Cyberball3D+: A 3D Serious Game for fMRI Investigating Social Exclusion and Empathy

Evangelia Mavromihelaki
Dept. of Electronic and Computer Engineering
Technical University of Crete, Greece

Jessica Eccles Neil Harrison Thomas Grice-Jackson Jamie Ward Hugo Critchley
Brighton and Sussex Medical School
Sackler centre for Consciousness Science
University of Sussex, UK

Katerina Mania
Dept. of Electronic and Computer Engineering
Technical University of Crete, Greece

***Abstract*—This paper presents a 3D interactive gaming paradigm for the secluded space of an fMRI scanner. The Cyberball3D+ game is a virtual ball-toss game in which the participant is either excluded or not from ball tossing played by three virtual players and the subject in the scanner. It has been used in simple sketch mode by neuroscientists for research on ostracism, social exclusion or rejection as well as discrimination and prejudice. The game proposed is designed to render an interactive Virtual Environment (VE) on an fMRI display, enabling the conduct of formal neuroscientific experiments and investigating the effects of social exclusion, empathy and different level of anthropomorphism on human brain activity. Although, here, the focus is on the technical implementation of the system, the goal is to use this system to explore whether the pain felt by someone when socially excluded is the same when observing other people get socially excluded and whether there are differences in relation to empathy for friends and strangers. Moreover, for the first time, we propose a validated neuroscientific measure of character believability and emotional engagement. The system was developed in close collaboration between the Technical University of Crete where the technical implementation took place and the Brighton and Sussex Medical School where the initial fMRI experiments were conducted using the system proposed. A broader aim of this work is to assess whether such powerful social-psychological studies could be usefully carried out within VEs advancing cognitive neuroscience and computer graphics as well as serious gaming research.**

***Keywords*—cyberball, social exclusion, empathy, level of anthropomorphism**

I. INTRODUCTION

3D characters are used in the film and game industry but it still remains undetermined how design, stylization and behavioral factors interweave to make a character believable. When using synthetic characters in experiments simulating realistic scenarios, the aim is that people emotionally respond to them in a similar manner to humans. It has been shown that there is no significant difference in relation to skin conductance response (SCR) scores when comparing psychological activity for certain events between scenarios involving either real actors or animated characters [5]. Although research has shown that users show empathy for 3D characters, it is challenging to identify at which level of anthropomorphism such emotional experiences occur. Anthropomorphism refers to the attribution of a human form and behavior to non-human entities such as robots, animals, etc. However, uncanny valley effects – ie dips in user impressions – can arise: behavioural fidelity expectations increase alongside increases in visual fidelity and vice versa. Moreover, the influence of anthropomorphism and perceived agency on presence, copresence, and social presence in a Virtual Environment (VE) [14] has been investigated. The level of anthropomorphism of the image shown to participants was varied between high anthropomorphism, low anthropomorphism, and no image. Participants interacting with the less-anthropomorphic characters reported a higher level of presence and social presence than those interacting with either no image at all or with a highly anthropomorphic image. This indicates that high level anthropomorphic images set up higher expectations that lead to reduced presence when these expectations were not met.

It has been shown that people tend to respond realistically to events within synthetic environments and even to virtual humans in spite of their relatively low fidelity compared to reality [10]. For example, VEs have been used in studies of social anxiety and behavioural problems and individuals with paranoid tendencies have been shown to experience paranoid thoughts in the company of virtual characters [6]. These provide specific examples of 'presence' – the tendency of participants to respond to virtual events and situations as if they were real. One recent study suggests that people interact with virtual characters in a realistic and emotionally engaged way [18]. This study reported a scenario in which experimental participants took part in a virtual version of the Milgram experiment, in which people were asked to administer increasingly severe punishments to virtual characters performing a memory task [13]. Participants showed autonomic responses which were consistent with states of intense emotional arousal, as would be expected if the experiment had used real participants. Thus, it is evident that people are able to emotionally engage with synthetic spaces and virtual characters as if they were real. Previous research evaluating whether virtual characters fulfill their role employs ratings of pleasantness through self-report after the viewing experience has occurred [11]. It would be valuable to understand the cognitive processes involved while interacting with 3D characters in a gaming scenario. 3D characters could be employed to simulate experimental scenarios as part of neuroscientific protocols in the fMRI.

