A Tangible VR-Based Interactive System for Intergenerational Learning

Subjects: Computer Science, Hardware & Architecture
Contributor: Chao-Ming Wang, Cheng-Hao Shao

The recent years have witnessed striking global demographic shifts. Retired elderly people often stay home, seldom communicate with their grandchildren, and fail to acquire new knowledge or pass on their experiences. Digital technologies based on virtual reality (VR) with tangible user interfaces (TUIs) were introduced into the design of a novel interactive system for intergenerational learning, aimed at promoting the elderly people's interactions with younger generations.

Keywords: e-learning ; interactive system ; intergenerational learning ; virtual reality

1. Physical and Mental Health of the Elderly

According to a report by the European Union, more than half of the world's population will comprise 48-year-olds or above by 2060, indicating that aging will keep accelerating in the next few decades [1]. Meanwhile, Taiwan has an aging population and a declining birth rate, giving the older and younger generations fewer opportunities to interact than they did in the past. Many studies showed that college students generally had a slightly negative view of the elderly, especially concerning the latter's physical and mental health [2][3][4]. However, it is worth noting that the two generations have fewer interactions. As the elderly age with time, they continue to suffer from physical and mental functional decline and become subject to increasing pain, discomfort, and inconvenience in life, giving rise to psychological changes. Furthermore, aging can be both physiological and psychological. In terms of physiology, Zajicek [5] held that the elderly could not see clearly and would easily become tired due to vision and memory degeneration. In addition, they easily forget how to operate a computer. With respect to their psychological conditions, the elderly are more likely to feel depressed in hard times, such as when they lose family members, friends, social roles, and physical functions. Thus, according to Shibata and Wada [6], some recreational activities may be adopted as an option when communicating with the elderly. Chatman [7] also found that some of the elderly in a community were so afraid of being sent to nursing institutions after retirement that they did not want to share their health conditions with others, even pretending to look healthy.

Research on the aging of seniors revealed that despite physical and mental changes of the elderly people, an aging society is blessed with a remarkable advantage—abundant older human resources. The most valuable thing that the elderly have lies in their wealth of work and life experiences, considering they lived through diverse situations. If older people can participate in more meaningful activities, their experiences can be shared with younger people to promote social progress. Moreover, their physical and mental health will be improved, reducing medical expenditures.

2. Intergenerational Learning

Intergenerational learning programs were implemented in 1963 when the P.K. Yonge Developmental Research School in the United States developed the "Adopt a Grandparent Program". Thereafter, many colleges and universities have begun studying and implementing intergenerational learning programs. In response to generational estrangement caused by population aging, intergenerational learning, which refers to the establishment of mutual learning between the older and younger generations, has emerged globally [8]. Intergenerational learning has been regarded as an informal activity passed down from one generation to another for centuries—a culture bridging tradition and modernization [9]. In modern times, influenced by an increasingly complex society, intergenerational learning is no longer limited to the family, but its influence extends to society and improves the overall social value [10].

Ames and Youatt [11] proposed a comprehensive selection model for intergenerational learning and service activities in classifying conventional intergenerational learning, which can help planners design more diverse and richer learning activities. The model can be divided into three parts: the middle generation, program categories, and selection criteria. In addition, Ohsako [12] divided intergenerational learning into four models/profiles: (1) older adults

serving/mentoring/tutoring children and the youth; (2) children and the youth serving/teaching older adults; (3) children, the youth, and older adults serving the community/learning together for a shared task; and (4) children, the youth, and older adults engaged in informal leisure/unintentional learning activities.

