Cognitive benefits of computer games for older adults

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E.M. Zelinski, R. Reyes. Cognitive benefits of computer games for older adults. Gerontechnology 2009; 8(4):220-235; doi: 10.4017/gt.2009.08.04.004.00 The purpose of this paper is to develop a basis for the hypothesis that digital action games may produce cognitive benefits for older adults. First, a discussion of the relationship between cognitive and physical health shows the increasing weight given to the role of declines in cognition in the development of dependency in older adult population studies. Second, evidence that cognitive training produces 'far transfer' in elders is presented. The key issue is that one approach, known as extended practice training, has been successful in producing far transfer to memory and other processes. Its principles, which are consistent with those associated with positive brain plasticity effects, are identified. Those principles are then related to the mechanics of digital action games, which also have the important added feature of producing the experiences of presence, engagement, and flow, the subjective elements of game play that are likely to sustain interest and emotional investment in the skills practiced so that the play produces cognitive benefits. The specific cognitive abilities proposed to be improved by different types of game genres are outlined, and recent developments in game and interface design that may affect the willingness of older adults to play are described.

Keywords: video games, cognitive transfer, cognitive skills, cognitive training

The population of adults age 65 and over is expected to increase from 12% of the 2003 US population to 20% by 2030, or 72 million[1]. This increase makes solutions to reducing and delaying dependence critical. For example, estimates of the value of treatments that delay the impairment and hence diagnosis of Alzheimer's disease by one year suggest that trillions of dollars would be saved and that there would be 9.2 million fewer cases of the disease in 2050[2]. Recent findings from the Health and Retirement Study, a nationally representative survey of Americans over age 50, indicate that between 1993 and 2004 there was a significant reduction in the percentage of adults over age 70 with cognitive impairments[3]. This reduction in prevalence is associated with more years of education in the more recently assessed group, and possibly by continued cognitive stimulation during work and leisure[4]. Recent findings suggest that participating in cognitive activities is associated with a delay in onset of rapid memory decline in those who develop dementia[5]. Thus, there is evidence that engaging in activities associated with cognition affects the prevalence and the onset of cognitive impairment. It is also possible that engaging in cognitive activities, including those associated with digital action games, may potentially help older adults who do not develop dementia to improve or otherwise maintain cognitive abilities.

Research on the relationship between cognitively stimulating activities and development of cognitive impairment was key to the implementation of a clinical trial of cognitive strategy training of nearly 3000 adults over age 65 to determine whether training would improve cognition and eventually reduce risk of dependence. The study, funded by the USA National Institutes of Health[6], was known as ACTIVE, (Advanced Cognitive Training for Independent and Vital Elderly). Its goal was to evaluate the efficacy of three different cognitive skill interventions on test performance within and between the three types of skills trained as well as the temporal duration of training effects. There were 2832 healthy participants aged 65 to 92 in this randomized controlled trial. The interventions trained the use of strategies to improve reasoning, memory, or visual speed of processing, and the primary outcomes included measures of each of the three cognitive abilities as well as cognitively demanding functional abilities such as being able to use information correctly from everyday items like medication labels. A no-contact control group was used for comparisons of training efficacy and duration. Findings for the cognitive outcomes showed that improvements were observed only for the ability that had been trained for each group, and that these improvements persisted, especially with booster training (limited retraining in the strategies) for two years. There was no improvement on the primary functional outcomes over the two year evaluation[6]. This suggested little evidence over the two year follow up period for transfer of the training to other abilities or to functional outcomes. However, the issue of transfer of training, which is critical to the argument that digital game play can improve cognition in older adults, is complex and is discussed next.

Transfer of training

Two major approaches have been used successfully to train older adults directly in cognitive abilities: (i) strategy training; and (ii) extended practice training. Strategy training is a 'top down' approach and has been used for training memory, reasoning, and complex planning tasks. Strategy training such as use of various memory training techniques, including specific mnemonics[7], general approaches to improving memory[6], self monitoring of learning and retrieval[8], and a multimodular program integrating memory training, psychosocial support, and goal management training[9], all improve recall. Other abilities successfully trained include complex coordination, such as organizing a carpool[10], and reasoning[6]. Thus strategy training, broadly defined, improves performance on a range of different cognitive tasks compared with control conditions where there is no training.

