proceedings of the 24th International ACM SIGACCESS Conference on Computers and Accessibility* (Athens, Greece) *(ASSETS '22)*. Association for Computing Machinery, New York, NY, USA, Article 37, 16 pages. https://doi.org/10.1145/3517428.3544820

[22] Xiaofu Jin, Xiaozhu Hu, Xiaoying Wei, and Mingming Fan. 2022. Synapse: Interactive Guidance by Demonstration with Trial-and-Error Support for Older Adults to Use Smartphone Apps. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 6, 3 (Sept. 2022), 1–24. https://doi.org/10.1145/3550321

[23] Xiaofu Jin, Emily Kuang, and Mingming Fan. 2021. "Too Old to Bank Digitally?": A Survey of Banking Practices and Challenges Among Older Adults in China. , 13 pages. https://doi.org/10.1145/3461778.3462127

[24] Xiaofu Jin, Tong Wai, Xiaoying Wei, Xian Wang, Xiaoyu Mo, Emily Kuang, Huamin Qu, and Mingming Fan. 2024. Exploring the Opportunity of Augmented Reality (AR) in Supporting Older Adults Explore and Learn Smartphone Applications. In *Proceedings of the CHI Conference on Human Factors in Computing Systems (CHI '24), May 11–16, 2024, Honolulu, HI, USA (CHI '24)*. Association for Computing Machinery, Honolulu, HI,USA. https://doi.org/10.1145/3613904.3641901

[25] Shaun K Kane, Jeffrey P Bigham, and Jacob O Wobbrock. 2008. Slide rule: making mobile touch screens accessible to blind people using multi-touch interaction techniques. In *Proceedings of the 10th international ACM SIGACCESS conference on Computers and accessibility*. 73–80.

[26] Eric Klopfer and Kurt Squire. 2008. Augmented reality: Research and design of mobile educational games. *The TechTrends* 49, 3 (2008), 38–45.

[27] Serdar Küçük, Samet Kapakin, and Yüksel Göktas. 2016. Educational Augmentation of Anatomy Learning: An Analysis with Augmented Reality Techniques. *Anatolian Journal of Cardiology* 16, 4 (2016), 123.

[28] Rock Leung, Charlotte Tang, Shathel Haddad, Joanna Mcgrenere, Peter Graf, and Vilia Ingriany. 2012. How Older Adults Learn to Use Mobile Devices: Survey and Field Investigations. *ACM Transactions on Accessible Computing* 4, 3 (Dec. 2012), 1–33. https://doi.org/10.1145/2399193.2399195

[29] Yu-Hao Lin, Suwen Zhu, Yu-Jung Ko, Wenzhe Cui, and Xiaojun Bi. 2018. Why Is Gesture Typing Promising for Older Adults?: Comparing Gesture and Tap Typing Behavior of Older with Young Adults. In *Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility*. ACM, Galway Ireland, 271–281. https://doi.org/10.1145/3234695.3236350

[30] Ziyi Liu, Zhengzhe Zhu, Enze Jiang, Feichi Huang, Ana M Villanueva, Xun Qian, Tianyi Wang, and Karthik Ramani. 2023. InstruMentAR: Auto-Generation of Augmented Reality Tutorials for Operating Digital Instruments Through Recording Embodied Demonstration. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. 1–17.

[31] Tamir Mendel and Eran Toch. 2022. Meerkat: A Social Community Support Application for Older Adults. In *CHI Conference on Human Factors in Computing Systems Extended Abstracts*. ACM, New Orleans LA USA, 1–4. https://doi.org/10.1145/3491101.3519909

[32] Tracy L Mitzner, Jyoti Savla, Walter R Boot, Joseph Sharit, Neil Charness, Sara J Czaja, and Wendy A Rogers. 2018. Technology Adoption by Older Adults: Findings From the PRISM Trial. *The Gerontologist* 59, 1 (09 2018), 34–44. https://doi.org/10.1093/geront/gny113 arXiv:https://academic.oup.com/gerontologist/article-pdf/59/1/34/27456596/gny113.pdf

[33] Claudia Müller, Dominik Hornung, Theodor Hamm, and Volker Wulf. 2015. Practice-based Design of a Neighborhood Portal: Focusing on Elderly Tenants in a City Quarter Living Lab. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. ACM, Seoul Republic of Korea, 2295–2304. https://doi.org/10.1145/2702123.2702449

[34] United Nations. 2017. World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100. *United Nations Department of Economic and Social Affairs* (June 2017). Retrieved June 15, 2023 from https://www.un.org/en/desa/world-population-projected-reach-98-billion-2050-and-112-billion-2100

[35] Arthur Nishimoto and Andrew E Johnson. 2019. Extending virtual reality display wall environments using augmented reality. In *Symposium on spatial user interaction*. 1–5.

