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Older peoples' preferences and challenges when using digital technology: a systematic review with particular reference to digital games

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Abstract

Digital games offer an increasingly important way for older people to access new knowledge and skills particularly in terms of improving health and well-being. Currently there is limited research exploring how older people interact with digital games, and this review of the literature contributes insights into the preferences and limitations that older users encounter when using digital technology.

Although older users of technology do not present as a homogeneous group due to differences linked to experience, specific older age cohort, dexterity and sensory loss, several key considerations are identified. Key factors include those linked to usability, learnability, efficiency, and satisfaction for the user and the article concludes with a suggestion that bespoke tools should be developed in an inclusive way with older peoples' needs and experiences as a central consideration.

Key words: Digital games, digital technology, older people's learning needs

Introduction

Digital technology has a growing impact on everyday life supporting communication, online shopping, and booking medical appointments. It offers new ways of accessing information and learning through interactive games that reinforce new knowledge and skills (Dicheva et al., 2015). Increasingly digital technology is being used to help older people as for learning and leisure activities (Chua et al., 2013). This literature review has been undertaken as part of a wider project exploring digital learning games to increase scam awareness for older people in the UK. It is important to underpin the development of such games using an inclusive approach which considers the needs of older uses in terms of their cultural context, age and motor abilities (Cañas-Bajo et al., 2016; Jonsson et al., 2016). This includes combining elements which integrate learning, social interaction and enjoyment to create accessible formats which older users will find easy to use (Seah et al., 2018). The novelty of technology can provide excitement in people`s lives, offering a sense of achievement alongside possibilities for accessing information. Currently there is a dearth of research exploring digital game preferences of older people (Salmon et al., 2017), and this review contributes insights into how to create meaningful digital games for older people.

Digital Games for Older People

Digital games are played through technology such as televisions, computers, game consoles, and mobile devices (Hall & Marston, 2017). Digital game-based learning can personalise learning and increase motivation effects which can be important for developing older

people's digital skills (Wang & Burton, 2010). Increasingly digital media and games are used with older people to support active ageing (Hall & Marston, 2017), social connectedness (Seah et al., 2017) and cognitive ability (Pyae, 2017).

Despite growing research exploring active ageing through digital game technology, some researchers are tentative about its usefulness in facilitating real change in older people's physical or cognitive abilities (Howes et al., 2017). Older people may face barriers in accessing digital games due to their inexperience with technology (Mertens et al., 2016). Such challenges underline the importance of creating digital games which are meaningful in the lives of older users (Cañas-Bajo et al., 2016; Jonsson et al., 2016), and the needs and preferences of the end user should be central in the development phase to optimise usefulness.

Digital technology and older people

Computer anxiety is a common barrier encountered by older people who may be fearful of technology, and concerned about damaging devices (Wagner, Hassanein & Head, 2010). The increased use of mobile devices suggests increasing use by older people. However, data from the U.S shows that only 32% of people 65+ use mobile devices (Roque & Boot, 2018), and their unwillingness to engage is linked to a series of factors (Fernández et al. 2017; Simek et al. 2012; Vaziri et al. 2016). These include motor and cognitive impediments affecting ability to use a mouse or keyboard (Kurniawan et al. 2006), resulting in users blaming themselves for being too slow to understand the technical requirements of the device (Palacio et al. 2015).

Current marketing strategies and design choices in the development of tablets and phones create 'exclusive' environments that appear to be targeted at younger people. Older people find it difficult to engage with this technology due to its rapid changes and lack of internet access within their homes (Braun, 2013). Research suggests that with training older participants engage with more confidence and tackle barriers with new technologies (Mertens et al. 2016). Content variety is another consideration to prevent the user becoming bored (Vaziri et al., 2017).

