Designing Serious Games for Elders

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ABSTRACT

Games are often considered a pastime for the youth, and most digital games are specifically designed to appeal to this demographic. Recently however, there has been an increased focus on "serious games" intended to produce positive effects for elders (i.e., older adults aged 65 and above). Digital games have been shown to have potential beneficial effects on elders' cognitive abilities (e.g., [13]). Simple computerized games (such as CogState [11]) potentially allow elders to independently monitor their own cognitive health. Yet there are very few games specifically targeted at the elderly population. Designing such games poses distinctive challenges, since designers must take account of the potential cognitive, sensory and/or physical limitations of elders, as well as their limited experience with gameplay interfaces and conventions that may be second-nature to younger players. Cognitive abilities can vary greatly among elders, especially within populations at risk for dementia or already diagnosed with early-stage dementia. Hence, games that target specific sub-groups of the elderly population should focus on different cognitive abilities depending on the purpose of each game. In this paper we will discuss cognitive abilities that are implicated in different stages of (normal and abnormal) cognitive aging. We will also examine how these abilities influence gameplay mechanics design for elders with different levels of cognitive impairment, and will also identify some fundamental design considerations for making games more accessible and stimulating for elders.

Categories and Subject Descriptors

H.1.2 [**Models and Principles**]: User/Machine Systems – *Human factors, software psychology.* K.8.0 [**Personal Computing**]: General – *games.*

General Terms

Design, Human Factors.

Keywords

Serious games, game design, elderly, cognitive aging, dementia.

1. INTRODUCTION

The 2012 annual report published by the Electronic Software Association (ESA) indicated that 49% of US households own at least one dedicated game console, and that up to 38% of these households play games on portable devices (e.g., smart phones and tablets) [5]. With such widespread use of modern devices including smart phones, tablets, and personal computers, digital games are making their way into the lives of many around the world. Mere years ago, these games were limited to a specific demographic: technologically savvy youth. Digital games are now increasingly within the grasp of the general population. A myriad of digital games have emerged in recent years, targeting players of all ages and interests. A study by Pratchet et al. [18] indicated that approximately 18% of adults in the UK aged 51 to 65 play digital games. This number has likely grown significantly since then with the increased adoption of smart devices. In fact, the 2011 ESA annual report indicated that more than a quarter of game players surveyed are over the age of 50 [4]. This number is likely to increase as electronic devices become more widely adopted by the aging population.

With an increase in elder gamers, one important question for game designers and game researchers should be: What purpose should games designed for elders aim to fulfill? The first and most obvious purpose would be entertainment value. However, the value of serious games goes beyond that. A number of researchers have studied the *therapeutic* effects of digital games on aspects of elders' cognitive functioning. For example, Whitcomb [26] reported that computer games have the potential to enhance reaction time and motor abilities such as hand-eye coordination and dexterity, which in turn can have a direct positive impact on elder participants' daily life (e.g., executing household chores). More recently, Miller [13] reported improvements in memory and attention as a result of regular use of a game the researchers specially designed to target these cognitive abilities. Serious games for elders also have the potential to be used for non-intrusive *diagnosis* and *evaluation* of elders' cognitive abilities. For example, Cogstate [11] is a suite of computerized tasks designed for the evaluation of cognitive abilities in elders. Such games would be valuable for high-functioning elders (who are aging normally, or are only minimally impaired). Additionally, we believe that there is a substantial, but largely unexplored, market for serious games that target highly impaired elders (mid-late dementia). Commercially, serious games that target therapy and diagnosis may also be candidates for a medical rather than consumer/retail model of distribution, meaning that the games could be purchased and distributed by healthcare providers and insurers.

Given the potential benefits of game playing for elders, a second question game designers and researchers face would be: How can a game be made to appeal to more elders, especially those who have had limited experience with digital devices? McLaughlin et al. [12] recently reported the key considerations of elders when deciding whether or not to play digital games. These considerations include the perceived challenge by the elders in operating a game interface, the memory demands of the interface (e.g., unintuitive, unlabeled icons), and stereotype threat (e.g., that elders are not good at games). For elders who have limited experience with digital devices, a big hurdle is in *learning* to operate the game on an unfamiliar device. Hence, in addition to engineering an accessible user-interface, designing gameplay for *cognitive accessibility* would reduce the perceived learning effort required, and could thereby improve uptake among elders.