Over the past few years, the degree of interaction has been considered a classification criterion. Kaplan [8] thought that this criterion could more effectively explain the positive or negative results of intergenerational learning, and classified intergenerational programs and activities accordingly into the following seven different levels of intergenerational engagement, ranging from initiatives (point #1 of the below) to those that promote intensive contact and ongoing opportunities for intimacy (point #7 of the below): (1) learning about other age groups; (2) seeing the other age group but at a distance; (3) meeting each other; (4) annual or periodic activities; (5) demonstration projects; (6) ongoing intergenerational programs; and (7) ongoing, natural intergenerational sharing, support, and communication. Ames and Youatt [11] put forward the most comprehensive selection model of intergenerational learning and service activities, while Ohsako [12], from a different perspective, enabled planners to design diverse and interesting activities. On the other hand, Kaplan [8] used the interaction degree as a classification criterion, and discussed how interactive methods are generated and how deep and sustainable interactions are conducted based on commonality.

Furthermore, Ames and Youatt [11] found that conventional intergenerational learning activities were mostly service-oriented. Thus, the value and significance of activities to participants must be taken into account when selecting and evaluating the topics involved in the intergenerational activities. A good intergenerational program should not only meet the expected goals, but also provide balanced and diverse activities to participants. Moreover, it is important to introduce digital technology to make intergenerational activities more interactive and recreational for the two generations.

Finally, it is worth noticing that some scholars have investigated the applications of group learning or education from wider points of view. For example, Kyrpychenko et al. [13] studied the structure of communicative competence and its formation while teaching a foreign language to higher education students. The results of the questionnaire survey of the students' responses provided grounds for the development of experimental methods for such competence formations by future studies. Kuzminykh et al. [14] investigated the development of competence in teaching professional discourse in educational establishments, and showed that the best approach was to adopt a model consisting of two stages based on self-education and group education. The research results revealed that communicative competence may be achieved through a number of activities that may be grouped under four generic categories. Singh et al. [15] proposed an intelligent tutoring system named "Seis Tutor", that can offer a learning environment for face-to-face tutoring. The performance of the system was evaluated in terms of personalization and adaptation through a comparison with some existing tutoring systems, leading to a conclusion that 73.55% of learners were strongly satisfied with artificial intelligence features. To improve early childhood education for social sustainability in the future, Oropilla and Odegaard [16] suggested the inclusion of intentional intergenerational programs in kindergartens, and presented a framework that featured conflicts and opportunities within overlapping and congruent spaces to understand conditions for various intergenerational practices and activities in different places, and to promote intergenerational dialogues, collaborations, and shared knowledge.

3. Virtual Reality

The concept of virtual reality (VR) was first proposed in 1950, but was not materialized until 1957. Heilig [17] developed Sensorama, the first VR-based system with sight, hearing, touch, and smell senses, as well as 3D images. In 1985, Lanier [18] expressed that VR must be generated on a computer with a graphics system and various connecting devices in order to provide immersive interactive experiences. Burdea [19] proposed the concept of the 3I VR pyramid, and maintained that VR should have three elements: immersion, imagination, and interaction. Currently, VR can be classified into six categories according to design technology and user interfaces: (1) desktop VR; (2) immersion VR; (3) projection VR; (4) simulator VR; (5) telepresence VR; and (6) network VR; therefore, in recent years, many experts and scholars assumed that the VR technology can improve participants' attitude toward and interest in learning, and that the interactions in learning tasks can be strengthened in an immersive environment to improve learning effects [20][21].

Many applications have been developed using VR technology in the past. A specific direction of VR applications for human welfare is the use of VR in the healthcare domain. In this research direction, Nasralla [22] studied the construction of sustainable patient-rehabilitation systems with IoT sensors for the development of virtual smart cities. The research results showed that the proposed approach could be useful in achieving sustainable rehabilitation services. In addition, Sobnath et al. [23] advocated the use of AI, big data, high-bandwidth networks, and multiple devices in a smart city to improve the life of visually impaired persons (VIPs) by providing them with more independence and safety. Specifically, the uses of strong ICT infrastructure with VR/AR and various wearable devices can provide VIPs with a better quality of life.

