Space Connection - A Multiplayer Collaborative Biofeedback Game to Promote Empathy in Teenagers: A Feasibility Study

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Abstract: Biofeedback videogames are physiologically driven games that offer opportunities to individually improve emotional self-regulation and produce mental and physical health benefits. To investigate the feasibility of a novel collaborative multiplayer methodology, we created *Space Connection*, a videogame to promote empathy in teenagers. *Space Connection* depicts a futuristic adventure aboard a spaceship in which players have to jointly use their powers to solve a set of physics-based puzzles. The game relies on the use of physiological self-regulation to activate the playing partner powers. Using a low-cost brain computer interface and a respiration rate sensor we provided players with two game powers, namely telekinesis and time-manipulation which are mapped to changes in attention and relaxation. In this paper we describe the game mechanics in three different scenarios: i) the cryogenic room, ii) the space ship corridor and iii) the cargo hold. Finally, we performed a feasibility study with 10 users (aged 22.2 ± 5.6) to evaluate the game experience. Results revealed high scores in enjoyment and empathy but low scores on interface control. Our preliminary data supports the use of novel biofeedback strategies combined with videogames to promote positive emotions and incentive collaboration and teamwork.

1 INTRODUCTION

Recent surveys show that more than 90% of Americans between the ages of two to seventeen play video games (NPD Group, 2011) and that a total of 22.41 billion US dollars were spent in 2014 on content, hardware and accessories in the US alone (Entertainment Software Association, 2015). The growing importance of videogames in teenager culture has raised multiple concerns, of which the effect of violent contents in games such as *Grand Theft Auto or Call of Duty* on player behavior gained most of the attention in the popular press and was the focus of a large number of studies exploring both the negative impact of videogames on teenagers: violence, addiction and depression (Nakaya, 2014), (Anderson et al., 2007) and the health benefits of playing videogames (Granic et al., 2014), (Mishra et al., 2016, p.)

Studies have shown the potential of novel videogame-based therapies to improve psychological and physical factors in teenagers and the impact of videogames in multiple health-related domains such as the development of cognitive skills (Anguera and Gazzaley, 2015), fitness and exercise promotion (Guy et al., 2011), adherence to treatment (Kato et al., 2008), pain management (Jameson et al., 2011) and self-regulation. Furthermore studies conducted by Johnson et al. (2013) and Jones et al (2014), have shown the positive impact of videogames on mental wellbeing with potential for benefit in domains such as positive emotion, emotional stability, self-esteem, optimism, vitality, resilience, engagement, and competence.

Biofeedback is a novel interaction mechanism that offers a way to control, quantify and boost the health benefits produced during gaming experiences. Biofeedback takes advantage of physiological signals to train voluntary self-regulation thus promoting physical and mental wellbeing. Using biofeedback, videogame interaction is physiologically driven and can be used to help overcome the monotony of classic biofeedback training (Pope et al., 2014). Examples of recent and commercial biofeedback training systems blended in videogames are: The Journey of Wild Divine (Wild Divine, Las Vegas, USA), NeverMind (Flying Mollusk, California, USA) and Focus Pocus (NeuroCog, Wollongong, Australia). A study

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conducted using *Focus Pocus* revealed efectiveness in improving behavior and reducing symptoms of ADHD in chinese children (Jiang and Johnstone, 2015).

A physiological modulation training program teaches players to integrate physiological self-regulation in order to get mastery in the game. More recent biofeedback investigations have envisioned a multiplayer games that harness physiological modulation technologies for creating new opportunities to collaborate, cooperation and competion in videogames through biofeedback (Pope et al., 2014). Since 56 % of gamers play a multiplayer game at least once a week (ESA, Entertainment Software Association, 2015), there is an opportunity for the development of positive, socially engaging biofeedback multiplayer videogames.

2 RELATED WORK

Traditionally, biofeedback videogames have been limited to a single-user interaction where game parameters are modulated only by the self-regulation of their own physiological signals. The addition of the social aspect has been proposed in biofeedback videogames in two different game design paradigms: collaborative and competitive.