By cognitive accessibility, we mean intentionally minimizing the severity and number of *cognitive demands* (as opposed to demands related to physical decline such as arthritis or poor eyesight) that gameplay imposes on an elder player. Researchers such as Salthouse [21] have identified important cognitive abilities, including memory, visual-motor functioning, and spatial problem solving, that are impacted in aging. Cognitive decline affects how elder game players process game information, such as rewards, punishments, goals and interaction mechanics, and careful consideration of these effects will help designers to understand what design elements can make a game cognitively accessible or inaccessible to elders.

Different sets of cognitive abilities are implicated at different stages of normal and abnormal cognitive aging (dementia). For example, memory is affected in early cognitive aging (both normal and abnormal), while praxis -- fluent and accurate performance of physical actions -- is typically only affected in later stages of dementia. Therefore, game designers should be aware of what abilities are most likely to be impaired in their target population and what game design factors are most relevant to these abilities, in order to ensure that their games are cognitively accessible.

Researchers such as Ijsselsteijn et al. [9] have discussed user-interface design issues in games targeting elder users. Other researchers (e.g., Fisk et al. [6]) have discussed general guidelines (e.g., font sizes) in the design of software targeted at elder users. Our discussion is offered in the same spirit, but focuses on gameplay mechanics design, with separate recommendations offered for target groups of elders with different levels of impairment. As far as we are aware, there is no report in the literature that offers this sort of fine-grained mapping between elements of cognitive decline and game design factors such as reward and punishment schedules, release of information to players, or in-game action-and-effect mechanisms. We believe that these considerations are at least as important as the user interface issues in elder-oriented serious games that have been the focus of most research in this area.

2. COGNITIVE AGING AND GAME DESIGN FACTORS

"Cognitive aging" refers to the decline in cognitive abilities that occurs with age. This decline can be broadly classified into two types: normal and abnormal. Studies show that while many core abilities like memory and reaction time degrade with increasing age, some abilities are more or less strongly affected than others during different stages of decline [21]. For example, as reported by Salthouse [21], vocabulary abilities are not strongly affected by normal cognitive aging. In abnormal aging, the rate of cognitive decline is significantly faster ([16]; also see Figure 1). Also, as we will discuss in the remainder of this section, the onset of decline are generally earlier for some cognitive abilities. By and large, cognitive abilities that are first implicated in normal aging or the very earliest stages of dementia will continue declining as one progresses to later stages of dementia. In this section, we will discuss cognitive abilities implicated in different stages of cognitive decline and their implications for game design.

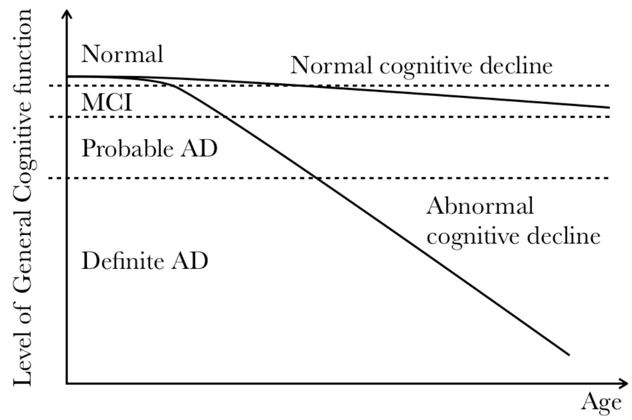

Figure 1. Change in general cognitive function in normal and abnormal cognitive decline.

