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Developing Serious Game Design Guidelines Based on a State-of-the-art Review

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Developing Serious Game Design Guidelines Based on a State-of-the-art Review

Serious games have become more common, and they are often used for educational purposes. For these games, VR technology has become a useful tool for creating alternative training environments. This raises the question of which game design choices would best optimize the learning effect. The purpose of this thesis was to research design guidelines for educational serious games and recommend design changes for three existing game modes of a simulation game called PaimioVR, which teaches players to change electricity pole insulators. The research review revealed that Multimedia Learning Theory contained the most promising state-of-the-art guidelines for developing educational serious games. Design elements from the PaimioVR game were collected and compared with research findings. This formed the basis of the design change recommendations for the game. While the single-player mode followed most of the theoretical recommendations, the same was not true for the co-op, or competitive modes, both of which had minor shortcomings in the game tutorial. A common deficiency for all the game modes was a lack of final evaluation at the end of the game. While PaimioVR has some room for improvement, it still follows most of the good design principles to support learning and its different game modes allow some flexibility with players. Finally, it is recommended to further research the effect a timer may have on player behavior and learning.

Keywords:

Serious games, learning, game design

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Hyötypelien suunnitteluohjeiden kehittäminen huippuluokan katsauksen perusteella

Hyötypelit ovat yleistyneet ja niitä käytetään usein opetuksellisiin tarkoituksiin. Näille peleille VR-teknologiasta on tullut hyödyllinen työkalu vaihtoehtoisten harjoitteluympäristöjen luomiseen. Siksi on hyvä pohtia, mitkä pelisuunnittelun ratkaisut tukisivat parhaiten oppimista. Tämän opinnäytetyön tarkoituksena oli tutkia opetuksellisten hyötypelien suunnitteluohjeita ja suositella muutosehdotuksia kolmeen olemassa olevaan pelimuotoon PaimioVR-simulaatiopelissä, joka opettaa pelaajaa vaihtamaan sähköpylväiden eristeen. Opinnäytetyössä saatiin tuloksena, että lupaavin ohjeistus opetuksellisten hyötypelien kehittämiseen oli multimedian oppimisteoria. PaimioVR-pelistä kerättiin suunnitteluelementit ja niitä verrattiin tutkimustuloksiin. Tämä loi pohjan pelin muutossuosituksille. Vaikka yksinpelitila noudatti useimpia teoreettisia suosituksia, sama ei pätenyt yhteistyö- ja kilpailullisissa pelimuodoissa, joissa molemmissa oli pieniä puutteita pelin opastuksessa. Yleinen puutos kaikissa pelimuodoissa oli loppuarvioinnin puute pelin lopussa. Vaikka PaimioVR:ssä on parantamisen varaa, se silti noudattaa suurinta osaa hyvistä suunnittelukäytännöistä oppimisen tukemiseen ja sen erilaiset pelitilat mahdollistavat joustavuutta pelaajien kanssa. Työtä voisi jatkaa tutkimalla tarkemmin ajastimen vaikutuksia pelaajien käyttäytymiseen ja oppimiseen.

Asiasanat:

Hyötypeli, oppiminen, pelisuunnittelu

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1 Glossary

Competitive agent	An entity that the player competes against, for example, another player.
Competitive game	A game where two or more players compete with each other.
Co-op game	Co-op is short for cooperative game where two or more players cooperate with each other to progress the game.
Educational game	A game that is created for educational purposes to teach something specific to the player.
Narrator	An entity withing a game that explains the game or story within game for player.
PvP	Short for player versus player and refers to game mode where the players compete with each other.
Serious game	A game designed for educational or other useful purposes, unlike normal games that are for entertainment.
Single player	A game mode where only one player plays the game.
Unity 3D game engine	A physics engine intended for game development, developed by Unity Technologies.
User interface	User interface or UI for short refers to visual and auditory elements player or user interact with when using software.
VoIP-Support	Short for voice over internet protocol support which can be used, for example, support voice chat in games.

VR	Short for virtual reality. Virtual reality is a computer-generated environment where players can interact with objects in the game in similar ways to the real world, creating a sense of immersion.

1 Introduction

All kinds of games exist as do different game mechanics. However, there still remains the question of which design solutions are best for learning purposes. In this thesis we research best practices for serious games to support learning. Based on the findings, we aim to create design change recommendations for an existing serious game.

The commissioner of research was the Futuristic Interactive Technologies (FIT) research group at Turku University of Applied Sciences who wanted to improve the learning experience in an existing educational virtual reality (VR) game. The game is designed to teach players how to replace an insulator on an electricity pole. The Commissioner hoped to receive design change recommendations based on state-of-the-art serious game mechanics. These recommendations were intended for three different game modes: single-player, player-versus-player (PvP), and cooperative (Co-op) multiplayer.

