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Designing A Collaborative Serious Game For Team Building Using Minecraft

Viktor Wendel, Michael Gutjahr, Philipp Battenberg, Roman Ness, Sebastian Fahnenschreiber, Stefan Göbel, Ralf Steinmetz
Technische Universität Darmstadt, Darmstadt, Germany
viktor.wendel@kom.tu-darmstadt.de
gutjahr@psychologie.tu-darmstadt.de
p.battenberg@googlemail.com
us93buza@rbg.informatik.tu-darmstadt.de
uh93ozoc@rbg.informatik.tu-darmstadt.de
stefan.goebel@kom.tu-darmstadt.de
ralf.steinmetz@kom.tu-darmstadt.de

Abstract: For collaborative learning scenarios to be successful many factors are necessary, like group formation, the setup of the group task, and the team members' ability and willingness to work or collaborate in a team. With easily moddable sandbox games like Minecraft being available today, new opportunities for Serious Games arise, especially in the field of multiplayer games. Due to the popularity of games like Minecraft, we believe that both acceptance and usability of mods based on such a game are rather high.
In this paper, we propose an approach for a game-based solution of collaborative learning. This approach focuses on soft skills, especially communication as well as on improving both the motivation and the ability to collaborate and work in a team. We created a Minecraft mod for a collaborative gaming experience focusing on solidarity and teamwork. We designed a special obstacle course for a set of four players using especially designed game mechanics to improve collaboration skills. Communications skills are required as well as the ability to work in a team in order to win the game.
Our hypothesis is that the mod can be used as a team forming and motivational tool in the context of collaborative learning by increasing the willingness to collaborate with other people by playing the game. We performed an evaluation in which seven groups of four random players (total 28 participants) played our game. Before and after the gaming session, the players played a version of the prisoners' dilemma game in order to test their willingness to cooperate before and after playing the game. In a control group, participants worked together at solving a puzzle instead.
Results show that our Minecraft mod provides a better game experience and group experience than a non-digital game with cooperative aspects. It also shows the impact of the participants' working and social background in terms of an initial willingness to cooperate.

Keywords: Serious Games, Collaborative Learning, Minecraft

1 Motivation

Serious Games have arrived in various parts of today's learning environments (Sports & Health, opinion forming, advertisement, or learning). Various Serious Games for learning, or Digital Educational Games, exist today for use in schools or in higher institutes of learning. While many of these games have been specifically designed as Serious Games, in recent years a new form of creating Serious Games has emerged. Modding APIs (Minecraft) or game/level editors of successful games (e.g. Neverwinter Nights, Starcraft 2) enable easy and rapid development of Serious Games. One prominent example is MinecraftEdu[1], which was created as a modification to Minecraft for use in the classroom.
The concept of collaborative learning is being used in schools and institutes of higher learning as well as in various training scenarios today, ranging from mere group works over concepts like mutual teaching (learning by teaching) to collaborative working on complex projects. In the classroom collaborative learning is used as an addition and an alternative to traditional learning. Whereas soft skills like the ability to work in teams and to communicate with group members are vital, they can be trained specifically by using collaborative learning principles.
So, it seems promising to combine the concept of Serious Games with the concept of collaborative learning. Games, especially multiplayer games, inherently offer many of the features which are necessary for collaborative learning to be successful, like common goals, or the necessity to communicate with fellow players. In previous work, we described first approaches for collaborative

[1] minecraftedu.com/

multiplayer Serious Games focusing on either collaboration itself (Wendel et al. 2013) or for using such a game for learning specific contents (Wendel et al. 2010).
In this paper, we propose a new approach for designing collaborative multiplayer Serious Games with the purpose of training soft skills, focusing on the ability and the willingness to collaborate and to work in a team. This concept is based both on previous work, and on concepts for collaborative learning (Johnson and Johnson 1994) and for collaborative gaming (Zagal et al. 2006). Our hypothesis is that our game design can be used to create games which encourage collaborative and team focused behavior and subsequently for a training of those soft skills.
We decided to implement these concepts by creating a Minecraft mod. The basic functionality is identical with Minecraft, thus enabling an easy access. Our hypotheses are as follows: A digital serious multiplayer game for cooperation...

