

Art behind the mind

Exploring new art forms by implementation of the Electroencephalography

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Abstract—The wide spread of emerging new technologies affects and modifies the artistic creation and practice. In this article the authors present proliferating technology of electroencephalography (EEG) within the field of art. Focusing on the applications of creative or artistic character and introducing the changes that have experienced different artistic disciplines such as sound, video, videogames and augmented reality by implanting the EEG technologies. Analyzing the recent examples of artworks that involve the EEG for the user interaction. Explaining how the user's immersive experience in applications using EEG increases by applying the vision of virtual content through Head Mounted Display (HMD) and stereoscopic projection. The authors also present their own “Neuro-ARt-Game” experimental project called “Robot & Robotnik”, inspired by Karel Čapek's theater play “R.U.R.”. An interactive stereoscopic augmented reality installation which employs the EEG to grant the interaction between the user and the artwork. The interaction is entirely conditioned by the user's brain activity, creating in this manner a unique brain computer interface (BCI) for art and Augmented Reality.

Keywords—EEG; Augmented Reality; Neuro-ARt-Game; EEG art, Brain-Computer interface

I. INTRODUCTION

New technologies reveal a new dimension of the perception of art, for both the spectators and the creators. Offering new opportunities for viewer's interaction with the artwork in a completely unique and transcendental way. The interactivity until now depended on a deliberate and premeditated user action and often demanded some response in form of body movement. EEG technology reached a point of intersection between the conscious and unconscious interaction. It reflects the perception of the artwork not only at the level of consciousness and opinion that can be formulated in the spectator's mind, but also as a more primary reaction of the spectator's brain. By using the EEG is plausible to quantify the different states of mind such as the level of attention, frustration or meditation. It provides an access to the viewer's neurofeedback caused by the observation of the artwork and concedes the power to convert these neural impulses in creative

and transforming force capable of influencing the artwork. The interaction depends on viewer's brainwaves, but the viewer is not always aware of the actions that it can cause. In the relationship spectator-artwork, this kind of behavior assigns to the spectator the role of a simple observer. That is due to the fact that humans usually do not perform this kind of task. Although it is possible to assume the more interactive role through a training. EEG technology creates an intangible interface for the interaction and the perception of art through the brain reactions. Establishing a new channel of art communication. An intuitive channel that allows us to recede from the physical framework established in digital art.

In the section II. we briefly define the terms and describe the specific aspects of the technologies applied to create the art applications that include the Electroencephalography (EEG) and Augmented reality (AR). In the section III.-IV. we will focus on the examples of the artworks and videogames that involve the EEG technologies. Section V. is dedicated to the analysis of the proper “Neuro-Art-Game” and its different aspects.

II. EEG AND AUGMENTED REALITY TECHNOLOGIES

A. Augmented Reality

We can understand the augmented reality (AR) and the expansion of information from the physical world that allows us to perceive the virtual part that surrounds us. Enabling us to distinguish the digital information flowing through the physical space. It creates a sensory interface that allows us to appreciate the virtual part that is hidden in physical space.

According to Pierre Lévy [1], the virtual is not opposed to reality, and so it cannot be identified as a fictitious, or inaccurate, but can it be understood as a way of strengthening the real, augmenting the process of creation by introducing the digital into the real world.

The term augmented reality first emerged in 1992 [2], and two years later it was defined and categorized by Milgram and Kishino [3], who established the “Continuum of Real-Virtual”. A taxonomy of the real and the virtual environment, depending on the amount of applied digital content. The intermediate states of this continuum are formed by the Augmented Reality and Augmented Virtuality, where real and

virtual contents are able to coexist in the same space. This definition was subsequently completed by Ronald Azuma [4], who identified a number of characteristics that should be accomplished in augmented reality environments: combination between real and virtual, real-time interaction and it must be registered in a 3D environment.

According to Bimber [5], in the AR environments, the real environment is not completely suppressed, but forms an essential part of it. Instead of total user immersion within purely digital world, as occurs in the case of the Virtual Reality (VR), AR introduces the digital content to the real world.

