Older adults and video gaming for leisure: Lessons from the Center for Research and Education on Aging and Technology Enhancement (CREATE)

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W. R. Boot, R. Andringa, E. R. Harrell, M. A. Dieciuc, N. A. Roque. Older adults and video gaming for leisure: Lessons from the Center for Research and Education on Aging and Technology Enhancement (CREATE). Gerontechnology 2020;19(2):138-146; https://doi.org/10.4017/gt.2020.19.2.006.00 **Background** Video games are often designed by younger adults for younger adults. When older adults are considered targets of game design, the focus is often not on leisure, but rehabilitation (e.g., cognitive training, stroke recovery, physical therapy). Commercial video games, if they are aimed toward older adult consumers at all, are typically marketed based on older adults' concerns about cognitive decline. Although there have been extensive investigations into the potential of video games to improve cognition and health, a comparatively smaller number of studies have been devoted to the development and design of games for older adults primarily for fun and recreation. In the Center for Research and Education on Aging and Technology Enhancement (CREATE), we believe this is an important oversight. **Methods** This paper first provides a review of the demographics of aging gamers, what has been learned about older gamers in terms of preferences and barriers to adoption and then reviews research published over the past decade conducted by CREATE researchers on video gaming, and what has been learned relevant to the design of games for leisure for older adults. **Results** Research has found consistent preferences among older adults regarding preferred video games and game features, but also striking individual differences. Just as not all younger adults prefer the same types of games, older adults are not a homogenous group in terms of preferences. Data suggest that contrary to stereotypes, given the opportunity (access) and support (design, training), many older adults can become active gamers and reap the benefits of gaming for leisure. **Conclusions** Video games can support the leisure activities of individuals of all ages. However, to achieve success, game designers must conform to principles of good design for older adults and engage them directly in the design process.

Keywords: Computers, technology, entertainment, digital games, video games

Introduction

There persists a significant "digital divide" between younger and older adults in many countries, with older adult cohorts adopting new technology at a lower rate compared to younger adults. In the United States, for example, 27% of adults 65 years of age or older do not go online, and 47% do not own a smartphone (Pew Research Center, 2019). This is in sharp contrast to the near-universal adoption of these technologies by younger adult cohorts. This digital divide puts some older adults at a significant disadvantage when it comes to engaging in digital activities that help support mental and physical health, productivity, independence, and quality of life. In general, technology holds great potential for improving the lives of older adults if these technologies consider the needs, preferences, and abilities of older users. Over the past 20 years, the Center for Research and Education on Aging and Technology Enhancement (CREATE) has investigated barriers to the use and adoption by

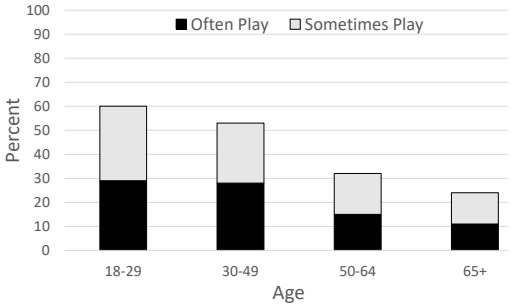

Figure 1. Percent of adults in the U.S. who play video games on a compuer, TV, gaming console, or mobile device. Source: Pew Research Center (2017).

older adults of technology to support these activities (see this issue), and has developed design and training guidelines to overcome these barriers (e.g., Czaja, Boot, Charness, & Rogers, 2019; Czaja & Sharit, 2016).

The study of the potential for technology to support older adults has often focused on developing and designing technology to facilitate the performance of everyday activities that are important for independent living, such as transportation, communication, and healthcare. There has been substantially less research on exploring technology solutions that support hobbies, leisure activities, and new learning opportunities. These activities fall under the category of what has been termed Enhanced Activities of Daily Living (EADLs; Rogers, Meyer, Walker, & Fisk, 1998; Rogers et al., this volume). The coining of the term EADL recognized that quality of life and well-being are determined by more than just one's ability to manage everyday tasks and that research should also explore how technology might facilitate leisure and recreation among older adults. Video gaming has the potential to support these aims assuming barriers to adoption and use can be conquered.