1. ... provides better user experience for the player ...
2. ... leads to more trust in the other group members ...
3. ... leads to more cooperative behavior ...

...than a common game that includes aspects of multiplayer cooperation (e.g. a puzzle).
We performed an evaluation with 28 participants. One group played our game for 25 minutes. A second group of participants worked together at solving a puzzle game for 25 minutes instead of playing our game. Results showed, that the participants were much more willing to collaborate using our game.

2 Related work

2.1 Digital Educational Games
In the field of Digital Educational Games, or game-based learning, the research is mainly focusing two aspects: Motivation for the use of Serious Games for learning, and Serious Game design. The use and potential of Serious Games has been argued by (Gee 2003), (Prensky 2003), (Squire 2003) and (Van Eck 2006) in terms of learning, or (Delwiche 2006), (Steinkühler 2004), or (Mansour and El-Said 2008) in terms of Serious Games design. (Harteveld 2011) provides useful guidelines looking at the design process from the three dimensions reality, meaning, and play. A Serious Game design document is provided in (Bergeron 2006).

2.2 Collaborative Learning
This work is mainly based on concepts derived from (Johnson and Johnson 1994) which identified five essential elements which foster cooperative work in face-to-face groups. (Zea et al. 2009) provide first concepts for introducing collaborative learning techniques into educational video games. Apart from that approach, Computer-supported Collaborative Learning (CSCL) research mainly focuses on e-learning tools, like shown in (Onrubia and Engel 2009), or (Larusson and Altermann 2009). Concepts from those traditional CSCL fields of application might be transferable to Serious Games, too.

2.3 Motivation in Games
(Prensky 2002) argues that games can provide the necessary motivation for people who otherwise are not properly motivated to learn. However, in order for (Serious) games to be motivational, they need to fulfill several requirements. The game needs to provide the right amount of challenge (Gee 2003), (Lepper and Henderlong 2000). The concept of '*Flow*' as first proposed by (Csikszentmihalyi 2000) and later refined especially for games by (Sweetser and Wyeth 2005) becomes important in this context.

2.4 User Experience and Collaboration
User experience is a versatile construct that describes the whole experience a user has by playing a game (Nacke 2009). This includes aspects of cognition, emotion, physiology, etc. This is to say many aspects like positive and negative emotion, cognitive load and arousal, usability, immersion and flow (and many more) are part of this experience. To measure trust and cooperative behavior we used the prisoner's dilemma game approach of (Sheese and Graziano 2005). This approach allows differing between trust and cooperative behavior.

2.5 Creating Games with Minecraft
Today, Minecraft is already being used in various projects in schools (Duncan 2011), (Bayliss 2012), (Levin 2011), (Shifter 2012). The most prominent example is MinecraftEdu, a modification of Minecraft especially for a use in the classroom. As an official modding API is not yet released, the most

promising alternative is the use frameworks Bukkit[2] and Spout[3]. As tutorials and documentation are very rare, the most important resources are the respective APIs. Using the Spoutcraft client instead of the original Minecraft client, client-sided modifications are also possible without touching the client itself. The complete modification is done inside a server-sided plugin similar to Bukkit.

3 Approach

3.1 Game Design Foundations

Our game design is based on the five essential elements which according to (Johnson and Johnson 1994) foster cooperative work in face-to-face groups:

- *Positive Interdependence*: knowing to be linked with other players in a way so that one cannot succeed alone
- *Individual Accountability*: individual assessment of each student's performance and giving back the results to both the group and the individual
- *Face-to-Face Promotive Interaction*: Promoting each other's success by e.g. helping, encouraging and praising
- *Social Skills*: Interpersonal and small group skills are vital for the success of a cooperative effort
- *Group Processing*: Group members discussing their progress and working relationships together