Table 1 summarizes the following key points, based on relevant cases and the literature integrating both VR and the elderly: (1) VR is proven effective and has a positive effect on improving the body and cognition of the elderly; (2) VR-based learning activities can effectively enhance the learners' interest and help them make more progress; and (3) older people can adapt to VR, which can stimulate their memory according to their familiarity with a given scene, thereby achieving the effect of memory therapy [24]. As Davis mentioned regarding the technology-acceptance model (TAM) model [25][26][27], users' acceptance of science and technology is affected by "external factors", such as their living environment, learning style, and personal characteristics. Thus, it is impossible to determine whether the above method can have the same effect on the elderly in a specific society or country. In order to determine the usefulness and acceptability of VR for older Taiwanese people, Syed Abdul et al. [28] invited 30 older people over 60 years old in Taiwan to experience nine different VR games within six weeks, with each experience lasting 15 min. Then, they analyzed the users' performances with a scale based on the TAM model by Davis. The results showed that the elderly enjoyed the experience, finding VR useful and easy to use, which indicated that the elderly held a positive attitude toward the new technology.

Table 1. Relevant cases in which VR was used for the elderly.

Author, Year	Perceived Usefulness	Perceived Ease of Use
Benoit et al., 2015 [24]	**Memory therapy, which used VR to present images familiar to participants, could effectively stimulate the memories of the elderly.**	**This case was simulator VR. Users only watched immersive projected images in a confined space similar to VR movies.**
Manera et al., 2016 [29]	**VR could be used to treat patients with cognitive impairment and dementia, arousing their interest in therapies.**	**After wearing 3D glasses, users watched a 3D projection screen and switched among pictures by clicking a mouse.**
MyndVR, 2016 [30]	**Immersive experiences that were diverse, meaningful, and interesting were provided to the elderly to slow down their mental aging and treat relevant diseases.**	**Users could see images by wearing a simple head-mounted VR display without any external operation.**
George and David, 2017 [31]	**After performing practical tasks in a 3D VR-based environment, the elderly held a more positive attitude toward VR.**	**Users wore a head-mounted display and used a controller to move around, and located their hometowns in a 3D street view.**
Rendever, 2018 [32]	**A memory therapy that used 3D technology to recreate meaningful scenes or places the elderly want to visit was developed, providing immersive experiences through VR.**	**Users could see images by wearing a simple head-mounted VR display without any external operation.**

4. Tangible User Interfaces

The use of tangible user interfaces (TUIs) is a brand-new user-interfacing concept proposed by Ishii and Ullmer [33]. Unlike graphical user interfaces (GUIs), TUIs emphasize using common objects in daily life as the control interface, making the control action beyond screen manipulations. They allow users to operate the interface more intuitively by moving, grabbing, flipping, and knocking, and in other ways that people think are feasible to control the human–computer interface. Furthermore, TUIs grant a tangible form to utilize digital information or run programs [34].

More specifically, TUIs enable digital information to show in a tangible form. A digital interface consists of two important components: input and output, also known as control and representation. Control refers to how users manipulate information, while representation refers to how information is perceived. The tangible form shown in the use of TUIs may be regarded as the digital equivalent to control and representation, and the tangible artifacts operated in applying TUIs may be considered as devices for displaying representation and control. In other words, TUIs combine tangible representation (e.g., objects that can be operated by hand) with digital representation (e.g., images or sounds), as shown in **Figure 1**.

