Seeker: A Serious Game for Improving Cognitive Abilities

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Abstract — Seeker is a serious game developed using the Unity game engine that focuses on a learning outcome: improving users’ cognitive abilities. The user is confronted with a series of puzzles, has complete liberty in terms of traveling between game scenes and must adequately manage the available resources in order to solve the game. Cognitive abilities are challenged for resource management and decision making, while pleasure and fun are provided while solving different puzzles. Preliminary results of our validation show that users enjoyed playing the game, but the lack of scene ordering and the limited number of provided hints are facts that should be improved in the future version.

Keywords — Serious games, game-based learning, cognitive ability, resource management, casual games.

I. INTRODUCTION

Serious games have become a major business, one of their application domains being education. As stated by the co-founder of Serious Games Initiative, Ben Sawyer, this market is only 20 million out of 10 billion per year digital gaming market [1]. However, a growth over the last years has been observed due to the wide applicability of such games and the steadily increasing interest in research projects (e.g., dedicated calls within the European Comission Horizon 2020 funding program). Serious games have had many definitions over the years, but summing up, a serious game is an interactive application, a simulation of real life events designed for training and educating the users. Today, serious games refer mainly to computer games. These games are not intended to be played for amusement and they sometimes sacrifice fun in order to teach the user. The obvious advantage of serious games consists of enabling users to experience situations that are unavailable to them in real life because of high costs or safety issues.

The main difference between serious versus entertainment games is that serious games combine two dimensions, “serious” and “game”, while entertainment games have only the “game” dimension. From this perspective, an entertainment game can be transformed in a serious game. This can be done by applying a technique called „purpose-shifting” in which the entertainment purpose is changed (see Fig. 1) [2, 3]. This technique is very common in education where teachers use entertainment video games as teaching materials. In this case, teachers have to create their own „serious” scenario in order to influence the way students think and act. The difference between a serious game and a game transformed by “purpose-shifting” is the design process. For the first one, designers have full control over the content of the game, while for the second one, the game scenario previously designed has to be adapted to a serious goal.

Another way of transforming an entertainment game into a serious game is to make software modifications to the first one - this process involves creating “mods” or modifications [4]. Mods are defined as a type of computer games, most of them being first-person shooters, role-playing games or real life strategy games. These can be entirely new games or can add/change content from a game. Two categories can be distinguished: partial conversions (mods that add new content to an existing game infrastructure) and total conversions (mods that create a totally new game). For example, Chivalry Total War1, a strategy game placed in medieval Europe between roughly 1070 and 1450 AD, is a complete and historical modification of Rome: Total War2.

![Fig. 1. Relations between serious games, serious gaming and the corresponding intersections with entertainment games](image_url)

1 www.moddb.com/mods/chivalry-total-war
2 www.ign.com/games/rome-total-war/pc-498739
Besides modifying existing games, the serious games industry also develop completely new games. Here we can identify two categories: games created by companies which invest several years in the development process and games developed by universities. The difference between these two is the invested time, graphical quality and design.

Seeker is a game from the second category, it is an educational game [5] that focuses on increasing users’ cognitive abilities, such as decision making, resource management, memory and problem solving, through a series of mini-games and real life situations. Moreover, in order to keep the user anchored in the game, we develop in Seeker a story that is supposed to be attractive by transforming the user into a hero while following the storyline presented in the gameplay section.

In this paper, we begin by describing serious games domains and game based learning approaches. We then introduce the envisioned gameplay, the development process and the validation study conducted to measure the adequacy of our approach. We conclude by describing possible future improvements.

II. SERIOUS GAMES DOMAINS

The domains in which serious games can be used are diverse. Games are categorized according to different types of markets: military games, government games, educational games, corporate games, healthcare games, political games, religion games, and art games. Despite this categorization, many games can belong to more than one category. According to Manoharan and Holzer [6], many users of serious games belong to the US government and the healthcare market.

A. Military games

Military games have evolved from games with simple rules, which helped soldiers improve their skills in planning battles, to complex battle and flight simulators. This is probably the most successful domain for serious games because of the reduced costs for a game in balance with a traditional simulator.