We also take into account the rules and pitfalls as to regard when designing collaborative games as stated by (Zagal et al 2006):

- *Lesson 1:* To highlight problems of competitiveness, a collaborative game should introduce tension between perceived individual utility and team utility.
- *Lesson 2:* To further highlight problems of competitiveness, individual players should be allowed to make decisions and take actions without the consent of the team.
- *Lesson 3:* Players must be able to trace payoffs back to their decisions.
- *Lesson 4:* To encourage team members to make selfless decisions, a collaborative game should bestow different abilities or responsibilities upon the players.
- *Pitfall 1:* To avoid the game degenerating into one player making the decisions for the team, collaborative games have to provide a sufficient rationale for collaboration.
- *Pitfall 2:* For a game to be engaging, players need to care about the outcome and that outcome should have a satisfying result.
- *Pitfall 3:* For a collaborative game to be enjoyable multiple times, the experience needs to be different each time and the presented challenge needs to evolve.

The use of these fundamental elements for a game design for collaborative multiplayer Serious Games is described in more detail in (Wendel et al. 2013). In this paper, we address how a game can be designed based on these rules and guidelines in order to create a collaborative multiplayer game specifically for enhancing teamwork and collaboration.

3.2 Game Design for Team Building

Based on the foundations stated in the previous section, we derived the following game elements for creating a necessity for collaboration inside a team-based multiplayer game. Our design is for a team of four players.

3.2.1 Minecraft (sandbox) mechanic

By the nature of the game, players are able to control their character in the way they want. They cannot be forced to certain decisions. At several points throughout the game, players will have to choose between selflessly helping the team (by getting themselves into danger) or staying safe. However, the team can never force one player to do something. This implements *Lesson 2*.

[2] http://bukkit.org/
[3] http://get.spout.org/

3.2.2 Creation of a common goal
The players are provided with a background story telling them what they need to do in order to win the game and what failure means. The players' task is to save the 'last gnome on earth' (idea from the *Left For Dead 2* gameplay mutation). If they are not able to save that gnome in time, the game will be lost. There are only two possible outcomes: victory and failure. By providing the players with such a narrative background, a foundation for the fact that players need to care about the outcome is created. This way we address *Pitfall 2*. Moreover, it becomes clear that the game cannot be won alone. If the players achieve their goal, they all won, if someone fails, the whole team fails. This refers to *Positive Interdependence*.

3.2.3 Player Separation
According to (Reuter et al. 2012), '*Player Separation'* is a concept for multiplayer puzzles. In our concept, we use player separation to prevent one player from being able to solve all tasks (*Pitfall 1*). When players are physically divided only those players being present at position x can solve the respective puzzle there. Thus, we also address *Lesson 4*; we bestow players with different abilities, whereas the abilities are based on their location.

3.2.4 Gnome Handling
The handling of the gnome is vital for the game mechanics. Only one player at a time can carry the gnome. This player will continuously slow down until he/she cannot move at all. Furthermore, this player cannot jump. This mechanic forces players to hand over the gnome between each other in order to be able to move the gnome forward and to overcome certain obstacles. This mechanic implements *Positive Interdependence* as well as *Lesson 1*. Players might always decide to take over the gnome (team utility), getting into danger of being caught by enemies following them or just to try to stay safe by not carrying the gnome. Here, it is important for players to learn about the consequences of their choices (*Lesson 3*). Staying safe while the fellow player, which is carrying the gnome, becomes too slow, thus getting caught by enemies might lose the game.

3.2.5 Team Highscore
At the beginning and at the end of a game session, the players can see the highscore including their own score provided they won the game. This rather simple method prevents *Pitfall 3*, as it creates a motivation to beat the highscore, thus to play the game again. As the collaborative puzzles are changing from game session to game session, the challenge is renewed each game, making another game session interesting, again.

3.2.6 Need for Communication
Resulting from the player separation, players often possess information which the other part of the team needs (see Section 3.3). This makes communication inevitable. Also, telling another player that he/she needs to take over the gnome is necessary. Several puzzles require the players to coordinate their actions (see Section 3.3), thus making communication essential. This requires *Social Skills* and *Group Processing*. During this procedure, also *Face-to-Face Promotive Interaction* takes place.