2.1 Collaborative Biofeedback

Many researchers emphasize that collaborative multiplayer dynamics can increase the engagement level of players optimizing any learning effect (Zea et al., 2009). D'Ornellas and colleagues proposed a multiplayer perspective into a videogame-based rehabilitation treatment (d'Ornellas et al., n.d.). They used a biomechanical biofeedback approach, where a Kinect sensor is used to analyze the optimal position of the upper limbs in a videogame for hemiparesis rehabilitation. In the collaborative multiplayer mode, players are challenged to collect as much virtual fruits as possible to achieve a target defined by the therapist. Biomechanical measurements are independently showed in real-time while users are collaborating together to achieve a common goal. Similar projects have been developed to encourage a synchronized work in rehabilitation tasks using multiplayer game dynamics (Tang et al., 2015), (Rubio Ballester et al., 2012).

A system to create two different game roles in a multiplayer biofeedback experience is proposed by Pope and colleagues (Pope and Palsson, 2011). The first role is called the physical operator and will be responsible to provide a physical activity control via conventional game controllers. The second role is called the physiological operator and its function is to modulate the game through physiological activity measured by body sensors. The collaborative effort arises when the system modulates the game controllers of the physical operator using the physiological signals of physiological operator. In this way, the game performance could be either limited or boosted via the self-regulation skills of the other player.

The concept of collaborative multiplayer has been used in several serious games to promote collaborative learning showing user's improvements in leadership, decision making, trust-building, communication and conflict-management skills (Wendel et al., 2010).

2.2 Competitive Biofeedback

In a competitive game environment, any knowledge about the human opponent can give an important advantage to win the game. Using brain computer interfaces (BCIs), a game called Brainball was developed to have two players competing. The goal was to achieve a relaxation state in order to win the game. The competition is made more interesting by adding a visualization of the players' performances that control a ball moving on a table placed between the players. Brain activity of players is measured and compared to determine the direction of the ball (moving into the direction of the player who is less relaxed) (Hjelm and Browall, 2000). The addition of visualization has a clear impact in the player's game performance providing both, positive and negative effects (Nijholt, 2015).

A different strategy relying on the physiological signals to provide information that is used to balance the videogame via helping the player with lower game performance was addressed by Stach and colleagues (Stach et al., 2009). They used a heart-rate modulated videogame to change the speed of a virtual car in order to close the fitness gap between players. Results demonstrated that the heart-rate scaling strategy reduced the performance gap between players with different fitness levels and the adaptive mechanism did not affect players' engagement.

3 SPACE CONNECTION: PHYSIOLOGICAL APPROACH

To promote positive psychological emotions and behaviors in teenagers, *Space Connection* uses a multiplayer collaborative biofeedback approach to encourage teamwork and communication through empathy. We defined empathy in accordance to (Happ and Melzer, 2014) as "an emotional response that stems from another's emotional state or condition and is congruent with the other's emotional state or condition". In *Space Connection*, players have to collaborate in order to achieve common goals by assuming the responsibility to activate their partner's powers. Thus, we hypothesize that empathy comes through the need of understanding other's abilities. To facilitate the collaboration, we created a system with two physiological operators using brain signals and respiration rates. As described in (Pope and Palsson, 2011), this approach can make virtual tasks more engaging and hence more effective in training physiological self-regulation (attention and relaxation in this case). Studies have shown the importance of attention in creating empathy connections in virtual environments (Happ and Melzer, 2014). Neuroscientific investigations concluded that attention impacts empathic processing leading to positive changes in everyday interactions (Morelli and Lieberman, 2013). Moreover, studies have shown the effects of relaxing videogames in mood and social behaviors, indicating that playing relaxing videogames not only decrease aggression but also increase prosocial behavior (Whitaker and Bushman, 2012). Thus, relaxing videogames can help to promote positive mood states facilitating the collaboration between players in a multiplayer videogame.

The idea to activate the powers of each user using the partner's self-regulation skills aims to reinforce player's empathy and collaboration. *Space Connection* requires players to jointly solve puzzles through the collaborative use of physiologically-driven skills. Collaborative behaviors are rewarded by completing challenges in each game stage. Through these challenges, players learn how to deal with problematic situations by using his/her skills to support the other player's problems. Thus, the collaboration context of *Space Connection* exposes players to the synergetic effects of collaboration namely that what is jointly achieved is greater than the sum of each player contribution (Wendel et al., 2010).

In contrast to other cooperative approaches in where the problem is divided into sub-problems and each co-operator can solve one at a time, the collaborative approach require a coordinated effort to solve the problem together (Wendel et al., 2010).