B. Electroencephalography

The electroencephalography is a technique by which is measured the electricity generated by brain structures, upon the scalp [6]. We will focus on non-invasive techniques [7], able to measure the cortical surface by EEG. We can obtain specific values that reflect the electrical activity produced by the activation of the brain neurons which causes the flows of electric currents [8]. Using the EEG allows users to control devices in their environment and establishes a direct communication between computer and user [9].

“EEG measures changes in electric potentials caused by a large number of electric dipoles formed during neural excitation. EEG signal consists of different brain waves reflecting brain electrical activity according to electrode placements and functioning in the adjacent brain regions.” [7]

During the last decades has significantly increased the use of Brain Machine Interface (BMI) and Brain Computer Interface (BCI) [10].

BMI focuses on how the new visual perspectives are capable of generating changes in the perception of body scheme, producing experiences of the illusion of a body exchange [11].

In the example of BMI application using the AR, created by Kansaku, Hata and Takano [9], was proposed the control of external devices by the user. Specifically, it was the position and orientation of a robot, through which users could observe the environment in the first person, adopting the vision of the robot. Additionally, employing the AR, users were capable to manipulate the light control panel. These experiments demonstrated that using the electrical signals generated by the human brain can control the movements of a robot in the physical environment and the light control through multitasking, which might be employed in the future to assist people with physical disabilities.

BCI can be categorized into two types [12]:

- BCI Process Control: Directly controls the motor or muscle to generate an action.
- BCI Goal Selection: Recognize the intention of the user.

As an example of BCI using AR, we highlight the Mind-Mirror application [13], which enables users to view in real-time the active areas of their brain. The virtual 3D model of

the brain is superimposed on the user's head and the colored areas symbolize the active parts of the brain. It can produce direct feedback between users and EEG as well as originate a natural extension of the understanding and learning.

This direct relationship in the perception of the brain patterns of the user by using the EEG is known as a neurofeedback. Permitting the users to be aware of control of the state of their brain activity, in order to achieve specific mental states [14].

C. Augmented Reality, Virtual Reality and Electroencephalography Spatial Presence:

The spatial presence can be understood as "the sense of being in an environment" as stands Steuer [15]. This sense of presence is conditioned by internal and external factors, as define Usoh and Slater [16]. Describing the internal factors as a single user experience and the external factors in relationship to the type of technology used, like screens, head mounted display (HMD), three-dimensional environment, stereoscopic view [17].

1) *Internal factors:* The sense of presence in AR and VR environments is proportional to the degree of immersion. Greater is the immersion, the greater should be the degree of sense of presence, generating similar behaviors to those produced in real environments. AR has a capacity to share the information from the physical world and the virtual world in the same time, which enables the awareness of what happens around us and it is complemented by the virtually added content. The implication of actions that requires user interactivity, increases the degree of immersion and generate much more convincing experiences [18].

2) *External Factors:*

a) *Displays:* In this regard we found a proportional relation between the screen size and an immersive perception, larger screen involves greater degree of immersion. The size of the effective angle of user's view improves successful immersive navigation so the use of HMD that occupy the entire vision of the user generates a very high degree of immersion, finding no interference from the generated seams between virtual space and physical space. This was demonstrated in experiments based on displaying of virtual content using monitors, as shown in [19] and [20].

b) *Perspective projection:* As for the difference between stereoscopic view and monocular view (2D), two-dimensional vision causes less understanding of the depth in virtual environments. This occurs due to the fact that the human brain is accustomed to perceive the world in three-dimensional view, produced by combining the information originated in left and right eye by the brain. Two-dimensional environments cause much less accuracy in observing the the constructed three-dimensional environments. Stereoscopic view is able to particularly increase the immersion of users in virtual environments and the space navigation [20].

The study completed by Keshner and Kenyon [21], demonstrates that VR is able to generate the subjective feeling of presence. The sense of presence in virtual environments that use the subjective view of the users is greater when the position within the virtual environment is unknown to the users and so there is no correlativity between real space and virtual space [20]. The use of visual interfaces with high resolution in the AR applications strengthens the feeling of living these experiences through a visual stimulation. The user can even induce his body to feel sensations of heat or cold [22].

