Accessibility in Serious Games for Adults Aging with Disability

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Abstract. As serious games rise in number and popularity, particularly for therapeutic purposes, so rises the importance of making these games accessible to those with disabilities. We discuss the state of accessibility for commercial and research-based serious games, common age-related considerations for accessible designs, and recommendations for usability testing protocols. We close with a case study of a visual accessibility investigation of a research-based cognitive training game, *Food for Thought*.

Keywords: Aging · Design · Accessibility · Age-related change · Cognition · Perception · Movement · Displays · Serious games · Cognitive training games

1 Introduction

Zyda (2005) defined a serious game as "a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives." We extend that definition to include any game with a purpose other than entertainment, not necessarily involving a computer, and that purpose may be educational, for skill development, job training, rehabilitation, or improvements in health and well-being. What constitutes a game can also be defined as any task with a goal, rules for achieving that goal, feedback, and voluntary participation (McGonigal, 2011). In this paper, we first review a handful of examples of serious games and their applications. We take a look at the portion of the population who might benefit from accessible games, then discuss age related changes that should be taken into consideration when designing for older adults. We explore accessibility concerns using a case study of a current serious game project. We close with final thoughts and suggestions for developing accessible serious games in the future.

Some serious games are intended for older adults, and their benefits have been studied in experimental settings. For example, persons recovering from a stroke often have the most difficulty fully extending their arm. Physical therapy encourages such movement, but it has been found that a serious game can provide a level of motivation,

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feedback, and reward difficult to achieve in traditional physical therapy (Harley et al. 2011). In this pinball-type game, the more the patient extended their arm, the more "power" behind the ball and the further it bounced through the obstacles. Game sounds and visuals gave feedback and a feeling of accomplishment for this difficult task. In another therapeutic application Imbeault et al. (2011) created a game to improve memory, planning skills, initiative and perseverance in older persons with progressing dementia. Players performed cooking tasks in multi-step sequences (e.g., toast a piece of bread and then butter it) and were shown their progress throughout the task via a percentage value. Multi-tasking was encouraged by the game (e.g., toast your bread while making coffee), and a timer provided the rules and feedback motivating play. Even commercial games can be "serious": *Rise of Nations*, a real time strategy game, was successfully used as a cognitive training intervention for older adults. The game required complex planning and task execution, with the motivating rewards, visuals, and audio typical of a high-budget commercial game. Participants in the study showed improvements in executive control functions after play (Basak et al. 2008). Unfortunately, there is a growing audience of potential players for whom these games are difficult or impossible to use: those with a disability. Persons at older ages reported higher levels of disability, (Ferrucci et al. 1996), however there are a large number of persons at younger ages aging with a disability (USCB, 2012).

Perhaps due to their focused goals and populations, both commercial and research-based serious games have not made accessibility a priority. However, with the aging of the baby boomer generation, more adults with disability than ever before will be aging with their disability. The combination of disability and age-related changes in perception, cognition, and movement control is challenging, and we discuss the importance of considering potential disability and age-related interactions in serious game design, iteration, and testing. As the goal of many serious games is to support older persons in recovery or in living independently, those in most need of the games are likely those with a disability.

A small number of commercially available games for entertainment consider accessibility issues and there are resources available to designers interested in accessibility (e.g., Atkinson et al. 2006). Some have made progress such as in the game *Final Fantasy XIV: A Realm Reborn*, which was selected by the AbleGamer Foundation as the most accessible mainstream game of 2013 (Ablegamers, 2013). Much of the accessibility was due to the allowed choice and customization of interface and controls and the time allowed to use the controls during gameplay. The creators of *Final Fantasy* admitted this was no easy task, and they incorporated feedback into iterations of the design to achieve high accessibility (Ablegamers, 2013). In recent news, the company who produces the game *World of Warcraft* has introduced settings that will aid color-blind users, allowing them to customize filters (BBC News). This will help distinguish between characters, a good step toward leveling the playing field between normal-sighted and color-blind users. However, success stories such as *Final Fantasy* and *World of Warcraft* demonstrate that accessibility in mainstream games is possible, not that it is common (Bierre et al. 2005; Yuan et al. 2010).