Unfortunately, the age-related digital divide extends to the domain of video gaming, though the gaming divide has received less attention. Although gaming is a common activity among children and younger adults, relatively few older adults play video games or consider themselves gamers (Duggan, 2015). In the United States, for example, 60% of adults from 18 to 29 years of age report playing video games, compared to only 24% of older adults (65+; Brown, 2017a). Only 11% of older adults report playing video games frequently, compared to nearly 30% of those from 18-29 years of age (*Figure 1*). However, there is evidence that even though many older adults do not play video games, those who do play regularly can play at an intensity (in terms of daily gameplay) that is equal or even greater compared to younger gamers (Lenhart, Jones, & MacGill, 2008). Older adults may have more time to engage in gameplay due to retirement. Age is not the only demographic characteristic associated with differences in gameplay. Whereas almost half of men (47%) report playing video games, significantly fewer women report gameplay (39%; Brown, 2017a). The gender gap is large for younger adults (72% men vs. 49% women; ages 18-29 years) but shrinks in older cohorts and is almost non-existent among older adults (25% men vs. 23% women; 65+ years; Perrin, 2018). In sum, video games are a form of technology that provides fun and recreational opportunities for many younger adults, yet barriers appear to exist that prevent many older adults from reaping the same benefits.

Barriers to video game adoption

There are a variety of explanations for older adults' lower adoption of video games for leisure compared to younger adults. First, many older adults have not adopted the prerequisite technologies required for gaming (e.g., internet, smartphone, game consoles). More than half (56%) of the youngest adult cohort in the U.S. owns a video game console, but only 8% of older adults do (Anderson, 2015). Today, the smartphone is the most common device used by adults to engage in gaming (Entertainment Software Association, 2019) but older adults lag substantially in their smartphone ownership. Lack of device ownership serves as a key barrier to gaming, however, it is not the only one. Even older adults who have adopted these technologies can have lower technology proficiency compared to younger adults (Roque & Boot, 2018), making finding, downloading, and playing digital games a challenge.

Unlike many other technologies that are designed to be as easy to use as possible, a unique aspect of video games is that they are designed to challenge the abilities of the user. Well-designed games are appealing, in part, because they engender feelings of accomplishment and mastery as players overcome obstacles. The level of challenge that good games provide is not so low as to result in feelings of boredom, but also not so high as to generate feelings of stress or frustration. Good games continuously test the player at exactly the right level so that their abilities closely match the demands of the game. In this sense, the appeal of video games has been understood within the framework of flow theory (Csikszentmihalyi, 1990), which states that these types of experiences generate a positive, energized, and enjoyable feeling known as 'flow' or 'being in the zone'. The unique difficulty in designing games is that younger adults and older adults can differ substantially in their perceptual

and cognitive abilities (see Roque & Boot, 2017, for review). Games that are well-calibrated to match the abilities of younger adults, producing a positive flow state, may be too difficult for some older adults and result in frustration. In short, video game design that does not account for the different abilities of younger and older players can be a barrier to adoption.

Another barrier to the adoption of video games by older adults is attitudes toward gaming, sometimes based on negative stereotypes about aging and video games. Older adults may perceive video games as a waste of time (Brown, 2017b). Some older adults either perceive video games as childish or have concerns that others might perceive them as childish for playing games (De Schutter & Abeele, 2010; McLaughlin, Gandy, Allaire, & Whitlock, 2012; Quandt, Grueninger, & Wimmer, 2009). They may think of games as "not for them," and this perception is understandable given the primary target for video game sales has often been younger people.

Lack of familiarity and experience with video games and common gaming conventions relate to adoption. The first commercial video games began appearing in the early 1970s, including the extremely popular arcade game Pong. The 1970s also featured the introduction of the first home game consoles. Many young people in the 1970s and onward grew up with gaming technology that was easily accessible (through video arcades, early home consoles, and personal computers), and enjoyed and became familiar with gaming technology and conventions early in their development. This was not true for many of today's older adults. A lack of mental models for gaming and gaming conventions can make video games, already poorly calibrated for their abilities, even more, challenging for older adults.

Game preferences

Although many older adults are not gamers, over the past decade CREATE and other researchers have explored the types of games older adults prefer, including through surveys and focus groups involving older gamers and older adult non-gamers exposed to brief sessions of gameplay. A few common themes have emerged. One consistent theme is a preference among older adults for games that challenge knowledge and intellectual ability over quick reflexes (e.g., Pearce, 2008; Salmon et al., 2017). Although violent games are among the most popular games played by younger adults, in many studies, older adults reported a strong aversion to games featuring violent content, including first-person shooters and other action games (e.g., Nap et al., 2009; McKay & Maki, 2010). For younger gamers, favorite video game genres include fast-paced action games, shooter games, and sports games, whereas, for older gamers, favorite genres include slower-paced card games, puzzle games, and virtual board games (Entertainment Software Association, 2019).

