Learning with Educational Games: Adapting to Older Adult's Needs

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Abstract: Creating effective online educational games for seniors requires adapting these games to the target players and their specific educational objectives. To improve seniors' quality of life with games, we must develop games that adapt to the cognitive and physical requirements of this audience. Using a user-centered design methodology, we considered ergonomic criteria (i.e., utility and usability) to design an online educational game for seniors. This paper presents the variables of the study, the way we adapted the design of the game *Solitaire* for older adults, and the results of the field test done with 42 seniors. The participants reported a high degree of satisfaction with the game's design and demonstrated learning. We present recommendations to guide the development of online educational games for older adults.

1 INTRODUCTION

What do we know about the ergonomic requirements for creating effective online educational games to facilitate lifelong learning for older adults? Researchers (Diaz-Orueta et al., 2012; Astell, 2013; Marston, 2013, 2014) have pointed out that the effectiveness of educational games depends on players' needs and individual characteristics and that we need to develop systems that can adapt to the demands of the target audience.

An inappropriate design can discourage seniors' use of online educational games, reducing the physical, cognitive and social benefits these games can bring and consequently diminishing older adults' health and quality of life (Whitlock et al., 2011).

Commercially available games present challenges in terms of their ease of use for many seniors due to a lack of knowing their needs (De Schutter and Vanden Abeele, 2010; Hwang et al., 2011). Given the importance of a well-constructed educational gaming interface and the costs involved in its development, it is important to identify the ergonomic requirements to be considered during the design process to adapt the game to older adults' characteristics and needs. We view an online educational game as effective when it meets two quality criteria: it must be useful, i.e., adapted to its users' learning objectives and prior knowledge, and usable, i.e., easy to learn and use.

Although extensive literature has recently been produced on video game ergonomics and ergonomic standards (Barlet and Spohn, 2012; Game Accessibility Guidelines, 2012-2015), it is clear that these discussions have little or no interest in online games and even less in games with explicit learning objectives for older adults.

In this article, we first define what we mean by ergonomic game design. Then, we describe how we have adapted the design of a well-known game, Solitaire, for seniors. We then briefly present the results of a field test of the educational game, "In Anticipation of Death", made available online for testing by 42 seniors to determine their degree of satisfaction with the game's design and their acquired knowledge. Finally, in the discussion, we offer recommendations to guide the development of effective educational games for older adults.

2 THE NOTION OF ERGONOMICS

In the development of online educational games, the ergonomist's job is to implement solutions to inform and guide the user in order to reduce as much as possible the cognitive load of information (effectiveness) (Millerand and Martial, 2001), while

ensuring that the game is easy to play (comfort), safe (security) and fun for the player.

Our game development approach is rooted in a User-Centered Design methodology, which integrates an ergonomic approach into product development. This approach is based on criteria of both utility and usability.

Utility refers to the ability of the game to facilitate specific learning (meeting defined learning objectives) for a specific target audience. In other words, the more meaningful the learning, the more useful the game.

Usability refers to the ability of the game to adapt to the characteristics of the target user (user-centered design) and to be intuitive (user-friendly and readable). In other words, usability will be high if a game is stimulating (design) and easy to understand (navigation and display) so that the player-game interaction is simple and fluid while maintaining a sufficient level of difficulty (challenge / competition) in order to maintain a satisfying gaming experience (Schell 2010; Dinet and Bastien, 2011).

In this article, we discuss our adaptation for older adults of the Solitaire game design and its utility as measured in a field test.

3 CHOOSING THE TYPE OF GAME AND ITS EDUCATIONAL CONTENT

We initially relied on a survey of 931 seniors from Quebec and British Columbia, as part of the project "Aging Well: Can Digital Games Help?" (2012-2016), in which the game of Solitaire was identified as one of older adults' favorites (Kaufman et al, 2014).

For the game's educational theme, we interviewed 167 seniors aged 55 and over in a second study, "Promoting Social Connectedness through Playing Together - Digital Social Games for Learning and Entertainment" (2015-2020). These participants were interested in the actions to be taken upon the death of their spouse; more than 72% expressed a lack of knowledge about putting the affairs of their spouse in order, recovering what is due to their spouse, paying debts and fulfilling their spouse's wishes concerning the disposition of their body (Sauvé et al., 2017).

4 THE OBJECTIVES OF THE STUDY

The study objectives were: (1) to evaluate the ergonomic design of the educational game in terms of its suitability for seniors and (2) to investigate whether the number of games played with a single educational game can influence the acquisition of knowledge that is offered in the game.