2.1 Normal Aging and Mild Cognitive Impairment

Mild Cognitive Impairment (MCI) is the clinical condition between normal aging and early dementia [16]. MCI is characterized by decline in cognitive abilities (particularly memory) that is greater than that experienced in normal aging, but not severe enough to be categorized as dementia. MCI can be further broken down into two sub-types. Amnestic MCI involves greater decline in memory compared to normal cognitive aging, and has memory loss as the primary symptom of decline (though other cognitive impairments, such as in planning and reasoning, may also be present). Patients with amnestic MCI have a relatively high rate of transition to Alzheimer's Disease (10-15% per year compared to 1-2% in normally aging elders [17]). Non-amnestic MCI typically involves primary decline in functions other than memory (e.g., processing efficiency) and is potentially indicative of vascular dementia [16]. For present purposes, we will focus on the amnestic forms of MCI.

2.1.1 Episodic Memory

Episodic memory is memory for specific events, such as a frightening encounter with a grizzly bear during one's trip to a national park ten years ago. In games, episodic memory could be involved in the memory of specific experiences during earlier game sessions, such as the first encounter with a particular type of environment or opponent several months prior. Impairment of episodic memory in elders is generally one of the first signs of cognitive aging or amnestic MCI.

Impairment in episodic memory typically involves a reduced ability to encode new information, as well as difficulty in both free- and cued-recall exercises. An example of a test present in many standard psychological instruments targeted at episodic memory is the East Boston Story test [23]. In this test, a short story comprising a few sentences is read to the participant. Each sentence contains one or two key ideas. The participant is then asked to recall (either cued or freeform) details of the story. The recall exercise may be immediate, or may be conducted following a distractor task (delayed recall). Another common test for episodic memory in dementia questionnaires involves word list recall, where the experimenter reads a series of words to the participant, followed by an immediate or delayed recall exercise [2]. Salthouse et al. [20] reported the gradual degradation of episodic memory beginning at about 25 years old, accelerating at around 50 years old to reach levels below but still within 1 standard deviation of the mean, and eventually reaching levels about 1.5 standard deviations below the mean beyond age 75.

This form of impairment is mild, though noticeable, for elders who are aging normally or who are in the very early stages of dementia [11]. However, such impairment is rarely a cause for major functional disruption until the more advanced stages of dementia.

2.1.1.1 Information from In-Game Events
A decline in episodic memory potentially impairs an individual's ability to remember specific in-game events that could provide useful information pertaining to the actions a player might take to achieve rewards or avoid punishment. For example, details that are mentioned in animated cut-scenes or interactions with Non-Playable Characters (NPC) could provide clues (e.g., an NPC is shown pickpocketing gems from other NPCs and sneaking off to his hideout in the mountains) to completing a puzzle more efficiently (e.g., to locate the hideout and confront that "pickpocket" when the victims ask for help in a later part of the game to find the stolen goods). An individual with declining episodic memory would also find it difficult to relate a current event that references past events (e.g., an NPC is now giving the player the cold shoulder because the player had previously made an unfavorable choice against that NPC). Such references would not be evident, and might even be confusing for an elder with impaired episodic memory. Therefore, it would be helpful for elder players if in-game events are structured to be independent as far as possible, or if the game is narrative-centric, employ minimal number of cues.

2.1.2 Semantic Memory
Semantic memory deals with meaning, concepts, and categorical relationships. For example, although a torch, a tent, canned food, and a parka normally belong to different categories (i.e., tool, portable shelter, preserved food, clothing), they could all also belong to the "wilderness survival-kit" ad-hoc category, and could be items that a player needs to collect from various locations in the game world before embarking on a quest.

Similar to episodic memory, semantic memory is one of the cognitive abilities that begins to show significantly faster rate of decline in cases of mild cognitive impairment. A commonly used psychological instrument for measuring decline in semantic memory is the Boston Naming test [2, 10]. In this test, participants are shown drawings of objects and asked to name them. Some objects are commonplace items that one would encounter frequently (e.g., a toothbrush), while more difficult items in the test would involve more obscure objects (e.g., protractor). Another test used in psychological batteries is the National Adult Reading Test [14, 15], in which participants are asked to read a list of words aloud. Also commonly used to assess semantic memory ability are category fluency tests (used in instruments like the Mini-Mental State Examination or MMSE [7]), in which participants are asked to list as many items from a given category as possible (e.g., animals with four legs).