We did, however, not directly incorporate *Individual accountability* into our design, as is seems rather counter-intuitive to reward selfish actions. Furthermore, it should not be important which player pressed a button but rather that the team figured out which button to press together.

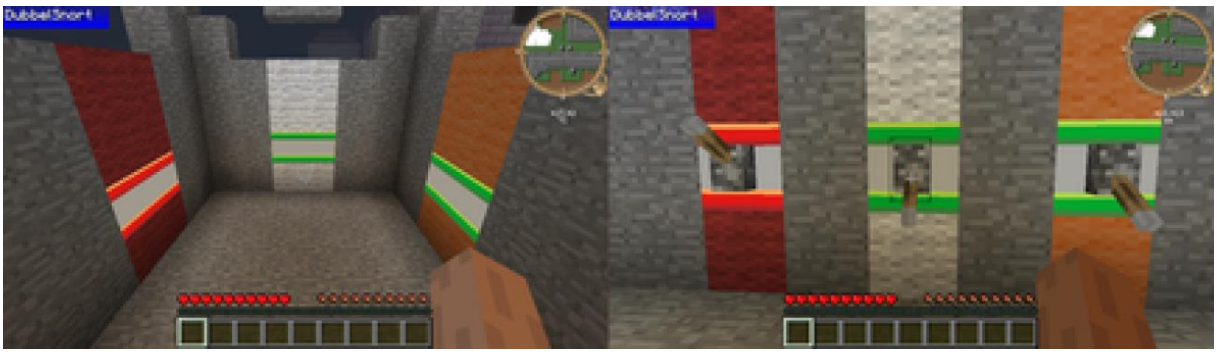

Figure 1: Colored Lever Puzzle

3.3 Collaborative Puzzles

The collaborative puzzles we designed are based on the concepts for multiplayer puzzles as described in (Reuter et al. 2012). We make use of the concepts of *'Player Separation'* and *'Heterogeneous Resources'*. Using these, we designed the following puzzle types:

- *Lever Puzzle*: This puzzle is based on player separation. Players of both parts need to pull levers in order to open doors, etc. This simple puzzle prevents single players from being able to advance alone.
- *Lever Color Puzzle*: An extension to the previous puzzles is coloring levers. Players need to know which levers the have to pull. The information is given to the other part of the team such that they need to find that information and provide their teammates with it. The information is a resource which at first is only available to one part of the team (see Figure 1).
- *Gnome Button*: We introduce a special button which can only be pressed by the player possessing the gnome. This supports the *'Heterogeneous Resources'* feature.
- *Simple Math Puzzle*: Again, using division of information, we designed math puzzles in the form of: *'Find d*'. Hints are given in the form of *'d = c + 5*', *' c = b -3'*, *'b = a + 1'*, and *'a = 8'* with one part of the team having the first and the third hint and the other part having the other hints. This puzzle can only be solved if the team can give information back and forth.
- *Heavy Block*: At some points, the players need to place a block in order to create a step to climb. Therefore, a heavy block needs to be moved from a starting point to its destination. The player carrying the block cannot move so that the players need to form a human chain to pass the block on. This requires all four players to move and work together.
- *Difficult Terrain*: This puzzles type requires the gnome to be carried to several locations to press the gnome button there. The terrain is designed in a way such that one has to move a long way alone. However, handing over the gnome at special locations shortens the distance drastically. This requires all four players to move and work together.