An economic game combined with Milgram's original experimental scenario has been implemented which, in the future, could be interactively played in an fMRI scanner [16]. A lighting system has been designed to render an interactive VE on an fMRI display, enabling the conduct of formal neuroscientific experiments and investigating the effects of visual fidelity as well as varied lighting configurations of an indoors/outdoors space on feelings of presence, 'reality' and comfort [1]. A 3d virtual system for fMRI has been designed investigating the influence of two prominent VR parameters, e.g. 3d-motion and interactivity, while brain activity is measured for a mental rotation task [17]. The subjects perform a variation of the mental rotation task in a simple VE and brain activity was recorded during three conditions of varied 3d-motion and interactivity. Also, an interactive digital game based on the Re-Mission videogame has been designed for cancer patients in the fMRI in order to determine whether mesolimbic neural circuits associated with incentive motivation are activated, and if so, whether such effects stem from the participatory aspects of interactive gameplay, or from the complex sensory/perceptual engagement generated by its dynamic event-stream [2]. However, acquiring user input while immersed in the constrained environment of an fMRI scanner while the system is expected to react to it in real-time is challenging, even more if 3D characters are included as part of the neuroscientific protocol. fMRI experiments usually employ simple display material, for example using photographs, video clips or simple computerized stimuli [8]. It is argued that the precise presentation and control of dynamic perceptual stimuli (visual, auditory, olfactory, gustatory, ambulatory, and haptic conditions) in the VE allows neuropsychologists the opportunity to develop statistically and clinically significant tasks within a virtual world [15]. Using VEs and 3D characters in fMRI has the advantage that it is possible to involve participants in interactive animated environments which more realistically reflect social and emotional situations.

This paper presents an interactive 3D gaming framework for fMRI experiments exploring whether artificial characters of varied anthropomorphism recruit brain activation associated with empathy and social pain [12]. Such input is non-obtrusive derived at the same time as the experience occurs. The 3D interactive gaming paradigm presented here, named Cyberball3D+, is based on the original Cyberball game, however, it is implemented for the secluded space of an fMRI scanner. The Cyberball game is a virtual ball-toss game in which the participant is either excluded or not from ball tossing played by three virtual players and the subject. It has been used in simple sketch mode by neuroscientists for research on ostracism, social exclusion or rejection as well as discrimination and prejudice.

The Cyberball3D+ game presented here involves four players represented by 3D characters of different levels of anthropomorphism. The main player plays the game while immersed in the fMRI scanner interacting with three 3D characters for which their player behavior is programmed. The scenarios evaluated are either fair or unfair to the players simulating social exclusion. The system monitors the main player's reaction to the occluded players, e.g. players not receiving the ball in the game, by potentially throwing more balls to them because of empathy for social exclusion. The neuroscientists defined the fMRI gaming scenarios using a dedicated user interface in order to select the level of anthropomorphism applied to all characters, the gender of each character and the fairness and behavior of the three players with which the main player interacts, during each round of the game. In this paper, we focus on the technical implementation of the Cyberball3D+ neuroscientific protocol. Subsequently, a summary of initial results and a sample of data acquired are presented.

The aim of this work was threefold: To create a 3D interactive gaming paradigm, e.g. Cyberball3D+, for the secluded space of an fMRI scanner; To study whether the emotional response of inclusion and exclusion of self and other will be modulated by the level of anthropomorphism of the players; to investigate whether exclusion of others will activate similar networks (social pain matrix) to watching exclusion of self, therefore, eliciting empathy. For the first time, we get a validated neuroscientific measure of character believability and emotional engagement at the same time the experience is taking place.

II. Experimental Scope

The empathy feeling is a crucial component of human emotional experience and social interaction. The ability to share the affective states of our closest ones and complete strangers allows us to predict and understand their feelings, motivations, and actions. Empathy allows humans to understand and share one another's emotional experiences and is important for successful social interactions [3]. Empathy refers to experiencing an affective response that is more consistent with another person's situation than one's own situation which suggests that vicarious emotions are pivotal to empathy [7].

During the first Cyberball experiments, participants were recruited to log on to an online experiment in which they played a virtual ball-tossing game with two other participants who had logged on from somewhere else in the world [20]. Before the experiment, the participants were informed that Cyberball was a means to an end, and was, by itself, unimportant for the experiment. It was portrayed as merely a task that helped participants exercise their mental visualization skills, which they would purportedly use in the subsequent experimental task. After reading the instructions, they would view a game in which the players were represented on the screen by animated icons. They would then play the Cyberball for about 5 min. The results showed that if participants were over-included (getting the ball for half the throws) or included (getting the ball for one third of the throws), they felt better than if they received the ball for only one sixth of the throws. Still, getting the ball for a sixth of the time was significantly better than not getting it at all. Fully ostracized participants answered a post-experimental questionnaire indicating lower levels of belonging, self-esteem, control, and meaningful existence [19].