2.1.2.1 Meanings and Affordances of In-Game Items and Icons
Games that utilize a modifier mechanism, that is, having rare items capable of affecting ones scores or producing other beneficial effects, would pose greater difficulties to MCI patients, where semantic memory is declining significantly faster than normally aging elders. One well-known example of an item modifier is the "super mushroom" item in Nintendo's 1985 Super Mario Bros, which increases the size and sturdiness of the player-controlled character. It would be harder for elders who are suffering from a decline in semantic memory to learn and retain in-game information such as needing to use an item such as a "haste potion" to increase ones damage per second that would in turn net the player X number of bonus combo points. Our suggestion is for games to minimize the use of modifiers. In cases where such modifiers need to be used, the item appearance and effects should be consistent and simple (e.g., health potions are always red, and are the only red potions in the entire game) so as to make the item-effect relationship obvious and easier to learn.

2.1.2.2 Item Interactions
A decline in elders' semantic memory also puts a limit on game complexity in terms of in-game object interactions. A number of games, especially those in the puzzle solving or Role-Playing Game (RPG) genres, implement an interaction mechanic where certain items must be used in conjunction with other items to solve a puzzle or reach an objective. The logic governing which items may be combined, and to what effect, may have some basis in reality but may also involve puns or other leaps of logic. For example, using a "frozen iceberg lettuce" in one's inventory to cool a boiling pool so that the player might cross safely (from "King's Quest VI: Heir today, Gone tomorrow", 1992, by Sierra Entertainment). Complex and/or idiosyncratic relationships between items thus load semantic memory in two ways: their discovery may depend on recall of existing relevant knowledge from real-world experience, and their recall once discovered requires the formation of new semantic memories. Item-based games that provide only a moderate challenge to young or adult players could thus be excessively challenging to a player experiencing decline in semantic memory.

2.1.2.3 Reward and Punishment Schedules
Reward/punishment schedules in games dictate when, how and why rewards and/or punishments are doled out to the player. A general decline in semantic memory in the early pre-dementia stage or even during normal aging has obvious implications for the design of reward/punishment schedules in games. A decline in semantic memory potentially impairs an individual's ability to associate specific actions with the resulting rewards or punishment, for example, that a "rumble" in the ground always signals the appearance of a quest related plant that the player should quickly locate and "harvest" (action) X number of fruits for a reward. An individual with declining semantic memory will find it easier to process ratio reward/punishment schedules where rewards/punishments are provided after a consistent series of actions (e.g., successfully collecting X number of fruits from the plant will always yield 5 points immediately when the Xth fruit is collected). Consistent reward and punishment schedules reinforce the idea of "good" and "bad" actions making it easier for players to understand the action structure of the game. Therefore, games that use interval reward/punishment schedules where reinforcements are only given after either a fixed or variable time interval (e.g., constructing buildings in a town where different buildings would produce "rent" for the player after X minutes) are particularly unsuitable for elders who would find it difficult to associate an incoming reward or punishment with the sequence of actions or choices he had previously made.

2.1.3 Processing Efficiency

In addition to memory, one of the most easily noticeable age-related declines in cognitive ability is that in processing speed. With age, elders take longer to process and react to information presented to them, and do so with less accuracy.

A standard test of processing efficiency in adults is the Digit Symbol test from the Wechsler Adult Intelligence Scale (WAIS [25]). In this test, adults are given a series of digits, and their task is to quickly write down the symbol that corresponds to each digit based on a provided table of digit-to-symbol pairs. The Letter Comparison and Pattern Comparison tasks proposed by Salthouse and Babcock [22] comprises pairs of items (letter-letter or pattern-pattern), where each item contains either consonants (for letter-letter pairs) or line-segments (for pattern-pattern pairs) arranged in a 4x4 matrix format. The subject then indicates as fast as possible whether each presented pair is the same or different.