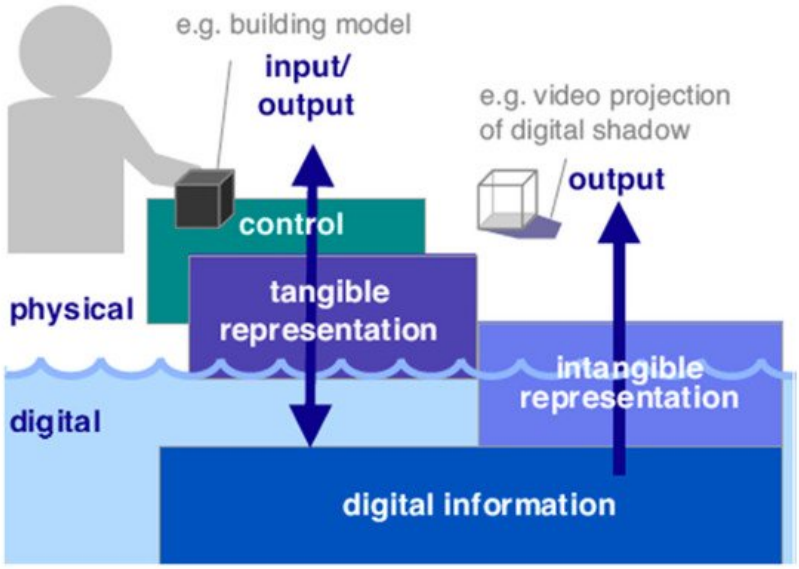

Figure 1. The conceptual framework of TUIs.

The concept of TUIs has been constantly discussed in man–machine interfacing seminars, and has been applied in various fields such as education and learning [35][36][37], music and entertainment [38][39][40], and professional solutions [41][42][43]. From the environmental psychology perspective, psychologists believed that TUIs had a tangible form and took advantage of the “affordance” of objects [44]. Some scholars, who employed the perceptual-motor theory as their research core, focused on user actions generated between them and TUIs, as well as on the dynamic presentation of TUIs [45][46][47][48].

Furthermore, TUIs provide a simpler and more intuitive way to help users accomplish goals. By combining physical manipulations with convenient digital technology, a TUI serves as a bridge connecting users and digital content. Moreover, TUIs have expanded the concept of interface design. Thus, scholars have conducted several discussions of the theoretical basis and scope of the conceptual framework of TUIs.

References

1. Proposal for a Council Recommendation on key Competences for Life-Long Learning. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018SC0014 (accessed on 4 April 2022).
2. Kimuna, S.R.; Knox, D.; Zusman, M. College students’ perceptions about older people and aging. Educ. Gerontol. 2005, 31, 563–572.
3. Lee, Y.S. Measures of student attitudes on aging. Educ. Gerontol. 2009, 35, 121–134.
4. Frenchs, M.; Pearl, M.; Mosher-Ashley, E. College students’ attitudes toward residential care facilities. Educ. Gerontol. 2000, 26, 583–603.
5. Zajicek, M. Interface Design for Older Adults. In Proceedings of the 2001 EC/NSF Workshop on Universal Accessibility of Ubiquitous Computing: Providing for the Elderly, Alcácer do Sal, Portugal, 22 May 2001; pp. 60–65.
6. Shibata, T.; Wada, K. Robot therapy: A new approach for mental healthcare of the elderly—A mini-review. Gerontology 2011, 57, 378–386.
7. Chatman, E.A. The impoverished life-world of outsiders. J. Am. Soc. Inf. Sci. 1996, 47, 193–206.
8. Kaplan, M.S. International programs in schools: Considerations of form and function. Int. Rev. Educ. 2002, 48, 305–334.
9. Hoff, A. Patterns of intergenerational support in grandparent-grandchild and parent-child relationships in Germany. Ageing Soc. 2007, 27, 643–665.
10. Newman, S.; Hatton Yeo, A. Intergenerational learning and the contributions of older people. Ageing Horiz. 2008, 8, 31–39.
11. Ames, B.D.; Youatt, J.P. Intergenerational education and service programming: A model for selection and evaluation of activities. Educ. Gerontol. 1994, 20, 755–764.