Creating accessible serious games is unlike creating other accessible interfaces, or even other games. Serious games have a purpose, and often that purpose is tied directly to the gameplay, interface, goals, rules, and feedback of the game. As a simple example, imagine the game *Rise of Nations* made more accessible by removing time constraints and the need to juggle multiple demands. Though these changes would make it playable by a variety of older persons, particularly those who need cognitive accessibility changes, it would likely no longer have a therapeutic effect. These challenges are over and above “pure” accessibility. However, we believe there are heuristics and processes that can make games more accessible without changing the nature of the therapeutic gameplay.

As a last challenge, many serious games are research projects, with the understandably narrow initial focus on a particular sub-population expected to benefit from the game. For example, we created the game *Food for Thought* to teach multi-tasking skill for older adults as a cognitive training game. In recruiting participants for testing the efficacy of the game, older adults with dementia or other cognitive disabilities were excluded to reduce uncontrolled variability. However, those older adults would be key toward understanding how to make the game more accessible. In sum, serious games have emerged as an important focus for society and it is time to design and test them for accessibility, particularly those targeting older players (Gamberini et al. 2006).

2 Age-Related Change

When discussing the needs of older persons aging with a disability, it is useful to understand what age-related changes in ability tend to occur in all persons and how those may interact with an existing disability. First, the signifier “age-related” is important: persons differ greatly in their abilities across the lifespan. Second, it is important to remember that older age is not only a time of decline - forms of cognition and ability are maintained or even increase until late in the lifespan. If designers only consider declines, they miss taking advantage of the knowledge and skills possessed by many older persons and how those attributes may compensate.

In many areas, older persons perform more highly than younger. These include tests of crystallized knowledge (called declarative knowledge), in emotional regulation, in social tasks, and in domains where they achieved high skill over time. Examples of declarative knowledge include vocabulary, factual knowledge, and political knowledge. Examples of emotional regulation would be that older persons report more positive emotions in general and focus on positive emotional stimuli, going against the stereotype of the depressed older adult (Carstensen and Mikels, 2005). Examples of social expertise include a more nuanced judgment of the disposition and actions of other people when given information about a person’s behavior (Blanchard-Fields et al. 2007). Last, skills built over a lifetime, such as the skills of a pilot or architect, are well-maintained into older age (Hardy and Parasuraman, 1997). These capabilities can be leveraged in design and in accessibility accommodations. For example, logins or identifiers can be made memorable by connecting them to a piece of declarative knowledge and feedback can focus on accomplishments that resonate with the selection of positive emotional states.

The abilities that do tend to decline with age generally fall under the category of fluid abilities, such as spatial ability, response time, and executive function. However, even as age-related declines are discussed, many of the skills that are composed of these fluid abilities are maintained, provided they were well learned and practiced (to the point of automatization) across the lifespan. Age-related change is typically divided into the categories of perceptual change, cognitive change, and motor change.

Physical changes drive the changes in perception. For example, the aging of the lens in the eye tends to result in yellowing of the lens and general muscle weakening extends to the ciliary muscles that flex the lens in the eye. Most recommendations for aiding older vision include increasing the visual angle of text or icons, but colors and the time needed to focus must also be considered. In hearing, older ears tend to lose the highest and lowest frequencies. Fortunately, most human speech occurs in the middle frequencies, but the feedback or auditory rewards in a game may not. Pathological hearing loss at older ages tends to be due to lifetime exposure to extreme or long-term sound, and thus is age-related but only because an older person has had more time for exposure. Skin on the fingers tends to thicken with age, with the result of less tactile acuity. The fingers also tend to sweat less and be less conductive, meaning that some touch technologies that depend on capacitance work poorly or not at all for older persons.

Age-related changes in cognition relevant to serious games include changes in attention, visual search, and working memory capacity. For attention, it can be difficult to selectively attend to game elements while ignoring irrelevant elements. In our work, we found that entertaining background characters and movement, while stimulating to younger participants, were distracting to our older participants, who were not always able to separate the interaction elements from the decorative ones. Although pre-attentive search ability is preserved with age, visual search that requires the combination of attributes can become more difficult due to the need for working memory. For example, finding the red dot among blue is not slowed or more difficult, but there can be increased difficulty for finding the red, left-facing icon in a field of red and blue right and left facing icons. This is an effortful search at all ages, but the combination of attributes can make a task impossible for an older player.

Age-related changes in motor skills include changes in response time, reaction time, precision, and skill acquisition time. Response time can be thought of as having two parts: the time it takes to perceive a stimulus plus the time to initiate a response. In general, response time increases with age, but this increase is attributed to a delayed physical response rather than a slowed RT. Precision also can become more difficult, but older persons can activate small targets quickly when they are physically separated from other targets (Rogers et al. 2005).