III. EEG IN ART

In the field of art appears to be a complex task to find the artworks that employ the EEG. The current boom in the commercialization of EEG devices and related decrease of its selling price has enabled the application of these technologies in different artistic fields such as sound art, textile art, video art and the artistic applications of augmented reality. We highlight some examples of the artworks that incorporate EEG data as a part of artistic practice.

A. Sound Art

Eunoia (2013) and Eunoia II (2014), works by the artist Lisa Park, are the sound performances controlled by a EEG. In the first one was used a single electrode NeuroSky EEG headset. Through this EEG device the artist is able to connect the electrical impulses from her brain to the Max/MSP software and generate sounds. By the combination with the Reaktor software, the installation generates sound in real time depending on the degree of concentration and meditation on the artist/user. These sounds are also displayed by a layer of water placed in the pools upon the speakers that generate sound. The water acquires specific shapes depending on the sound vibrations as the sound is generated. Due to the brain activity the vibrations change, more calmed is the user, less vibrations occur. This visualization is based on the metaphor of the human body, composed mostly of water and able to react according to the electrical stimuli generated by the brain. The artist Lisa Park claims: "I wanted to create an artwork that represents the inner part of myself..."[23]. In the second version of this sound installation called Eunoia II is employed Emotiv EEG device, that applies a system that permits to use information concerning the emotional response of the user. Based on the 48 emotional states as proposed by the author B. Spinoza [24] in his book "Ethics", such as sadness, anger, desire, commitment, frustration, excitement, happiness and others. In this second version the increasing number of electrodes can also increase the number of emotions, which are transformed into variables and send to Max/MSP. Allowing the generation of a greater number of sounds and increasing the number of speakers to 48, establishing a direct connection between the speakers and the emotions.

Another interesting project of sound art is the application called EEGJ "Electroencephalography jockey", created by Richard Warp, Erica Warp and Chung-Hay Luk [25]. EEGJ is able to use the electrical impulses produced by the brain and its relationship with face muscle movements. The application communicates the data obtained by the EEG with Max/MSP

software using Open Sound Control (OSC) and enables the user to generate music in real time according to the excitement, frustration or meditation. It is producing a biofeedback that allows listening to the user's different moods by turning it into music. This application has allowed them to create the mind-controlled music, light and sculpture installation "NeuroDisco" [25], where the DJ is able to perform the sessions with the support of an EEG. Which besides being in charge of generating music in real time, is also able to select different samples depending on the DJ's cognitive status. To increase the EEG neurofeedback, the lighting of the club is also handled simultaneously, connecting the application with 600 LED bulbs through open source electronic platform Arduino. These LED are placed inside a sculpture representing neuronal communication. The application uses Emotiv EEG device, capable of capturing three cognitive states, 13 facial expressions and head movements. The EEGJ application consists of a specific software which offers the possibility to train and allows DJs to exploit the sound and visual environment in a controlled way.

B. Textile & Sound Art

In the mix between textile art and sound art we find the "NeuroKnitting" project (2013) by Varvara Guljajeva, Mar Canet and Sebastian Mealla [26]. This work combines Knitic project and utilization of Emotiv EEG device. Knitic is an Open Hardware project designed to control knitting machines by Arduino. This collaboration of devices is able to generate tissues in real-time depending on brain waves activated by hearing of musical composition "Goldberg Variations" by J. S. Bach. These brain waves are visually represented as knitted patterns, while the music is considered as an inducer of different range of moods. Represented by the mental states, which in this case are based on relaxation, emotion and cognitive load. This technique generates a unique pattern for each user, by implementing the idea of building the Brain Tangible User Interfaces (BTUI) [27].

C. Video Art

As an example of interactive video art that use EEG we mention the installation "Environmental Disturbances" [28]. A work by Anni Garza Lau in collaboration with Alejandro Palomino and Francisco EME, presented in the "Toolkit" festival held in Venice in 2013. This video installation shows the urban landscapes that vary due to the user's brain activity, monitored by EEG. It presents a daily life of urban landscape, viewed through the window, which is affected by the users' perception of these contents. It is leading to entail the changes in them through the mental states like concentration and meditation of users. The artwork relates these mental states with video layers that create visual changes in climate, lighting and color of the projected city. Thus, each user generates its own involvement in the artwork as a function of the brain patterns produced by the installation. It is a metaphor of mood swings occasioned by the seasonal changes. The installation employs a single electrode EEG, which sends the information via Bluetooth to a program developed by the artist connected with the "vvvv" software and manages the different video layers according to predefined variables.