Brain imaging studies demonstrate that physical pain sensations are processed across a network of connected brain regions, which together are proposed to form the 'pain matrix'. Most of the pain matrix is also activated if we observe empathically someone else in physical pain [4]. Interestingly, experiencing the ‘pain of social exclusion’ also engages these same regions during brain imaging studies of the original Cyberball task, consistent with the notion of social pain. There is early work suggesting that a similar brain activation pattern is present when one sees and empathizes with someone else being ostracized [4]. The motivation behind our novel experiment was to assess how rendering this game in a computer generated VE displayed in fMRI would alter the experience of the game. Furthermore, the game was designed with both low and high anthropomorphism avatars in order to investigate the relationship between avatar fidelity and character believability.

The general aim of this work was to create a 3D interactive gaming paradigm for the secluded space of an fMRI scanner. The goal was to experimentally explore changes in regional brain activity associated with the pain of social exclusion as well as with feelings such as the empathy felt when people observe other people get socially excluded and whether there are differences in relation to empathy for friends and strangers. The term social exclusion involves the lack of resources, rights, goods and services, and the inability to participate in the normal relationships and activities, available to the majority of people in a society. Many people face social exclusion in their daily life as well as other people empathizing with excluded people [9]. In addition, this research investigates whether the level of anthropomorphism of the avatars may affect game playing as well as fMRI data acquired at the same time the game playing occurs. The goal is to discover the neural circuitry that supports such feelings as well as, for the first time, devise behavioral fidelity metrics of character believability and emotional engagement based on neural activity.

III. EXPERIMENTAL PROTOCOL

We implemented Cyberball3D+ in the Unreal Development Kit (UDK) allowing one user in the fMRI scanner to play with three players modeled in three levels of anthropomorphism (Figures 6, 7 and 8) while undergoing an fMRI scan examining the neural basis of empathy for social exclusion as an effect of level of anthropomorphism. 10 healthy adult volunteers (eight female, two male mean age 41.5 years, range 29-65) underwent functional echo planar imaging at Brighton and Sussex Medical School, Sussex, United Kingdom.

Whole brain functional Magnetic Resonance Imaging (fMRI) data was acquired on a 1.5 T Siemens Avanto scanner. To minimise signal artefacts originating from the sinuses, axial slices were tilted 30º from the intercommissural plane. Thirty-four slices (3mm thick, 0.75 mm interslice gap) were acquired with an in plane resolution of 3 x 3 mm (repetition time = 2.52 per volume, echo time = 43ms.

In a block design they participated in 14 rounds of the Cyberball3D+ task (combinations of low and high anthropomorphism, inclusion of all avatars, exclusion of self and exclusion of other, simulating social exclusion or empathy for social exclusion). Each round was 75 seconds long. 2 buttons from a 4-button interface were used by the participants to throw the ball left or right respectively (Figure 9). User interactions were synchronised to the fMRI scanner by using trigger information. A frequency modulated audio signal was generated at prescribed times within the experimental phase. The audio signal was fed into a biometric recorder, which also recorded heart beat, scanning synchronisation etc. A log was generated marking the exact time the sync pulses were sent to the biometric recorder as well as logs for user interactions. The neuroscientists used a dedicated user interface to select the level of anthropomorphism of all avatars, the gender of each avatar and the fairness of the game.

The fMRI scanner acquired brain images at strictly specified timings while the participants followed the experimental protocol, performing the tasks assigned to them while being immersed in the VEs such as throwing the ball to a player. Meanwhile, participants’ physiological measures were acquired, such as heart rate and heart pulse oximetry. In this paper, we focus on the technical description of the system. The neuroscientific protocol implemented maintained the imposed time limits and was completely synchronized with the fMRI scanner.

Before the game begun, the neuroscientists used a dedicated user interface to fill in the overall number of rounds of the game (Figure 10). Moreover, the neuroscientists selected the level of anthropomorphism of all avatars, the gender of each avatar, the level of fairness of the round represented by the selected players to be excluded from the game and the duration time of each round. When the researchers filled in all parameters of the game, the game begun and the participants in the fMRI scanner interactively played Cyberball3D+ by using the button boxes.

Participants followed a formal neuroscientific experimental protocol for fMRI Cyberball3D+ task for which healthy controls were recruited to an existing study of abnormal skin sensations. This study included structural imaging and DTI. They undertook an fMRI emotional processing task exploring effects of skin and infestation related images. They also complete questionnaire measures of Alexithymia (TAS), Anxiety (BAI), Interoceptive Sensibility (Porges Body Perception Questionnaire), Empathy (BEES) and hypermobility (Beighton score). In addition, the participants underwent laboratory testing for Interoceptive Sensitivity (heartbeat detection and mental tracking tasks) and the Rubber Hand Illusion. During the completion of the Cyberball3D+ task they underwent simultaneous heart rate recording and pupillometry.