Last there are other age-related individual differences that can affect an older person's experience in a serious game. For example, game-specific displays and input devices may be unfamiliar, although many older adults have computer experience. It is common to claim that the current cohort of older adults will be the last that is unfamiliar with computers, but we believe that there will always be novel technologies unfamiliar to older persons, even those who are currently young and consider themselves technologically savvy.

3 Case Study: *Food for Thought*

We use a serious game, *Food for Thought* (FFT), as an example of how *visual* accessibility concerns may be measured and addressed, particularly for the sub population of older adults aging with a disability. The purpose of FFT is cognitive training, particularly for multi-tasking skill. Thus, the game requires the player to shift priority for different tasks co-occurring in time. Any accessibility integration must preserve the core mechanic of multi-tasking with varying priorities for the tasks, but we have discovered numerous ways of maintaining the multi-tasking core while taking into account varying perceptual, cognitive, and movement needs.

The game itself was based around multi-tasking during cooking. The display for the game was designed with older players in mind - all clickable targets were large (at least 1” × 1”) and drawn in a high-contrast style with bright colors (Fig. 1). The left side of the screen was divided into four “stations,” a cooking station, a chopping station, a mixing station, and a spicing station. Each of these stations could have 1–4 sub-stations that would hold and process ingredients. The right side of the screen contained the “counter” where ingredients were stored and the processing steps required for each ingredient were displayed. Multi-tasking was induced by time limits that required ingredients to be processed at the same time, moving back and forth between counter and processing station while avoiding being left on a station until they were over processed (burned, over spiced, over chopped, or over mixed).

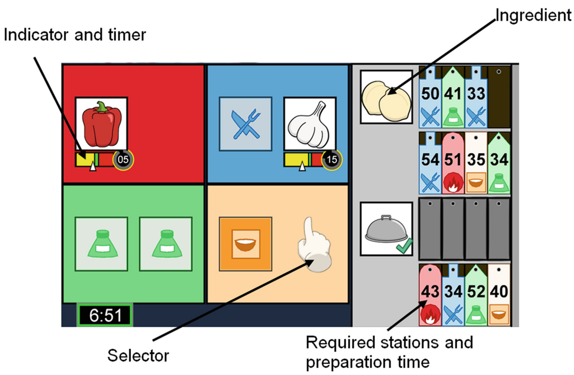

Fig. 1. The *Food for Thought* interface, displaying a simple version of the game used in a early tutorial. The ingredients and steps are on the right side of the screen and the food preparation occurs on the left.

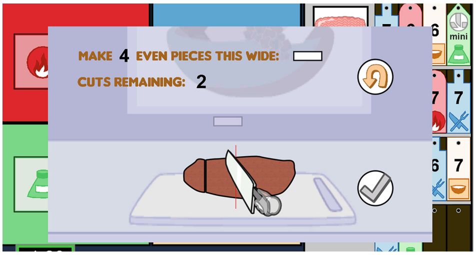

Fig. 2. A minigame in *Food for Thought* that requires the player to "cut" even slices in a loaf of bread (by clicking) with a specific number of cuts. This task requires ability to spatially judge how wide each slice should be.

Additionally, the game contained "minigames" within the main game to add multitasking and difficulty (Fig. 2). These mini games included such tasks as cutting a loaf of bread into even slices, stirring vegetables in a pan to keep them from burning, and sorting colored apples into groups of the same color. These mini games had varying levels of difficulty, with the most difficult requiring multiple steps and coordinated movements (e.g., click and drag). They were introduced one by one, beginning with the simplest, as the player progressed through the game. Players played the minigame while simultaneously monitoring the ingredients occupying their stations. All of the minigames required higher levels of vision, cognition, and motor control than the main game, however they were optional and could be excluded during level design.

In testing the game we discovered several areas in which the gameplay was not accessible to those with a visual disability or those experiencing age-related changes in visual ability. These discoveries were made via multiple stages of user testing, including a formal human factors analysis for users with visual impairments utilizing "aging suit" methodologies (McClellan and Williams, 2014).

3.1 Visual Impairment

Like most serious games, *Food For Thought* required players to process complex visual information such as symbols, indicators, animated graphics, and color coding. For individuals with certain visual impairments, understanding what to do in the game could be compromised by not being able to perceive all the information of the screen.