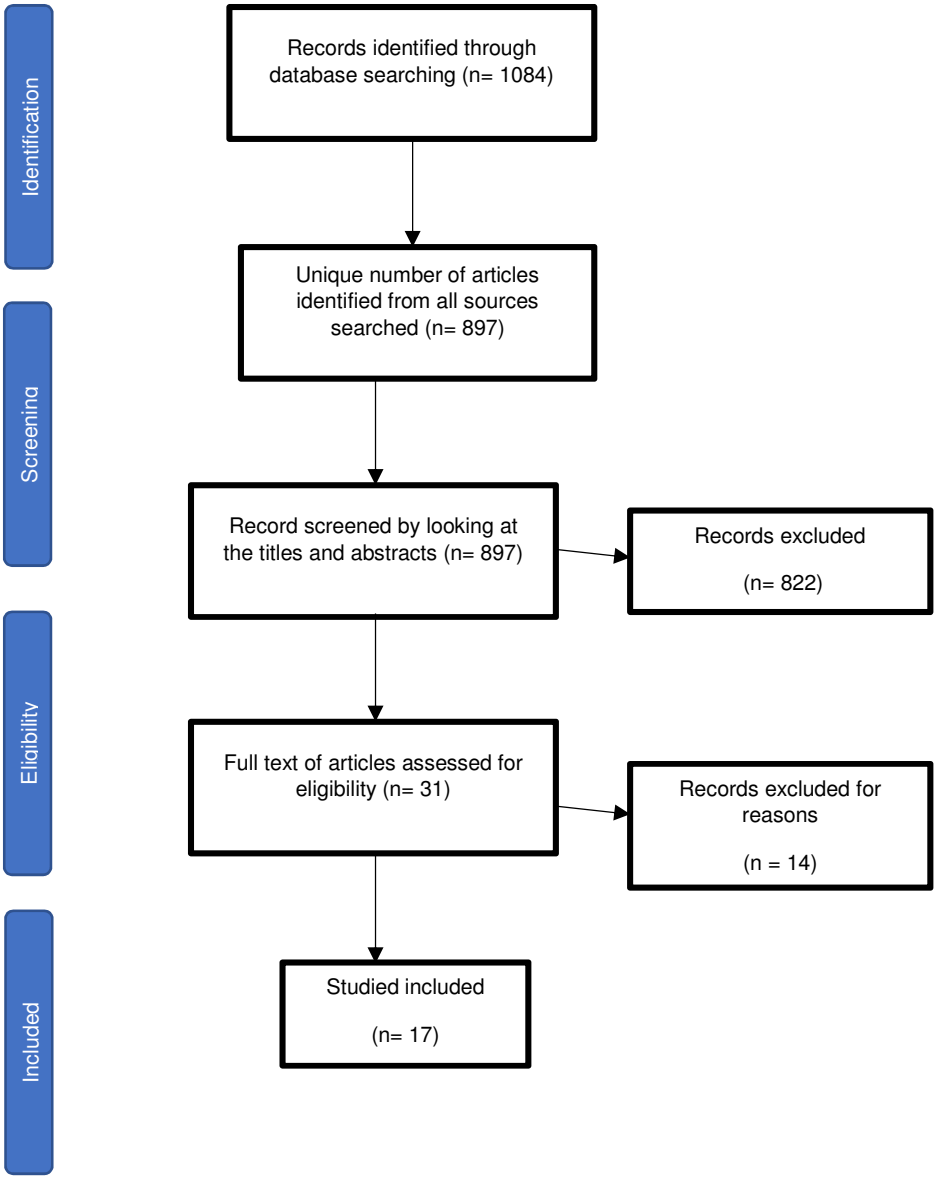
Health and social care agencies are increasingly interested in how new technology can enhance the wellbeing of older people (Gibson et al., 2016), particularly to combat loneliness, social isolation and improve health and wellbeing (Cotten et al. 2012; Hwang et al., 2011; Palacio et al., 2015; Weaver et al. 2010; Winstead et al., 2013). Multiple studies have used digital games to improve physical and mental wellbeing including fine and gross motor skills, eye-hand coordination, problem solving and reaction to unexpected events (Palacio et al., 2015). A correlation between physical activity and digital games offered by devices such as Wii indicate a beneficial contribution to wellbeing compared to regular games (Khosravi et al., 2016). To optimise a positive outcome from digital technology it is important to focus on the usability of a device for older people. The following systematic review explores the potential of digital devices in supporting learning in older generations.

Methods

Search Strategy

Two distinct approaches were utilised to identify relevant studies relevant. Firstly, keywords were used in mySearch database for articles published from 2010 to 2018 in English. This focused on academic articles excluding unpublished data, books and dissertations. To define

the search, three categories were used. The first terms related to older people (older people, elderly, silver age, senior citizens, elders, ageing society). The second related to hardware devices (digital devices, mobile devices, tablet, computers, phones, smart phones, iPad, iPhone, laptop, android). Thirdly, generic interactive media terms were included (videogames, applications). All were entered in a keyword function using a Boolean search: (‘older people’ OR elder* OR ‘silver age’ OR ‘senior citizen’ OR ‘aging society’) AND (tablet* OR computer* OR phone* OR ‘smart phone*’ OR iPad* OR iPhone* OR laptop*) AND (‘video game*’ OR app OR apps). This search generated a total of 1084 articles among a series of databases: Academic Search (777), SocINDEX (91), Education Source (52), Business Source (48), MEDLINE (37), CINAHL (32), IEEE Xplore (31), Science Direct (16).



Following the keyword search, other articles were found using a backwards search. The inclusion criteria included: older people aged 55 or over; older people's interaction with technology; the device and application used during testing; and older peoples' feedback regarding the interaction with a device. Exclusion criteria used were: no explanation of the device and application used provided; no presentation of issues encountered during user testing; and papers published prior to 2000.

Results

Out of the 31 selected papers 14 were excluded. Two were excluded because they did not present details on the use of the device or application (Devos et al., 2015; Lindhardt & Nielsen, 2017). Two focused on security in eHealth technology used by older people but did not mention interaction (Grindrod et al., 2018; Ray, 2017). One focused on training of lower limbs using a custom device app, but did not explore their design (Chen et al., 2012). Another was excluded due to the younger age of participants (Rajan et al., 2016). Two focused on physical exercises correlated with technology but did not explore the technology used (Belchior et al., 2013; Lai et al., 2013). Two used technology only to record information about the user (King et al., 2016; Santos et al., 2017). Two did not include information relevant to the search (Guo, 2017; Hepp, Berg & Roitsch, 2017). Therefore 17 studies were included in this review. Studies that include focus group have participants aged between 55 and 98, with most sitting between 60 to 70 years old. Studies where carried out in Sweden and Latvia (Jonsson et al., 2016), the UK (Pitts et al., 2015), Germany (Mertens et al., 2016), USA (Ip et al., 2017), Singapore (Chua et al., 2013) and Spain (Rosales & Fernandez, 2016). However, not all studies disclosed their location.