4 METHODOLOGY

4.1 Videogame

4.1.1 Design and Implementation

Space Connection, is an online multiplayer collaborative biofeedback videogame in which players control their partner's power, and are challenged to solve game puzzles together. During gameplay, each player has to self-regulate his/her own physiological signals in order to enable their partner access to his/her special power, individual powers of telekinesis and time control. A head-up display element (power-bar) is used to show the power-level for each player (see figure 1). Thus, players can see both their own power-level and their partner's power level during the game. The powers can only be activated by reaching a 50 % threshold. Once this is achieved, the power bar turns green and players are allowed to use their powers.

Figure 1: Power bar used to display power's levels.

Space Connection was developed as a mod (modification) for the videogame *Garry's Mod* (Facepunch Studios, Walsall, UK), which is a first-person sandbox game with an unlimited set of wacky tools (Champion, 2013). The 3D game level design of a fictional spaceship was created with the map editor Valve Hammer Editor (Valve, Bellevue, USA). Then, with Unity 3D game engine (Unity Technologies), a software was developed to communicate the physiological signals to our modified Garry's Mod dedicated server. The RehabNet Control Panel (Reh@Panel) software (Vourvopoulos et al., 2013) was used to interface the physiological sensors with Unity.

In *Space Connection*, players learn by experiencing how to relax and improve self-control and also, how to stay focused in stressful situations. The videogame incentivizes teamwork by proposing different physics-based puzzles which, to be solved, require both players to jointly use their unique powers. Three different physics-based puzzles were created: i) the cryogenic room, ii) the spaceship

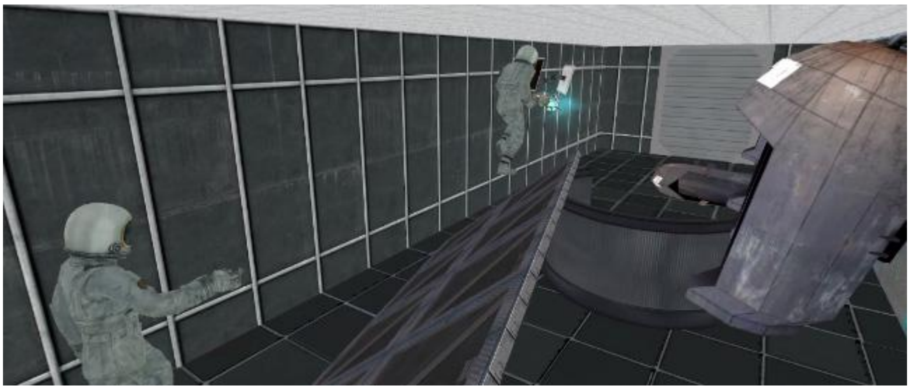

Figure 2: A screenshot of the Cryogenic Room. Players are separated by fallen debris in a futuristic spaceship.

corridor and iii) the cargo hold. After completing all puzzles, players gain access to the engine room and are able to finish the game.

- *The Cryogenic Room:* the game starts in a cryogenic room (figure 2) with the players separated by fallen debris and a blocked exit door. Here, players are encouraged to explore their powers and analyze the responsiveness of the physiological self-regulation in activating their partner's power. The objective is to remove the debris from the way and get out of the room. First, the telekinetic player has to use the gravity gun to clear a path to the big metallic door. To do that, the time-manipulator player has to reduce his respiration rate in order to give his partner access to telekinesis. After getting respiration rates below the 50%, the telekinesis power is activated and the telekinetic player can use it to move objects out of the way. After, both players can open the door, which leads them to a corridor.
- *The Spaceship Corridor:* The second physics-based puzzle proposed is the spaceship's corridor (figure 3A). In order to access the ship's control room and unlock the elevator, players have to avoid getting hurt by an electrical malfunction on the ship. There are damaged high-voltage electrical power cables on the floor and players must avoid contact with the deadly short-circuit. In order to solve the puzzle, players are required to use an object to create a bridge over the deadly shot-circuit. First, the time-manipulator player has to slow down the respiration rate to activate the telekinesis power. Then, the telekinetic player uses his ability to move objects beyond his/her reach and put platform over the wires. This gives the time-manipulator player a way to go over the wires as long as he/she maintains a relaxed state. As the telekinetic player cannot use the powers to raise him/her-self of the floor, the time-manipulator player has to use time-freezing capsules to freeze the improvised bridge so it is sustained over the electric accident, providing a safe path to cross. Therefore, the telekinetic player has to increase his/her attention levels for his/her partner's powers be accessible. In summary, both players have to use their powers to: i) raise an object in a controlled way and position it over the short-circuit and ii) freeze the object in time to facilitate the path. Finally, both users will have passed safely to the control room where the elevator door can be unlocked.
- *The Cargo Hold:* after unlocking the elevator from the control room, both players can now descend into the cargo hold, which can be seen as a sandbox level, with lots of dynamic objects to interact with (figure 3B). Because players are not constrained by time restrictions to achieve the final goal, the sandbox also serves as an open area in which the physiological modulation of each power can be freely explored. However, in order to complete the mission, players have to solve the last physics puzzle. It is required that the players gain access to a raised platform, where they will unlock the admission to the engine room back in the top level. The two players must do the unlocking at the same time. To achieve that, the telekinetic player has to place his/her partner in the first level of the raised platform. Then, the time controller player has to freeze some objects creating a path to facilitate the access to his/her colleague. Once both players are in the same platform level, they have to create a path of objects that will allow reaching the button to unlock the engines room. This is achieved by a synchronous and sustained regulation of their psychophysiological states: player is moving and rotating the objects to be