Casual games are especially popular among older adult gamers (De Schutter, 2011). Casual games are typically defined as games that feature relatively simple rules and game mechanics and do not require an extended game session to enjoy, or a long-term commitment to complete a complex story within the game. Part of the popularity of casual games is related to the fact that they are easy to learn due to their simpler game mechanics. This may be an especially appealing feature to older adults, who tend to take longer learning new technology compared to younger adults, especially in the absence of prior experience with similar technology (Charness, Kelley, Bosman, & Mottram, 2001). Further, a general preference for games that involve intellectual challenge over quick reflexes is consistent with the Selection, Optimization, and Compensation (SOC) theory of successful aging (Baltes & Baltes, 1990). SOC theory, in part, posits that available resources, including cognitive resources, change throughout development, and that successful aging involves the selection of goals and activities that match closely with current resources. In the course of development, later in life, knowledge about the world remains stable, or even increases late in life, while processing speed decreases substantially, making word, trivia, and puzzle games a good fit with the strengths of many older adults.

From these and other studies, we get a sense of, in general, older adults' video game preferences. This information can help advance the goal of encouraging gaming for leisure among older adults. However, it is also important to recognize the variability in preferences. Just as all younger adults do not enjoy the same video game genres, older gamers enjoy a diversity of game experiences. Many younger adults prefer casual word and puzzle games over action games, and there are older adults who enjoy fast-paced first-person shooters. For example, the 'Silver Snipers' are members of a competitive e-sports team who play the first-person shooter Counter Strike (Webster, 2017). The youngest team member is 61 years old, and the oldest member is 81. For video games to serve as a beneficial leisure activity for all, it is important to recognize individual differences and not think about younger or older gamers as homogenous groups.

CREATE gaming research

We now turn to a review of studies conducted by CREATE researchers involving aging and video games. Although many of these studies were not

initially designed to provide insight into older adults' game preferences, or gaming for leisure among older adults, important lessons related to these issues were learned. These studies and their findings have led to a greater explicit focus by CREATE on the potential of technology, including video games, to provide meaningful leisure opportunities for older adults.

Game-based interventions and adherence

Boot et al. (2013) examined the potential cognitive benefits of hand-held game-based interventions in a sample of older adults (65+). Participants were randomly assigned to play an action video game (Mario Kart) or a brain fitness game (Brain Age 2), and were then trained to operate a hand-held gaming system, the Nintendo DS Lite, and provided with a brief tutorial and demonstration of their assigned game before being instructed to play at home. Specifically, participants were asked to play their assigned game five times a week, one hour per session, for three months (a total of sixty hours of game training). Participants recorded their adherence and game experiences in diaries that were collected at the end of the study.

Mario Kart was the intervention of greatest interest because of previous studies finding cognitive benefits associated with action gameplay in younger adult samples (see Bavelier & Green, 2019 for review). Most previous studies used fast-paced and violent first-person shooters as the intervention. However, as discussed previously, many older adults find these types of games aversive. For our intervention, we selected what we thought would be a more acceptable alternative action game: Mario Kart. This game involves racing cartoon characters around various racetracks and competing against computer-generated players. We reasoned that this game featured many of the same visually- and attentionally-demanding elements of most first-person shooters but without the violent content. This game was compared to Brain Age 2, which had an explicit focus on improving cognition through a variety of math, word, and puzzle games.

Although we anticipated that Mario Kart would be an acceptable alternative action game, we were surprised that this was not the case. On average, participants played only 20 out of the requested 60 hours, not including the 33% of participants who dropped out of the Mario Kart condition entirely. Eyestrain and arthritis were reported as problems, and many older adults indicated an explicit lack of interest in the content of the game. In contrast, adherence was high for Brain Age 2, which was rated as significantly more enjoyable by participants, and significantly more likely to improve everyday functioning. Results were consistent with the model developed by McLaughlin, Gandy, Allaire, and Whitlock (2012), which proposed that older adults weigh a variety of factors, including perceived costs and benefits when deciding whether to adopt gaming technology.

These data provide valuable information when it comes to designing video games for older adults. First, the pattern of preferences was consistent with the previously reviewed literature. The game that was perceived as more intellectually stimulating was preferred over the game that relied heavily on quick reflexes. This was confirmed by both game ratings and adherence data. Second, consideration for the human factors of games and gaming devices is crucial for supporting positive gaming experiences. The small screen and controls of the hand-held gaming system presented a significant challenge to many older adults in the Mario Kart group. In contrast, most Brain Age 2 activities involved using a stylus or voice commands rather than buttons on the device itself, which may have alleviated some of these human factors challenges. Brain Age 2, for the most part, also presented participants with large, high-contrast visual displays. As a result, few problems were reported with respect to eyestrain or arthritis in this condition. Both human factors and attitudinal challenges appeared to explain the negative experiences of older adults within the Mario Kart condition. Finally, preference variability was evident in this study, as a small number of older adults in the Mario Kart condition reported positive experiences with the game and their adherence was quite high.