2.1.3.1 Reaction Time

A mechanism favored by many games is to manipulate difficulty based on the time needed to react to in-game stimuli and to take appropriate actions. For example, in games like Diner Dash, players have to schedule sequences of actions (e.g., seat patrons, take orders, serve dishes, collect payment, and clear up) as patrons at the restaurant arrive at increasing rates. For elders, most of whom experience a decline in processing speed, reaction time games could quickly become overwhelming. These elders would have difficulty processing the barrage of stimuli within the short time limit. While it is not advised, elders experiencing very mild forms of decline could possibly still cope with games that utilize a limited amount of reaction time gameplay. For games where the reaction time mechanism is crucial, designers should attempt to either reduce the number of different stimuli that must be processed at any one time, or limit the number of actions/options a player has (e.g., in Fruit Ninja by HalfBrick Studios which is essentially a gamified version of the experimental “go / no go” paradigm).

2.2 Early Onset of Dementia

2.2.1 Working Memory

One of the most noticeable forms of memory decline at the onset of dementia is that in working memory. Working memory is the ability to retain information necessary for ongoing tasks, for example, remembering the digits of a phone number long enough to type it in, or remembering that one has traveled to a certain in-game location to talk to a particular Non-Playable Character (NPC).

A number of psychological tests have been designed to measure working memory, and have been used in instruments for detecting whether performance levels have dropped to a level characteristic of dementia. The Digit Span subtask in the Wechsler Memory Scale (WMS [25]) presents the participant with a sequence of 3 to 11 numbers and requires participants to recall the numbers in order. The Word Span task, also from the WMS, is similar to the Digit Span task but uses words in place of digits. Another set of similar tasks are the Computation Span and Listening Span tasks introduced by Salthouse and Babcock [22]. The Computation Span task involves having the participant perform a computation exercise comprising 3 to 7 simple arithmetic problems and then recalling the answers in order at the end. The Listening Span task is similar, in that the participant is read short sentences and asked to answer an easy question after each sentence while also remembering the last word of the sentence. After being read all the sentences, participants are then asked to recall all the final words.

2.2.1.1 Real-Time Information Flow

Especially for elder gamers who suffer from a decline in working memory, and who would thus have problems retaining information relating to quests or current game objectives, games should utilize a real-time information flow mechanism wherein rewards and punishments) are presented immediately following the eliciting activity. For example, scoring could be displayed via salient pop-up scores or bonuses at the point of the action that elicited those scores, instead of waiting and displaying an aggregate bonus score total at the end of a round. An absence of real-time feedback on the utility of actions weakens the link between actions and actual rewards/punishments, making actions and effects seem ambiguous, especially when a player may have forgotten that he/she had performed an action earlier in the game (e.g., a farmer NPC rewarding the player with crops grown from the seeds the player had sown the previous "day").

2.2.2 Prospective Memory

Prospective memory involves remembering actions that one intends to perform or events that one should attend to at a particular time in the future, and performing the action when the right moment comes. An example is remembering that one has to pick up a friend who is arriving at the airport on a certain date and time, or remembering to cast a particular spell required by a quest at the end of a long dungeon.

A good psychological measure of prospective memory is a subset of the Rivermead Behavioral Memory test [27] in which participants are asked to complete a set of tasks relating to actions the participants have to take at appointed times in the future. For example, in the hidden object task, participants are shown an object at the start of the experimental session. The object is then hidden from view, and the participant is tasked with remembering to ask for the object when the session ends. The session then proceeds with a distractor task, and the experimenter notes if the participant remembers to ask for the target object at the end of the session. In the remember appointment task, participants are told a simple question and requested to ask that same question when an alarm clock goes off (after a time interval unknown to the participant).

Though prospective memory generally degrades with normal aging, elders in the early stages of dementia often experience a greater rate of decline in prospective memory [27].