In order to meet the objectives of the study, the interface of the Solitaire game was adapted to allow us to introduce educational content in the form of quizzes.

Solitaire is a single-user game that is played with a deck of 52 cards. The first 28 cards are arranged into seven columns of increasing size, which form the Board. Only the last card of each column on the Board is placed face up. The 24 remaining (face down) cards make up the Stock pile, also called the Deck. Cards from the Stock pile are discarded, according to the player's choice, one or three at a time (Figure 1). Design adaptations were made to the interface to meet the ergonomic requirements of the study, as discussed below.
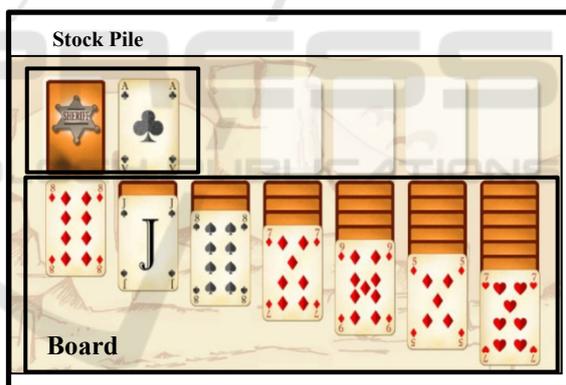

Figure 1: Basic Solitaire Interface.

For this study, the Solitaire interface is coupled with a questionnaire game. At regular intervals, depending on the number of card displacements, the player encounters a question. The player's answer, right or wrong, affects the player's accumulated credits, which correspond to the score and are used to buy advantages from the online game store. Time is also important since a bonus or a penalty is given according to the length of the game.

Finally, the game ends when all the cards are placed into four places piles for each suit and sorted in ascending order (from Ace to King), or when a player declares forfeit because they cannot move

any more cards. In the latter case, the player can start a new game.

5 THE GAME DESIGN FOR SOLITAIRE

The design of an educational game deals with the components of the game: gameplay duration, challenge (game modes, degrees of difficulty, playing time), score and game materials. It also encompasses the educational aspects of the game, including how the learning content and feedback are integrated into the game (Sauvé 2010, 2017).

5.1 The Game Components

We based our educational game, called Solitaire Quiz, on Solitaire, which has a short duration to maintain player motivation and was identified as one of older adults' favorites in our initial survey (Kaufman et al., 2014).

In the "In Anticipation of Death" game, we incorporated three sets of initial option choices to vary the sense of challenge: the game mode: turning over one or three cards (Figure 2); the degree of game difficulty in relation to the number of credits the player receives: Easy ($200), Intermediate ($100) or Difficult ($0) (Figure 3); and playing time to for a bonus: 0-5 minutes (+$250), 5-10 minutes (+$125) or 10 minutes and more (-$100).
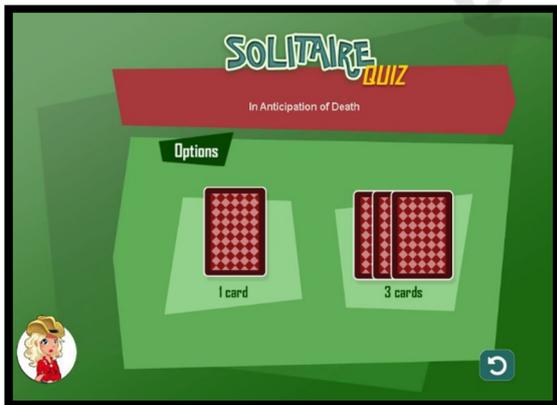

Figure 2: Game Options - Game Mode.

Figure 3: Game Options - Degree of Difficulty.

For scoring related to the movement of cards in the game, which we found in some online Solitaire games, we added scoring related to the learning of educational content. Points either reward or penalize the player as they respond correctly or not to a question. The penalty is 50% less than the gain in order to maintain the player's interest (Sauvé, 2017), especially for those who have little knowledge of the content to be learned.

To augment the game's original materials, we added privilege cards that a player can buy at any time if they have enough credits. These privileges allow a player to finish a game or accumulate money credits; for example, the Hazardous Freedom card randomly releases a hidden card from the Board to the Stock pile.

5.2 The Game Contents

In order to make the game educational, we incorporated a mechanism to display a question card (Figure 4) after every five card movements in the game. If the player answers the question correctly, they earn points and if they do not answer the question correctly, they lose points.