The 3D Cyberball3D+ paradigm conducted investigates two hypotheses. The first hypothesis is that the emotional response of inclusion and exclusion of self and other will be modulated by the level of anthropomorphism of the players. The second hypothesis is that the exclusion of others will activate similar networks (social pain matrix) to watching exclusion of self, therefore, eliciting empathy.

During the experiments, the participants played several rounds of the game. Each round included varied scenarios simulating situations of social exclusion or empathy as well as varied levels of anthropomorphism of the avatars. A typical paradigm of an experiment was to consist of six rounds and each of these rounds to be played twice but not consecutively, lasting 1.3 minutes. The first round simulated the inclusion of all players and used a low level of anthropomorphism, the second round simulated the inclusion of all players as the first round but used a high level of anthropomorphism for all players. The third and the fourth rounds of the game simulated the exclusion of the participant in the scanner and used low and high level of anthropomorphism respectively. In addition, the fifth and the sixth rounds of the game simulated the exclusion of the programmed players and used low and high level of anthropomorphism respectively. The task took 20 minutes. Between each round there was a 5-second break displaying a black screen. The order of rounds was counterbalanced amongst participants.

We will now discuss the technical implementation of the interactive Cyberball3D+ which supported the experimental protocol as described above. A summary of preliminary results is provided in Section VII.

IV. Implementation

The 3D virtual game which incorporated the experimental protocol described in Section III was developed with the Unreal Development Kit (UDK, http://www.unrealengine.com/udk/). The UDK is a powerful framework used mostly in creating computer games and visualization. UDK consists of different parts, making it act both like a game engine and a 3D authoring environment. It provides the necessary tools to create 3D objects and assign materials on these, import 3D objects such as characters and their animations from 3ds Studio Max and import and use sounds and sound effects. It, also, allows the designed application to seemingly attach to Flash User Interfaces (UI). UDK can also be used to render computer graphics scenes as well as create and respond to events while playing the game. UDK offers the ability to use both C/C++ and UnrealScript, which provides the developers with a built-in object-oriented programming language that maps the needs of game programming and allows easy manipulation of the actors in a synthetic scene. The main components inside the UDK are: the Unreal Editor which is used to create or import objects and edit VEs handling all the actors and their properties located in the VEs; the Unreal Kismet, which allows for the creation of sequences of events and corresponding actions and the Unreal Matinee which is responsible for the animation of actors or real-time changes in the actors' properties.

3ds Studio Max modeling software and the Adobe Flash Professional platform were also employed. 3ds Studio Max provides the necessary tools to create 3D objects such as virtual characters and assign materials on these. Additionally, it provides the tools to create animation on 3D objects by applying a Physique or skin modifier. Also, 3ds Studio Max exports the 3D objects in FBX format supported by UDK. 3D characters of varied anthropomorphism were modeled and animated, catching and throwing the ball (Figures 1, 2, 3, 4 and 5). Motion capture data were not utilized and the movement was as natural as possible. The derived 3D objects and animations were imported in UDK, by selecting the import option in the asset library of the Unreal Editor.

The Adobe Flash Professional is a Flash authoring environment. A Flash application can be used as a User Interface in UDK, because it incorporates the ability to display animated graphics, text or buttons on the screen on top of the scene being rendered. It can also receive user input and provide feedback according to it. A Flash application consists of many frames, placed in the main timeline. The flow of the frames being displayed can be changed through ActionScript - Flash's scripting language. Each frame can have its own set of graphics, texts, movie clips and buttons and a script controlling the behavior of the frame's components. The integration of a Flash application in a UDK scene requires that it should first be compiled into an SWF file and imported in UDK's asset library. Afterwards, either UnrealScript or Unreal Kismet can initiate the Flash application, interact with it, hide it or instruct it to stop playing. While a Flash application is playing in a scene, UnrealScript can initiate a call of an ActionScript function and vice versa. We used the Adobe Flash Professional to create the main menu of the game used by neuroscientists to fill in the parameters of the game.