D. EEG & Augmented Reality Art

"EEG AR: Things We Have Lost", is an Augmented Reality application by John Craig Freeman and Scott Kildall (2012). The project shows contents related to things that disappeared in recent decades like animals, empires and objects that no longer exist [29]. These contents are managed according to the brain activity of users. The application is divided into two parts, one in a closed experimental space and the other part, the augmented reality application, performed in the public space of Liverpool city. The application implements users EEG readings to load a virtual object from its database. These virtual objects can be observed through the screen of the mobile device (iOS or Android) by using augmented reality. Liverpool citizens were interviewed to determine the content's relevance and its location in physical space. Thus establishing the location where the contents were placed and linking them by GPS coordinates. Creating in this manner a unique "portrait of what the city has lost, a collective imagination of what's important to Liverpool" [29]. The project also took place in Coimbra (Portugal, 2014), Basel (Switzerland, 2014) and Los Angeles (USA, 2015), using the same idea of creating databases fulfilled with the memories of citizens. As it was expected, particular elements were lost at each location, therefore the results and the virtual contents are different and specific for each location. The relevance of this application consist in mixing the EEG and AR technologies. Although in the case of users who execute the application within the city public space, the loading of the virtual contents which they can observe is not conditioned by the use of EEG. It is possible to perceive a neurofeedback in the part of the installation that takes place inside the experimental space, but the user cannot control the choice of the the database contents. These series of contents are displayed in a random manner.

"The Future Slave"[30], was a proposal for AR and EEG application by Mark Skwarek in the city of Liverpool and the art center FACT (2012). The application intended to transfer the viewer into future, where Liverpool is transformed into a city of slaves and managed by a military company. The application was divided in two parts, one part taking place in the streets of Liverpool and another was placed within the FACT art center. The streets can be explored by users in order to perform different tasks as slaves. Large parts of the city are restricted to the slaves by virtual barriers, passing through these barriers causes the generation of unpleasant sounds. In the part placed within the FACT art center, the user can work on the construction of these virtual walls. The user is placed in front of the screen, acting as a mirror, in which the user can see himself as a slave of the future. The user/slave is being controlled by an EEG sensor, so when he/she does not reach a suitable degree of concentration, the lighting and audio in the room is affected in real time and act as a punishment.

IV. VIDEO GAMES USING EEG

At present, companies and investigations aimed at videogames are looking for more natural way to interact with users and players. Video games, alike the thoughts, can be considered as virtual entities, as it is not possible to perceive them in the real world without human-machine interaction. The ability to interact mentally with video games increases the

realism of virtual action, as it is external to a physical involvement [31]. Recognizing the mental state of players can be manipulated and enables the balanced correspondence between skill and challenge [32]. The field of videogames implements rapidly the technological innovations, we can observe attempts to implement EEG from the earliest period of development of this genre. In the first games with EEG, the goal was to dispense with the traditional controls of the game as joystick, keyboard or mouse.

One of the first examples guides us to 1977, when the first video game controlled by a BMI was designed by J.Vidal [33]. This BMI was capable of capturing the eye movements of the player. It was a simple game where the player could move a virtual object within a two-dimensional environment shaped as a labyrinth.

Brainball is a multi-player game, which is able to transfer the EEG data into the action upon a real world physical elements [34]. The game features two players who fight a mental struggle, by using the value of meditation extracted from EEG in real time. The game consists of a ball which is moved in a tube, approaching the player who is less meditated. When the player believes himself/ herself to be close to win, the player increases his/her emotions and causes the loss the state of relaxation necessary to maintain high values of meditation.

It is worth mentioning the first video game performed in a first person perspective, called Bu [35], where the horizontal movement from left to right was controlled by EEG.