Extended practice training, in contrast, is a 'bottom up' approach and has been used for training memory, dual task performance, abilities related to attention, and discrimination in memory. It may or may not involve suggesting a strategy for those trained; however, hundreds to thousands of trials are completed during the course of extended practice training. It therefore appears that the extensive repetition of the skill is the crucial element of this type of training. Extended practice training has been used successfully to improve continuous recognition skills[11], in identifying the direction and order of sound frequency sweeps[12], and performance on a go/no continuous response task[13], as well as increasing efficiency by producing reductions in the response time costs of switch tasks[14], and simultaneous dual tasks[15,16], as well as in reducing performance variability[17] and in improving the accuracy of visual selective attention[18].

Although both strategy and extended practice training improve performance on the targeted tasks, whether the trained skills produce far transfer to untrained tasks is much more controversial. Several recent reviews argue that there is little evidence of transfer to untrained cognitive tasks or to other abilities[19], including memory[20], though others suggest that it depends on the approach used[21]. Zelinski[22] has suggested that there is evidence of far transfer in aging training studies, based on a categorization of effects into the taxonomy of transfer proposed by Barnett and Ceci[23]. This taxonomy was devised to provide a basis for evaluating the existence of transfer effects, which has long been contentious, in the educational psychology literature. It organizes findings by classifying transfer on a continuum of near to far on multiple content and context dimensions. The content dimensions reflect what is transferred such as the generality of the skill, the type of outcome against which transfer is expected, and whether memory has to be actively used to complete the transfer task. These dimensions affect the likelihood of transfer and are embedded in the context of transfer, that is, when and where transfer occurs. The context dimensions of transfer are used to estimate the distance between training and transfer and thus can be used to evaluate whether transfer is near or far.

The dimensions of context transfer effects observed in the aging literature include the temporal context, the amount of time between training and transfer, with far transfer increasing over time; the functional context; that is, the function for which the skill is positioned; far transfer involves extending the functional context to one that is very different from that of the skill trained, for example, from handicapping horses at a racetrack to handicapping stocks in the stock market[24]; and modality, the sensory modality in which the transfer is tested (for instance, visual or auditory), with far transfer involving different sensory modalities or different test formats (for instance, recognition or recall). Rather than attempting to quantify the 'distance' of near or far training, Barnett and Ceci[23] suggested that the types of context transfer be nested in a hierarchy, with theoretical reasons used to determine the relative distance or importance of particular types of context transfer. At each level in the hierarchy, near and far transfer is operationalized as categories in a matrix (*Table 1*). The distance of transfer increases with the number of far transfer attributes identified in the outcome measure. Studies showing more far transfer are at the right side of the 2 x 2 (near/far temporal transfer x near/far modality transfer) matrix; those with less far transfer are closer to the left.

Table 1 identifies behavioral studies published or in press by December 2008 for which functional far transfer was observed, and classifies them in a hierarchy of near and far transfer with temporal near and far transfer at the highest level, based on the idea that duration of the training effect is most important: training effects that fade shortly after training is completed are not worth the effort. Modality transfer, with the skill extended to different testing contexts, is here considered to be somewhat less important an aspect of far transfer than temporal far transfer. The studies in Table 1 are identified as to whether the protocol was strategy training, extended practice training, and a combination. Only one strategy training study successfully produced functional far transfer; the remainder producing functional far transfer used extended practice or combined strategy with extended practice training. Although the reasoning training arm of the ACTIVE study (the only strategy training study in Table 1) did produce functional far transfer to a reduction in reported disability of instrumental activities of daily living (IADLS), the memory strategy training arm of ACTIVE did not, either immediately, after 2 years[6] or after 5 years[25]. Thus, memory strategy training did not show far transfer, as suggested elsewhere[19,20]. On the other hand, extended practice training of memory skills significantly transferred to recall of word lists and of material in working memory[12,26]. Extended practice training, as seen in Table 1, also improved supervisory abilities in recognition memory, including source memory, which is assumed to require frontal involvement[21,26]. Digital action games may also produce far transfer to specific cognitive abilities because games use principles of brain plasticity that closely approximate those of extended practice training.

Plasticity effects

Research in brain plasticity shows that the brain reorganizes resources to strengthen the fidelity of the learned stimulus or behavior[27], which is essentially a memory function that affects information processing efficiency. If there is considerable experience in engaging in a particular activity, the area of the brain associated with that activity shows enhanced function, whereas unspecialized stimulation reduces ability to discriminate and allows for overlapping response fields for multiple stimuli, producing negative plasticity effects[28]. It has been suggested that the negative effects of plasticity explains cognitive decline in aging: insufficient attention, poorer sensory inputs, a higher noise to signal ratio, and poorer neuromodulation all lead to reduced discrimination and specialization of brain function[27]. To reduce decline, activities that increase attention and improve the signal to noise ratio include those that increase the discrimination of information[29]; to improve discrimination, activities have to be adaptive to the individuals' abilities so that a high level of challenge is maintained[27]. Extensive practice with discrimination is needed to reinforce this ability, as reorganization of the underlying brain activity requires substantial repetition of the action. Finally, Mahncke et al.[27] propose that sustained interest in the tasks increases and maintains attention during task performance, further increasing reorganization and positive plasticity.