A. *Creating visual content*

The synthetic scene of the Cyberball3D+ game consists of 4 players and one ball, created in the Unreal Editor. The four players are positioned on the scene so as to form a rhombus, e.g. they are placed on the vertices of a rhombus. Player 1 is placed on the left side, Player 2 on the right and directly opposite of the participant in the fMRI scanner is Player 3. Three levels of anthropomorphism (low, medium and high) were employed and in each round of the game the appropriate 3D characters of the scene (Figures 6, 7, 8) are displayed based on the parameters selected by the neuroscientists as entered in the initial menu. The 3D characters of the 'low level' of anthropomorphism (Figure 1) consist of human form of the face and the body but their gender is not distinguishable. This was considered as the lowest fidelity 3D character. While, the gender of the 3D characters of the 'medium level' of anthropomorphism (Figures 2, 3) is distinguishable, however, they do not have hair or beard and they wear uniform clothing. Finally, the 3D characters of the 'high level' of anthropomorphism (Figures 4, 5) consist of high fidelity human characteristics and wear distinguished clothes. The low-level 3D characters and their animations were modeled in 3ds Studio Max. The 3D characters of medium and high level of anthropomorphism were downloaded from the https://charactergenerator.autodesk.com/ site, however, the animations of ball-throwing were created in 3ds Studio Max.

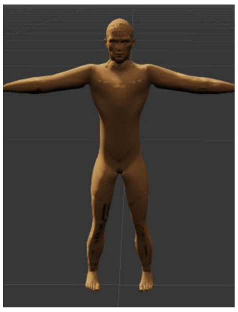

Fig.1. 3D character of low level of anthropomorphism

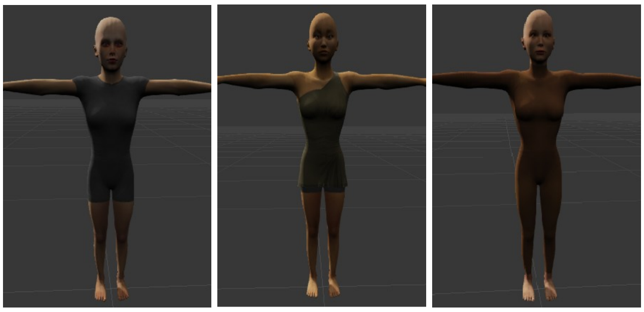

Fig.2. 3D female characters of medium level of anthropomorphism

Fig.3. 3D male characters of medium level of anthropomorphism

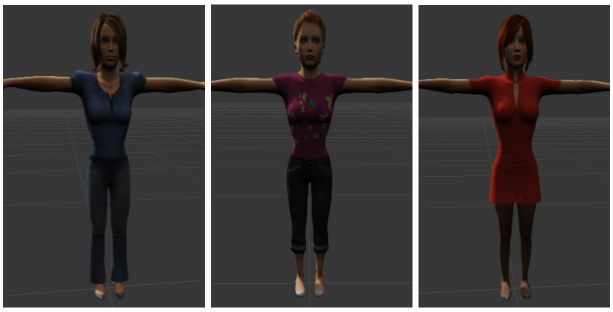

Fig.4. 3D female characters of high level of anthropomorphism

Fig.5. 3D male characters of high level of anthropomorphism

Fig.6. Cyberball3D+ game of low level of anthropomorphism

Fig.7. Cyberball3D+ game of medium level of anthropomorphism

Fig.8. Cyberball3D+ game of high level of anthropomorphism

B. Interaction

The core development of the complete application was implemented in UnrealScript. Several classes were created in UnrealScript which handles the aspects of the application's interaction with the synthetic scenes. One of the main requirements of the application was that the synthetic scenes were to be interactively manipulated and that the application was required to react to user input throwing the ball to the players. In order to achieve this, the buttons corresponding to the physical button boxes placed in the fMRI scanner and utilized for interacting with the scene were registered, with their respective commands. These are shown in Figure 9. A Current Designs 932 set up is utilized. Two buttons from a four-button interface are used to throw the ball left or right respectively. The remaining two buttons of the 4-button-boxes are not used. The two main methods that handled the participant's actions were *ThrowLeft* and *ThrowRight.* When the participant pressed a button to throw the ball left or right the *Controller* class executed the *ThrowLeft* or *ThrowRight* method respectively. These methods check first whether the participant has the ball and then act to throw the ball to either Player 1 or 2.

Fig.9. Photo of the Current Designs HHSC-2x4-C response pad used in the experiments.

C. Logging of player's actions

The application is recording every action by the players in a separate log file dedicated to each experimental round of the game. For each participant, a different log file is created for each round which follows the following naming convention: log(Participant Number)_r(Number of Round).csv. Each ball tossing occurring by all players is being recorded in the log file. The first data column records the time stamp when a player throws a ball, the second column which player throws the ball and the third column which player catches the ball. The time was measured in milliseconds starting just at the start of the current round of the experiment assumed to be time point 0.