Summary of Age, Technology and Applications Used in previous Studies

A summary of information was extracted from papers found from the Boolean function (Table 1). Some of the papers are based on existing applications and others on customised software. None of the included papers have used a custom designed device.

References	Age range	Device/s	Application/s	Activities and/or Objectives
(Palacio et al., 2015)	60-79	• 2 Kinect • 3 computers • 3 projectors • 3 video cameras • 2 audio devices • 1 Xbox 360 console • 1 Nintendo Wii • 1 Touchscreen	• Angry Birds • Happy Sky	(1) In pairs one older and one younger person played 2 levels of Happy Sky using Kinect. First level familiarised users with the device. Activity two was collaborative and players had to capture dragons. Angry Birds game played on four devices: a tablet, Xbox 360, Nintendo Wii and Kinect
(Meneses Fernández et al., 2017)	57-87	• Epson Moverio AR glasses • Lakento MVR virtual reality headset with Smartphone hook up • Tablets and Smartphones	• video calls • mobile apps • Internet • Augmented Reality • QR codes	(1) ColAR application to visualise 3D images in augmented reality (AR) from printed artwork. (2) Read newspapers with the use of an application that allowed the older person to use AR in certain sections of the article.

				(3) Scan QR code to access information about historical building, using google street view.
(Vaziri et al., 2017)	65	• Kinect	• IStopFall	Users exercise with a Kinect application to improve balance and strength.
(Ip et al., 2017)	65	• Computer • Tablet	• Custom	A custom application to recognise older people with cognitive impairment
(Chua et al., 2013)	76	• Nintendo Wii	• Wii Party • Wii Sport • Cooking Mama	Users play a series of mini-games from selected apps. Games selected for simplicity in interaction and use.
(Jonsson et al., 2016)	75	• Android mobile	• Custom	A custom app to help find housing solutions for the user. Designed to be easily accessible for older people.
(West et al., 2017)	55 -75	• Wii	• Super Mario 64	Participants had 6 months training at home playing Mario 64 on a Wii console using standard controller. Exploring if games

				improve cognitive abilities.
(Mertens et al., 2016)	60	• Ipad	• Custom	A custom app to remind and keep track of daily medication intake. Also held information such as blood pressure.
(Hwang et al., 2011)	>60	• Computer	• Custom	App designed to remove complicated interfaces to improve accessibility. Subdivided into 3 games (a) categorising food health (b) comparing symbols of countries and guessing the correct one (c) a racing game. Games interacted with by gestures or movement via webcam.
(Rosales & Fernandez, 2016).	>60	• Smartphones	• WhatsApp	WhatsApp focused on communication in and outside their house.
(Luna-Garcia et al. 2015))	60-98	• Tablet	• Facebook for elders	App designed for older people to use as social media. Given to older participants during a focus group, to improve understanding of design flow and interaction during a series of steps.

Challenges and best practice

To optimise the usefulness of digital games as learning tools for older people, it is essential to have knowledge of how they interact with such devices, so that apps can be developed to create sustained interest from the learner alongside ease of use. For those looking to develop such games it is important to understand how familiar the participant is with the device and how to pitch instructions at the right level (Boot et al., 2015).

The benefits of using interactive computer software and applications are strongly linked to the users' motivation and ability to use the device consistently to increase learning over time (Vaziri et al., 2017). However, current technology interfaces have not been designed and developed for older users who require more streamlined and user-friendly interface and devices (Arfaa & Wang, 2014; Khosravi et al., 2016). These factors are fundamental to compensate for any limitations generated by ageing such as reduced manual dexterity or reduced sensory capacity (Palacio et al., 2015).

Challenges for older users interacting with digital technology include sight problems linked to processing visual information and light changes, and difficulties in seeing small details (Rute- Pérez et al., 2014). Other challenges may be linked to hearing limitations associated with certain frequencies and sounds. Motor abilities, including fine or gross motor skills alongside general physical weakness, can limit the accessibility of a device as well as cognitive capabilities such as attention span and memory loss. A study by Palacio et al. (2015) describes four objectives to improve older peoples use of technology, and these are useful elements for future game designers to consider.

1. Understanding how older users feel and experience the interaction with technology.

2. Presenting older people with new technologies and exploring how they can be used to communicate and connect.
3. Selection of appropriate technologies most suited to older users' needs.
4. Understanding older people's perception and gratification from using interactive devices (Palacio et al., 2015).