The extended practice approach uses the brain plasticity principles outlined here. The approach, by definition, involves hundreds to thousands of repetitions of the skill to be trained. For example, training in the study by Jennings et al.[26] was for approximately 1464 trials. Smith et al.[12] provided 40 hours of practice of a set of six systematic exercises, Li et al.[30] 45 15-minute sessions, and Buschkeuhl et al.[31] 24 45-minute sessions. The sheer repetition ensures greater fidelity of representations, important in promoting memory retrieval.

Extended practice training in the aging literature additionally trains contextual and perceptual discrimination and memory[12,26]. Jennings et al.[26] trained discrimination in a continuous recognition task. Items were shown one at a time and the task was to identify whether the presently shown item was new, from a list studied earlier, or had been seen in a prior recognition trial. Older adults were initially only able to discriminate list items from previously shown items with a lag of 2. However, Jennings and her colleagues systematically increased the lags between identical items and maintained task difficulty by requiring accurate performance for several trials before increasing lags. The adaptive approach was successful in that by the end of training, the older participants were accurate in the source discrimination for lags of up to 28[11]. Similarly, the auditory processing training approach of the study by Smith et al.[12] kept performance at approximately 80-90% correct at a given level and improved discrimination in identification of sound sweeps so that participants who initially required 116 ms between sounds could discriminate and correctly order those presented at 48 ms on average at the end of training.

Extended practice, as seen in the Jennings et al.[26], Smith et al.[12], and Buschkeuhl et al.[31] studies, may facilitate transfer to memory skills by reducing the difficulties that strategy training does not address: by using gradual and adaptive increases of difficulty, the task is relatively easy, retrieval requirements for strategies are reduced because of increased discrimination between items, and suboptimal encoding habits can be bypassed. Thus, extended practice training may require less self regulation in retrieval from memory[32] than memory strategy training[21]. Gradual adaptation may ensure that the training remains challenging, yet not overwhelmingly difficult, which maintains engagement[33].

Challenge is key to plasticity effects. Dustman and White[34] suggest that during difficult cognitive tasks, there are dynamic effects of increases in oxygen or glucose to the brain: heart rate is elevated during performance of cognitive tasks, and glucose uptake increases, suggesting that mechanisms within the cardiovascular system increase deliv-

*Table 1. Functional far transfer findings for strategy, extended practice and combined approaches training studies with older adults, adapted after Zelinski22; *=Strategy training; **=Extended practice training; ***=Combined strategy and extended practice training*

Study characteristics	Tested shortly after training		Tested at a delay after training	
	Modality near	Modality far	Modality near	Modality far
Study	**Basak et al.[47]	**Edwards et al.[58]	**Kramer et al.[14]	***Ball et al.[6]
Delay	Immediate	Immediate	2 months	2 years
Tasks	Video game to 4 executive/supervisory abilities	Speed of Processing to Timed IADL Test	Cancelling and tracking dual task to monitoring and alphabet arithmetic dual tasks	Speed of Processing to Timed IADL Test
Sensory modality	Visual to visual	Visual to visual	Visual to visual	Visual to multiple
Testing modality	Response selection to response selection	Response selection to multiple, including manual manipulation	Response selection to response selection	Response selection to multiple, including manual manipulation
Study	**Buschkeuhl et al.[31]	**Roenker et al.[59]	**Li et al. [30]	**Roenker et al.[59]
Delay	Immediate	Immediate	3 months	18 months
Tasks	Colored square span to block span and free recall of visual material	Speed of processing to road sign test	Spatial 2-back to numerical 2-back and to spatial 3-back and simple RT	Speed of Processing to Road Sign Test, on-road driving test
Sensory modality	Visual to visual	Visual to visual	Visual to visual	Visual to visual
Testing modality	Recall to recall	Response selection to multiple, including turning and braking	Recognition to recognition	Response selection to multiple, including turning and braking
Study	**Jennings et al. [26]	**Smith et al. [12]		**Roenker et al.[59]
Delay	Immediate	Immediate		18 months
Tasks	Lagged recognition to N-back, pointing, source recognition	Speeded discrimination and working memory span to neuropsychological memory and working memory tests		Speed of processing to road sign test, on-road driving test
Sensory modality	Visual to visual	Auditory to auditory		Visual to visual
Testing modality	Recognition to recognition	Recognition to recall		Response selection to multiple, including turning and braking
Study	**Kramer et al.[16]			*Willis et al.[25]
Delay	Immediate			5 years
Tasks	Monitoring and alphabet arithmetic dual tasks to paired associates and scheduling dual tasks			Reasoning to IADLs
Sensory modality	Visual to visual			Visual to multiple
Testing modality	Response selection to response selection			Response selection to endorsement of impairments