Social interaction to support game-based intervention adherence

Souders, Boot, Charness, and Moxley (2016) conducted a study inspired by the low adherence observed in Boot et al. (2013) and investigated two factors that might shape older adults' adherence to game-based interventions: whether games involved competition or cooperation, and whether games were played alone or with a partner. Like the previous study, some participants were assigned to play the game Mario Kart, a competitive racing game. Other participants were assigned to play the game Lego Star Wars: The Complete Saga, a game that was cooperative. Participants were given a Nintendo DS Lite to take home and were asked to engage in 7 hours of gameplay over 10 days. Critically, older adults were recruited in dyads – they participated in the study with a co-located spouse or partner. Dyads either engaged in gameplay together in multi-player mode (during the same 10-day period), or participation was staggered and participants played their assigned game in single-player mode (1 dyad member played for 10 days, then the other for the next 10 days).

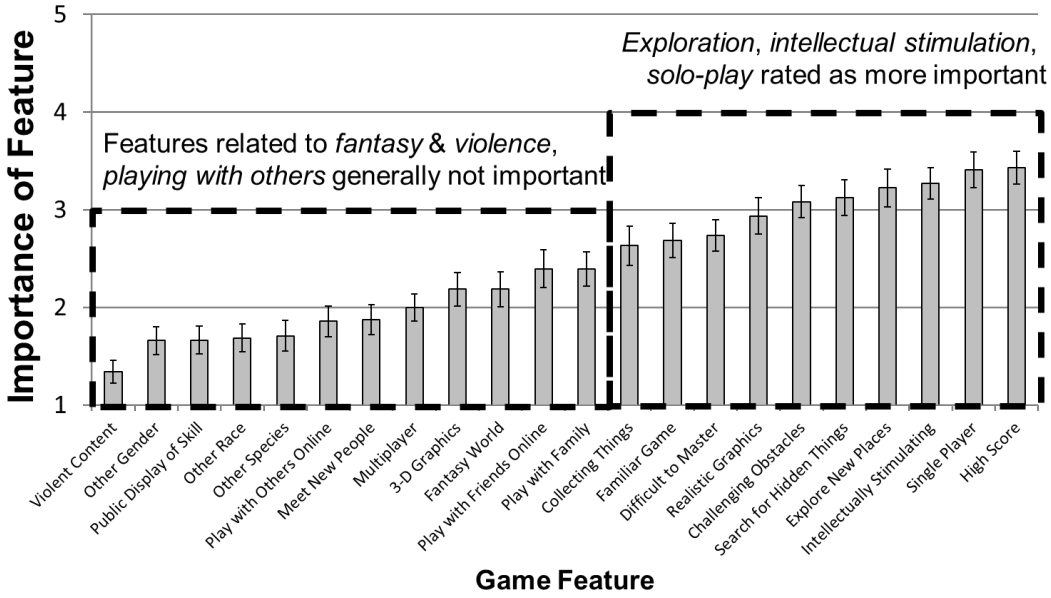

Figure 2. Older adults' rating of how important game features are (for older gamers), or would be (for older non-gamers), to their enjoyment of a video game (adapted from Blocker, Wright, & Boot, 2014). Likert scale from 1 (Not at All) to 5 (A Must-Have Feature); 3 = neutral.

Based on previous literature, it was predicted that older adults asked to play the cooperative game and older adults asked to play together (multi-player mode) would demonstrate greater intervention adherence. However, these predictions were not supported by the data. Adherence overall was generally high, which may have been due to the shorter duration of the intervention compared to the intervention conducted by Boot et al. (2013; 10 hours vs. 30 hours). However, participants in the multi-player groups did report greater enjoyment of their assigned game. This is a notable result as enjoyment is a precursor of long-term adherence. This study has implications for game design and the design of game-based leisure programs: playing with others has the potential to enhance older adults' game experiences.