A fundamental aspect to consider when involving older people with digital technology is linked to usability, including factors linked to learnability, efficiency, memorability, errors and satisfaction (Fisk et al., 2009). Learnability can be measured by looking at time required to complete a task. The usefulness of an application and how it fulfils the users learning needs should also be considered. Efficiency of use can be calculated by looking at the time required from an experienced user to perform a task. Memorability may be particularly important for older people who are less familiar in using a digital technology and can be tested by looking at time spent in repeating a task (Fisk et al. 2009).

To promote the effectiveness of digital games or applications for older people it is important that it occurs in the right context (Hsieh, 2011). Using something out of context can lose its purpose, resulting in a negative experience even when a tool is perfectly designed. For example, Fisk et al. (2009) discovered through focus group discussions that more than 50% of reported issues could have been solved by design adjustments and improved training. Motivation is a major factor in using an application or a device effectively, whereas a lack of interest can hinder possible benefits (Jaeggi et al., 2013). To improve interest in the use of digital technology, it has been suggested that a reward system be introduced to provide visual feedback to older users (Cujzek & Vranic, 2017; Haesner et al., 2015). Such feedback may include score systems and certificates when key activities are achieved or completed.

User Experiences

For those hoping to involve older people in digital learning games it is important to consider how the user experiences this type of interaction. For example, a study involving 28 older participants found that older people reported feeling engaged and interested in using a computer when they found benefit in using it (Burnett et al., 2011). Some older users report difficulties in co-ordinating a series of actions, and double clicking on an icon can be quite a challenge due to the required fast movement in timing to succeed. Another challenging element for older users can be linked to a click and drag element, where the constant strength required to hold the button can prompt discomfort (Palacio et al., 2015). To prevent these challenges some researchers have designed games which remove any interaction with a mouse or keyboard, replacing these with gross motor movements/gestures (Hwang et al., 2011). For those with no prior experience of digital game technology using gross motor movements/gestures felt more natural, however skilled users felt disoriented by this new way of interacting with the game. Despite these difficulties the overall feedback was positive and demonstrates that gestures contextualised within the context of a game can provide a positive experience for older users (Hwang et al., 2011).

Some older people are using portable technology for self-assessment of physical health through sensors which record physical activities (Helbostad et al., 2017). The portable nature of such devices is an advantage, but they are also easy to lose and this may pose a risk if personal information is recorded (Vaziri et al., 2017). The way in which portable devices are used can pose challenges for older users. A study in which older people played Angry Birds using a touch screen gave participants an easy way to aim at the target (Palacio et al., 2015), however when required to produce more complex movements such as touch-move-release,

this was more challenging, particularly if required to hold their arm over the tablet. Research into the use of smartphones for email access found that older users often avoided answering via their phone and waited to return home as they found a touch screen more complicated to use compared to a classic computer keyboard (Mertens et al., 2016). Small fonts pose a major issue for older users of mobile devices, and some information or interactive options might be hidden within some menus (Luna-García et al., 2015).

Some digital games require more physical interaction and fatigue can become an issue for some older users. Kinect requires gross motor and coordination skills to interact with the game, and older users have encountered difficulties in engaging with it (Palacio et al., 2015). Wii controls often require coordination and multitasking across different actions such as arm/wrist movement (gross motor), aim (sight and reflex) and finger interaction with buttons (fine motor). These complex range of actions can be difficult to apply at the right time and in the correct order (Palacio et al., 2015), although some older users were able to improve coordination and gain control. Simple games, which require simple input and repetitive actions result in older users encountering less issues and supports learning at a faster pace (De Schutter, 2011). Research has demonstrated how supporting older users with simple games reduces feelings of being overwhelmed. A study of a simple bowling game in Wii Sport, using a single button and a movement of the arm, offers multiple benefits to improve familiarisation with the game, console, and controller (Chua et al., 2013). Other games have been used to boost cognitive capacity in older people. A Super Mario 64 game was used to encourage older people to use their cognitive abilities through increased motor coordination and spatial memory (West et al., 2017). Problems encountered were felt to be linked to the development of the game, which was targeted at users with gaming experience and without

cognitive or motor difficulties. To ameliorate these difficulties, training sessions in the older persons home were undertaken to try to improve their ability in playing the game.

Augmented Reality (AR) has an ability to merge digital and real-world information, and is defined as the most attractive type of digital interaction (Zhou et al., 2011). This study found limited research exploring specific use of AR for older users, and the current apps market using AR is not focused on older users limiting its potential. Usability problems may restrict its viability particularly as a headset may be problematic for those with balance and/or eye sight issues (Meneses Fernández et al., 2017).The use of AR in digital applications for older people is therefore an area requiring further research.

Discussion

This systematic review has been concerned with the current state of interaction between older people and digital technology including challenges and best practice in game development. Most of the studies in this review concerned older people aged 57 to 87, and the needs and experiences across these age ranges are not homogeneous. The oldest old may have little interaction with digital technology with less than 5 % of those 85+ using the internet (Friemel, 2016). Alongside differences in users' skills and confidence in using digital technology, differences across mental and physical limitations, motivation, costs and level of external support will also influence how older users interact with digital learning (Lee, Chen & Hewitt, 2011). It is therefore important to recognise diversity of experience in older peoples use of technology and to avoid making generalisations (Alexander & Ellen, 2015). Future research should therefore explore age cohort differences in digital use, for example, comparing the needs and experiences of those aged 57-67, with those in older age cohorts (75+). As usability and perceived usefulness are important dimensions, research also needs to

consider the perceived benefits of digital device use to the older user and how this may facilitate their interaction with it.