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(Table 1 Continued)

Study characteristics	Tested shortly after training		Tested at a delay after training	
	Modality near	Modality far	Modality near	Modality far
Study	**Li et al.[30]			***Wolinsky et al.[60]
Delay	Immediate			2 years
Tasks	Spatial 2-back to numerical 2-back and to spatial 3-back and simple RT			Speed of processing to SF 36 ratings
Sensory modality	Visual to visual			Visual to multiple
Testing modality	Recognition to recognition			Response selection to rating

ery of metabolic substrates. This intriguing hypothesis suggests that the physiological mechanisms induced by a sustained mental challenge may partially underlie the effects of extended practice training.

Thus, the principles of brain plasticity of increasing discrimination and memory using approaches adapting to the individual's level of proficiency yet maintaining task difficulty and therefore engagement in the tasks, not only improves performance on the training tasks, but most important, extend to improvements in memory and supervisory skills on transfer tasks.

Digital action games

Digital action games use general principles similar to those of extended practice training. Games involve continual repetition; they are designed to be played for many hours. For example, Medal of Honor published by Entertainment Arts in 2002, a game used in research on cognitive enhancement (see below) may involve approximately 10 hours of play to completion by an experienced gamer. Other games provide even longer basic play experience. Starcraft published by Blizzard in 1998, for example, is designed for approximately 30 hours of play.

Digital action games require sensory discrimination, leading to efficient and rapid information processing, they are adaptive, with increasingly difficult levels made available after achieving success at lower levels of performance, and are challenging. Games developed for entertainment do differ from activities in extended practice training, however, because they are designed to be fun. Klimmt and Hartmann[33] suggest principles of games that produce an enjoyable experience: first, players enjoy being the central causal agent who affects the game environment. Second, the player is uncertain about what will actually happen, so the suspense created increases the emotional investment in attaining success. Third, when the player successfully overcomes a challenge, this creates a positive experience. Fourth, the exploration of characters and actions is inherently interesting. For example, games provide the opportunity for the player to play a role, such as being a soldier or a leader of an alien race. These principles have the potential to increase the likelihood and duration of play, as well as considerable engagement during play in the game tasks.

A recent approach to understanding why players enjoy games is the Presence-Involvement-Flow Framework[35] which conceptualizes presence as incorporating perceptual-attentive and spatial-cognitive processes which place the user in the space of game play, involvement as representing the user's acceptance of and adaptation to the play space and his or her role in it, and flow as a response to the ability-challenge tension that motivates the user to continue to play. These elements of enjoyment are crucial to keeping players at play; low levels of presence, involvement, and flow are predicted to be associated with terminating play. This subjective experience of play may very well be a crucial element in the possible use of games as an intervention: entertaining interventions have potential to be more effective at creating behavior change than those lacking an entertainment component[36,37] because of the positive subjective experiences they produce. This has not been tested specifically with digital action games; however, in an intervention study described below, young men with no game experience continued spontaneously to play a digital action game five months after the game intervention was discontinued[38].

There is growing evidence that such games may produce far transfer to cognitive performance even though they were not developed to improve cognitive skills. Studies with young adults show that shooter games (described below) improve attentional skills apparently because of the emphasis on discrimination and rapid visual information processing, and the need to monitor the entire screen. Green and Bavelier found increased visual selective attention measured by useful field of view, attentional blink, and enumeration[39,40] and improved target-distractor discrimination[41] with the shooter game Medal of Honor: Allied Assault than with the puzzle game Tetris published by Tetris Holding LLC, in 1985. A study evaluating gender differences in the breadth of the useful field of view and mental rotation after naïve participants played 10 hours of Medal of Honor compared to those who played 10 hours of a visuospatial puzzle game, Balance published by Atari in 2004, showed that women improved more than men, presumably because their initial performance was lower. In a 5-month follow up, the women maintained their improved visuospatial performance. Recently, Li[42] found improvements in visual contrast sensitivity, long thought to be correctable only with eyeglasses, contact lenses, or surgery, after naïve young adults played 50 hours of shooter games.