In order to implement the log file operations, a .dll file was bound to the Controller class, providing the necessary methods to record each log entry. This was implemented because UDK's support for I/O operations is limited avoiding extreme overhead for the application since UnrealScript is very slow and inefficient for such operations. Whenever a new log entry was recorded in the log file, the controller could simply call the C/C++ function residing in the .dll file and let it perform the operation.

D. Time Synchronization

The game consists of a number of rounds and each round is played at preordained time defined by the neuroscientists in the initial menu. The application was timed perfectly in order to be synchronized with the brain images acquired by the scanner.

The *Controller* class was developed in order to control the time limits and react so as not to exceed them. At the end of each ball tossing, the *Controller* class calls a C/C++ function residing in the .dll file to check if the time limit was exceeded or calculate the remaining time.

The experiments were conducted inside an fMRI scanner and the application was required to be perfectly synchronized with the scanner, in order to be able at a later stage of the game to identify the exact action of the application associated with each brain image acquired by the scanner. The application was instructed to send a specific sound sync pulse to be recorded from the PC that was dedicated to recording the spike signals sent from the synchronization box of the scanner, as well as the heart rate data and pupillometry of the participant. The sound sync pulses were directed through the left audio channel of the application, leaving the right audio channel available to the participant.

The required synchronization between the fMRI scanner and the application was achieved by sending such sound sync pulses to be recorded as an analog spike signal, whenever a ball tossing occurred in the application while at the same time recording that action and the exact time it happened in the log file. The log file describes the state of the application associated to a specific brain image taking into account the sound sync pulse sent last before receiving that image.

V. USER INTERFACE

Although UDK includes preliminary support for User Interfaces (UI), Flash User Interfaces can be transparently displayed on top of the rendered scene. The Flash application is imported as .SWF file in UDK and loaded and displayed in a scene by connecting the Open GFx Movie action to the Level Loaded and Visible event, which is automatically generated and activated by UDK, when the virtual scene becomes visible. The Open GFx Movie action is provided by UDK and it accepts an imported Flash UI as an argument, which it loads and displays on the centre of a screen or on a specified surface.

The initial menu of the game (Figure 10) is used by neuroscientists defining the parameters of the game and a 'return' menu is displayed on the screen at the end of the game. The initial menu is displayed on the top of the screen when the game is initiated. The neuroscientists select the level of anthropomorphism of all avatars, the gender of each avatar, the scenario of the round as well as define which player initially has the ball at the start of each round. In addition, they fill in the duration limit for each round.

The neuroscientists have the ability to select one of five scenarios. By 'participant' we refer to the human player in the fMRI. In the first scenario no player is excluded. In the second and third scenario programmed Players 1 and 2 (left and right player) exclude the participant from the game and programmed Player 3 (player opposite the participant) respectively. In addition, in the fourth and fifth scenario either programmed Player 1 or Player 2 excludes Player 3 and the participant from the game respectively. Furthermore, the neuroscientists have the ability to save the rounds and the parameters of each round in a file through a C/C++ function residing in a .dll file which is called by the *Controller* class as well as load them by selecting the name of the file.

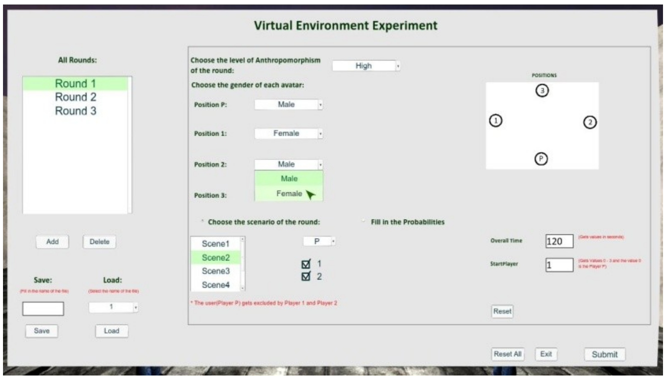

Fig.10. The settings screen for the neuroscientists

VI. Data Analysis

As this paper focuses on the technical implementation of the system, a summary of brain imaging data is going to be provided. Functional neuroimaging involves the measurement of brain activity. The scanner produces a map of the brain that is represented as voxels. A voxel represents a value on a grid in three-dimensional space – a combination of volume and pixel. As such each voxel represents the activity of a particular co-ordinate in the three dimensional space of the brain.

Acquired images are conventionally pre-processed before statistical analysis to remove noise and correct for sampling error.