Exploring game preferences via survey

Blocker, Wright, and Boot (2014) conducted a survey that was also a direct response to the previously discussed intervention in which action game adherence was so low. This study sought to understand the gaming preferences of older adults to better design interventions that use video games and game elements to promote adherence. Results also have important lessons for designing games for leisure. Sixty-eight older adult participants completed a series of questionnaires that assessed demographics, personality, technology experience, video game preferences, video game interest, and gaming history. Both older adult gamers and non-gamers were assessed regarding how important different features of a video game are or would be, to their enjoyment of a game (*Figure 2*). Features included, for example, being able to visit a fantasy world, play as another species, play with friends, and explore new places. A strikingly consistent pattern was observed. Violent content and fantasy elements were rated as unimportant features, whereas intellectual stimulation and exploration were rated as important features. A similar pattern was observed for gamers and non-gamers. Participants were also provided with text descriptions of different game genres and were asked to rate their interest in playing each game. Results again indicated that participants were most interested in intellectually stimulating games, with older participants preferring puzzle games and educational games, and having the least interest in first-person shooters and massively multiplayer online games. Results provided not only a general overview of different types of games older adults prefer but also guidance for individual game elements that might either be removed or added to games to increase their appeal.

A second aim of the study was to identify individual difference predictors of game preference. Being able to predict which games might be preferred by an older adult in advance might facilitate the introduction of video games as a leisure activity. Although some demographic and personality variables appeared to predict game preference, the strength of these associations was small, accounting for little variance in reported preference.

Exploring game preferences via observation

Boot et al. (2018) examined video game use among older adults at risk for social isolation. The PRISM (Personal Reminder Information & Social Management) randomized controlled trial involved installing a custom-designed computer system in the homes of older adults who lived alone, engaged in few activities outside of the home, and had minimal computer experience (Czaja et al., 2015). The purpose of the PRISM computer system was to support social connections through email and internet, skill acquisition, and knowledge through "classroom" activities, prospective memory through an electronic calendar system, and access to local and national resources through curated websites. The system also featured 11 different video games: Chinese Checkers, Crossword, Droplets, Gem Swap, Memory, My Jong, Solitaire, Sudoku, Tetris, Poker, and Word Search (see Boot et al., 2018 for a full description of each game). PRISM was installed in 150 older participants' homes and system and feature use was monitored remotely for one year. The trial explored the effect of access to the system on a variety of psychosocial outcomes including loneliness and perceived social support.

The PRISM trial afforded the unique opportunity to explore game preferences directly by monitoring the game behaviors of older adults over an extended period. Although video games were not a primary focus of the study and participants were not explicitly asked to play the games as part of the intervention, many participants became habitual gamers. During the year-long trial, on average, participants chose to engage in gameplay on 197 days. However, gameplay was highly variable (SD = 107 days). The minimum number of days on which a participant played was 3, whereas the most active gamer played almost daily (359 days). Given the opportunity, training, and access to a well-designed computer system, many participants with little previous technology experience became active and long-term gamers.

Solitaire was by far the most played game. Cluster analysis revealed different types of gamers within the sample. Some participants exclusively and heavily played Solitaire. Another group of participants exhibited moderate Solitaire play and little or no play of other games. Another group of participants played Gem Swap, My Jong, and Solitaire frequently, and about equally in terms of the number of days played. This group also played other games, though infrequently. Cluster analysis also identified a group of non-gamers and a group of infrequent gamers. Individual differences in game preference were evident, though the most popular game tended to be the most familiar game (Solitaire). This accords with previously described studies.

Similar to Blocker, Wright, and Boot (2014), the PRISM study explored predictors of individual differences in preference. Overall, women engaged in gameplay more than men. This is contrary to inaccurate stereotypes that men are more likely to play video games compared to women, although the PRISM sample was majority female. Within the older adult sample, older participants were more likely to play Crossword. Cognitive and personality variables also predicted the play of certain games. However, overall, few consistent predictors were observed, and when significant relationships were observed predictor variables accounted for only small amounts of variance in gameplay behavior.

Exploring game preferences after game exposure

Andringa, Harrell, Dieciuc, and Boot (2019) reanalyzed previously collected data that were part of a cognitive intervention study to better understand older adults' experiences and attitudes toward video games. The primary focus of the study was to explore the potential of game-based and skills-based training to reverse age-related cognitive decline and improve the performance of important everyday tasks (i.e., driving, financial management). Participants' cognitive and everyday abilities were assessed before and after about 20 hours of engagement with their assigned game or non-game intervention. Although changes in outcomes were of primary interest, this study also afforded a detailed exploration of older adults' experiences with different types of gameplay. Analyses focused on addressing two main questions. First, what are older adults' perceptions of different video games after the extended game experience? Second, what are potential obstacles to long-term gameplay? As part of the intervention, participants were asked to complete one of three game-based interventions: a popular 'brain game' software package (BrainHQ training); a commercially available real-time strategy game (Rise of Nations); or digital puzzle games (Sudoku, crossword, word search).