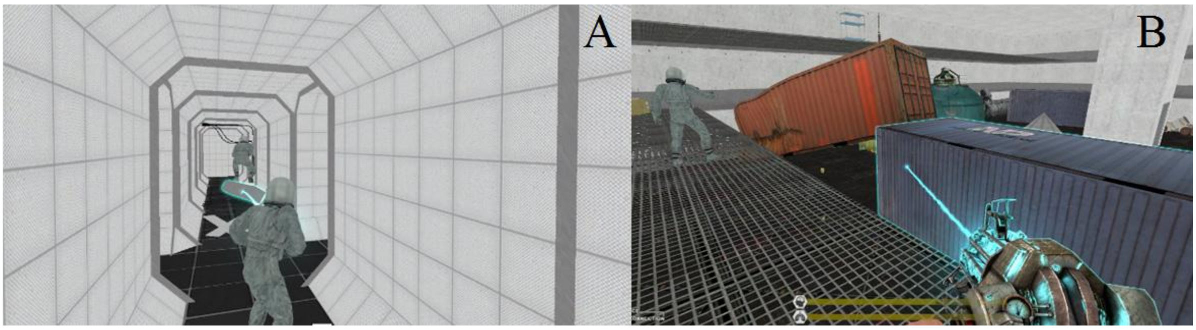

Figure 3: A. Screenshot of the spaceship's corridor. The telekinetic player is using his power to help the time-manipulator to overpass the short circuit. B. Screenshot of the cargo hold. The telekinetic player is using the power to move a container. The time-manipulator player is freezing the containers to create an accessible path.

used, the time controller player has to use the time-freezing capsules to lock these objects in a attention and relaxation. While the telekinetic way that the path will be effectively placed and accessible. Then, both users unlock the engine room and return to the elevator. The mission ends when both users arrive to the engine room showing a mission complete message.

4.1.2 Setup

The setup for *Space Connection* includes two PCs, two physiological sensors and a local server. Two different hardware systems were used for the two different game characters and player roles, defined by their unique powers (telekinetic and the time-manipulator). For the telekinetic player we used the MindWave (Neurosky), a low-cost BCI system to measure attention levels. The sensor has a dry electrode located in the central part of the frontal lobe and communicates with a computer via Bluetooth protocol. For the time-manipulator we used a piezoelectric respiration sensor connected to the Biosignal Plux toolkit (Plux Wireless Biosignals), a wearable body sensing platform. Figure 4 shows the setup for the *Space Connection* videogame.

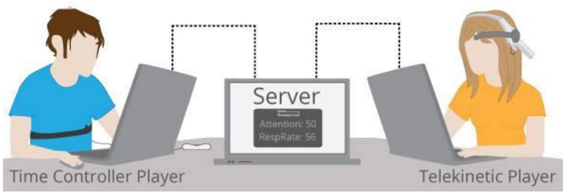

Figure 4: *Space Connection* setup.

An elastic strap is used to measure the displacement variations induced by inhaling or exhaling. The respiration sensor was used to map low frequency respiration values with time-freezing power. A local server runs the *Space Connection* standalone server, which is used to connect both players, Garry's Mod's clients, with each other, and enforce our modified game mechanics.