Pre-processing is performed so data would approximate the following assumptions – all voxels in any given image of the series of images taken over time were acquired at the same time; each data point in the time series from a given voxel was collected from that voxel only; residual variance will have a Gaussian distribution; when carrying out analyses across different subjects any given voxel will correspond to the same brain structure in all the subjects in the study. For example, to account for the motion of the head between scans, images will be adjusted so each of the voxels corresponds to the same site in the brain; this is known as realignment. As imaging studies involve multiple participants who will have slightly differently shaped brains, a process of normalization is employed so that each 3D image is transformed so that key brain structures line up. They are then set into standard space. Images are smoothed so voxels are averaged with their neighbours using a Gaussian filter to reduce noise. As such, standard spatial preprocessing [realignment, coregistration, segmentation, normalisation to Montreal Neurological Institute (MNI) space, and smoothing with an 8-mm FWHM Gaussian Kernel] was performed. Voxel size was interpolated during pre-processing to isotropic 3 x 3 x 3 mm.

Results were analysed using Statistical Parametric Mapping software (SPM8) on a Matlab platform. First level (individual) analysis modeled timing of block stimuli (i.e type of round of the game – level of anthropomorphism and level of inclusion) using the general linear model; a full factorial design was used at the second level (group) of analysis (random effects analysis).

VII. Results

A whole brain analysis was performed with an uncorrected significance threshold of $p < 0.001$. Preliminary results demonstrated that participating in a high anthropomorphism environment rather than a low anthropomorphism environment revealed significant activations (Table 1) in both frontal cortex and superior temporal gyrus:

TABLE I. Activations In Frontal Cortex And Superior Temporal Gyrus

Region	Co-ordinate (x,y,z)	Voxels	Z-value	P value
R. Inferior frontal gyrus, orbital part	38, 34, -18	54	3.68	<0.0001
	20, 20, -22	11	3.28	0.001
L. Superior Temporal gyrus	-40, 8, -26	12	3.33	<0.0001

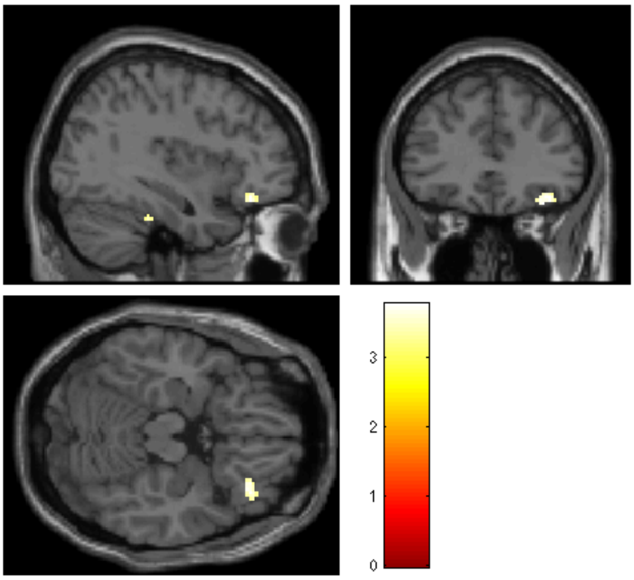

Fig.11: Activation map at 38, 34, -18. Colour bar indicates t statistic

One can attribute this activation pattern to the imprecise mapping of avatar features to normative 'top-down' representational expectancies of the human body within extrastriate visual cortices (particularly areas like Superior Temporal Sulcus that are functionally tied to humans emotional signals) and to the processing of negatively-valenced stimuli, activating lateral orbitofrontal cortex. This suggests that compared to more human like avatars, playing the non-anthropomorphic avatars is less subjectively rewarding and putatively anxiogenic. Therefore, when studying complex emotional responses, a high level of anthropomorphism of synthetic characters is not only required but also able to engage common neuroscientific patterns of brain activation as in real-world circumstances.

VIII. Conclusions

The presented framework puts forward a sophisticated interactive real-time gaming system called Cyberball3D+ incorporating virtual characters to be played interactively in functional Magnetic Resonance Imaging (fMRI) for the study of empathy, social exclusion and ostracism. The 3D game proposed is designed to render an interactive VE on an fMRI display, enabling the conduct of formal neuroscientific experiments and investigating the effects of social exclusion, empathy and different level of anthropomorphism on human brain activity.

A potential extension of the Cyberball3D+ game is to program players to be dynamically intelligent. We can integrate new rules and create intelligent opponents modeling their decision making behavior using reinforcement learning.