In the following chapters, we will go through previous studies highlighting their key findings which we will use later as basis for our design change recommendations. Next, we will introduce the game used in our research, followed by our proposed design improvements. Finally, we will discuss how the impact of these changes should be evaluated in future studies.

2 Serious games and their design considerations

The multimedia learning theory by Moreno and Mayer (2003) was developed on three assumptions: dual-channel assumption, limited-capacity assumption and active-processing assumption. Dual-channel assumption assumes that humans have separate systems to process pictorial and verbal data while limited-channel assumption indicates that those channels have limited capacity for information processing. Meaningful learning, however, involves the active-processing assumption whereby substantial amounts of cognitive processing in visual and verbal channels (Mayer & Moreno 2003). Based on multimedia learning theory Moreno and Mayer (2003) introduce nine ways to reduce cognitive load (Figure 1).

Load-Reduction Methods for Five Overload Scenarios in Multimedia Instruction

Type of Overload Scenario	*Load-Reducing Method*	*Description of Research Effect*	*Effect Size*
Type 1: Essential processing in visual channel > cognitive capacity of visual channel			
Visual channel is overloaded by essential processing demands.	Off-loading: Move some essential processing from visual channel to auditory channel.	Modality effect: Better transfer when words are presented as narration rather than as on-screen text.	1.17 (6)
Type 2: Essential processing (in both channels) > cognitive capacity			
Both channels are overloaded by essential processing demands.	Segmenting: Allow time between successive bite-size segments.	Segmentation effect: Better transfer when lesson is presented in learner-controlled segments rather than as continuous unit.	1.36 (1)
	Pretraining: Provide pretraining in names and characteristics of components.	Pretraining effect: Better transfer when students know names and behaviors of system components.	1.00 (3)
Type 3: Essential processing + incidental processing (caused by extraneous material) > cognitive capacity			
One or both channels overloaded by essential and incidental processing (attributable to extraneous material).	Weeding: Eliminate interesting but extraneous material to reduce processing of extraneous material.	Coherence effect: Better transfer when extraneous material is excluded.	0.90 (5)
	Signaling: Provide cues for how to process the material to reduce processing of extraneous material.	Signaling effect: Better transfer when signals are included.	0.74 (1)
Type 4: Essential processing + incidental processing (caused by confusing presentation) > cognitive capacity			
One or both channels overloaded by essential and incidental processing (attributable to confusing presentation of essential material).	Aligning: Place printed words near corresponding parts of graphics to reduce need for visual scanning.	Spatial contiguity effect: Better transfer when printed words are placed near corresponding parts of graphics.	0.48 (1)
	Eliminating redundancy: Avoid presenting identical streams of printed and spoken words.	Redundancy effect: Better transfer when words are presented as narration rather narration and on-screen text.	0.69 (3)
Type 5: Essential processing + representational holding > cognitive capacity			
One or both channels overloaded by essential processing and representational holding.	Synchronizing: Present narration and corresponding animation simultaneously to minimize need to hold representations in memory.	Temporal contiguity effect: Better transfer when corresponding animation and narration are presented simultaneously rather than successively.	1.30 (8)
	Individualizing: Make sure learners possess skill at holding mental representations.	Spatial ability effect: High spatial learners benefit more from well-designed instruction than do low spatial learners.	1.13 (2)

Note. Numbers in parentheses indicate number of experiments on which effect size was based.

Figure 1. Five overload scenarios and nine ways to reduce cognitive load (Mayer & Moreno 2003).

2.1.1 Feedback

Feedback is an important way to support learning. Feedback should be immediate, positive and corrective with visual cues and minimal text (Boyce et al. 2013). Research by Erhel and Jamet (2013) in Digital Game-Based Learning: Impact of Instructions and Feedback on Motivation and Learning Effectiveness highlights that providing corrective feedback enhances cognitive processing, strengthens memory retention, and ultimately improves learning outcomes. While feedback should be corrective, it should not simply highlight the solution for problem or point out player's mistake, but it should guide the player toward the correct approach. Additionally, rewarding players for positive achievements can enhance motivation. Games should also provide proper and precise evaluation of players' performance (Bellotti et al. 2011).

2.1.2 User interface

A serious game interface should be appealing to the player to encourage them to play the game. From a pedagogical point of view, however, it is important to identify relevant and irrelevant functionalities. These functionalities should be displayed in appropriate places and times according to their visibility. Appropriate use of audio is also important for fostering learning (Bellotti et al. 2011).