The first serious game used for military training was Army Battlezone\(^1\), designed by Atari in 1980 and used by the US Army for training gunners on the Bradley Fighting Vehicle. One of the most well known games is America’s Army\(^2\) in which the weapons and vehicles were models of the real thing. The US military invested 16 million dollars in this game which helped them recruit soldiers at 15% of the cost of other recruiting programs according to Susi, et al. [7]. Besides recruiting volunteers, the game helped pre-training people. Also, after adding a new extension, it was used in preparing for missions.

Serious games in military training enhance soldiers’ abilities such as: better eye-hand coordination, multitasking, ability to work in a team using minimal communication and willingness to take aggressive actions [7].

B. Educational games

Educational games are designed to teach people about certain concepts, to help them learn a new skill, to understand a historical event or a culture, etc. These games became widely used in the 1990s together with the evolution of technology. The quality of the games was poor, they were referred to as “educational software lightly sprinkled with game like interfaces and cute dialog”, as reported by Zyda [8], so the interest for them soon decreased. This made game developers move from the idea of presenting paradigms in their games to a situational approach. Still, games in education are not as widely used as in other domains, mainly because producers need to provide research evidence of the acclaimed benefits.

C. Healthcare games

Healthcare is a particular domain in which serious games best apply. The concept of “health” has been used in most games, describing the state of a character: his “health” is lower if he gets injured and it increases when performing some actions.

Healthcare is a wide domain, therefore areas where serious games can be applied are also wide [7]:

- Education in self-directed care – games teach nutrition skills and healthy eating habits. They can also help patients adjust their lifestyle to deal with their diseases.
- Distraction therapy – to help chronically ill children deal with pain, distract them from uncomfortable treatments.
- Diagnosis and treatment of mental conditions.
- Physical fitness – promoting physical activities.
- Training and simulation – gives doctors a way to practice surgeries.
- Cognitive functions – memory training.

III. GAME BASED LEARNING

Game based learning (GBL) is a type of gameplay which has certain learning outcomes. It is designed to balance the learning objective with the gameplay. There are many theories that state the benefits of games. For example, van Eck [1], discusses Piaget’s concepts of assimilation and accommodation. When assimilating, one fits new information into existing categories, while accommodation implies modifying the own existing model to accommodate new information that doesn’t fit in an existing category. These two concepts are highly related to cognitive disequilibrium [1] which greatly impacts the learner’s experience. Good games create cycles of cognitive disequilibrium and accommodation, but they also let the player be successful.

There are three approaches for integrating games into the learning process [1]. First, professional game development usually takes longer (up to two years), but it integrates learning and design. This approach offers the player a wide variety of resources because the quality and functionality must be comparable to the other games available on the market. Second, students build games from scratch; in this way the students learn programming languages and gain problem-solving skills by developing the algorithm. This approach has

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1 www.arcade-history.com/?r=battlezone&page-detail&id=210
2 aa3.americasarmy.com
been limited only to the domain of computer science. Third, the purpose change of entertainment games consists of taking existing games that are not developed for gaining knowledge and use them as learning games. The advantages of this method is that it is the most cost-effective approach, can be used in any domain and it leaves the design of the learning process up to teachers. On the other hand, because they are not developed to teach, each game has to be analyzed in order to eliminate the inappropriate content and the weaknesses.

**A. Game attributes**

Several game features, presented in the Summit of Educational Games [9], can be implemented in order to improve the outcome of education and training:

- **Clear learning goals** – in a serious game, the user should know why s/he is learning several concepts and where he can apply that knowledge.
- **“Broad experiences and practice opportunities that continue to challenge the learner and reinforce expertise”** [9] – the world in a game should not be represented as an enumeration of abstract concepts, but as a virtual place where users can experience a set of feelings or actions which are unavailable to them in real life. This may mean, for example, looking into the DNA structure or performing surgical procedures. The game can be played over and over again until the user gains the required skills.
- **“Continuous monitoring of progress, and use of this information to diagnose performance and adjust instruction to learner level of mastery”** [9] – games should monitor the progress of the user and give him feedback by rating his actions. A suggestion here is to add levels to the game so that the user keeps track of his progress.
- **“Encouragement of inquiry and questions, and response with answers that are appropriate to the learner and context”** [9] – games should motivate players to try to learn more, seeking information or game strategies from web sites, friends or other gamers.
- **Contextual Bridging** [9] – many games only teach the user concepts or theories, but they are missing the way the player will use the knowledge. For example, when learning a foreign language, one must take into account the situations where the language skills will be used. A cook must first know the name of the ingredients and of the terms used in recipes rather than conversational terms.
- **Duration of tasks** – a game should capture the attention of the user and still allow him to finish the task in a reasonable amount of time.
- **Motivation** – motivation makes players continue playing the game although they have failed in finishing one task. This is probably the most important attribute one game should have to keep players connected in the game.
- **Scaffolding** – games should provide a tutorial and a few hints during the game, to help beginners achieve skills.
- **Personalization** – games should be personalized using the knowledge background of the target public.

**B. Learning effects**

Depending on the game content and theme, game teach users how to improve their existing skills, learn new ones, expand their cognitive abilities, or learn how to behave in new situations. A list of skills that can be taught through games consists of [9]:

- **Strategic thinking** – users can learn how to exploit their opponent weaknesses, how to make his strategy considering the geographic position and landscape, etc.
- **Resource management** – most games of civilization and city building allow the user to interact with people, money, food and natural resources and learn how to manage all of those.
- **Decision making** – the scenarios change quite rapidly and the user must make decisions.
- **Compromise, relation management and leadership** – are present mostly in multiplayer games.
- **Commerce and negotiation** – are also present in multiplayer games.
- **Practical skills** – can be exercises in an environment where users learn without the fear of damaging expensive equipment or risking lives. In this category are simulators for different machines (cars, aircrafts, and space simulators), actions on the human body (surgery, chemical reactions), etc.
- **Training for crisis** – like natural disasters, terrorist attacks etc.
- **Military training.**
- **Team building** – some games focus on information sharing, forming relations between people, solving problems under pressure, improving communication.

**IV. GAMEPLAY**

In Seeker, the user controls Ted, the protagonist, from a first person perspective as he is trying to rescue his friend, Rosalie, who mysteriously disappeared during a laboratory test. The main character is Ted, a scientist working on a secret governmental project, searching for time travel solutions. One late night, while doing some experiments, Ted and his colleague, Rosalie, discover a way to create small portals and transfer objects back in time. Considering this breakthrough, they go out to celebrate.

Without telling Ted, Rosalie goes back to the laboratory the same night, continues the experiments and succeeds in building a bigger portal. The next morning, when Ted goes to work, he finds the laboratory ravaged and Rosalie missing. The only clue left for Ted is a note from Rosalie saying “I did it!” and a blue butterfly that sits on the broken test tubes. Ted decides to solve the mystery and find Rosalie, so he starts looking for more clues.
In the tutorial mode, Ted discovers some dark circles on the floor, very similar to those made by their portals which he and Rosalie used to transport small objects. His goal is to follow Rosalie’s steps and create bigger portals, which could transport human beings. The purpose of this level is to find a way to create portals.

Once the portal is built, Ted must prepare for his journey. Because he doesn’t know where the portal will take him, he must be prepared for any unexpected situation. That is why he takes some food, water, medicines and tools to help him on the way. Ted can choose which tools to take with him, the amount of water and food and what type of medicine he might need; but he must hurry, because the energy of the portal is diminishing and the portal might vanish. The tutorial mode ends with Ted passing through the portal.

A. Inventory

During the game, Ted carries a backpack in which he can store a limited number of items, like weapons and tools that help him pass the challenges of each level, food, water and medicines. Food and water help Ted survive, keep his energy level up, and medicines keeps him healthy. At first, Ted’s backpack contains only the items that he took from his laboratory. Along the way, he can upgrade the backpack to sustain more items that he can craft, find or receive. At every moment, Ted must have in his backpack food, water and medicines, or else he might get sick and even die.