ROMA NOVA [36] is based on Rome Reborn 3D video game that reproduces the origins and destruction of Roma in an educational manner. This new version completely removes the traditional navigation system for videogames, replacing the use of hands by the use of brain data. The movement in the virtual space is performed through the analysis of the values obtained by the EEG. It also allows access to specific content related to the mood of the players/users. There are two versions of the game. One that uses a single electrode EEG device by which it is more difficult to achieve the correct movement. And the other, where a 16 electrodes EEG is employed, giving as a result an easier way of moving the character in the virtual environment. Although it is noteworthy that it can be complex task for users to perform the movement of virtual avatars based on the neuronal information related to the mood rather than movements.

Affective PacMan [37] is a version of the traditional game PacMan, in which the user's movements are limited both by the physical controls and the EEG. The limited mobility and generation of faulty or unexpected movements induce users to experience the states of frustration.

We can also find games that do not intend to completely abandon the traditional navigation interfaces, seeking the combination with neural interfaces. In the case of Bacteria Hunt (2009)[38], the keyboard allows the movement of virtual avatar and mental state modulates the difficulty of the hunt by changing the distance between avatar and the targets.

In the similar sense is designed Alpha-World of Warcraft [39] a modification of the multiplayer game World of Warcraft®. This modification does not replace the mode of movement of virtual avatars, because it would imply a complete change of the game dynamics. It goes a little further, by introducing the option of the virtual avatar to include the mental state of the player. Which generates a greater symbiosis between player and virtual avatar. When the moments of relaxation, alertness or frustration are produced, the skills of virtual avatars vary accordingly to these changes in the player mental states.

In this regard we can highlight an actual reference, the video game "The Shooting" [40], that uses the traditional controls to move the avatar in a three-dimensional environment and complements it by the use of EEG, allowing to link the moods of the player and his virtual avatar. In this way the brain activity of users enables additional control in the game. Which corresponds to the change of other virtual avatars, that can actuate in the role of enemy or friend. The colors of virtual avatars change by swapping the red and blue textures. When enemies are red, the user/player can attack or destroy them, when avatars are blue they act in friendly or neutral role. The user can perceive the neurofeedback and understand the importance of brain activity. This distinction between virtual avatars based on brain activity can affect the difficulty and consequently a playing time.

V. NEURO-ART-GAME

A. Introduction

In "Robot & Robotnik" installation we employ the combination of technologies AR and EEG for the users' immersion and interaction. AR helps to invoke the brain processes capable of binding the real and virtual dimensions, influencing the perception of space where our own mind locates us. EEG establishes a communication channel of the double sense between the artwork and the viewer. The user has the influence on the course of the game, while the actions within the game causes the changes of the user's mental state. The the interactive element of the game is elicited by the EEG data, so we define it as a "Neuro-ARt-Game".

The story of the "Robot & Robotnik" is inspired by the theater play "R.U.R. - Rossum's Universal Robots" (1921)

written by Karel Čapek. It was the first time when the word "robot" has appeared, taking its origin from the Czech word "robota", meaning work. In Čapek's drama the robots are in the war with the humanity, which culminates in the extinction of the human race. These robots are biologically based human-like characters, different from nowadays common perception of robot as a metallic machines. The play depicted the fear of technological evolution that experienced the society of early 20th century and had an immense influence worldwide as it was traduced to over thirty languages in a few years.

In the Neuro-ARt-Game "Robot & Robotnik" we adapt this scenario to refine and deliver the message in the context of today's society. With the intention to fade or completely extinguish the fear induced by the use of new technologies and to originate a reflection on our powers and positions that we can adopt in this "technological mental struggle." The game features the robot characters and humans characters - "Robotnik", which means "worker". The human characters have a different morphology which represent a whole humanity. The robots are designed as a cold metallic entities which posses a primitive artificial intelligence. They share the same virtual space on a round scenario, simulating a circular theater, where the user can move freely and observe the the installation from 360 degrees. The characters play their role depending on the mental state of user, which has the power to maintain the state of peace or war between the humans and robots. The state of meditation grants the peaceful behavior and the high attention level in addition to the lack of meditation induce the characters to persecute each other. The state of the persecution is reinforced by the sound and light effects. Employing the technology of AR and EEG enables the direct connection between user and artwork which creates a mutual influence. In this manner it resembles to what Roy Ascott defines as a *technoetic theatre*, we generate "...a new kind of theatre, which we shall call "technoetic theatre", as it arises from the confluence of researches into artificial life, interactive drama and the field of consciousness"[41].