Jim began playing the tutorial for Food for Thought but is having difficulty understanding what to do. The instructions indicate that he should take the ingredient out of its cooking station when its timer reaches the green zone, but due to his color blindness, he cannot distinguish the green zone from the red zone. To him, the ingredient appears to be "ready" when the timer reaches the very end of the indicator bar, but when he receives feedback at the end of the level, he finds out that all of his ingredients were over processed.

In this example, we highlight the limitation that occurred when the game interface required players to interpret meanings based on one sensory modality (Figs. 3 and 4). Jim could not perceive the colors of the indicator bars, therefore he failed the task.

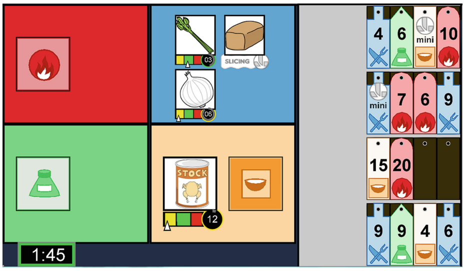

Fig. 3. *Food For Thought* interface as seen by a person with normal color vision. There are indicator bars for how "done" the ingredient is that use the colors yellow, green, and red to represent underdone, done and overdone.

Fig. 4. *Food for Thought* interface as seen by a person with deuteranopia, which causes lowered sensitivity to green and red. Indicator bars cannot be interpreted correctly.

Jimmight not be able to distinguish the colors of the indicator bars, but he could detect motion. One solution to this problem might involve adding a blinking element to the interface to signal that an ingredient is "ready." Color blind users would also benefit from auditory information, such as a rising tone that changed as the indicator moves between color-coded zones. Although not technically color blindness, age-related changes in color perception also created problems in differentiation, typically issues with blue hues, which could be addressed using the same solutions as for color blindness.

Individuals with visual impairments such as glaucoma and macular degeneration experience occlusion in their field of view (Figs. 7 and 8). Macular degeneration typically begins in the fovea. Frustratingly, if the user moves his or her eyes toward an attention grabbing stimulus in the periphery, that area becomes foveal and therefore occluded. However, visual focus and attentional focus can be dissociated, meaning that a user may focus on the center of the screen, but direct attention to different parts of their periphery. In some games it is possible to move important elements to the periphery and changing their size according to established peripheral acuity guidelines (Anstis, 1974). When this is possible, games may retain their challenge and therapeutic value.

Popular game mechanisms can be included in the design of the game to retain playability for those with glaucoma as well. One standard mechanism is the "spotlight," usually visualized as a flashlight controlled by an input device that reveals only portions of a screen at a time. This is opposite to the symptoms of macular degeneration, where the fovea is lost - with issues such as glaucoma the fovea is retained as the periphery becomes more difficult. The flashlight mechanism operates at two levels: it can make competitive or cooperative play more possible by limiting the field of view of the fully sighted player and it can also be a way to ensure the game is designed so that a spot-lit display, whether via the game or due to the player's vision, is playable and enjoyable.

McClellan and Williams (2014) initiated an analysis plan (Fig. 5) centered on visual accessibility for older players. Through heuristic analyses and initial testing with

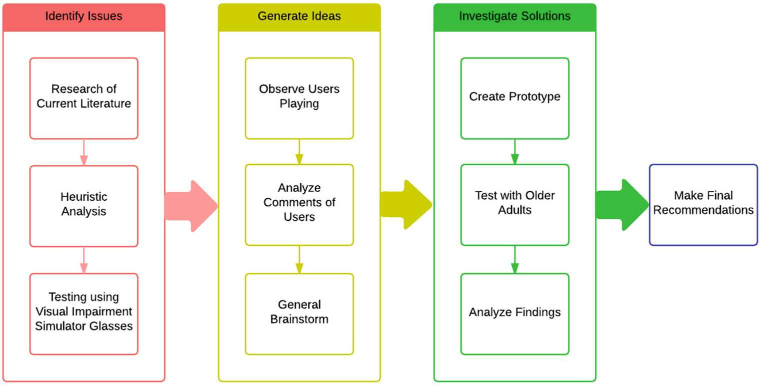

Fig. 5. Human factors methods for testing visual accessibility in a cognitive training game for older adults chosen by McClellan & Williams (2014).

glasses to simulate visual impairment, they found that several game elements were imperceptible: small moving objects such as the white triangle to indicate "doneness" and the cursor. An iterative re-design with larger fonts, indicators and greater contrast between figure and ground was tested on older users. Results found that the indicators were more easily followed and that the new designs were preferred.