2.2.2.1 Release of Information to Players

An important consideration of any game design is the kinds of information that should be provided to the gamer at any one stage of the game. It is important that the right information be presented at the right time, so that the gamer can understand what they need to do at each stage without being overwhelmed by information they cannot currently use. The decline in *both working memory and prospective memory* often seen in the early stages of dementia means that patients would have difficulty processing and retaining the amount of information a normal functioning adult would be comfortable with. Such an elder would find it particularly challenging when important information is embedded in a long quest narrative that is only shown at the beginning of a game (e.g., to remember to activate item X in the inventory when the player arrives at location Y), because even with cued recall, these players might not be able to retrieve from memory the crucial clue. Hence, player success in the game should not hinge upon the player being able to retain information (e.g., that pertaining to encounters), from one game session to the next, and any information that would contribute to successful game completion be presented in small enough chunks to be easily processed by the elder player.

2.2.3 Executive Function

Elders who are experiencing normal aging typically, as mentioned in Section 2.1., experience a slowdown in their processing speed and reaction time. However, by and large, these elders retain much of their ability to make complex decisions, and suffer no significant loss to their reasoning skills.

However, an elder who is in the early stages of dementia would likely experience a decline in their reasoning skills, such as in performing abstract mathematical computations (e.g., arithmetic problems, computing the right change in monetary transactions). These elders would generally find it hard to process and make sense of crucial in-game information required to make decisions to successfully complete a game, and assuming they could eventually arrive at such decisions, would require more time to do so. Hence, these elders would find it challenging when a game requires them to make increasing tougher decisions (e.g., more complex scheduling), particularly if the game imposes time pressure. Many commonly used items for detecting and measuring executive functioning capabilities involve arithmetic calculations and discerning meaning from abstract patterns or numbers sequences. The Matrix Reasoning Test from Raven's Progressive Matrices test [19] presents patterns arranged in a matrix form where the patterns and positions of elements follow an abstract rule. Participants are asked to determine what pattern best fits an empty cell in the matrix. The Shipley Abstraction test [28] is similar to Raven's test in that the participant is asked to determine numbers or words that best complete given sequences.

2.2.3.1 Reaction Time (Revisited)

For elders suffering from even the early stages of dementia, there should be a further reduced reliance on the reaction-time mechanic or a countdown mechanic, where a number of actions must be taken within a short timed limit. Such mechanics should be avoided for elders past the early stages of dementia and who are suffering from impaired executive function, as games utilizing reaction times run the risk of requiring a number of actions per unit time far beyond the limit impaired patients can process.

2.2.4 Spatial-Visualization

Visual-spatial ability affects one's ability to judge and understand spatial relationships, and thus the ability to perform mental manipulations of perspective or spatial arrangement, or to be able to understand perspective in a line drawing. For example, when an individual encounters bottles shown at different orientations and from different perspectives in a quest that requires the player to search for certain types of bottles, this ability would be required for recognizing the target items at different orientations.

In the early stages of dementia, the decline in visual-spatial ability commonly causes topographic disorientation in elders. This decline also results in poor ability to construct and manipulate mental representations of objects from drawings [8]. Common tests of spatial-visualization ability include the spatial relations test [1] where subjects are told to judge the relationship between a 3D drawing and a set of 2D drawings. Variants of the Paper Folding and the Paper Form Board tests (first proposed by Ekstrom et al. [3]) are also common instruments for testing visual-spatial ability in elders. The Paper Folding test asks subjects to determine the pattern of holes in a piece of paper after the paper has been folded in a particular manner and a hole punched through the folded piece. The Paper Form Board test involves having subjects determine the combination and spatial arrangement of standard shapes to produce a larger space with a pre-specified shape, much like the Tangram puzzle popular in certain Asian and European cultures. A series of tests similar to the ones described above is found in Raven's Progressive Matrices test [19].