For experimental purposes, we split the learning content into small units, which resulted in 70 closed questions (true/ false or multiple choice with one or more answers), divided into three levels of difficulty (22 easy, 24 medium and 24 difficult) identified by one, two or three stars. This division ensures that the questions repeat at least once during a game with the goal of completing the four piles. Finally, the questions address the aspects of the will of a person who dies.
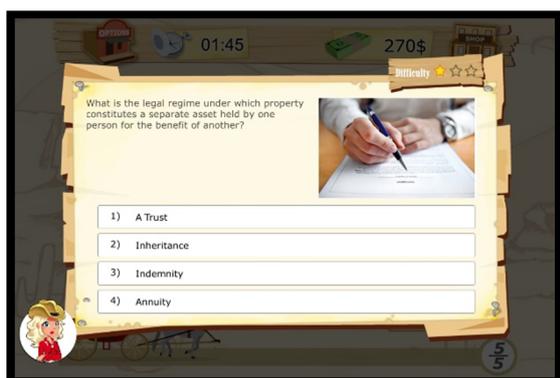
Figure 4: Displaying a Question.

To ensure a balance between playing and learning, question cards are displayed after five card movements. These movements are represented by a stagecoach that moves on a progression bar, with a fraction to indicate its progress (Figure 5). The number of movements needed to display a question card was determined during the first two tests of the game (paper and prototype) with older adults.

Figure 5: Movement of the Stagecoach in the Game.

5.3 Feedback

When displaying question cards, we also incorporated visual feedback on the outcome of the activities in the form of a smiling or sad face as well as textual and audible feedback to explain the correct answer (Figure 6).

As noted above, we added to the game's original materials, privilege cards that a player can buy at any time if they have enough credits. These privileges allow a player to finish a game or accumulate money credits, for example, the Hazardous Freedom card which randomly releases a hidden card from the Tableau to the Stock pile.

Figure 6: Feedback.

Finally, as in other digital Solitaire games, we post feedback on the player's performance as a score at the end of the game (Figure 7). This score consists of money credits earned during the game plus a bonus if the player has chosen the option of playing with a time limit.

Figure 7: Ending the Solitaire Game.

Figure 8: Ranking.

In order to motivate seniors to play more often, a ranking of all players registered for the game is

available at the end of the game by using the Ranking button (Figure 8).

6 THE METHODOLOGY

In order to assess the design of the educational game as adapted for seniors 55 and older, we tested the tablet game on Android and iPad devices with 42 retired older adults.

6.1 The Measuring Instruments

Before the experiment, we administered a questionnaire on socio-demographic data and seniors' habits (12 items) as well as their knowledge about legal aspects of wills (10 questions). After the experiment, a self-administered questionnaire on the game design relating to challenge (six statements), learning content (three statements) and feedback (five statements) was given online. The items were operationalized by a Likert scale of five levels (from *strongly agree* to *strongly disagree* and the option *does not apply*). The questionnaire also included a box to collect written comments from respondents. We also included 10 questions concerning the knowledge developed through gameplay and three items on players' interest in using educational games for learning. Finally, we integrated a system to track players' responses to the game questions; this is done for every game in order to measure the degree of knowledge acquisition by the players during the experiment.

6.2 The Experiment

The experiment took place over the course of two months. Participants were invited to play the game at least five times. This experiment was approved by the university's ethics committee. Each participant was made aware of the research purpose and signed a paper or online consent form.

7 RESULTS

We first describe participants' demographic data, followed by an analysis of their participation in digital games in general. We then present our results regarding the game design and participant learning.

7.1 Demographic Data

Among the 42 participants in the Solitaire Quiz experiment, there were 19 women and 23 men. The sample included 20 participants aged 55 to 60 years (48%) and 22 subjects aged 61 and over (52%). Among the sample, nine players said that they did not have the skills to use digital games, while 18 players identified themselves as "beginners" and 15 as "intermediate" participants. Of the 42 participants, 90.5% played the game at least five times for an average duration of 7.3 minutes, and 42.9% played between six and nine times for the duration of the experiment. It should be noted that eight participants were not included in the analysis because they did not complete the questionnaires at the scheduled times (before, during and after the experiment) and three of them did not play the game five times.

7.2 Participants' Gaming Habits

Most participants (37 of 42 or 88%) had already played Solitaire. Some of them (33 of 42 or 78.6%) had some experience with other digital games: six players had experience of one year or less, more than half (19) had between one and five years of experience, and eight had been playing for more than six years. Of the 33 players who had some experience with these type of games, five people (15%) used them only one day per week. Eleven players (33%) used digital games two or three days a week, and the same number of participants played between four and five days a week, which shows a strong preference among seniors for the use of technology for entertainment purposes (66% of participants played between two and five days per week). Also, of the 33 players who had experience with playing games, 11 played up to 60 minutes a day and, interestingly, 21 people (64%) used them between two and three hours per day.