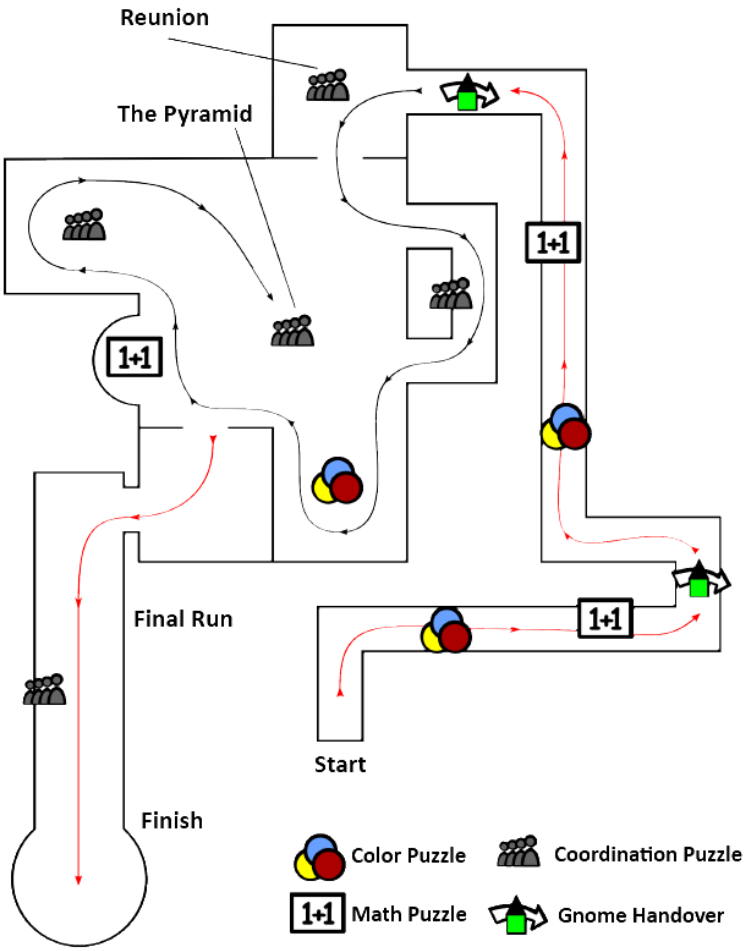

Figure 2: Schematic level overview

4 Implementation

4.1 Spout and Bukkit

As it seemed reasonable to be able to use our Mod with future Minecraft versions, we decided not to mod the Minecraft client itself, but instead to use the Bukkit framework. This way, it is possible to create a Mod which can be used together with other available mods due to the modularized use of mods in the Bukkit framework. The access to the client is limited without modding the client itself. Therefore, we decided to use spout, which is a framework enabling multiplayer Bukkit plugins with an access to the client when using the SpoutCraft client. The SpoutCraft client is a modified version of the Minecraft client. Thus, using the SpoutCraft client and SpoutPlugin as a plugin for Bukkit, a server-side API for client side changes is available.

4.2 Level Design

All players start the game together in one room. From there they can decide which two players will walk through the hallway carrying the gnome. The remaining two players will help them from upstairs. Once two players used the one-way teleporters towards the gnome hall, and they pick up the gnome, the game actually starts. The players then move along the hallway as shown in Figure 2. Throughout the game, the players will solve colored-levers-puzzles (colored circles), math puzzles (numbers). At the points with the gnome symbol, the gnome is handed over to the other two players, effectively switching roles. The icon with the four players means that the *'Player Separation'* is revoked and all four players meet to solve a task. The pyramid is a puzzle where all players need to build stairs with heavy steps by forming a human chain. During the red arrow parts, the players are under time pressure, as they are chased by zombies. This is in the beginning during the colored-lever-puzzles and the math puzzles and in the last part as to create a thrilling finale. Players need to run while being chased by zombies. They need to hand over the gnome frequently while pulling a lot of levers in order to open doors. Moreover, the terrain is difficult in this part so that handing over the gnome becomes more vital.

4.3 Modded Features

Following, we describe in detail the main features which were created for this mod in order to implement our game design.

4.3.1 Building Restrictions

Free placement of blocks as well as destroying blocks was forbidden. This was necessary in order to prevent players from creating shortcuts.