2.2.4.1 Visualization of Game Space

A decline in patients' visual-spatial abilities, wherein patients experience reduced ability to produce accurate mental models of three-dimensional objects rendered on a two-dimensional screen, impacts the domain in which the game is played and the choice of presentation for the game. Gameplay should favor a simple two-dimensional play space over more visually complex three-dimensional game environments. The physical dynamics of objects and interactions in the game should also be obvious and simple to understand. For example, Tetris (created by Alexey Pajitnov in 1984) uses simple 2D geometric objects with intuitive, easy to understand relationships with each other (e.g., how the blocks might fit together). More challenging for elders with visual-spatial impairments would be the projectile trajectories and gravity-based object interactions in Angry Birds by Rovio Entertainment. Games that occur in a 3D space such as Modern Combat (by Gameloft) would be far beyond the abilities of these elders.

2.3 Mid-level to Advanced Abnormal Aging

Beyond early dementia, almost all the abilities impacted at earlier stages will exhibit significant decline. Many cognitive abilities become so severely impaired in the later stages of dementia that many of the psychological instruments described in the earlier sections become unusable. In addition to the cognitive abilities described earlier, motor abilities and language function may also become noticeably impaired.

2.3.1 Praxis

Motor ability, characterized by an individual's ability to manipulate physical objects, is by and large unaffected in normal aging and even early dementia, but signs of significant decline begin to appear in moderate cases of dementia. There are two commonly used tasks used by neuropsychologists to evaluate the extent of apraxia (motor impairment). The first is the Clock Drawing Test (CDT [24]) in which participants are asked to draw the hour and minute hands of a clock to show a particular time of the day. The second task requires participants to copy a figure (showing two overlapping pentagons) on a separate piece of paper. Patients are evaluated based on how well they complete the drawing and on the eventual relative positioning of lines and other elements that make up the complete drawing.

2.3.1.1 Gamer Actions on In-Game Items

Multi-gesture gameplay is increasingly common, particularly in tablet-based games. For multi-gesture gameplay, there are obvious memory concerns where elder players with failing memory have trouble remembering and executing supported finger gestures. Another concern is where games require minute manipulations to objects (perhaps to combine one object with another). An individual in the advanced stage of dementia would be significantly impaired not just in terms of the different forms of memory but also their ability to execute fine motor movements (apraxia). Hence, gameplay should avoid in-game tasks requiring fine movements on the part of the player to say, rotate a piece in a Tangram puzzle game app.

2.3.2 Language Function

Language abilities tend to decline much later, if at all, than the other abilities discussed above. Somewhat counter-intuitively, studies by Salthouse on healthy elders have reported that language abilities of adults actually show gradual improvement with age [21]. The improvement in language abilities is hypothesized to be due to gradual accumulation of knowledge over time. Language abilities tested by Salthouse include knowledge of definitions, synonyms, antonyms, and general vocabulary. In his paper, Salthouse posited this improvement as an explanation for why elders enjoy, and reliably perform better than younger adults at, word-related games such as crossword puzzles (notwithstanding their slower pace of play).

Despite age-related improvement in vocabulary abilities in cases of normal aging, language function may become severely impaired in later stages of dementia. Decline in language function is characterized by fluent and non-fluent aphasias, and even mutism [8] in very late stages of dementia. Elders in this group could experience difficulty in comprehending instructions and other in-game text (such as quest descriptions) in games.

2.3.2.1 Real-Time Information Flow (revisited)

Even more important for elders who are suffering from advanced dementia--where memory, praxis, executive functioning, and language are highly impaired--games should be designed to be simple and easy to understand, with direct cause-and-effect relationships. That is, any rewards or punishments that are consequences of in-game action should be obvious, be given as soon as possible after the eliciting actions, and be presented with intuitive illustrations, sounds, and minimal use of words due to impairment in language function. There should also be minimal ambiguity as to the cause of effects that players experience. For example, an action A1 that yields reward R should always only lead to that same reward, and there should be a minimal number of situations where another action A2 would produce R. Rewards and punishments should also be easily distinguishable and obvious (e.g., fireworks, animations, and audible cheers that accompany success). Information in the game should be as localized as possible, where current in-game actions can be executed successfully based solely on information that is present and easily extracted. Games should not assume that the player can retain and apply any form of information gained from previous rounds of gameplay.