7.3 Player Perceptions of the Game Design

For player perceptions concerning the challenge presented by the game, all the items had positive outcomes in that average ratings were are above the favorable perception threshold (in agreement), that is to say, 4.00 on all items (Table 1). In addition, the standard deviations show a low dispersion of responses, especially when participants commented on the appropriateness of the game duration (item QD1), the effect of privileges purchased in the store for maintain their interest in finishing the game (item

QD2), and the effect of the scoring system on motivation (item QD6). In other words, the respondents' opinions were generally grouped around the average. The standard deviations of all items are below 1.00.

Table 1: Perceptions of the Participants of the Challenges Posed by the Game.

Items		Mean	SD
Length of Game	QD1	4.57	0.91
Privileges and Interest	QD2	4.67	0.53
Question Difficulty	QD3	4.37	0.89
Limited Time	QD4	4.15	0.97
Game Mode	QD5	4.34	0.76
System of Points	QD6	4.36	0.69

With respect to the game content, participants expressed a favorable opinion on the elements of this component (Table 2). The averages of the items surpassed the threshold of 4.00. In addition, the standard deviations are below 1.00 in the three Likert scale items. When asked about the representativeness of the images in relation to question content (QC9), the average of this item (4.74) was the highest for the variable "content of the game" and the standard deviation (0.50) was the lowest. This supports the importance of the meaning conveyed by the visual elements of the game.

With regard to the perception of the correspondence between prior knowledge and the accumulation of points (QC7), as well as the repetition of questions as an effective strategy to reinforce learning (QC8), respondents showed a very favorable opinion on these mechanisms for promoting learning in the game.

Table 2: Participants' Perceptions about Game Content.

Item	Prior Knowledge	Repetition of Questions	Representativeness of Images
	QC7	QC8	QC9
mean	4.55	4.52	4.74
SD	0.67	0.51	0.50

With respect to players' perceptions about feedback in the game (Table 3), the average for the items is very high. Respondents were strongly in agreement that the feedback for the answers helped them to progress in the game (item QR10). The results also show that a smiling or sad face, indicating whether a question was correctly or incorrectly answered, conveys the desired meaning (item QR11). A very favorable perception was also identified in the QR12 item, which indicated the effect on motivation of the sound emitted during a good answer. In addition, respondents strongly agreed that the automatic audio playback of questions and feedback facilitates understanding (item QR14). For all these items, the average was 4.40. Yet, there are some differences between their standard deviations. In other words, the dispersion of responses between these items is variable.

Table 3: Participants' Perceptions about Game Feedback.

Items		Mean	SD
Game Progression	QR 10	4.40	0.63
Smiley Face	QR11	4.40	0.59
Sound and Motivation	QR12	4.51	0.68
Reinforcing Learning	QR13	4.35	0.79
Facilitation of Understanding	QR14	4.63	0.67

Regarding the learning that was achieved, we examined the number of questions that were correctly answered by the players based on the number of times they played the game (Table 4). The first time the game was played, respondents answered 24.2% of the questions correctly. As a result of using the game, the number of correct answers increased from 24.2% to 88.4% after playing the game for the fifth time, indicating a progressive learning experience in relation to the number of times the game was played.

Table 4: Rate of Correct Answers in the Game According to the Number of Games.

	Number of Respondents	Easy Questions	Intermediate Questions	Average
Questions		22	6	
1st Game	42	31.8%	16.7%	24.2%
2nd Game	42	40.9%	50.0%	45.5%
3rd Game	38	90.9%	83.3%	87.1%
4rd Game	38	91.2%	83.9%	87.5%
5rd Game	37	92.2%	84.6%	88.4%

In addition, the vast majority (92.86%) of the participants liked to play Solitaire enhanced with a Quiz (item QI1) and 90.48% of the players wished they could try a new quiz (item QI2). All participants would recommend the game to others (item QI3) (Table 5).

Table 5: Interests of Participants.

	Desire for Playing Solitaire Quiz	Interest in Trying New Quizzes	Would Recommend the Game to Others
	QI1	QI2	QI3
Yes	39	38	42
	92.86%	90.48%	100.00%
No	3	4	0
	7.14%	9.52%	0.00%

7.4 Modulation of Responses on the Ergonomics of the Game

Differences in perceptions by age group (under 60 and 61 or over), gender, computer skills (beginner, intermediate, expert) and skill level as an online player (beginner and intermediate) were all examined with the Student t-test with a bilateral distribution of unequal variance with two examples (heteroscedastic). A difference was considered statistically significant when the associated p value was less than or equal to 0.05.