For one month, after each game session, participants rated different aspects of the game they were assigned to play and completed short-form journal entries. Overall, participants found the digital puzzle games to be the most enjoyable and Rise of Nations to be least enjoyable and most frustrating. An analysis of diary entries revealed a number of unique obstacles to gameplay. For one, participants found Rise of Nations too complex and too challenging. Although in-lab training and custom manuals were provided to all participants, this was not enough for many participants to gain a sense of mastery of the game. Participants in the Rise of Nations condition also mentioned an aversion to the battle components of the game, which they found to

be too violent. Finally, participants asked to engage with the 'brain games' software found these games too repetitive, and were also more likely to report eyestrain.

Overall, these results support and confirm previous findings that more casual and familiar games are, on average, preferred by older adults. Although Rise of Nations is not as violent as most first-person shooters, a number of older adults found the violent content within the game aversive. Finally, learning challenges served as a major barrier to play for the most complex game, Rise of Nations.

Implications for designing video games and gaming programs for leisure for older adults

Currently, older adults do not engage in video gameplay to the same extent as younger adults, despite there being the potential for video games to promote the quality of life and well-being of older adults through the entertainment, enjoyment, and sense of purpose they can provide. The studies reviewed here offer guidance for how video games might be better designed for older adults, and how to introduce older adults too, and engage them with, gaming activities that could be part of a community or assisted living-based leisure program.

In terms of game design, game developers should recognize that the perceptual and cognitive abilities of older adults are often different compared to younger adults, and developers should design games accordingly to ensure that they can be enjoyed by all. It is common for video games to allow players to choose from different levels of game difficulty to customize their game experience (e.g., easy, medium, hard). However, these difficulty levels may not appropriately account for age-related ability changes. An 'easiest' option, developed and tested with individuals of all ages and experience levels, would likely help not just older adults, but all novice gamers. Game tutorials may not adequately account for older adults' less experience and familiarity with common gaming conventions. Game tutorials designed specifically for novice gamers have the potential to benefit many individuals, including many older adults.

The principles of good design for older adults should be applied to the menus and interfaces within video games, controllers and other game input devices, and gaming consoles (Czaja, Boot, Charness, & Rogers, 2019). Before gameplay can even begin, users must often complete a number of steps, including turning the system on and navigating menus to select the desired game and game options. CREATE researchers have found that each of these steps can be associated with usability challenges, especially for older users (Harrington, Hartley, Mitzner, & Rogers, 2015; Marinelli & Rogers, 2014). Many older adults with limited video game experience can find gaming systems unnecessarily complex and the knowledge required to use them overwhelming (Barg-Walkow, Harrington, Mitzner, Hartley, & Rogers, 2017). A potential solution to this problem is training, but well-designed 'quick start' guides may also be especially beneficial (Harrington, Hare, & Rogers, 2017). For community and assisted living-based leisure programs, these guides have the potential to help older adults quickly get started and engaged in gameplay without assistance from others.

In terms of game preferences, in general, older and younger adults appear to prefer different types of video games. The games older adults tend to prefer are casual games (games with relatively simple rules that do not require a substantial time commitment) and games that rely on knowledge rather than quick information processing and rapid responses. Older adults often demonstrate an aversion to violent content and disinterest in fantasy game elements. However, it is important to recognize individual differences in preferences. A simple solution would be to offer many different game options that older adults can choose from (similar to the PRISM study). Just as not all younger adults have the same game preferences, older adults too are diverse in their favorite types of games. Offering access to multiple games, including games that tend to be preferred by many older adults, maximizes the opportunity for older adults to find games that match both their interests and abilities.

Finally, a major barrier to gameplay is a lack of meaningful access to the necessary technology. Making technology more readily available and providing technology training are crucial steps to overcoming the age-related digital divide in the domain of gaming and beyond. Senior centers, libraries, retirement communities, and assisted living facilities can help overcome this barrier by making gaming technology available in common areas and offering relevant technical training.