Much of the research highlights specific needs that older users of digital technology may encounter linked to reduced motor skills (Ip et al., 2017; Palacio et al., 2015), sight (Luna-García et al., 2015; Meneses Fernández et al., 2017), hearing (Rute-Pérez et al., 2014) and cognitive abilities (Kurniawan et al., 2006; West et al., 2017). These challenges require developers to consider the most appropriate support to enable older people to best use digital games. To produce a successful application developers need to understand all the needs and requirements of their audience (Bates, 2004). It is important to seek feedback from potential users early in the development process so that features are tested for usability and limitations understood.

Most studies in this review used tablets and smartphones (Ip et al., 2017; Jonsson et al., 2016; Luna-García et al., 2015; Mertens et al., 2016; Palacio et al., 2015; Roque & Boot, 2018; Rosales & Fernández-Ardèvol, 2016). The reasons for using mobile devices differed but usability defined by a single tap or swipe, was considered a positive approach for older users. This raises important considerations for game developers concerning the dexterity of older users, the usability of devices, and the actions required to engage with them.

Mobile devices, however, do not provide an issue free experience as those with sight and fine motor limitations experience barriers producing a precise tap on a small surface (Ip et al., 2017). Sight problems are more common for older people, and to compensate it is important to consider the use of larger fonts to reduce frustration (Luna-García et al., 2015). A solution can be a dynamic adjustable font size which can be set by a user to fit their needs. However,

customised fonts can force changes in the user interface which can be less appealing and interesting to the user (Kurniawan et al., 2006). Although aesthetics is important to improve engagement, increasing the size of items or text and hiding options behind layers can make navigation through the app more difficult for older users. Solutions to support the uptake of digital technology in older people may incur extra costs for developers. Due to lack of familiarity and confidence in using computers or other devices, basic training may be required to improve usability which may add a cost element to implementation (Roque & Boot, 2018). Further costs may result from customising content specifically for older users (Helbostad et al., 2017). Due to the current low levels of uptake in older age groups this represents a restricted market undermining its commercial viability.

Devices such as computers, Kinect and Wii have been occasionally used in studies focused on older peoples' physical health (Chua et al., 2013; Hwang et al., 2011; Palacio et al., 2015; Vaziri et al., 2017; West et al., 2017). Using Kinect proved enjoyable for older users who reported increases in their daily movement although the activities provided a high level of fatigue (Palacio et al., 2015). However, as most studies rely on small samples it is difficult to generalise about their effectiveness (Khosravi et al., 2016). Long-term results are limited making it difficult to access the benefits for older people over time (Cujzek & Vranic, 2017).

To increase the use of digital technology across older age groups, government and business need to work together to promote access to devices across a range of social settings that older people access. For example, the lack of technology in sheltered housing or care home environments makes digital technology unfamiliar and a more frightening experience when it is encountered (Braun, 2013). Support and education is required to shift older people's perceptions of digital technology and promote confidence in using it. Organisations which support older people, such as Age UK, may be important allies when rolling out and

supporting such digital games, particularly for those older people require additional support to engage with it. Future generations of older people will hopefully be more computer literate and should encounter less problems with basic interactions and digital games (Cujzek & Vranic, 2017). However, current cohorts of older people may require state funded support and education to develop confidence to embrace digital technologies which may be helpful in promoting their long-term health and wellbeing.

Conclusion

To date there has been limited research exploring digital game preferences of older people (Salmon et al., 2017). However, digital games offer a useful approach to learning and leisure activities for older people, and it is imperative that those developing new tools focus on the specific needs of the older people to improve usability and uptake. Key considerations should be for bespoke learning tools which consider learnability, efficiency, memorability, errors and satisfaction factors for the older user (Fisk et al., 2009). It was noticeable that most studies in this review did not consider re-designing devices specifically for older users, but fitted them into existing applications. If the aim is to develop meaningful and useable learning tools, it is important to ensure that the digital applications are developed in an inclusive way with older people's needs and experiences as a central consideration. Alongside this it is important to promote the digital inclusion of older people within government policy to ensure equality of access across cultural contexts and specific older age cohorts.

References

Alexander, J. A. M. v. D. & Ellen, J. H. (2015). A nuanced understanding of Internet use and non-use among the elderly. *European Journal of Communication, 30*(2), pp.171-187.

Arfaa J. & Wang Y. (2014) A Usability Study on Elder Adults Utilizing Social Networking Sites. *Design, User Experience, and Usability. User Experience Design for Diverse Interaction Platforms and Environments* (eds). Heraklion, Greece: Springer, Cham: Switzerland.