These results indicate that the level of ability in using digital games modulates perceptions in terms of feedback, especially for beginners. For the aspects of challenge and content, the age and gender criteria, and computer skills give substantially the same results, that is, the differences are negligible.

8 DISCUSSION

Our results confirm the importance of offering games of short duration to maintain seniors' motivation, while integrating allowing players to vary the duration of the game (Whitlock et al., 2011; Kickmeier-Rust et al., 2012; Shang-Ti et al., 2012; Theng et al., 2012; Sauvé et al., 2015; Sauvé 2017). In terms of the challenges the game brings, the addition of new elements to the game, including privileges that can be purchased in the game store, have helped to maintain players' interest in finishing the game. This is consistent with the findings of Al Mahmud et al. (2012) as well as Mubin et al. (2008), who suggest incorporating new rules (add-ons) to maintain a sense of challenge in known games. Seniors prefer to play games that they know, with add-ons that engage them.

These results show that players place a high value on the degree of difficulty of the questions (represented by ★★ ☆ icons) in relation to the challenge they pose. Similarly, Lavender (2008), De Schutter (2010) and Sauvé (2010) note the importance of how the learning content is treated (from simple to complex) in the game in order to offer multiple degrees of difficulties. Marston and Smith (2012), Shang-Ti et al. (2012) and Sauvé (2017) recommend that players be informed that the easy level corresponds to the basic knowledge of the players, thus encouraging everyone to participate.

Participants confirmed that the option of "Playing with a time limit", to gain additional points, was a motivating challenge. The availability of two game modes (one-card or three-card) also represented different challenges in the game, according to the players' responses. The in-game scoring system was seen as an additional source of motivation. These facts align with the findings of several studies (Sauvé 2010; Rice et al., 2011; Diaz-Orueta et al., 2012; Senger et al., 2012; Sauvé et al., 2015) whereby one should incorporate different difficulty levels or challenges to the user to foster competition, facilitate learning, build self-confidence and concentration, and better engage older adults in the game.

Relative to game content, using closed questions facilitates the use of prior knowledge in order to accumulate points and progress in the game. In two previous studies (Sauvé et al., 2015; Sauvé 2017), we concluded that it is crucial to analyze the learning content and to break it down into small units of information; this makes it possible to formulate simple questions in order to avoid cognitive overload in seniors. These findings were verified by the results of this study.

Players emphasized the importance of question repetition for reinforcing learning. Indeed, limiting the number of learning activities in a game allows seniors to recognize them and consider them useful for their progression in the game (Sauvé 2010; Sauvé et al., 2015). The results also reveal that it is important to ensure the representativeness of images used in the questions (Lopez-Martinez et al., 2011; Shang-Ti et al., 2012; Sauvé et al., 2015).

Breaking up the learning content is of primary importance in order to balance learning time and playing time (Sauvé 2010) so that not all game activities require learning success. In a previous study (Sauvé 2017), we recommended leaving room for actions related to the pleasure of playing. In this sense, participants emphasized the fact that Solitaire Quiz is an original way to learn more about certain topics.

The players in this study highlighted the usefulness of question feedback for progressing in the game. This agrees with observations of Sauvé (2010), Callari et al. (2012), Gerling et al. (2011) and Sauvé (2017) who emphasize the importance of integrating mechanisms that reinforce the results of learning activities with visual or audible feedback. For example, seniors who participated in our study commented that the face that accompanied each feedback comment, and the sound emitted for a correct response, made it easy to quickly identify whether the question was answered correctly or not. This is consistent with the results of Lopez-Martinez et al. (2011), Marston and Smith (2012), Senger et al. (2012) and Wu et al. (2012).

Finally, the results show that seniors achieved a significant amount of learning from the use of the game, while also having the pleasure of playing.

9 CONCLUSIONS

Although the perceptions observed in this study relate to a specific game (Solitaire Quiz), the results can be applied to different types of games. Our study shows that in order to make an educational game easier to use by seniors, it is important to provide an appropriate level of difficulty and be adapted for this audience. It is important to reduce the risk of frustration by proposing an interesting challenge.

The results of this study suggest several aspects to consider, such as an appropriate game duration, a clear way to finish the game, displaying game progression and the graphical representation of the level of difficulty of the questions related to lifelong learning.

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