Figure 3: Gnome Sockets

4.3.2 Gnome Handling

To prevent deadlocks due to Minecraft game mechanics (i.e. items despawn (disappear) after a few minutes when dropped), it was forbidden to throw or drop items. The gnome and the heavy blocks are passed from one player to another by clicking on the receiving player if he/she is close enough. In addition to that, special gnome related blocks (sockets) have been created. In Figure 3, those blocks are shown: from left to right:

- *StartSocket:* Players receive the gnome from there
- *SleepSocket:* The gnome can be placed there (this is used for puzzles where all four players need to be able to move)
- *SleepSocket with gnome:* The gnome can be taken back from there
- *EndSocket:* The players need to bring the gnome there to win the game

4.3.3 Logic Elements

The most important part of our mod is the logic-packet. It enables the freely definable combination of levers and buttons with doors and triggering of events without the 'redstone'-related delay[4]. Our logic system is based on two elements: triggers and responses. They are connected via a context. A context can have more than one trigger or response. They can be connected via logical ANDs and ORs. Whenever a trigger is fired, it sends an event to its context which checks the logical condition and sends a signal to the responses if the condition becomes true (see Figure 4).

4.3.4 Zombie Control

Our game design requires some sort of pressure at some points in the game. We create that pressure in form of time pressure. The players need to solve puzzles while being chased by zombies. Zombies are entities which are originally available in Minecraft. Therefore, a ZombieManager package was created providing functionalities for spawning zombies at desired locations, despawning zombies, setting targets and movement speed.

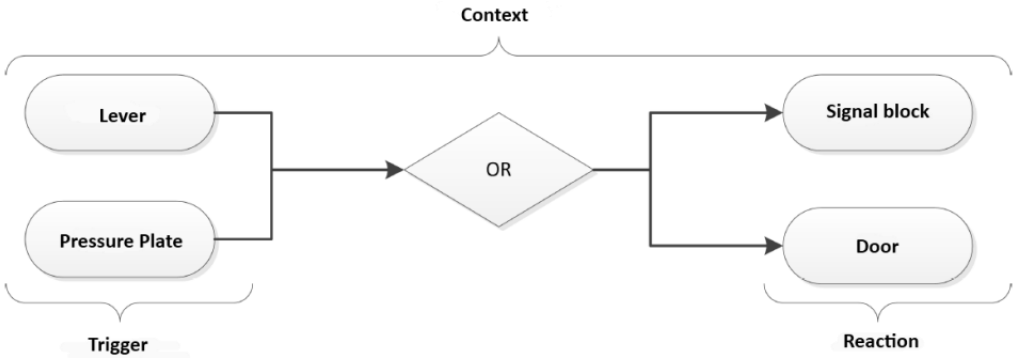

Figure 4: Logic Control

5 Evaluation

5.1 Participants

28 participants attended the study. Their age ranged from 21 to 45 years (*m=25.81; sd=5.16*). Two were female, 24 were male, two more did not name their age and gender. The mean time of playing video-games a week was *9.04* hours (*sd=10.64*).

5.2 Design

The study has a 2-factorial design between subjects. The independent variable is the kind of cooperative game (puzzle/ Minecraft). As dependent measurement a user experience questionnaire, a questionnaire asking for the quality of group-cooperation and a version of the prisoner's dilemma game was used (see Table 1).

Table 1: Prisoner's Dilemma Game

	Own decision	
Decision of other player	Share	Do not share
Share	Small candy	Choice of big candy
Do not share	nothing	Small random candy

[4] 'Redstone' is part of the vanilla Minecraft used to create logical circuits

5.3 Stimuli

The two games used were our Minecraft mod and a puzzle consisting of 2000 parts. The user experience questionnaire includes 7 sub-scales of user experience (negative emotion, positive emotion, cognitive load, motivation, immersion, flow and arousal). Each sub-scale includes three items (e.g. frustration, anger, boredom for negative emotion). Each of these items has to be answered on a 10 point scale. An evaluation of 145 of these user experience questionnaires using different games and settings showed a Cronbach's Alpha of *.93*, this is to say the questionnaire is measuring one homogeneous construct.