Baslyman, M. & Chiasson, S. (2016). *"Smells Phishy?": An educational game about online phishing scams.* Paper presented at the APWG Symposium on Electronic Crime Research (eCrime), Toronto, Canada.

Bates, B. (2001). *Game design: the art and business of creating games* (2nd ed.). Cambridge: Premier Press.

Belchior, P., Marsiske, M., Sisco, S. M., Yam, A., Bavelier, D., Ball, K. & Mann, W. C. (2013). Video game training to improve selective visual attention in older adults. *Computers in Human Behavior, 29*(4), pp.1318-1324.

Boot, W. R., Charness, N., Czaja, S. J., Sharit, J., Rogers, W. A., Fisk, A. D., Mitzner, T. & Nair, S. (2015). Computer proficiency questionnaire: assessing low and high computer proficient seniors. *The Gerontologist, 55*(3), pp.404-411.

Braun, M. T. (2013). Obstacles to social networking website use among older adults. *Computers in Human Behavior, 29*(3), pp.673-680.

Burnett, J. S., Mitzner, T. L., Charness, N. & Rogers, W. A. (2011). *Understanding Predictors of Computer Communication Technology Use by Older Adults.* Paper presented at the Proceedings of Human Factors and Ergonomics Society Annual Meeting, Santa Monica, CA.

Cañas-Bajo, J., Leikas, J., Jokinen, J., Cañas, J. J. & Saariluoma, P. (2016). How older and younger people see technology in Northern and Southern Europe: Closing the generation gap. *Gerontechnology, 14*(2), pp.110-117.

Chen, P.-Y., Wei, S.-H., Hsieh, W.-L., Cheen, J.-R., Chen, L.-K. & Kao, C.-L. (2012). Lower limb power rehabilitation (LLPR) using interactive video game for improvement of balance function in older people. *Archives of Gerontology and Geriatrics, 55*(3), pp.677-682.

Chua, P.-H., Jung, Y., Lwin, M. O. & Theng, Y.-L. (2013). Let's play together: Effects of video-game play on intergenerational perceptions among youth and elderly participants. *Computers in Human Behavior, 29*(6), pp.2303-2311.

Cotten, S. R., Ford, G., Ford, S. & Hale, T. M. (2012). Internet use and depression among older adults. *Computers in Human Behavior, 28*(2), pp.496-499.

Cujzek, M. & Vranic, A. (2017). Computerized tabletop games as a form of a video game training for old-old. *Aging, Neuropsychology and Cognition, 24*(6), pp.631-648.

De Schutter, B. (2011). Never Too Old to Play: The Appeal of Digital Games to an Older Audience. *Game and Culture, 6*(2), pp.155-170.

Devos, P., Min Jou, A., De Waele, G. & Petrovic, M. (2015). Technology applied to geriatric medicine: Design for personalized mobile health applications for enhanced older people participation. *European Geriatric Medicine, 6*(6), pp.593-597.

Dicheva, D., Dichev, C., Agre, G. & Angelova, G. (2015). Gamification in Education: A Systematic Mapping Study. *Journal of Educational Technology and Society, 18*(3), pp.75-88.

Fisk, A. D., Rogers, W. A., Chamess, N., Czaja, J., S. & Sharti, J. (2009). *Designing for older adults : principles and creative human factors approaches* (2nd ed.). Boca Raton, Fla: CRC.

Friemel, T. N. (2016). The digital divide has grown old: Determinants of a digital divide among seniors. *New Media and Society, 18*(2), pp.313-331.

Gibson, G., Newton, L., Pritchard, G., Finch, T., Brittain, K. & Robinson, L. (2016). The provision of assistive technology products and services for people with dementia in the United Kingdom. *Dementia, 15*(4), pp.681-701.

Grindrod, K., Khan, H., Hengartner, U., Ong, S., Logan, A. G., Vogel, D., Gebotys, R. & Yang, J. (2018). Evaluating authentication options for mobile health applications in younger and older adults. *PLoS ONE, 13*(1), pp.1-16.

Guo, P. (2017). How Adults Ages 60+ Are Learning to Code. *Communications of the ACM, 60*(8), pp.10-11.

Haesner, M., O'Sullivan, J. L., Gövercin, M. & Steinhagen-Thiessen, E. (2015). Requirements of older adults for a daily use of an internet-based cognitive training platform. *Informatics for Health and Social Care, 40*(2), pp.139-153.

Hall, A. K. & Marston, H. R. (2017) *Games for Health in the Home: Gaming and Older Adults in the Digital Age of Healthcare* (eds). Springer, Cham: Switzerland.

Helbostad, J. L., Vereijken, B., Becker, C., Todd, C., Taraldsen, K., Pijnappels, M., Aminian, K. & Mellone, S. (2017). Mobile Health Applications to Promote Active and Healthy Ageing. *Sensors, 17*(3), pp.1-13.

Hepp, A., Berg, M. & Roitsch, C. (2017). A Processual Concept of Media Generation: The Media-Generational Positioning of Elderly People. *Nordicom Review, 38*(1), 109-122.