However, these games have not been tested with older adults. Both young and older adults show far transfer to untrained memory tasks after extended practice training[30]. A recent study showed far transfer after extended practice in a group of adults over age 80[31]. It is intriguing to speculate that action games would also produce transfer to perceptual, attentional, and memory abilities in older adults. The literature from the 1990s suggests that older people do gain cognitive benefits from playing simple video games, compared to those who do not play.

Digital games and cognitive improvements

In the aging literature, studies using first-generation video games played on arcade machines indicated that older people had faster response time after 35 hours of Tetris compared to a no-practice control[43]; with freely chosen Atari games (Frogger or Ms. Pacman) compared to movie watching[44], and freely chosen (Pacman or Donkey Kong) arcade games versus no-game controls[45]. Another study reported higher WAIS IQs after playing Crystal Castles (Atari) compared to a no-game control[47]. However, these early studies showed no game play-related improvement on the Stroop task, a measure of supervisory skills[43] or list memory[44]. Thus, early games, which were relatively simplistic, produced some cognitive improvements in older adults but did not transfer to a full range of cognitive tasks.

The only published study in aging that using a current-generation action game, the authors are aware of, is the game Rise of Nations published by Microsoft in 2004. A simplified version of this strategy game (defined below) was played for 23 hours by healthy older adults[47]. It was hypothesized to benefit abilities associated with planning and organization, but not visual processing skills (see below). These predictions were supported: there were improvements in supervisory abilities, though there were no parallel increases in visual attention. Memory was not tested. This does suggest that games may improve some aspects of cognition in older adults.

Game play mechanics and cognition

Digital action games use certain mechanics that are likely to support far transfer to cognitive abilities. In this section, some common mechanics of play are described to explain how they may produce transfer for specific abilities. In general, learning to play a digital action game requires remembering a control scheme, adapting to changes in the challenges, and making quick decisions. Also, in most action games, hand-eye coordination is required. The pace at which a player operates within the game determines performance and adults who play with intent to progress or win will also have to engage in rapid processing. Although some games may exercise one skill more than other games do (visual attention in shooter games, for example), rule set memorization is fundamental to all. Thus, memory, decision making, speed, and motor coordination are practiced extensively in action games[48].

Most digital action games use failures (deaths or injuries) to motivate players to improve their performance and thereby advance to higher difficulty levels and/or completion of the game. If the player's character keeps dying in a particular environment within the game, the player has to develop alternative strategies to avoid the pitfalls causing the death. This opportunity to learn from mistakes is an element of nearly every game that encourages the player to develop and remember strategies for success in play.

Another element of game design that is likely to transfer to cognitive abilities is backtracking, a requirement to return to previously visited areas to complete a task that was not previously attainable until an item or power in the game has been obtained in a subsequently visited environment. For example, the player may see a switch high up on a wall that must be activated. However, he or she cannot activate it until an item needed for the activation has been obtained in a later game level. Some games do not initially indicate that backtracking is needed until an in-game character provides clues to indicate that forward progression requires completing a task from a previously visited environment. This suggests that the game requires careful attention to all surroundings, not just the obvious paths for completion. Mechanics like these may promote greater use of attention and reasoning in working memory to survey the environment to predict which possible tasks may require eventual completion, as well as the retrieval of elements seen earlier in the game from memory.

Genre-based potential cognitive benefits

In this section, speculations about what specific cognitive skills are likely to be trained

Table 2. Hypotheses about abilities improved by different game genres; x= the genre is hypothesized to produce significant improvements in performance; a=improvement expected in platformer games of this genre

Ability	Game genre				
	1st person shooter	3rd person action-adventure	Strategy	Role playing	Massive multiplayer
Eye-hand coordination	X	X	X	X	X
Memory			X	X	X
Mental rotation	X	X	X		
Reasoning			X	X	
Response speed	X	X			X
Supervisory			X	X	X
Visual attention	X	X[a]			
Working memory			X	X	X

and to transfer from digital action games based on their genre are summarized (*Table 2*). Shooter games are likely to improve visual attention and rapid response. Strategy games are hypothesized to benefit supervisory skills and working memory, and possibly long-term memory retrieval. Role-playing games are likely to improve retrieval from long-term memory, reasoning, supervisory abilities, and working memory. Massive multiplayer online games are hypothesized to improve response speed, reasoning, supervisory abilities, and working memory in the context of social interactions. If these hypotheses are supported, it is conceivable that game genres can be prescriptively recommended to older adults who would like to play while also improving specific abilities.