2.1.3 Tutorials

Good tutorials help the player to learn how to play the game. The faster the player learns the game mechanics, the faster the player can focus on learning from the game instead of focusing on how to play. In Practices of Making Game Tutorial. Chen (2021) has identified three key approaches to designing game tutorials: the "flashcard," the "follow-to-do," and the "tutorial mode." These methods provide structured ways to introduce players to game mechanics and

enhance the learning experience. A flashcard is a pop-up screen which displays information and often pauses the game. Flashcards should be designed to take up only the necessary space to avoid breaking player immersion. They should also be positioned near the relevant graphics to ensure clear and contextual guidance. A follow-to-do tutorial guides the player to complete actions simultaneously. The tutorial mode is usually accessed from the main menu and serves as a space where players can practice game mechanics. The tutorial mode is best suited for teaching complex mechanics. The choice of tutorial type should be based on the specific needs of the game (Chen 2021).

2.2 Competition

In How Does Competition Help Future Learning in Serious Games? An Exploratory Study in Learning Search Engine Optimization, Lee, Lui, and Chau (2019) examine the impact of competition in games. Their research indicates that competitive elements affect perceived challenge and perceived control, leading to higher self-efficacy. Consequently, features such as leaderboards and badges should be incorporated into serious games (Lee et al. 2019).

2.2.1 Competitive agents

When playing a competitive game, it is important what players compete against. In Competitive Agents and Adaptive Difficulty Within Educational Video Games, Nebel, Beege, Schneider, and Rey (2020) examine three competitive learning agents: “human competitive agent, artificial competitive agent and artificial leaderboard competitive agent”. Their research revealed that competitive agents increased players' engagement in the game, indicating competitive agents' usefulness for learning purposes. Human competitive agents increased player engagement most while leaderboard was least effective (Nebel et al. 2020).

2.2.2 Player versus Player (PvP)

Competition is an important factor to help realize a player's enjoyment in the game. Players' feelings to compete against each other create competitive situations and lead to player engagement. It is advisable for game developers to create a situation where the positive behavior of players negatively affects an opponent while negative behavior has a positive effect, which, in turn, has a positive effect on a player's attention level (Sekhavat 2020).

2.3 Co-op

The sense of playing with other players can affect the gaming experience. When a game includes collaborative elements that require players to act simultaneously to progress, it encourages coordinated behavior. These kinds of game elements can raise the players' attention level higher compared to a single player (Sekhavat 2020).

2.3.1 Communication

Communication is an important aspect in cooperative games. That is why it is important to consider how players can communicate with each other within the game. Depending on the game's needs, VoIP-support should be considered. Gameplay should encourage players to communicate, since players can communicate differently depending on whether they already know each other or not. Those who already know other players communicate more easily with each other (Buchinger & Hounsell 2018).

2.3.2 Sub -mechanics

In Game mechanics in the design of a collaborative serious 3D game, Oksanen and Hämäläinen (2014) introduced seven sub-mechanics: "spatial isolation,

shared space, shared object, encrypted information, complementary action, indirect action and flexible strategies", to further in-game cooperation among the players. Spatial isolation encourages social interaction while shared space creates interdependence. Shared object and encrypted information, which players need to interact with for completion, promotes interaction between players. Complementary action challenges a player's problem-solving ability and awareness of others when a problem cannot be solved alone. Indirect action refers to situations where a player is given information that requires other player's action to get reward. Flexible strategies make it possible for players to develop their problem-solving abilities through collaboration and coordination (Oksanen & Hämäläinen 2014).

3 Research prototype use case

PaimioVR is an educational virtual reality simulation game made with the Unity 3D game engine. In the game, the player is trained to change electricity pole insulators. The training takes place on an imaginary forest path where the player's goal is to climb the electricity pole and replace a broken insulator using tools they find on their virtual world tool belt. Currently, the game has three game modes: (a) single-player; (b) co-operative; and (c) player-versus-player. The FIT research group commissioned an investigation into the three existing application modes to recommend changes to further improve the learning for each.

3.1 Single player mode

In the single player mode, the player is instructed how to complete the task step-by-step by a narrator. To complete the exercise, the player must complete all instructed tasks. The tasks include climbing the pole, making sure that there is no current in the wire, removing broken insulator and replacing it. The player reward mechanics include the time-taken and successful insulator replacement (Komscha 2024).