Howes, S. C., Charles, D. K., Marley, J., Pedlow, K. & McDonough, S. M. (2017). Gaming for Health: Systematic Review and Meta-analysis of the Physical and Cognitive Effects of Active Computer Gaming in Older Adults. *Physical Therapy, 97*(12), pp.1122-1137.

Hsieh, H. C. L. (2011). Exploring the Impact of Cultures on Web Usability Test. *Lecture Notes in Computer Science,* 47-54.

Hwang, M.-Y., Hong, J.-C., Hao, Y.-w. & Jong, J.-T. (2011). Elders' Usability, Dependability, and Flow Experiences on Embodied Interactive Video Games. *Educational Gerontology, 37*(8), pp.715-731.

Ip, E. H., Barnard, R., Marshall, S. A., Lingyi, L., Sink, K., Wilson, V., Chamberlain, D., Rapp, S. R. & Lu, L. (2017). Development of a video-simulation instrument for assessing cognition in older adults. *BMC Medical Informatics and Decision Making, 17*(1), pp.1-11.

Jaeggi, S., Buschkuehl, M., Shah, P. & Jonides, J. (2013). The role of individual differences in cognitive training and transfer. *Memory and Cognition, 42*(3), pp.464-480.

Jonsson, O., Haak, M., Tomsone, S., Iwarsson, S., Schmidt, S. M., Mårtensson, K., Svensson, T & Slaug, B. (2016). Cross-National Usability Study of a Housing Accessibility App: Findings From the European InnovAge Project. *Journal of Usability Studies, 12*(1), pp.27-49.

Khosravi, P., Rezvani, A. & Wiewiora, A. (2016). Review: The impact of technology on older adults' social isolation. *Computers in Human Behavior, 63*, pp.594-603.

King, A. C., Hekler, E. B., Grieco, L. A., Winter, S. J., Sheats, J. L., Buman, M. P., Banerjee, B., Robinson, T. N. & Cirimele, J. (2016). Effects of Three Motivationally Targeted Mobile Device Applications on Initial Physical Activity and Sedentary Behavior Change in Midlife and Older Adults: A Randomized Trial. *PLoS ONE, 11*(6), pp.1-16.

Koivisto, J. & Hamari, J. (2014). Demographic differences in perceived benefits from gamification. *Computers in Human Behavior, 35*(1), pp.179-188.

Kurniawan, S. H., King, A., Evans, D. G. & Blenkhorn, P. L. (2006). Personalising web page presentation for older people. *Human Factors in Personalised Systems and Services, 18*(3), pp.457-477.

Lai, C.-H., Peng, C.-W., Chen, Y.-L., Huang, C.-P., Hsiao, Y.-L. & Chen, S.-C. (2013). Effects of interactive video-game based system exercise on the balance of the elderly. *Gait and Posture, 37*(4), pp.511-515.

Lee, B., Chen, Y. & Hewitt, L. (2011). Age differences in constraints encountered by seniors in their use of computers and the internet. *Computers in Human Behavior, 27*(3), pp.1231-1237.

Lindhardt, T. & Nielsen, M. H. (2017). Research paper: Older patients' use of technology for a post-discharge nutritional intervention – A mixed-methods feasibility study. *International Journal of Medical Informatics, 97*(1), pp.312-321.

Luna-García, H., Mendoza-González, R. & Álvarez-Rodríguez, F. (2015). Design Patterns to Enhance Accessibility and Use of Social Applications for Older Adults. *Patrones de diseño para mejorar la accesibilidad y uso de aplicaciones sociales para adultos mayores., 23*(45), pp.85-93.

Meneses Fernández, M. D., Santana Hernández, J. D., Martín Gutiérrez, J., Henríquez Escuela, M. R. & Rodríguez Fino, E. (2017). Full length article: Using communication and visualization technologies with senior citizens to facilitate cultural access and self-improvement. *Computers in Human Behavior, 66*(1), pp.329-344.

Mertens, A., Brandl, C., Miron-Shatz, T., Schlick, C., Neumann, T., Kribben, A., Meister, S., Diamantidis, C. J.,Albrecht, U., Horn, P. & Becker, S. (2016). A mobile application improves therapy-adherence rates in elderly patients undergoing rehabilitation: A crossover design study comparing documentation via iPad with paper-based control. *Medicine, 95*(36), pp.1-8.

NCA. (2015). 10 Top Scams targeting seniors. Retrieved from https://www.ncoa.org/economic-security/money-management/scams-security/top-10-scams-targeting-seniors/

Palacio, R., Acosta, C., Cortez, J. & Morán, A. (2015). Usability perception of different video game devices in elderly users. *Universal Access in the Information Society, 16*(1), pp.103-113.

Penhale, B., Lloyd-Sherlock, P. & Lachs, M. S. (2017). Presidential symposium: comparative perspectives on the financial exploration of older. *Innovation in Aging, 1*(1), pp.725-726.

Pitts, K., Pudney, K., Zachos, K., Maiden, N., Krogstie, B., Jones, S., Rose, M., MacManus, J. & Turner, I. (2015). Using mobile devices and apps to support reflective learning about older people with dementia. *Behaviour and Information Technology, 34*(6), pp.613-631.