Digital action games that appear to have promise for cognitive interventions with older adults are in the categories of first-person shooter, third-person action/adventure games, strategy games, and role-playing games. The specific skills that are hypothesized to be benefitted are described for each genre. However, skills are likely to overlap across genres based on the particular demands of individual games.

In first-person shooter games, the game is experienced from the point of view of the player in a role. One of the principles underlying shooter games is known as twitch game play, defined as fast and precise responses (twitches) with immediate feedback, while monitoring the display screen and moving through the environment. Continual monitoring of the display is also used in item collection within shooter games. Besides 'run and gun', that is, moving quickly through the game environment to evade enemies and shoot at them, players can collect various objects in the environment. Item collection may serve in part either to develop the storyline, to unlock bonuses or extra points during play, or to advance to a new level in the game progression. The existence of collectible items encourages players to pay close visual attention to objects in the game surroundings. Many popular third-person action/adventure games may only differ from shooter games in that the player's perspective shifts from first person to third person, that is, the player can see the entire body of his or her character, rather than just its extremities, during play. Like shooter games, action/adventure games require that players take full advantage of their characters' visual range, for example, scanning the environment for resources that may be needed for progression. These two game genres encourage visual monitoring, rapid responding, and accuracy.

A sub-genre of third-person games requires jumping from one platform to another in the environment. In these games, known as platformers, the need to time precisely when and where jumps are made adds to game complexity by requiring a player to gauge the trajectory of a jump needed to go through a level. This differs from many first-person shooter games where players need to be aware of what is in front of them at all times, hence, limiting the character's ability to also look down without overly complicating the range of available controls (although some shooter games add platform jumping). Occasionally, jumps are also implemented into puzzles that require both rapid processing speed and mental reasoning skills. For example, a series of jumps onto falling platforms requires supervisory visuospatial planning, precise timing and rapid input. The additional need to utilize a jump button in platformer game play while performing other actions may increase the transfer to dual task performance.

Strategy games also use twitch game play but the strategic component of these games is predominant: it involves gathering resources, building bases, and increasing technological development to prepare for battle against an enemy. The player has a top-down view of the battlefield, which is what distinguishes strategy from shooter games. Orders are given to various resource-gathering, construction, or combat units under the leader's (player's) command; the player does not execute the orders as in shooter games. There are two major subcategories of strategy games. Turn-based strategy games stop the action on the enemy's side either for a specific amount of time or until the player makes choices. Real-time strategy games continue the action while the player is making decisions, creating time-pressured multitasking. Both subcategories involve some of the same cognitive skills associated with visual attention as shooter games, but they will also involve decisions made in the context of complex rules. Strategy games may also engage memory and reasoning processes as rules must be remembered and applied to different stimuli. For example, the order of actions used to build a structure must be followed as required within the game for its successful construction. Details of the structures must be carefully planned so that they will be beneficial during combat. For example, doors must be placed so that combatants in the battle units can exit the building quickly and efficiently. The planning and decision process suggest that strategy games may increase reasoning, and working memory as reported by Basak et al.[47], and possibly long-term memory, to store and retrieve game-related decisions and rules.

On the other hand, role-playing games typically focus less than shooter or strategy games on visual attention, though reasoning and memory may also be practiced. Role-playing games require players to manage their characters' resources: their collected items, equipment, learned techniques, or magic spells. Each piece of gear that is acquired, for example, a new hat or weapon, changes the character's attributes; the player's choice of resources can potentially determine the outcome of play. This requires planning and weighing of multiple options in working memory. Additionally, role playing games rely heavily on appraisal of the dynamics of the enemy's strengths and weaknesses. For example, if an enemy character specializes in a water-based offense, a player would ideally resort to using a resource that neutralizes it, such as lightning or fire. Understanding different enemy weaknesses requires retrieval of both the characters' item inventory and knowledge of possible offensive techniques from long-term memory.

In addition, role playing games often allow a player to manage inventory for multiple characters, several of which are used simultaneously to defeat in-game enemies, so multitasking with a memory load, as in dual task performance, is practiced. This game genre is very complex in that every character's abilities adds a new dynamic to every in-game encounter; if one character is killed in battle, the player is forced to adapt his or her play strategy based on the abilities of the remaining characters. This type of in-game adaptation combined with a sizable inventory of resources should transfer to dual task performance, as well as working memory and memory retrieval benefits. Finally, before each enemy encounter, a player is free to strategize and arm his characters with whatever set of gear, equipment or spells the player sees fit. With these numerous possibilities, the player may engage in complex reasoning in determining what is best for each situation.