[36] Tiago Nascimento Ordonez, Mônica Sanches Yassuda, and Meire Cachioni. 2011. Elderly online: effects of a digital inclusion program in cognitive performance. *Archives of Gerontology and Geriatrics* 53, 2 (2011), 216–219.

[37] * Vanessa Palumbo and Fabio Paterno. 2021. Micogito: a Serious Gamebook Based on Daily Life Scenarios to Cognitively Stimulate Older Adults. In *Proceedings of the Conference on Information Technology for Social Good*. ACM, Roma Italy, 163–168. https://doi.org/10.1145/3462203.3475889

[38] Shraddha Pandya and Yasmine N. El-Glaly. 2018. TapTag: Assistive Gestural Interactions in Social Media on Touchscreens for Older Adults. In *Proceedings of the 20th ACM International Conference on Multimodal Interaction*. ACM, Boulder CO USA, 244–252. https://doi.org/10.1145/3242969.3243003

[39] Carolyn Pang, Zhiqin Collin Wang, Joanna McGrenere, Rock Leung, Jiamin Dai, and Karyn Moffatt. 2021. Technology Adoption and Learning Preferences for Older Adults: Evolving Perceptions, Ongoing Challenges, and Emerging Design Opportunities. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI '21)*. Association for Computing Machinery, New York, NY, USA, Article 490, 13 pages. https://doi.org/10.1145/3411764.3445702

[40] Alisha Pradhan, Ben Jelen, Katie A. Siek, Joel Chan, and Amanda Lazar. 2020. Understanding Older Adults' Participation in Design Workshops. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI '20)*. Association for Computing Machinery, New York, NY, USA, 1–15. https://doi.org/10.1145/3313831.3376299

[41] Patrick Reipschläger and Raimund Dachselt. 2019. Designar: Immersive 3d-modeling combining augmented reality with interactive displays. In *Proceedings of the 2019 ACM International Conference on Interactive Surfaces and Spaces*. 29–41.

[42] Patrick Reipschläger, Severin Engert, and Raimund Dachselt. 2020. Augmented displays: Seamlessly extending interactive surfaces with head-mounted augmented reality. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–4.

[43] Robin Rombach, Andreas Blattmann, Dominik Lorenz, Patrick Esser, and Björn Ommer. 2022. High-resolution image synthesis with latent diffusion models. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*.

[44] Mahmud Akhter Shareef, Vinod Kumar, Uma Kumar, and Yogesh K. Dwivedi. 2011. e-Government Adoption Model (GAM): Differing service maturity levels. *Government Information Quarterly* 28, 1 (2011), 17–35. https://doi.org/10.1016/j.giq.2010.05.006

[45] Ryo Suzuki, Adnan Karim, Tian Xia, Hooman Hedayati, and Nicolai Marquardt. 2022. Augmented reality and robotics: A survey and taxonomy for ar-enhanced human-robot interaction and robotic interfaces. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*. 1–33.

[46] Ana M Villanueva, Ziyi Liu, Zhengzhe Zhu, Xin Du, Joey Huang, Kylie A Peppler, and Karthik Ramani. 2021. Robotar: An augmented reality compatible teleconsulting robotics toolkit for augmented makerspace experiences. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. 1–13.

[47] Xiaoying Wei, Yizheng Gu, Emily Kuang, Xian Wang, Beiyan Cao, Xiaofu Jin, and Mingming Fan. 2023. Bridging the Generational Gap: Exploring How Virtual Reality Supports Remote Communication Between Grandparents and Grandchildren. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany) *(CHI '23)*. Association for Computing Machinery, New York, NY, USA, Article 444, 15 pages. https://doi.org/10.1145/3544548.3581405

[48] Salifu Yusif, Jeffrey Soar, and Abdul Hafeez-Baig. 2016. Older people, assistive technologies, and the barriers to adoption: A systematic review. *International Journal of Medical Informatics* 94 (07 2016). https://doi.org/10.1016/j.ijmedinf.2016.07.004