Pyae, A. (2017). The potential of digital games in promoting older people's active ageing in developing countries: the case of Myanmar. *International Journal of Education and Ageing*, 4(1), pp.19-33

Rajan, J. V., Moura, J., Gourley, G., Kiso, K., Sizilio, A., Cortez, A. M., Riley, Lee W., Veras, M. A. & Sarkar, U. (2016). Understanding the barriers to successful adoption and use of a mobile health information system in a community health center in São Paulo, Brazil: a cohort study. *BMC Medical Informatics and Decision Making, 16*(1), 1-11.

Ray, P. P. (2017). Understanding the role of internet of things towards smart e-healthcare services. *Biomedical Research, 28*(4), pp.1604-1609.

Roque, N. A. & Boot, W. R. (2018). A New Tool for Assessing Mobile Device Proficiency in Older Adults: The Mobile Device Proficiency Questionnaire. *Journal of Applied Gerontology, 37*(2), pp.131-156.

Rosales, A. & Fernández-Ardèvol, M., 2016. Beyond WhatsApp: Older people and smartphones. *Romanian Journal of Communication and Public Relations*, *18*(1), pp.27-47.

Rute-Pérez, S., Santiago-Ramajo, S., Hurtado, M. V., Rodríguez-Fórtiz, M. J. & Caracuel, A. (2014). Challenges in software applications for the cognitive evaluation and stimulation of the elderly. *Journal Of Neuroengineering And Rehabilitation, 11*(1), pp.88-88.

Salmon, J. P., Dolan, S. M., Drake, R. S., Wilson, G. C., Klein, R. M. & Eskes, G. A. (2017). A survey of video game preferences in adults: Building better games for older adults. *Entertainment Computing, 21*(1), pp.45-64.

Seah, E.T.W., Kaufman, D., Sauvé, L. & Zhang, F., 2018. Play, Learn, Connect: Older Adults' Experience With a Multiplayer, Educational, Digital Bingo Game. *Journal of Educational Computing Research*, *56*(5), pp.675-700.

Sheaves, B., Jones, R. B., Williamson, G. R. & Chauhan, R. (2011). Phase 1 pilot study of e-mail support for people with long term conditions using the Internet. *BMC Medical Informatics And Decision Making, 11*(1), pp.20-29.

Simek, E. M., McPhate, L. & Haines, T. P. (2012). Adherence to and efficacy of home exercise programs to prevent falls: a systematic review and meta-analysis of the impact of exercise program characteristics. *Preventive Medicine, 55*(4), pp.262-275.

Santos, T. S., Brito, T. A., Yokoyama, F. S., Guimarães, L. A, Sotou, C. S., Souza, S. N., Martins, L. E. & Pithon, K. R.. (2017). Development of an application for mobile devices to identify the frailty phenotype among the elderly. *Revista Brasileira de Geriatria e Gerontologia, 20*(1), pp.67-73.

Vaziri, D., Aal, K., Ogonowski, C., Von Rekowski, T., Kroll, M., Marston, H., Poveda, Rakel Gschwind, Y, Delbaere, K., Wieching, R. & Wulf, V. (2016). Exploring user experience and technology acceptance for a fall prevention system: results from a randomized clinical trial and a living lab. *European Reviews of Aging and Physical Activity, 13*(1), pp.1-9.

Vaziri, D. D., Aal, K., Gschwind, Y. J., Delbaere, K., Weibert, A., Annegarn, J., de Rosario, H., Wieching, R, Randall, D. & Wulf, V. (2017). Analysis of effects and usage indicators for a ICT-based fall prevention system in community dwelling older adults. *International Journal of Human - Computer Studies, 106*(1), pp.10-25.

Wagner, N., Hassanein, K. & Head, M. (2010). Computer use by older adults: A multi-disciplinary review. *Computers in Human Behavior, 26*(5), pp.870-882.

Wang, F. & Burton, J. (2010). A Solution for Older Adults' Learning of Computer Skills: The Computer Game-Based Learning Approach. *Society for Information Technology & Teacher Education International Conference* (eds). San Diego, USA: AACE.

Weaver, C. K., Zorn, T. & Richardson, M. (2010). Goods Wanted. *Information, Communication and Society, 13*(5), pp.696.

West, G. L., Zendel, B. R., Konishi, K., Benady-Chorney, J., Bohbot, V. D., Peretz, I. & Belleville, S. (2017). Playing Super Mario 64 increases hippocampal grey matter in older adults. *PLoS ONE, 12*(12), pp.1-18.

Winstead, V., Anderson, W. A., Yost, E. A., Cotten, S. R., Warr, A. & Berkowsky, R. W. (2013). You Can Teach an Old Dog New Tricks: A Qualitative Analysis of How Residents of Senior Living Communities May Use the Web to Overcome Spatial and Social Barriers. *Journal of Applied Gerontology, 32*(5), pp.540-560.

Zhou, S., Chen, Z., Liu, X. & Tang, H. (2011). An "Elder Mode" of New Generation Phone Using Augment Reality. *Procedia Environmental Sciences, 10*(Part B), pp.936-942.