Massive multiplayer games

A subgenre of role-playing games is the massive multiplayer online role-playing games that have arisen with advances in availability of broadband technology for the Internet. These are interactive game spaces that can be played together with multiple people and can literally involve players from all over the world. Massive multiplayer games vary from traditional role-playing games in that players do not manage several characters simultaneously; they play as one character only. These games are described here for two reasons: one is that they provide extensive social interaction, which may be important in cognitive outcomes[49] and they provide increased intellectual challenges to players because of the additional complexities created by the participation of many other players whose actions affect game progress and challenges.

Players of massive multiplayer games are encouraged to cooperate with one another while simultaneously making complex decisions to improve the group's chances of progressing further into the game. Every team of players is essentially concerned with maximizing its efficiency in moving forward. This makes the social pressure for individual players to excel an important dynamic. As in single player role-playing games, the death of a game character dynamically changes every enemy encounter. When playing with other players online, however, in-game strategy adjustment becomes very social with team members conducting live discussions about how to allocate remaining team resources to fill in any strategic gaps left by other player deaths. This topic is the majority of those discussed during in-game communications[50]. Notably, this happens in real time while the battle is in progress, so multitasking is inherent during play.

The level of control each player has over the character combined with considerable social interaction, planning and quick strategic decision-making creates the opportunity to improve skills associated with reasoning, working memory, and processing speed. The challenge in these games is highly motivating and undoubtedly selective; 49% of who play massive multiplayer online games are more likely to play every day or almost every day, compared to 26% of other online gamers, and 17% of offline gamers[51].

In December, 2008, it was reported that about 9% of gamers play massive multiplayer online games, and about 14% of 18-29 year-old gamers report playing them[52]. However, it is likely that participation in this particular genre will continue to grow and that increasingly older adults in the USA will be likely to join them, as they have with other social networking applications like Facebook, which in March 2009 had more adult members aged 26-44 than aged 17-25, with women over age 55 the fastest growing demographic group[52].

Next-generation games and interfaces

Some recently released games blur the lines between the current categories of game genres and may train even more complex cognitive skills. For example, Portal published by Valve Corporation in 2006, a first-person shooter game, replaces bullet-shooting guns with a portal 'gun' that is used to shoot portals through which the player moves. It replaces humanoid enemies with an 'enemy' in this game manifested as a voice, an invisible artificial intelligence creation that gradually reveals itself to be evil. An innovative aspect of this game is that its physics do not match those of the real world. The puzzles to be solved to advance in the game require overcoming one's knowledge of real-world physics, learning the in-game physics, and applying its rules. Each level consists of a new puzzle that encourages the player to think 'outside the box' and rearrange a room to allow passage to the next puzzle. With various traps and obstacles inside of each puzzle room that change dynamically based on player actions, this first-person puzzler retains the twitch game play elements of shooter games while requiring considerable cognitive flexibility. The physical makeup of each puzzle room also requires players to mentally rotate the scene to help solve the puzzle. The popularity of this game suggests that innovative approaches to game design will continue to increase the complexity of and possibly the opportunities for transfer to cognitive abilities.

In addition to new approaches to game design, innovative user interfaces are being introduced. The traditional PS2 type of handheld gamepad controller with a small joystick and buttons on the front and back of the controller or a mouse and keyboard is being replaced by game platform manufacturers with devices using remote accelerometers, such as the 'nunchuk' of Nintendo's Wii. This handheld device uses infrared signals and information from motion sensors as well as button presses to communicate with the game platform. This simplifies movement in play, as movement in the game is less reliant on combined button presses used to control action on the display. Instead of having to control aim manually, for example, players can simply use the interface device to point to the desired location on the display. Other console-based game platforms have introduced interfaces designed to be analogous to the objects that they emulate, such as the microphones, guitars, and drums for play-along music games, or guns for shooter games. Touch screen devices are also being introduced for use with game displays, though they may not yet be adequate for the complex games that are likely to have the potential to improve cognition.

The introduction of new interfaces like the Wii nunchuk can enhance the experience of play for naïve players such as older adults. These interface devices can remove an important barrier for older adults who might be reticent to use traditional PS2 type gamepads[54]. In turn, they may be more willing to play with grandchildren or adult children because one source of difficulty in play has been eliminated. The possibility of social interaction with family members in game play also has important implications for enhancing cognition because of the increased complexity of play and also the motivation to perform well.

It is thus plausible to consider that the development of future games will continue to make the player experience more intuitive while mixing and matching cognitive-beneficial elements from one category of games with others.