The group-cooperation questionnaire is based on the design elements for collaborative multiplayer Serious Games presented in (Wendel et al. 2012). It includes items like *'the communication in the group was good'*.

The prisoner's dilemma game has been conducted with the reward system shown in Table 1. The game includes two questions: At first, in respect to (Sheese and Graziano 2005): *'please mark with a cross the answer you think your opponent will choose*'. This enables to differ between uncooperative behavior that is caused by fear (of the opponent's choice) and hostility. The second question was *'please mark with a cross the answer you like to choose*'. In contrast to common versions of the prisoner's dilemma game the opponent was unknown (chosen randomly from the group members) because it is aimed to measure trust in the group and not in a specific person.

5.4 Aggregation

For the evaluation the data has been aggregated as followed. For each participant the mean of the items of the UX and the group cooperation questionnaire was built. For the prisoner's dilemma game the deviation between the two rounds was build. Therefore *cooperate* was rated with a value of '*+1*' and not cooperate was rated with a value of '*0*'. The value of the second round was subtracted from the value of the first round. So, participants who did not change their behavior had a value of '*0*', those how chanced from cooperate to not cooperate have a value of *'-1'* and those changing from not cooperate to cooperate have a value of *'+1'*.

5.5 Analysis

To analyze the data a two tailed ANOVA (between subjects) with the kind of game as independent measurement has been conducted for each depended variable (UX Questionnaire, group-cooperation questionnaire and the prisoner's dilemma game).

5.6 A Priori

It was more fun (*F(1,22)=3.73; p=.066*) to play the Minecraft Mod (*m=6.70; sd=0.90*) than to play the puzzle (*m=5.85; sd=1.23*). The group-interaction has been rated more positive (*F(1,22)=3.94; p=.060*) by playing the Minecraft Mod (*m=8.15; sd=0.70*) than by playing the puzzle (*m=7.43; sd=1.05*). Neither the expectation of the behavior of the other nor the own chooses of the prisoner's dilemma game are different in dependency of the kind of game (*p>.20*).

5.7 Discussion

5.7.1 Hypotheses

We hypothesized that our digital multiplayer game will lead to a better user experience than a common non-digital game with cooperative aspects. In fact, the user experience questionnaire as well as the group-cooperation questionnaire showed that the experience was better while playing the digital multiplayer game. So this hypothesis seems to be true. We also hypothesized that the digital multiplayer game will lead to more trust in the group members as well as to more cooperative behavior. But trust and behavior did not differ between the two games - so this hypothesis has to be rejected.

5.7.2 Shortcoming

One reason for the not significant differences in the prisoner's dilemma game may be the sample of the participants. Students and lecturers were accustomed to cooperative work. In this case they were even accustomed to each other. So they mostly started the prisoner's dilemma game with 'cooperate' and ended with 'cooperate' as well. In fact, 20 of the 24 participants did so. This assumption is also based on the cooperation values showing a mean value of *7.43* for the puzzle and a mean value of *8.15* for the game (on a 10 point scale). One could conclude that initial group-cooperation and trust was very good throughout all groups - perhaps too good to be improved by a 25 minute lasting game.

6 Conclusions

In this paper, we presented an approach for a multiplayer Serious Game for enhancing teamwork abilities. Our game design is based on design guidelines found in literature. It is designed in a way to support collaborative behavior in a game through the overall setup, special collaborative puzzles and the use of mechanics like player separation and heterogeneous resources.

We implemented our design as a Minecraft Mod. We decided to create a plugin for Bukkit using Spout-Plugin. Thus, we created a Minecraft level based to our game design. We also created an editor in order to enable further level creation for non-programmers. We evaluated our concept using our Minecraft Mod prototype.

Results showed that our Minecraft Mod provides a better game experience and group experience as a non-digital game with cooperative aspects. But to show a significant increase of trust and cooperative behavior a sample of participants might be required, that is not familiar to each other and therefore will not be so trustful to each other right from the start.

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