3.2 User Testing

One of the biggest challenges in the design and development of therapeutic games is access to a population for usability testing throughout the process. Ideally, representative users are included in formative as well as evaluative assessments, engaging in some portion of participatory design throughout the development cycle. Large companies with resources dedicated to human factors may be able to achieve such participation and iterative design (although many choose not to), but smaller operations and research labs will need to creatively approximate the ideal methods.

To quickly test iterative designs, a "suit" may be employed that mimics the accessibility needs of the target users. Such suits can be, literally, suits: for example, automotive designers have successfully used suits that mimic age-related perceptual, movement, and flexibility issues. Glasses with different lenses can be used to mimic the symptoms of myopia/presbyopia, macular degeneration, glaucoma, and other visual disabilities (Figs. 6 and 7). Although true performance data are difficult to gather from younger or abled users wearing these suits, their subjective experience with the therapeutic game in the suit is of value. Such suits have been widely used on the designers themselves, allowing more insight into the issues their users will face and influencing their designs. Thus far, these suits have mimicked perceptual and physical disabilities. However, the concept of the suit can be extended into the cognitive realm. For example, as mentioned earlier, older users tend to have more difficulty inhibiting irrelevant stimuli. With the large visual field in most games and the tendency to use attention grabbing visuals and sound, the first step would be to pare down the

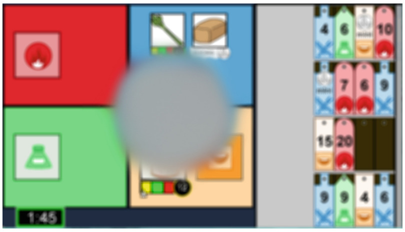

Fig. 6. *Food for Thought* interface as seen by a person with macular degeneration. This disorder is caused by the deterioration the center of the retina, which causes the center of the field of view to be obscured.

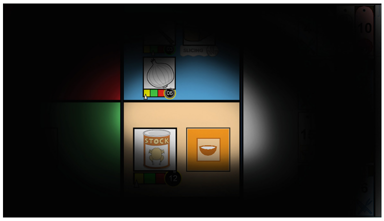

Fig. 7. *Food for Thought* interface as seen by a person with advanced vision loss from glaucoma. Increased pressure in the eye causes damage to the optic nerve, and peripheral vision decreases.

experience so that users can dedicate their resources to the portions of the game with therapeutic value. A cognitive suit might simply be a dual-task that requires the same sensory modalities as the primary task, with instruction to play the game while maintaining high performance on the secondary task. Specific to inhibition, an auditory or visual stimulus with much higher salience than the game could be displayed, with instruction to ignore its presence. We have found that young designers still tend to err on the side of more stimulation and demands rather than less. A cognitive aging suit could be a way to produce empathy and understanding.

Despite the benefits for early testing and promoting understanding and empathy in designers, accessibility "suits" are not sufficient for all user testing. Designs should still be tested with the target population, in representative tasks, and across a variety of accessibility needs. When such testing is done early it can often promote flexibility in the game design before the game mechanisms, inputs, and displays are too far advanced for changes. Advice specific to running usability analyses with older adults can be found in Pak and McLaughlin (2010).

4 Conclusion and Future Directions

It is clear that one of the biggest challenges in accessibility is to influence early game design, inputs, and mechanisms. Designers have an idea for a game mechanism, with its goals, rules, and feedback, and this tends to lock in certain interface elements. A sheet of heuristics should be developed to support a formative planning system for designers to consider at the earliest discussion of the game. Questions should include: "What are alternate ways to display the information gamers need for this part of the gameplay? Can visual be made auditory or tactile (or any reversal of these senses)? Would that affect the gameplay? How can it be revised to support the goal of the game through alternate means? Plan ahead for the interface to allow both." As concepts and prototypes develop, we recommend testing with representative users when possible but to also take advantage of simulations, including physical suits such as glasses that mimic vision problems, both for testing and to allow the designers themselves to experience the game as their players might.

Second, there is a need for the development of a taxonomy of symptoms and possibly their interactions paired with evidence-based ways of making serious games more accessible. The taxonomy does not need to address specific diseases or conditions, only their symptoms. In formulating the taxonomy, it will be important to include frequently comorbid symptoms (i.e., expect all age-related changes to be in combination with some other symptom of disability). Though a preliminary list, we have made several suggestions to address certain accessibility issues in serious games. More research is needed to expand and test these suggestions. These changes should only be considered if they do not interfere with the therapeutic nature of the game. For serious games in particular, we must promote performance that makes the serious game effective. This is an accessibility challenge beyond that faced by commercial games designed for entertainment. Serious games may be less flexible in their accessibility options to maintain the challenges required for effectiveness, but changes can still be made. For example, a game that trains multi-tasking requires multi-tasking, but it could have more easy levels early in training.