4.2 Physiological Signals

4.2.1 Respiration Rate (Time Control)

The respiration rate was used to compute the level of user's relaxation and thus to provide access to the time-freezing power. Relaxation and peaceful rest has been reported to lead slower and shallower respiration rates (Calvo et al., 2015). The sensor provides a respiration percentage by converting the values sampled for the sensor by the ADC (analog-to-digital converter) as follows:

$$PZT\ (\%) = \left(\frac{ADC}{2^n} - \frac{1}{2}\right) * 100\ \% \qquad (1)$$

Where *PZT* (%) is the displacement value in percentage, *ADC* is the value sampled for the channel and n the number of bits of the channel (16 bit-resolution in our case). Therefore, sensor values for inhalation are higher than for exhalation. The default sampling frequency of the respiration sensor is 1000 Hz. Considering the respiration signal as a quasi-static biosignal which exhibits relatively slow changes over the time (Kaniusas, 2012), the respiration signal was subsampled to 100 Hz to ease its processing. Then, the signal was detrended to focus the analysis on the fluctuations. A passband filter was implemented in Unity 3D using a high-pass and a low-pass filter with cut-off frequencies of 0.02 *Hz* and 100 *Hz* respectively. Finally, considering normative respiration frequency values for teenagers (West, 2012) which are between 12-30 Hz, the 30 Hz value was used as threshold to separate between relaxation and excitement (relaxation ≤ 30 Hz and excitement > 30 Hz). We then mapped those respiration frequencies to values in a 0-100 percentage scale. This scaling allowed us to create a subject-independent quantification of the respiration level. When exceeding the relaxation threshold, the time-manipulator player had access to his/her power, which provides the following ability:

1. Shoot time-freezing capsules that create a spherical field in which time is stopped for objects, structures and players.

4.2.2 Attention Levels with BCI (Telekinesis)

The attention level was measured by monitoring neurophysiological signals from the MindWave sensor. The MindWave sensor was preferred over other BCI sensors because it provides a "Sense Attention Meter" called eSense^{TM}, an algorithm which uses raw EEG data to indicate the intensity of a user's level of mental focus or attention, occurring in intense concentration moments. Distractions, lack of focus, wandering thoughts, and high anxiety levels may lower the attention levels.

MindWave enabled us to control the telekinesis power by mapping the attention levels on scale of 0 to 100. When attention levels are over the 50% threshold, the telekinetic player has the power of mind-control, implemented using Garry's Mod own gravity gun, which provides the following abilities:

1. Move objects at a distance (one at the time)
2. Pull objects closer or push them away
3. Rotate objects

4.3 Playtesting Evaluation

A playtesting session was carried out in order to evaluate the functionality of the physiological sensors in *Space Connection* as a feasibility study. Users were voluntarily recruited and the game dynamics were briefly introduced. The game was setup in an open space in a way that more people could attend the playtesting session. A custom questionnaire was designed to collect information related with the game experience and the usefulness perception. After around 30 minutes of interaction, the questionnaire's responses were gathered and individual-short interviews were performed. Eight items were evaluated in a custom 5-points-scale questionnaire (1-minimum, 5-maximum). The questions are listed in the table 1.

Table 1: Custom questionnaire developed for the playtesting session.

Question	Statement
Q1	Was the game fun?
Q2	How easy were the challenges in each level?
Q3	I feel that I know the other player better now than before playing the game.
Q4	How easy was for you to communicate your intentions with the other player?
Q5	I would play this game at home with my friends (even if my powers were not controlled by respiration/attention levels).
Q6	I feel that my respiration/attention control will be useful in my daily life.
Q7	This game helped me improve my respiration/attention control.
Q8	How easy was to control your attention/respiration levels?

5 RESULTS

A play testing session was carried out to evaluate the feasibility of the approach and player's reactions to Space Connection. A total of 10 subjects (8 males, ages 22.2 ± 5.6) played the videogame. Considering the number of users, only descriptive statistics were performed. Questions were grouped in the following dimensions (figure 5): Q1- enjoyment, Q2- perceived difficulty, Q3- empathy perception, Q4- ease of collaboration, Q5- replayability, Q6- ecological usefulness perception, Q7- usefulness perception and Q8- ease of control. Results revealed high levels of enjoyment (4.5) and ecological usefulness perception (4.3), which is related to what extent users think the self-regulation skills are useful in a real-time scenario. The in-time usefulness perception (usefulness perception) revealed low scores (2.9) as well as perceived difficulty (2.7).