B. Helpful items

One of the first items that Ted finds is a pair of gloves which help him move objects without harming his hands and without losing too much energy. The gloves are not essential to the game; the user can pass the levels without them, but with the risk that Ted will spend more time moving the items and he will need extra medicine afterwards. Another helpful item is the portal-builder or, as Ted calls it, Pete. Ted builds Pete from scratch, using the items that he collects during the first levels of the game. Being rudimentary, Pete can only create small portals, through which Ted can’t pass, but can grab or deposit objects. Clothes are another helpful item; they protect Ted from the weather. Even though he can only wear one set of clothes at a time, Ted can craft clothes to keep him warm, to protect him from insects, or to stand high temperatures.

C. Portal “ingredients”

Ted builds his first portal from purified ingredients that he carefully filtered in his laboratory. But on foreign land, when his resources are running out, he must improvise and find the ingredients, in one form or another, in the game scene. The ingredients that Ted mixed were: oxygen, crystal powder, gold powder, volcanic rock, maple syrup and energy. Along the game, Ted realizes that he only needs three types of elements to create a portal: minerals, energy and something liquid. Minerals can be found in resources like crystal powder or volcanic rock and can be combined to obtain colorful portals.

D. Puzzles

The purpose of the game is to build portals to travel from one place to another, but for that Ted needs materials. Finding materials is not an easy job, for this he needs to fulfill some tasks:

- **Overlap frequencies** – based on the ingredients, the portal created can be stable or less stable. For the less stable ones, Ted needs to overlap the portal’s frequency with the one of the first portal and make then resonate.
- **Moving boxes** – some levels require using the gloves and move several boxes in order to find objects or to unlock doors.
- **Opening small portals** – Once Ted’s backpack is full, the user can choose to solve a puzzle in order to open a small portal where Ted can deposit items. If the portal’s purity is low, there is a bigger chance for Ted’s items to be stolen or replaced by the portal masters. The user is shown three portals and the ingredients from which each portal is created. Based on his memory, the user must choose one portal and place the items there. He will be informed if the portal masters stole Ted’s items.
- **Find food and water** – in order to survive, Ted must find eatable resource. For food, he can pick berries or fruit, collect eggs or hunt. Water is easier to find, but he needs to filter it.
- **Craft tools** – various tools can be crafted: knives, bow and arrows, needles for sewing, water filters, etc.
- **Help villagers** – some of the villagers found on the way may ask Ted to craft materials, start a fire, help them move things faster, etc., in return for the items Ted needs.
- **Create medicines** (potions) – Ted learns from villagers how to prepare potions and medicines, and reproduces the steps later in his quest.

V. DEVELOPMENT

Seeker was developed using Unity³, a cross-platform game engine that enables easier and faster implementation of video games for PC, mobile devices, consoles and websites [10]. The main advantage of Unity consists of a simplified development workflow encompassing drag-and-drop objects, game preview window, on the fly change of objects’ properties, etc. Objects have attached behaviors, defined in any of three languages that can be used concurrently, into the same project: C#, JavaScript or Boo.

Seeker’s goal is to teach users how to improve their existing cognitive skills. The user controls Ted, the main character, from a first person perspective. This way, the user gets connected to the game and bonds emotionally with the characters. One of the most important aspects of a serious game [7] is that the user knows what s/he is supposed to learn and where s/he can apply the new knowledge [9]. In Seeker, these core mechanics are achieved by situations that mirror the

³ https://unity3d.com/
real world in which the user needs to find adequate resources in order to survive and progress throughout the game.

For example, the tutorial level (see Fig. 2) teaches the user how to build his first portal, how to collect and discard items. The user can play the scenes in any order, but there may be moments when a scene depends on the completion of another one or one scene can help the user pass others easily. By collecting evidence, Ted finds out the elements Rosalie used in making the portal and that it required a large amount of energy.

Resource collection can be done before portal creation step, but if the user consumed all resources without creating a portal, he must go back to Ted’s house to find more resources. If the inventory is already full, that means the user must let go some items.