Conclusions and future directions

When older adults are provided with the opportunity, appropriate support, and the right type of video game, many can become active gamers, allowing them to benefit from the potential of technology to support leisure activities. The development of video games for older adults for the sake of leisure has been relatively underexplored compared to games to support older adults' rehabilitation, health, and cognition, and games to support behavioral change (gamification). However, all of these lines of re-

search are likely to provide useful information to inform one another (just as the majority of CREATE studies were initially intended to explore games as a form of intervention, yet results have implications for how to design for leisure). The study of aging and gaming for leisure advances our understanding of how to better design serious games to benefit older adults and vice versa. Additionally, there may not be a clear distinction between games for leisure and serious games. EADLs, of which gaming is a type, is associated with better physical and mental health (Hughes, Chang, Vanderbilt, & Ganguli, 2010; Kuykendall, Tay, & Ng, 2015; Menec, 2003; though, the relationship between gaming and cognition is still controversial, Simons et al., 2016). In exploring whether there is a causal relationship between gaming and gamified interventions and various physical and mental health outcomes, it will be important for older adults to engage with these interventions for an extended period. Game designers, with appropriate attention to the needs, abilities, and preferences of older adults, can play an important role in achieving this goal.

The future of aging and gaming research is exciting, with many potential research directions that CREATE investigators and others will pursue. One question is how gaming behaviors and gaming preferences might change longitudinally. In 50 years, will today's younger action gamers still be playing video games when they are in their 70s and older? If so, will they be playing the same types of games or different games as their abilities change? Answers to these questions have important practical implications for the design of games for leisure and intervention, but also fundamental theoretical consequences for theories of successful aging (e.g., SOC theory, Baltes, 1990). How will older adults' attitudes toward, and adoption of, video games change as gaming technology rapidly changes? There is a trend for games to utilize augmented reality and virtual reality technology, technologies that may be novel and unfamiliar to both younger and older adults. What potential differences, or lack of differences, might exist between younger and older adults' attitudes and adoption of gaming as gaming technology evolves beyond the computer, smartphone, and console games? Answers to these questions have the potential to advance our understanding of factors that fundamentally contribute to the differential adoption of technology as a function of age and technology type. Video games have the potential to serve as a valuable testbed for advancing our understanding of the relationship between aging and technology use and adoption now and in the future as technology rapidly evolves and as today's younger cohorts age.

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References

Anderson, M. (2015). Technology device ownership: 2015. Pew Research Center. Retrieved from: https://www.pewresearch.org/wp-content/uploads/sites/9/2015/10/PI_2015-10-29_device-ownership_FINAL.pdf

Andringa, R., Harrell, E. R., Dieciuc, M., & Boot, W. R. (2019, July). Older Adults' Perceptions of Video Game Training in the Intervention Comparative Effectiveness for Adult Cognitive Training (ICE-ACT) Clinical Trial: An Exploratory Analysis. In International Conference on Human-Computer Interaction (pp. 125-134). Springer, Cham.

Baltes, P. B., & Baltes, M. M. (1990). Psychological perspectives on successful aging: The model of selective optimization with compensation. Successful aging: Perspectives from the Behavioral Sciences, 1(1), 1-34.

Barg-Walkow, L. H., Harrington, C. N., Mitzner, T. L., Hartley, J. Q., & Rogers, W. A. (2017). Understanding older adults' perceptions of and attitudes towards exergames. Gerontechnology, 16, 81-90.

Bavelier, D., & Green, C. S. (2019). Enhancing Attentional Control: Lessons from Action Video Games. Neuron, 104(1), 147-163.

Blocker, K. A., Wright, T. J., & Boot, W. R. (2014). Gaming preferences of aging generations. Gerontechnology: International Journal on the Fundamental Aspects of Technology to Serve the Ageing Society, 12(3), 174-184.

Boot, W. R., Champion, M., Blakely, D. P., Wright, T., Souders, D., & Charness, N. (2013). Video games as a means to reduce age-related cognitive decline: attitudes, compliance, and effectiveness. Frontiers in Psychology, 4, 31.

Boot, W. R., Moxley, J. H., Roque, N. A., Andringa, R., Charness, N., Czaja, S. J., & Rogers, W. A. (2018). Exploring Older Adults' Video Game Use in the PRISM Computer System. Innovation in Aging, 2(1), igy009.

Brown, A. (2017a). Younger men play video games, but so do a diverse group of other Americans. Retrieved from: https://www.pewresearch.org/fact-tank/2017/09/11/younger-men-play-video-games-but-so-do-a-diverse-group-of-other-americans/

Brown, J. A. (2017b). Digital gaming perceptions among older adult non-gamers. In International Conference on Human Aspects of IT for the Aged Population (pp. 217–227). Cham, Switzerland: Springer.

Charness, N., Kelley, C. L., Bosman, E. A., & Mottram, M. (2001). Word-processing training and retraining: Effects of adult age, experience, and interface. Psychology and Aging, 16(1), 110-127.

Czaja, S. J., Boot, W. R., Charness, N., & Rogers, W. A.

(2019). Designing for older adults: Principles and creative human factors approaches. CRC Press.