Additionally, participants were individually asked to list preferences and dislikes. All participants stated that they enjoyed the experience and the game design concept. As a reason for these preferences they mentioned greater challenge, exciting technology and originality. 3 users highlighted the physics of the game showing that the game engine was suitable to provide a realistic experience. Related with that, one user mentioned: "I liked the responsiveness and interactivity with objects in the game", referring to the use of the powers to move objects. 5 users found

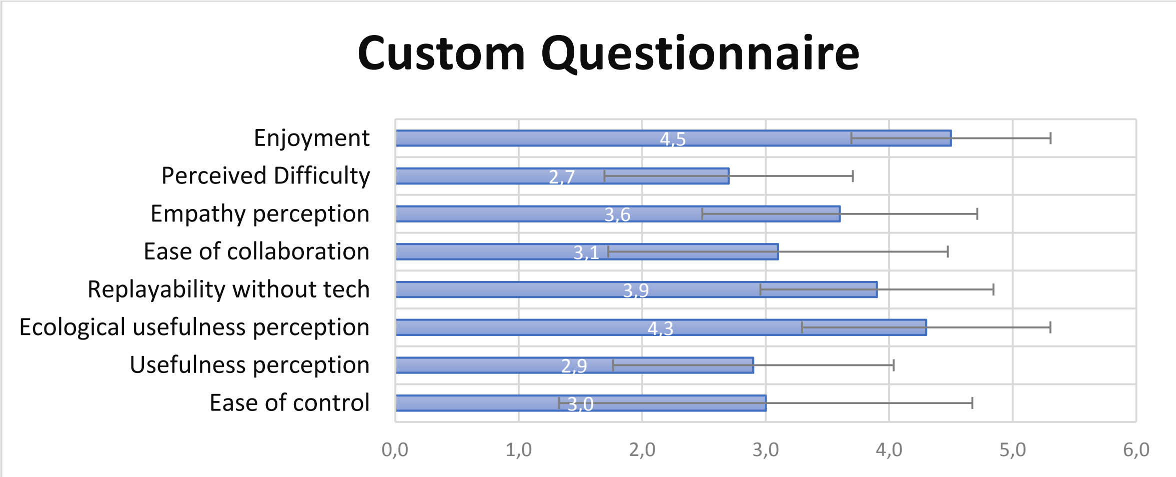

Figure 5: Results from the custom questionnaire applied in the playtesting session.

that multiplayer features such as communication, in-time discussions and teamwork were positive for gameplay. This behavior was intended because the aim of our collaborative multiplayer biofeedback approach was to provide a vehicle to incentive pro-social behaviors. 3 players stated that they felt good by disturbing their partners and 2 players reported being mad during the interaction due to bugs caused by server/connection fails (a good internet connection is needed to facilitate a fluid interaction). Further, 3 players pointed out as dislikes the lack of clear and well-defined goals in the game, as well as 3 players reported negative feelings (frustration and impotence) during the interaction. As a reason for these feelings they stated that the physiologically-driven inputs were difficult to control.

To conclude, collaboration, game originality and responsiveness were some of the more preferred game elements. On the other hand, the lack of clear goals and the perceived difficulty to control the interfaces were the less preferred game factors.

6 DISCUSSION

In this paper we described the design, development and feasibility testing of *Space Connection*, a collaborative biofeedback multiplayer videogame aiming to encourage teenagers to create and reinforce a sense of bonding and empathy. The videogame links two different physiological signals to the characters' powers: telekinesis (BCI) and time manipulation (respiration rate). Each power is activated by the partner's physiological self-regulation. This control paradigm differentiates *Space Connection* from past multiplayer biofeedback videogames (Kurt Smith, Crowin Bell, 2008). In order to facilitate access to the game, Space Connection was developed over *Garry's Mod*, a popular sandbox physics game-modification. Three different game puzzles were proposed to encourage players to collaborate aiming to complete the game mission. Each puzzle proposes different physiological challenges for players, such as: controlled modulation of attention or relaxation, ability to synchronize physiological self-regulation with partners to jointly carry out a task, and sustaining attention/relaxation states to pass the puzzles.