Behind the scenes, the interaction is done by intersecting a bounding box with a ray cast from the player controller. Each interactive object has a bounding box and a corresponding type attached. Depending on the type, there are two ways of interacting: adding it to inventory and moving to a different scene (see Fig. 3).

Resource management and decision-making are the first skills to practice. Ted’s inventory is limited, having only allowed a maximum of 10kg. Therefore, the user must decide which items to carry: food, water, medicines, books etc. Food has different properties, inducing similar behaviors to real life (e.g., eating fruits improves hunger and thirst; sweets boost the energy, but are not healthy). The second skills to practice are attention and problem solving, used within the mini-games that need to be solved in order to collect portal resources.

VI. VALIDATION STUDY

Seeker is an educational game categorized under casual games [11]. This means that it is easy to play, users do not require gaming skills and can start playing immediately. Therefore, the target for the game is casual users. They do not invest time in developing a character or reaching its maximum level, but seek to finish the game and complete the story.

By considering the specific type of game, 25 gamers of ages ranging from 23 to 30 years were asked to play the game and to participate in a survey to see whether the game achieves its learning goals (see Table I). The posttest questionnaire was structured into four sections: player profile, general game impressions, consumable items, and usability. The last three parts of the survey targeted game features. It was important to know if the users enjoyed the game and if they considered obvious the game target, as well as the steps required for completing the first level. Each participant interacted with the game individually during a single session that was not time restricted. Therefore, participants progressed at their own pace; some of them returned to a specific game scene several times, while other moved linearly within sub-sequent scenes.

**TABLE I. SURVEY QUESTIONNAIRE**

<table>
<thead>
<tr>
<th>Q1</th>
<th>Did you enjoy playing Seeker?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q2</td>
<td>The aim of the game is clear / confusing</td>
</tr>
<tr>
<td>Q3</td>
<td>Have you had the feeling that you do not know what to do next?</td>
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<tr>
<td>Q4</td>
<td>The difficulty of the puzzles was low / medium / high</td>
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<tr>
<td>Q5</td>
<td>Was it clear that you had to build a portal to go to the next level?</td>
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<tr>
<td>Q6</td>
<td>Was the capacity of the inventory too low?</td>
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<tr>
<td>Q7</td>
<td>Was it clear what kind of objects Ted needs for his journey?</td>
</tr>
<tr>
<td>Q8</td>
<td>Was it clear that Ted needs food and water to keep his energy?</td>
</tr>
<tr>
<td>Q9</td>
<td>Was it clear that Ted loses energy on each action he does?</td>
</tr>
<tr>
<td>Q10</td>
<td>Was it easy to find the first ingredients for the portal?</td>
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<tr>
<td>Q11</td>
<td>Was it easy to find the combination of ingredients for the portal?</td>
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<tr>
<td>Q12</td>
<td>What was the difficulty of the puzzle when creating the first portal? Low / medium / high</td>
</tr>
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</table>

Overall, results are promising (see Table II) as all the users agreed that they had enjoyed playing our game and that the inventory’s capacity was sufficient. Moreover, users easily observed that Ted needs water and food to survive and that he consumes energy while performing tasks, just like in real life. Also, a positive feedback was received for the resource collection mechanism. The adding operation to inventory was clear, but more than 90% of the users did not know a priori what kind of resources should be added. All of them got water and food because of the thirst and hunger bars, but were
overwhelmed by the food variety. Only 10% of the users took highly caloric food (e.g., sweets or soda) in order to keep their energy level up, while other 6% took meat and cheese.