Janet H. Murray in her book "Hamlet on the Holodeck" analyzes the aesthetic for the digital media and proposes a three categories: immersion, agency and transformation. Describing the first category as "The experience of being transported to an elaborately simulated place is pleasurable itself, regardless of the fantasy content. We refer to this experience as immersion" [42]. To fulfill this first condition, we use an AR technology



Fig. 1. "Robot & Robotnik". Some of the human and robot characters

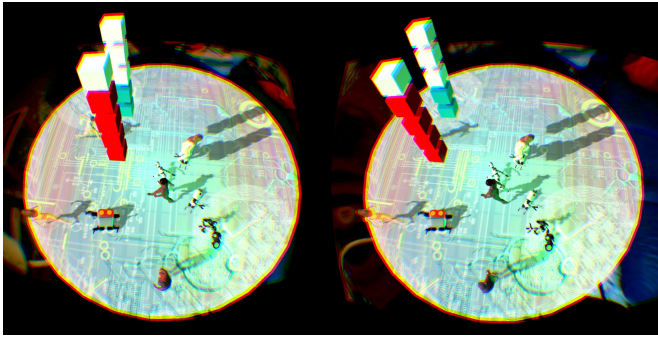


Fig.2. "Robot & Robotnik" stereoscopic user vision. Red and blue bars indicate level of attention and meditation.

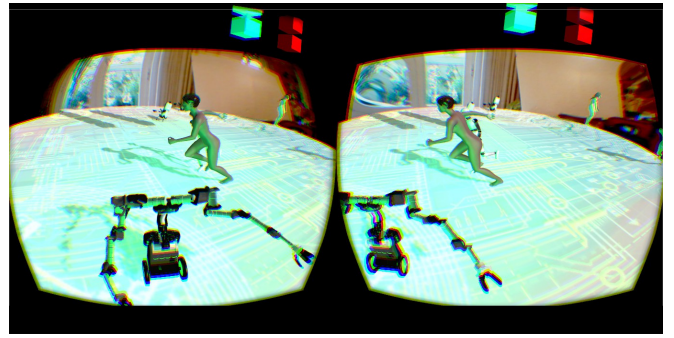


Fig.3. "Robot & Robotnik" stereoscopic user vision.

blending the real and the virtual, making the immersive experience more real. The second category deals with the possibility of the users' interaction: "Agency is the satisfying power to take meaningful action and see the results of our decision and choices" [42]. As the interaction is powered by the EEG data, the course of the game can be influenced in the two manners. A voluntary, or conscious for the users' that are able to control their level of attention and meditation. And unintentional, if the users' interaction isn't result of their effort. Changing their role from director to spectator and materializing what hitherto remained hidden in privacy, even for the consciousness of the viewer. Offering the user an opportunity to better know oneself. This different kind of behaviors lead us to another Murrays' category: the transformation. "...storytelling can be a powerful agent of personal transformation...Digital narratives add another powerful element to this potential by offering the opportunity to enact stories rather than to merely witness them"[42].

B. Narrative

The use of AR allows total freedom in users' angle of view position, establishing spatial relationships between virtual content and physical space within the user's view. We use a narrative of hybrid nature, where the relationship between the player and the game mechanics are produced in real time. We introduce environmental narratives based on the user interaction with the scenario/physical space. Allowing a nonlinear narrative, where game events occur regardless of temporal order. The use of these narratives within a AR game controlled by EEG, enables us to use the human brain waves as data input source. The application lets the user to modify the behavior of virtual characters. Depending on the mental state of users/players and their mental ability, they can move forward in time, due to the interaction produced by the level of attention and meditation. The playing time depends on this mental interaction of users, some players can reach the end of the game in a short time period, others can extend the duration by being able to control the states of meditation and attention.