Last, though we recommend initial and rapid prototypes be tested with abled-users using techniques such as simulation suits and glasses, there must be testing with older adults and older adults aging with disability. It is time we codified and standardized user testing and accessibility testing for serious games, as they leave the world of research and become established therapies for older adults.

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References

Ablegamers. Accessibility awards for 2013 including mainstream accessible game of the year (2013). http://www.ablegamers.com/tag/accessible-game

Anstis, S.M.: A chart demonstrating variations in acuity with retinal position. Vision. Res. **14**(7), 589–592 (1974)

Atkinson, M.T., Gucukoglu, S., Machin, C.H.C., Lawrence, A.E.: Making the mainstream accessible: redefining the game. In: Sandbox 2006: Proceedings of the 2006 ACM SIGGRAPH Symposium on Videogames, pp. 21–28 (2006)

Basak, C., Boot, W.R., Voss, M.W., Kramer, A.F.: Can training in a real-time strategy video game attenuate cognitive decline in older adults? Psychol. Aging **23**, 765–777 (2008)

BBC News. Colour-blind aid for World of Warcraft game (2015). http://www.bbc.com/news/technology-31502904. Accessed 12 February 2015

Bierre, K., Ellis, B., Hinn, M., Ludi, S., Westin, T.: Game not over: accessibility issues in video games. In: Proceedings of the 3rd International Conference on Universal Access in Human-Computer Interaction (HCI International 2005), pp. 22–27 (2005)

Blanchard-Fields, F., Mienaltowski, A., Seay, R.B.: Age differences in everyday problem-solving effectiveness: older adults select more effective strategies for interpersonal problems. J. Gerontol. B Psychol. Soc. Sci. **62**(1), 61–64 (2007)

Carstensen, L.L., Mikels, J.A.: At the intersection of emotion and cognition aging and the positivity effect. Curr. Dir. Psychol. Sci. **14**(3), 117–121 (2005)

Ferrucci, L., Guralnik, J.M., Simonsick, E., Salive, M.E., Corti, C., Langlois, J.: Progressive versus catastrophic disability: a longitudinal view of the disablement process. J. Gerontol. **51**(3), 123–130 (1996)

Gamberini, L., Raya, M.A., Barresi, G., Fabregat, M., Ibanez, F., Prontu, L.: Cognition, technology and games for the elderly: an introduction to ELDERGAMES Project. PsychNology J. **4**(3), 285–308 (2006)

Hardy, D.J., Parasuraman, R.: Cognition and flight performance in older pilots. J. Exp. Psychol. Appl. **3**(4), 313–348 (1997)

Harley, L., Robertson, S., Gandy, M., Harbert, S., Britton, D.: The design of an interactive stroke rehabilitation gaming system. In: Jacko, J.A. (ed.) Human-Computer Interaction, Part IV, HCII 2011. LNCS, vol. 6764, pp. 167–173. Springer, Heidelberg (2011)

Imbeault, F., Bouchard, B., Bouzouane, A.: Serious games in cognitive training for Alzheimer's patients. In: IEEE 1st International Conference on Serious Games and Applications for Health (SeGAH), pp. 1–8 (2011)

McClellan, A., Williams, C.: Visual accessibility analysis of food for thought. Technical report. North Carolina State University, Raleigh, NC (2014)

McGonigal, J.: Reality Is Broken: Why Games Make Us Better and How They Can Change the World. Penguin, London (2011)

Pak, R., McLaughlin, A.C.: Designing Displays for Older Adults. CRC Press, Boca Raton (2010)

Rogers, W.A., Fisk, A.D., McLaughlin, A.C., Pak, R.: Touch a screen or turn a knob: choosing the best device for the job. Hum. Factors **2**(18), 271–288 (2005)

United States Census Bureau. Nearly 1 in 5 people have a disability in the U.S., Census Bureau Reports (2012). http://www.census.gov/newsroom/releases/archives/miscellaneous/cb12-134.html

Zyda, M.: From visual simulation to virtual reality to games. Computer **38**(9), 25–31 (2005)