Simple games

It is less clear from the literature whether simple games such as Sudoku, crossword puzzles, word search, or other games, available on paper, but which have been translated to digital versions, are as beneficial to cognition as the complex digital action games we have described here. Although there is abundant literature that playing simple games of this type is associated with better memory and cognitive ability in correlational studies, it is not clear whether this effect is due to selection or to practice[54].

Simple games do not appear to involve the complex cognitive demands as the digital action games that are associated with brain plasticity. For example, they rely on previously learned information rather than learning and applying new rules, and they are less dynamic. The concept of battle and competition to survive in digital action games may contribute to their cognitive benefits, and it is therefore possible that action games produce stronger experiences of presence, involvement, and flow than more static games. On the other hand, the complexity of stimuli and rapid processing required to play action games may be important; in studies with young adults, digital games that may train some aspects of the skills used in action games, such as Tetris or Balance, have not been associated with visual or spatial improvements perhaps because they are simpler and not as demanding[48]. On the other hand, such games may improve other cognitive skills that have not been tested.

Conclusion

There is great potential for digital action games originally developed for the entertainment of young adults to produce cognitive benefits in older adults. At this time, however, very little is known about the efficacy of digital games and whether they produce improvements greater than those of other types of interventions for older adults that will transfer to untrained cognitive tasks. It is critical to test different types of games to understand what is effective and how relatively effective specific genres of games are. It is also critical to determine what principles support specific cognitive outcomes from games—that is, whether skills developed indirectly with game play or directly with straightforward exercises are differentially or equally effective in transferring to cognitive task performance in older adults. A critical question is whether the narrative and other elements of digital action games developed to engage players with strong experiences of presence, involvement, and flow,are key to cognitive improvement, along with the game mechanics. Finding that digital games improve memory and cognition in older adults would have important implications for using games as an intervention. Games are relatively inexpensive, without the side effects of medications. In addition, games are inherently enjoyable, and may yield greater compliance than other kinds of beneficial interventions because they are fun.

Older adults already show an increasing interest in digital game play. Data from a 2008 survey conducted by the Entertainment Software Association show some surprising findings. Contrary to assumptions that video or online gamers are children or teenagers, 49% of gamers are 18-49 years old, with an average age of 35. Women aged 18 and over represent a significantly greater proportion of the gamer population than boys aged 17 or less; 44% of gamers are women. About 26% of computer gamers are over the age of 50, compared with 1999, when the percentage was 9%, suggesting a cohort-related increase in older gamers[55]. Another survey indicated that 23% of respondents aged 65 and older play digital games[51], and that this is likely to be a cohort-based trend as the baby boomers grow older, with greater proportions of older adults playing. This follows a general trend. Digital games have become so popular as a form of entertainment that a market research survey released in May, 2009 indicated that 63% of Americans report having played a digital game in the past 6 months, and this exceeds the percentage of Americans who report having gone to the movies during that time period[56]. In fact, gamers aged 65+ play more frequently than any other age group, with 36% reporting play every day or nearly every day compared to 19-20% of gamers between the ages of 18 and 64. It is assumed that this is because gamers over age 65 have more leisure time for play[51].

In addition, older adults, the fastest growing age segment of the USA population, are very concerned with 'brain training'. They are investing in software to improve cognitive function as they attempt to reduce their risk of cognitive decline. Nintendo's Brain Age 2 game, which involves simple cognitive activities, has been marketed to older adults as a game that improves cognition and was the 16th top video game sold in 2007[56]. A report by a company advising the brain fitness industry indicated that the brain fitness software market reached US$265 million in revenues in 2008, led by consumers over age 50, senior communities, and insurance providers[57].

It therefore appears that there is a 'perfect storm' of forces that can produce rapid gains in an entertainment-oriented technology that is also beneficial: more user-friendly game interfaces, the interest of older people in digital games, and their interest in games marketed to improve cognition. Research in the efficacy of games for older adults is relevant to the implementation of games to encourage cognitive health. Positive findings could additionally encourage digital game companies to partner with cognitive scientists to develop health games that enhance cognition with design principles and narratives that specifically engage older adults. Such games could use 'stealth health' principles: they are engaging to play and produce important health outcomes. Improving or helping older adults maintain their cognitive abilities could have the effect of reducing risk for dependency because poor cognitive performance is one of its major risk factors. Delaying even one year of dependency would have major repercussions for the economy of the USA[2]. It is not likely that many would have foreseen that a technology developed for entertainment could have such a major potential impact on health and dependency. Time will tell whether this is indeed the case.

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