**TABLE II. STUDY FEEDBACK RESULTS**

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>1</td>
<td>All users enjoyed playing Seeker</td>
</tr>
<tr>
<td>2</td>
<td>Inventory capacity was sufficient</td>
</tr>
<tr>
<td>3</td>
<td>Positive feedback was received for the resource collection mechanism</td>
</tr>
<tr>
<td>4</td>
<td>Lack of scene ordering was considered confusing</td>
</tr>
<tr>
<td>5</td>
<td>Laboratory scene was considered too complex</td>
</tr>
<tr>
<td>6</td>
<td>The difficulty of the puzzle was considered too low</td>
</tr>
<tr>
<td>7</td>
<td>Users did not know what kind of resources to collect</td>
</tr>
<tr>
<td>8</td>
<td>Portal ingredients were too easy to find</td>
</tr>
<tr>
<td>9</td>
<td>The combination of portal ingredients was too hard to find.</td>
</tr>
</tbody>
</table>

In the end, the goal of the level consisting of building a time portal was clear to 84% of the users, while the rest of 16% considered it confusing and needed extra information. On one hand, portal ingredients were too easy to find for all users, as they stated that the difficulty level of the puzzle was overall quite low. On the other hand, the combination of ingredients for the portal was hard to find, as many users complained about the lack of hints. Even though all users discovered all the game scenes, 56% of them considered it confusing to have explored the scenes in an un-ordered manner and had problems figuring out the next step of the game.

Overall, the users’ rankings have shown a high reliability among the raters. Cronbach’s Alpha [12] of .977, as well as the Intraclass Correlation Coefficient [13] of .629 prove that the validation results are reliable. Moreover, the user feedback was grouped based on the game scenes:

**Laboratory**

Users considered the laboratory scene too complex as there are multiple options for changing scenes from this point (see Fig 4). Basically, any scene can be accessed from the laboratory. This is why many of the users went directly to the portal creation area without firstly visiting the explosion area. A suggestion here was to enable the portal creation interaction only after visiting the explosion area and collecting the resources.

**Ted’s house**

As seen in the upper diagram, this scene is also accessible from the laboratory. Almost 20% of the users visited this scene twice. First, they went here and did not add anything into inventory, but afterwards realized they needed resources for portal creation. A similar solution to the previous laboratory scene issue can be applied here: disable interaction until the user visits the portal creation scene. Secondly, users had difficulties choosing which items from the fridge to add to the inventory. There is no clue what kind of resources Ted needs in his journey. Players asked for some hints or a puzzle to help them decide what to take.

**Explosion area**

Among the provided puzzles, the maze depicted in Fig. 5 was considered too simple. Users stated that if they hold the “UP” arrow key and slightly press “LEFT” or “RIGHT” keys, the player controller finds its way through the maze. Furthermore, users considered that not all portal ingredients should be found in the same place. There could be 3 different puzzles for finding each resource type.

**Portal creation**

As stated previously, all users considered difficult finding the correct combination for the portal in the scene from Fig. 6. They requested a different approach in which additional hints are provided and users are further guided in their interaction.
VII. CONCLUSIONS AND FUTURE DEVELOPMENTS

Seeker is a serious game that focuses on enhancing the users’ cognitive abilities through different mini-games and puzzles that require resource management, decision-making, memory, attention, and problem solving. Each of these cognition abilities was targeted in the tutorial mode, where the user interacts with the resource management system (the inventory), plays the first puzzle and creates a portal that leads him to the next level. Overall, Seeker provided an enjoyable experience while keeping the user connected in the game. Decision-making and resource management are exercised through the inventory system, while attention and problem solving were rehearsed through mini-games.

The game software was tested using a series of test cases that covered multiple areas: installation, UI testing, feature testing, and performance and stress testing. The result was a list of bugs that will be implemented in the next phase of the project. User feedback was collected by conducting a survey on 25 gamers. They were asked to play Seeker and complete a post-test questionnaire. All of them enjoyed the game, but were confused by the lack of scene ordering. All the tutorial game scenes were enabled by default and that led to users going to the portal creation scene without firstly discovering the ingredients used by Rosalie in creating the portal. This feedback, together with the bugs raised from testing, will be implemented in the next phase of the project.

All gathered feedback will be implemented in the next version of our game. Future development includes increasing the number of puzzles, of hints and adding new game scenes. Also, a new concept will be incorporated in the game, collaborative puzzle solving [15]. Each puzzle of the game will be posted on the Seeker web page, enabling users to share their solution or to ask questions or potential hints.

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