Czaja, S. J., Boot, W. R., Charness, N., Rogers, W. A., Sharit, J., Fisk, A. D., & Nair, S. N. (2015). The Personalized Reminder Information and Social Management system (PRISM) trial: Rationale, methods and baseline characteristics. Contemporary Clinical Trials, 40, 35-46.

Czaja, S. J., & Sharit, J. (2016). Designing training and instructional programs for older adults. CRC Press.

Csikszentmihalyi, M. (1990). Flow: The psychology of optimal experience. New York: Harper & Row.

De Schutter, B. (2011). Never too old to play: The appeal of digital games to an older audience. Games and Culture, 6(2), 155-170.

De Schutter, B., & Abeele, V. (2010, September). Designing meaningful play within the psycho-social context of older adults. In Proceedings of the 3rd International Conference on Fun and Games (pp. 84–93). New York, NY: ACM.

Duggan, M . (2015). Gaming and gamers. Pew Research Center. Retrieved from http://www.pewinternet.org/2015/12/15/gaming-and-gamers/.

Entertainment Software Association (ESA) (2019). Essential Facts about the Computer and Video Game Industry. Retrieved from: https://www.theesa.com/wp-content/uploads/2019/05/2019-Essential-Facts-About-the-Computer-and-Video-Game-Industry.pdf

Harrington, C. N., Hare, K. J., & Rogers, W. A. (2017). Developing a quick-start guide to aid older adults in interacting with gesture-based video games. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 61, No. 1, pp. 32-36). Sage CA: Los Angeles, CA: SAGE Publications.

Harrington, C. N., Hartley, J. Q., Mitzner, T. L., & Rogers, W. A. (2015, August). Assessing older adults' usability challenges using Kinect-based exergames. In International Conference on Human Aspects of IT for the Aged Population (pp. 488-499). Springer, Cham.

Hughes, T. F., Chang, C. C. H., Vanderbilt, J., & Ganguli, M. (2010). Engagement in reading and hobbies and risk of incident dementia: the MoVIES project. American Journal of Alzheimer's Disease & Other Dementias, 25(5), 432-438.

Kuykendall, L., Tay, L., & Ng, V. (2015). Leisure engagement and subjective well-being: A meta-analysis. Psychological Bulletin, 141(2), 364-403.

Lenhart, Jones, & MacGill (2008). Adults and video games. Retrieved from: https://www.pewresearch.org/internet/2008/12/07/adults-and-video-games/

Marinelli, E. C., & Rogers, W. A. (2014, September). Identifying potential usability challenges for xbox 360 kinect exergames for older adults. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 58, No. 1, pp. 1247-1251). Sage CA: Los Angeles, CA: SAGE Publications.

McLaughlin, A., Gandy, M., Allaire, J., & Whitlock, L. (2012). Putting fun into video games for older adults. Ergonomics in Design, 20, 13–22.

Menec, V. H. (2003). The relation between everyday activities and successful aging: A 6-year longitudinal study. The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 58(2), S74-S82.

Perrin, A. (2018). 5 facts about Americans and video games. Retrieved from: https://www.pewresearch.org/fact-tank/2018/09/17/5-facts-about-americans-and-video-games/

Pew Research Center (2019). Internet and Tech Factsheets. Retrieved from: https://www.pewresearch.org/internet/fact-sheet/

Quandt, T., Grueninger, H., & Wimmer, J. (2009). The gray haired gaming generation: Findings from an explorative interview study on older computer gamers. Games and Culture, 4, 27–46.

Rogers, W. A., Meyer, B., Walker, N., & Fisk, A. D. (1998). Functional limitations to daily living tasks in the aged: A focus group analysis. Human Factors, 40(1), 111-125.

Roque, N. A., & Boot, W. R. (2017). Cognitive Aging. In International Handbook of Positive Aging (pp. 159-175). Routledge.

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), 131-156.

Simons, D. J., Boot, W. R., Charness, N., Gathercole, S. E., Chabris, C. F., Hambrick, D. Z., & Stine-Morrow, E. A. (2016). Do "brain-training" programs work? Psychological Science in the Public Interest, 17(3), 103-186.

Souders, D. J., Boot, W. R., Charness, N., & Moxley, J. H. (2016). Older adult video game preferences in practice: Investigating the effects of competing or cooperating. Games and Culture, 11(1-2), 170-200.

Webster, A. (2017). Meet the Counter Strike e-sports team where everyone is over 60. Retrieved from: https://www.theverge.com/2017/12/20/16800924/silver-snipers-senior-counter-strike-team