We believe that physiological self-regulation skills may be more easily learned in a collaborative environment in where the teamwork will avoid highly frustrated points. For instance, the level design of *Space Connection* provides a set of tests specifically designed to create empathy and comradeship by enabling players to influence remotely and dynamically the partner's powers. Moreover, *Space Connection* has a sandbox scenario (the cargo hold) which allows players to freely explore the physiological powers and train their self-regulation by raising, exploiting and moving objects.

We observed that the cargo-hold was the scenario in where users spent more time. Specifically, we noticed that users preferred be training in the control of their powers with the game elements instead of accomplish quickly the puzzle goal. This preference has to be considered in the design of novel biofeedback training programs based on videogames in where the use of goal-oriented dynamics create limitations in terms of engagement and long-term motivation (Khazan, 2013). Further research needs to be carried out in order to untangle the role sandbox levels in physiological self-regulation learning.

Additionally, to evaluate the game experience, a custom questionnaire was designed and used in a playtesting session involving 10 players. Importantly, scores related with players' empathy were relatively high (above 3.5) indicating that *Space Connection* has the potential to facilitate affective interactions between users. This feature was evaluated by asking to what extent players felt they better knew each other after the game. In addition, replayability reported an average score of 3.9 showing that *Space Connection* was perceived as appropriate to be played repeatedly. The enjoyment level revealed the highest scoring reinforcing the idea that a multiplayer biofeedback methodology can produce highly motivating and engaging experiences. The use of physiological metrics recorded during the interactions might reveal important features about specific psychological states such as stress, workload and engagement levels (Nacke, 2015).Finally, the system was not perceived as easy-to-use (perceived difficulty and ease of control). However, it is worth noting that mastery in conventional biofeedback systems requires at least 30 sessions (Fisher et al., 2013).

To conclude, we demonstrated that with the current advance in physiological sensing technology, the development of multiplayer biofeedback systems can be inexpensively done as suggested by (Placido da Silva et al., 2014). In addition, we believe that the idea to create novel biofeedback games in existent game mods or adapt physiological controls to existent and widespread games could boost the popularity of this technology. Space Connection is available at http://www.cee.uma.pt/edu/gamedesign/parallactive/

7 LIMITATIONS

Space connection was carried out as a proof of concept in a Game Design course and the development time was around one month. The playtesting session aimed to assess the feasibility of the proposed approach as opposed to validating the impact of the videogame in teenagers' empathy and collaboration. Thus, further work is needed in this domain. Thus, the main goal was the evaluation in real-users of the complete system, exploring possible technical aspects as well as users' responses. Although, the playtesting session with *Space Connection* showed promising results in terms of performance and control, more sessions are needed. The small sample size of the playtesting session limit the strength of the findings to raise firm conclusions. Finally, the lack of availability of multiplayer collaborative biofeedback videogames did not allow us to carry out a comparative analysis.

8 CONCLUSIONS

This paper described an effort to develop a collaborative multiplayer biofeedback videogame with the aim to promote empathy in teenagers. The work was motivated by the need of investigating how physiologically driven games can be used to incentivize positive feelings in a collaborative game design approach. The strategy of activate partner's powers via physiological self-regulation in a collaborative environment exposed promising results in terms of game mechanics and gameplay. Our preliminary data supports the use of novel biofeedback strategies combined with videogames to promote positive emotions and incentive collaboration and teamwork.

9 FUTURE WORK

A more complete evaluation of *Space Connection* will be necessary to proof its use as a tool to promote empathy and collaboration in teenagers. We propose the use of specialized questionnaires to measure empathy (such as the Toronto Empathy Questionnaire (Spreng et al., 2009)) and methodologies to quantify collaboration in games (Hwang and Karnofsky, 2005). Furthermore, the videogame should allow to store the physiological data in order to carry out a post-session analysis and identify which game level was producing better results in terms of physiological self-regulation. Additionally, a longitudinal study is necessary to produce measurable effects of the biofeedback techniques used in *Space Connection.*

10 CONTRIBUTIONS

J.E. Muñoz analyzed the playtesting data and wrote the paper, A. Gonçalves co-designed the game, designed the level and co-wrote the paper, T. Vieira produced and co-developed the game with D. Cró. Y. Chisik and S. Bermudez co-supervised the game design and development process and co-wrote the paper.

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