3.2 Cooperative mode

In the co-op mode, the narrator is replaced by another player who has a clipboard with updated instructions. Using the clipboard, the second player instructs the first player throughout the exercise until all tasks have been completed. Both players must be in the same room to be able to communicate because currently the game does not have any built-in chat or voice chat. Before players start the exercise, they can familiarize themselves with the tools found on the table. Once one player has picked up all the tools and the other

player has the clipboard, they can start performing the exercise (Komscha 2024).

3.3 PvP mode

In the PvP mode, players compete against each other. Both players receive clipboards so they can check the next task themselves. Players also receive wristwatches so that they can track their time. Once all tasks are completed, times are compared and the faster one wins. Similar to the co-op mode, players can familiarize themselves with the tools before starting the exercise. The exercise starts once both players are properly equipped and have marked themselves as ready (Komscha 2024).

4 Design findings and recommendations

Based on the literature review, the following design changes recommendations were compiled (Table 1). However, it is worth noting that the game is simple and straightforward, which has affected some design decisions.

Table 1. Design change recommendations.

Existing mechanics			**Recommended changes**		
Design element / Mechanic	**Existing mechanic**	**Theoretical rationale for Recommendations**	**Solo**	**Co-op**	**Comp**
Tutorial/ narration	Voice guide, step by step instructions	Reduce cognitive load, for example: move some essential processing from visual channel to auditory channel. Short bursts of just-in-time instruction with visual cues and minimal text.	Align with recommendations rationale.	Add this to tutorial mode to explain the goal of the game and for guiding players through the tutorial.	Add this to tutorial mode to explain the goal of the game, scoring system and guiding players through the tutorial.
Tutorial (Tutorial mode)	In the tutorial, players familiarize themselves with tools / mechanics independently	Important to have a well-made tutorial to teach gameplay. Suitability of different kinds of tutorials depends on the game. Add tutorial to teach gameplay mechanics.	Include this.	Add visible names for all tools on table and voiced name when picked up from table.	Add visible names for all tools on table and voiced name when picked up from table.

Existing mechanics			Recommended changes		
Design element / Mechanic	**Existing mechanic**	**Theoretical rationale for Recommendations**	**Solo**	**Co-op**	**Comp**
Collaboration	No voice guide (other player take that role) (2 players)	Sub-mechanics: spatial isolation, shared space, shared object, encrypted information, complementary action, indirect action, and flexible strategies. Gameplay should strongly induce communication if working with collaborative aspects.	-	Add voice chat.	-
Competitive element - Score	Timers for tracking personal time for both players	Use competitive or collaborative game mechanics to increase players' attention level.	-	-	Keep timer as the secondary scoring system and add new score based on correct actions/ answers. Wrong answers reduce the score gained from correct answer. Repeated wrong answers reduce points only few times. Add a global leaderboard. Prioritize score instead of time for the rankings.

Existing mechanics			Recommended changes		
Design element / Mechanic	**Existing mechanic**	**Theoretical rationale for Recommendations**	**Solo**	**Co-op**	**Comp**
Evaluation of performance - feedback	Winning time shown to players	Provide users with a proper evaluation of their performance. Add feedback supplying the right answers. Feedback should also be immediate and positive.	Corrective, positive feedback on mistakes. Evaluation at the end should show areas where correct actions and mistakes were made.	Corrective, positive feedback on mistakes. Evaluation at the end should show areas where correct actions and mistakes were made.	Score and time should be trackable during game. At the end, show individuals their own time, score and where mistakes were made.

5 Recommendations for future research

In the future, the addition of a timer and its effect on player behavior should be studied further. Players can behave differently when pressured with time, and this might affect their learning. For example, some players might use a trial-and-error approach to achieve a fast completion time. This could be tested with two versions of the game, one with a timer and the other without. Both versions would need separate test groups, which test only their respective versions. Before players begin playing, they would take a pre-questionnaire to determine their knowledge of the subject and previous experience with VR. After the game, a post-questionnaire should be held, and the results of both game versions compared. During the gameplay, game data, such as how long a player took to complete individual tasks and the game, and how many incorrect actions the player made during the game between different tasks, should be recorded and analyzed. Results of this type of research could be helpful when designing future serious games with competitive elements.

6 Conclusion

The purpose of this thesis was to research game design recommendations for serious games and propose design changes for the educational game PaimioVR. The game's single-player mode followed most of the recommendations, while the PvP mode and co-op mode had some shortcomings with tutorials. The greatest issue with all game modes was the lack of a final evaluation after the game, so players could see and reflect on their in-game actions. There are many considerations when designing serious games, and the VR environment brings its own benefits and challenges. Therefore, it is recommended to involve users from the early stages of game development to produce a satisfying end product.

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