REFERENCES

[1] G. Christodoulou, E. Radulescu, N. Medford, H. Critchley, P. Watten, and K. Mania. "A 3D lighting system for fMRI rendering fidelity experiments", (One of best papers of IEEE VSGames 2011), International Journal of Interactive Worlds (IJIW), Volume 2012, 2012.

[2] S. W. Cole, D. J. Yoo, and B. Knutson, " Interactivity and reward-related neural activation during a serious videogame", PloS one, Vol. 7, No. 3, e33909, 2012.

[3] N. Eisenberg and P.A. Miller, "The relation of empathy to prosocial and related behaviors", Psychological bulletin, Vol. 101, No. 1, pp. 91, 1987.

[4] N. I. Eisenberger, "The pain of social disconnection: examining the shared neural underpinnings of physical and social pain". Nature Reviews Neuroscience, Vol. 13, No. 6, pp. 421-434, 2012.

[5] H. B. Ekanayake, et al. "Affective Realism of Animated Films in the Development of Simulation-Based Tutoring Systems", International Journal of Distance Education Technologies (IJDET), Vol. 11, No. 2, pp. 96-109, 2013.

[6] D. Freeman, K. Pugh, A. Antley, M. Slater, P. Bebbington, M. Gittins, G. Dunn, E. Kuipers, D. Fowler and P. Garety, "Virtual reality study of paranoid thinking in the general population",The British Journal of Psychiatry, Vol. 192, No. 4, pp. 258-263, 2008.

[7] M. L. Hoffman, "Empathy and Moral Development: Implications for Caring and Justice", Cambridge University Press, 2001.

[8] S. Lee, G.J. Kim and J. Lee, "Observing Effects of Attention on Presence with fMRI", Proceedings of the ACM symposium on Virtual reality software and technology. ACM, pp. 73-80, 2004.

[9] R. Levitas, C. Pantazis, E. Fahmy, D. Gordon, E. Lloyd and D. Patsios, "The multi-dimensional analysis of social exclusion", 2007.

[10] K. Mania, S. Badariah, M. Coxon and P. Watten, "Cognitive Transfer of Training from Immersive Virtual Environments to Reality", ACM Transactions on Applied Perception, Vol. 7, No. 2, Article No. 9, 2010.

[11] R. McDonnell, M. Breidt and H.H. Bülthoff, "Render me real?: investigating the effect of render style on the perception of animated virtual humans", ACM Transactions on Graphics, Vol. 31, No. 4, Article No. 91, 2012.

[12] M. L. Meyer, C. L. Masten, Y. Ma, C. Wang, Z. Shi, N. I. Eisenberger and S. Han, "Empathy for the social suffering of friends and strangers recruits distinct patterns of brain activation", Social cognitive and affective neuroscience, Vol. 8, No. 4, pp. 446-454, 2013.

[13] S. Milgram, "Behavioral Study of Obedience", The Journal of Abnormal and Social Psychology, Vol. 67, No. 4, pp. 371, 1963.

[14] K. L. Nowak and F. Biocca, "The effect of the agency and anthropomorphism of users' sense of telepresence, copresence, and social presence in virtual environments", Presence: Teleoperators and Virtual Environments, Vol. 12 No. 5 pp 481 – 494, 2003.

[15] T. D. Parsons, "Neuropsychological assessment using virtual environments: enhanced assessment technology for improved ecological validity", Advanced Computational Intelligence Paradigms in Healthcare 6, Virtual Reality in Psychotherapy, Rehabilitation, and Assessment. Springer Berlin Heidelberg, pp. 271-289, 2011.

[16] F. Rivera, P. Watten, P. Holroyd, F. Beacher, K. Mania and H. Critchley, "Real-time Compositing Framework for Stereo fMRI Displays", ACM SIGGRAPH 2010 Posters. ACM, 2010.

[17] D. Sjölie, et al. "Effects of interactivity and 3D-motion on mental rotation brain activity in an immersive virtual environment.", Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, ACM, pp. 869-878, 2010.

[18] M. Slater, et al. "A Virtual Reprise of the Stanley Milgram Obedience Experiments", PLoS one, Vol. 1, No. 1, e39, 2006.

[19] K. D. Williams and B. Jarvis, "Cyberball: A program for use in research on interpersonal ostracism and acceptance", Behavior Research Methods, Vol. 38, No. 1, pp 174-180, 2006.

[20] K. D. Williams, C. K. T. Cheung and W. Choi, "CyberOstracism: Effects of being ignored over the Internet", Journal of Personality and Social Psychology, Vol. 79, No. 5, pp. 748, 2000.