2.4 General Design Considerations

Our suggestions in the previous sections are organized based on their relationship to cognitive abilities that are affected at a particular stage of decline. In addition to those suggestions, we believe that there are a few more general concerns that would apply to game design for elders at all stages.

2.4.1 Game Design Goals

Games for elders could pursue either (or potentially both) of two conflicting design goals-- (1) to make the game accessible to elders by minimizing the load on cognitive abilities that are impaired, and (2) to design gameplay in such a way that gameplay targets and stimulates the impaired cognitive abilities. The elements of design would be different in each case. Even games that aim to be stimulating, however, might find it advantageous to load as narrowly as possible on the specific cognitive abilities that they are designed to target, while minimizing load in other areas to keep the game accessible and enjoyable. This is where we believe our earlier discussion of cognitive decline and the standard psychological instruments that target each function would be particularly useful, in that the psychological instruments highlight the types of tasks for which one might derive similar gameplay features to focus on the cognitive ability of interest.

2.4.2 Difficulty Scaling

Decline in cognitive functioning means that game designers should rethink the issue of difficulty, that is, along what gameplay dimensions should difficulty scale, and the extent to which elder players can cope with the game as difficulty increases. Cognitive decline puts a limit on how difficult a game can get before it becomes intractable and ultimately frustrating for aging elders.

There are two ways to think about the issue of difficulty scaling. The first is scaling difficulty in such a way that it targets (and stimulates) the cognitive abilities that are directly impacted by cognitive decline. For example, requiring players to remember and learn at higher levels gradually more complex sets of goals (e.g., take Action A1 when object X1 appears, and also remember to do Action A2 after A1, and action A3 when object X2 appears) would tax working memory, and perhaps prospective memory; or making puzzles increasingly visually complex (e.g., increasing the number of distractors) would tax visual-spatial ability and perhaps executive function. However, scaling difficulty by targeting the cognitive abilities that are declining will quickly make these games inaccessible and frustrating to the elders the game was designed for. Elders who are suffering from different stages of cognitive impairment would exhibit different thresholds where a game transitions from being challenging to frustratingly difficult along each gameplay dimension. Determining such thresholds is important when the design goal is to stimulate and enhance a player's cognitive abilities. These thresholds may be determined empirically for particular games to establish baseline game performance for different sub-populations of elders, or by establishing within-player baselines via computer-adaptive algorithms that determine game difficulty based on current player performance.

The second is to scale difficulty based on cognitive abilities that are less affected in the targeted group of elders. For example, in the case of normally aging or MCI elders, where executive function is mostly intact, game difficulty scaling could be based on the amount of planning required. For elders in the later stages of decline, difficulty scaling that eases stress on cognitive abilities that are showing the most signs of impairment could be valuable in making games more accessible.

2.4.3 Communicating Game Related Information and Setting In-Game Goals

Often in a game round, game designers have to decide the amount of information the player needs at any point in the game, the amount of information the player can process at that point, and the manner in which the game presents the information to the player. As we have discussed earlier in the paper, elder players may have difficulty processing and retaining information, and therefore in games targeting elders the design goal should be to make essential information readily accessible to the players. Especially for more cognitively impaired elders, game rounds should be completely self-contained and not reliant on information from previous rounds or sessions with the game. The in-game goals should also be easy to understand and any sub-goals and information pertaining to these sub-goals should be "localized" (i.e., solvable when encountered) to avoid requiring the player to keep track of multiple goals at any one time.

3. CONCLUSIONS

In this paper, we have examined a set of cognitive abilities that are implicated in different stages of normal and abnormal cognitive aging and drawn out their implications for gameplay design. We believe that our discussion would contribute to existing literature on the design considerations involved in serious games targeted at elders either for therapeutic or monitoring/diagnostic purposes. We have also proposed specific considerations for games targeted at different stages of cognitive decline, and have considered the different requirements of games targeted at stimulation or at accessibility. We believe that an understanding of specific cognitive constructs affected by aging, and of the psychological tools that are used to evaluate these constructs, can be an important determinant of success in games targeted at elders.

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