12. The Role of Intergenerational Program in Promoting Lifelong Learning for All Ages. Available online: http://www.unesco.org/education/uie/pdf/uiestud36.pdf (accessed on 15 November 2009).
13. Kyrpychenko, O.; Pushchyna, I.; Kichuk, Y.; Shevchenko, N.; Luchaninova, O.; Koval, V. Communicative competence development in teaching professional discourse in educational establishments. Int. J. Mod. Educ. Comput. Sci. 2021, 13, 16–27.
14. Kuzminykh, I.; Yevdokymenko, M.; Yeremenko, O.; Lemeshko, O. Increasing teacher competence in cybersecurity using the EU security frameworks. Int. J. Mod. Educ. Comput. Sci. 2021, 13, 60–68.
15. Singh, N.; Gunjan, V.K.; Nasralla, M.M. A parametrized comparative analysis of performance between proposed adaptive and personalized tutoring system “seis tutor” with existing online tutoring system. IEEE Access 2022, 10, 39376–39386.
16. Oropilla, C.T.; Odegaard, E.E. Strengthening the call for intentional intergenerational programmes towards sustainable futures for children and families. Sustainability 2021, 13, 5564.
17. Morton Heilig. Available online: https://en.wikipedia.org/wiki/Morton_Heilig (accessed on 5 April 2022).
18. Lanier, J. Virtual reality: The promise of the future. Interact. Learn. Int. 1992, 8, 275–279.
19. Burdea, G.C.; Coiffet, G. Virtual Reality Technology; John Wiley & Sons: New York, NY, USA, 1993.
20. Virvou, M.; Katsionis, G. On the usability and likeability of virtual reality games for education: The case of VR-ENGAGE. Comput. Educ. 2008, 50, 154–178.
21. Merchant, Z.; Goetz, E.T.; Cifuentes, L.; Keeney-Kennicutt, W.; Davis, T.J. Effectiveness of virtual reality-based instruction on students’ learning outcomes in K-12 and higher education: A meta-analysis. Comput. Educ. 2014, 70, 29–40.
22. Nasralla, M.M. Sustainable virtual reality patient rehabilitation systems with IoT sensors using virtual smart cities. Sustainability 2021, 13, 4716.
23. Sobnath, D.; Rehman, I.U.; Nasralla, M.M. Smart Cities to Improve Mobility and Quality of Life of the Visually Impaired. In Technological Trends in Improved Mobility of the Visually Impaired; Paiva, S., Ed.; Springer International Publishing: Cham, Germany, 2020; pp. 3–28.
24. Benoit, M.; Guerchouche, R.; Petit, P.D.; Chapoulie, E.; Manera, V.; Chaurasia, G.; Drettakis, G.; Robert, P. Is it possible to use highly realistic virtual reality in the elderly? A feasibility study with image-based rendering. Neuropsychiatr. Dis. Treat. 2015, 11, 557–563.
25. Davis, F.D. A Technology Acceptance Model for Empirically Testing New End-User Information Systems: Theory and Results. Ph.D. Thesis, Sloan School of Management, Massachusetts Institute of Technology, Boston, MA, USA, 1985.
26. Davis, F.D. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q. 1989, 13, 319–340.
27. Davis, F.D. User acceptance of information technology: System characteristics, user perceptions and behavioral impacts. Int. J. Man-Mach. Stud. 1993, 38, 475–487.
28. Syed Abdul, S.; Malwade, S.; Nursetyo, A.A.; Sood, M.; Bhatia, M.; Barsasella, D.; Liu, M.F.; Chang, C.-C.; Srinivasan, K.; Raja, M.; et al. Virtual reality among the elderly: A usefulness and acceptance study from Taiwan. BMC Geriatr. 2019, 19, 223.
29. Manera, V.; Chapoulie, E.; Bourgeois, J.; Guerchouche, R.; David, R.; Ondrej, J.; Drettakis, G.; Robert, P. A feasibility study with image-based rendered virtual reality in patients with mild cognitive impairment and dementia. PLoS ONE 2016, 11, e0151487.
30. MyndVR. Available online: https://www.myndvr.com/ (accessed on 4 April 2022).
31. Coldham, G.; Cook, D.M. VR Usability from Elderly Cohorts: Preparatory Challenges In Overcoming Technology Rejection. In Proceedings of the National Information Technology Conference, Colombo, Sri Lanka, 14–15 September 2017; pp. 131–135.
32. Rendever VR for Seniors. Available online: https://www.rendever.com/?hsLang=en (accessed on 4 April 2022).
33. Ishii, H.; Ullmer, B. Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms. In Proceedings of the ACM SIGCHI Conference on Human Factors In Computing Systems, Atlanta, GA, USA, 22–27 March 1997; pp. 234–241.
34. Ishii, H. Tangible Bits: Beyond Pixels. In Proceedings of the 2nd International Conference on Tangible and Embedded Interaction, Bonn, Germany, 18–20 February 2008; pp. 15–25.

35. Resnick, M.; Martin, F.; Berg, R.; Borovoy, R.; Colella, V.; Kramer, K.; Silverman, B. Digital Manipulatives: New Toys to Think with. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Los Angeles, CA, USA, 18–23 April 1998; pp. 281–287.
36. Zuckerman, O.; Arida, S.; Resnick, M. Extending Tangible Interfaces for Education: Digital Montessori-inspired Manipulatives. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Portland, OR, USA, 2–7 April 2005; pp. 859–868.
37. Raffle, H.; Parkes, A.; Ishii, H. Topobo: A Constructive Assembly System with Kinetic Memory. In Proceedings of the SIGCHI Conference on Human Factors in Computing, Vienna, Austria, 24–29 April 2004; pp. 647–654.
38. Jordà, S.; Geiger, G.; Alonso, M.; Kaltenbrunner, M. The reacTable: Exploring the Synergy between Live Music Performance and Tabletop Tangible Interfaces. In Proceedings of the 1st International Conference on Tangible and Embedded Interaction, Baton Rouge, LA, USA, 15–17 February 2007; pp. 139–146.
39. Dunn, H.N.; Nakano, H.; Gibson, J. Block Jam: A tangible Interface For Interactive Music. In Proceedings of the 2003 Conference on New Interfaces for Musical Expression, Montreal, QC, Canada, 22–24 May 2003; pp. 170–177.
40. Schiettecatte, B.; Vanderdonckt, J. AudioCubes: A Distributed Cube Tangible Interface Based on Interaction Range for Sound Design. In Proceedings of the Second International Conference on Tangible and Embedded Interaction, Bonn, Germany, 18–20 February 2008; pp. 3–10.
41. Couture, N.; Rivière, G.; Reuter, P. GeoTUI: A Tangible User Interface for Geoscience. In Proceedings of the Second International Conference on Tangible and Embedded Interaction, Bonn, Germany, 18–20 February 2008; pp. 89–96.
42. Kim, M.J.; Maher, M.L. The impact of tangible user interfaces on spatial cognition during collaborative design. Des. Stud. 2008, 29, 222–253.
43. Piper, B.; Ratti, C.; Ishii, H. Illuminating clay: A 3-D Tangible Interface for Landscape Analysis. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Minneapolis, MN, USA, 20–25 April 2002; pp. 355–362.
44. Norman, D.A. The next UI breakthrough, part 2: Physicality. Interactions 2007, 14, 46–47.
45. Dourish, P. Where the Action is: The Foundations of Embodied Interaction; MIT Press: Boston, MA, USA, 2004.
46. Kaptelinin, V.; Nardi, B.A. Acting with Technology: Activity Theory and Interaction Design; MIT Press: Boston, MA, USA, 2006.
47. Price, S.; Sheridan, J.G.; Pontual Falcão, T. Action and Representation in Tangible Systems: Implications for Design of Learning Interactions. In Proceedings of the 4th International Conference on Tangible, Embedded, and Embodied Interaction, Cambridge, MA, USA, 24–27 January 2010; pp. 145–152.
48. Ross, P.R.; Wensveen, S.A. Designing aesthetics of behavior in interaction: Using aesthetic experience as a mechanism for design. Int. J. Des. 2010, 4, 3–13.