C. Technical aspects

Using BCI techniques offer a new kind of interaction, but also includes a number of disadvantages, mostly associated with a decrease of the game performance. EEG registers and sends a wide range of values which can cause deceleration of the game's course. It is possible to increase the speed of the

game by reducing the data flow of the EEG, allowing latency of 5 milliseconds in data capture. The implementation of neural interfaces into the augmented reality applications permits the creation of applications in which the involvement of the hands' movements is no more necessary[41]. Occasioning the interaction between brain and computer, which allows troubleshooting and performing of the actions that could not be executed in other context. These specific actions can be improved without the prior preparation and even may result if the user is not aware of applying them, "the state of the player becomes part of the game mechanics" [34].

We considered the internal and external factors of the sense of presence in the environment of this Neuro-ARt-Game. One of the most important internal factors is the interactivity, in this case is produced by the employing the EEG device, and making the application responds to the mental states of a user. The external factors which contribute to the user immersion is strengthened by visualizing the 3D virtual contents, using the head mounted display - Oculus Rift2 in combination with the Ovrvision stereoscopic camera. Which enables the users' view within the virtual environment corresponding to the head movements.

1) Hardware

a) Computer characteristics:

- Windows (8.1).
- 2.5 GHz Quad processor.
- 16 GB system RAM.
- 2 GB Nvidia Video Card 3DDR
- DirectX 10 or OpenGL 3 compatible video card.
- Bluetooth Version 2.1 w/ EDR

b) Oculus Rift2: HMD Resolution 960x1080 px per eye.

c) OVRvision: Stereoscopic camera, resolution 640 x 480 px per eye. Fish lens corresponding to the Oculus Rift lens.

d) NeuroSky® MindWave: One sensor electrode EEG, using eSense™ system algorithms that calculate different mental states, concentration and meditation, in the range of values between 0 and 100.

2) Software

a) ArUco: AR Software oriented at flat pattern recognition using a marker system based on the binary code,

where the white squares correspond to 1 and black at 0. Allows the generation of a coordinate axis X, Y, Z, coinciding in physical space and virtual space.

b) *MakeHuman*: 3D software aimed at automation the of creation of human shape 3D geometries.

c) *Blender*: Free software 3D. In this case it permitted the modification of the geometries obtained by MakeHuman as well as generate our own models and 3D animations.

d) *Unity*: Game engine that allows us to create the application introducing the characteristics and specific needs of hardware and software by employing different libraries. In this case, the interaction between the EEG, OVRvision and graphics generated in real time. It also allowed us to establish a basic artificial intelligence (AI) of the characters, which allows to relate the mental state of the user with different behaviors commanded by the AI.

D. User test

We have effectuated the experimental test with users, in order to establish a valuation that would allow us to learn factors affecting Neuro-ART-Game “Robot & Robotnik”. The factors dealing with the perception of action control between the user and EEG, the movement in the real environment and the integration of digital elements in the real environment. In the experiment have participated 14 users aged between 22 - 54 years and none of them have used EEG before.

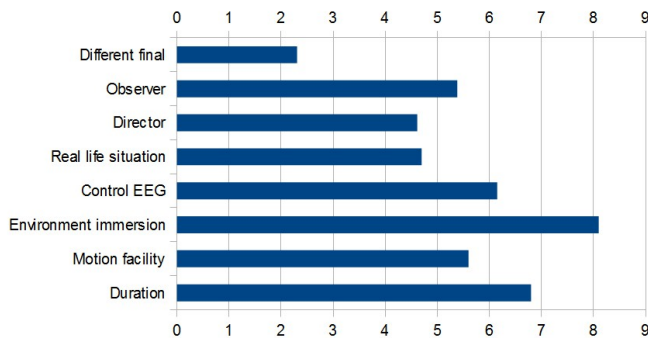


Fig.4. “Robot & Robotnik” users' test results.

The most significant results revealed a high grade of integration of the virtual contents into the real environment and user's immersion through the use of AR for HMD. Another remarkable factor was, whether the users felt as directors or observers. In this case the results reveal that there was a similar percentage between directors and observers, which leads us to the conclusion that almost half of the group experienced a feedback of EEG control. Interesting was the fact that almost half of the users considered the argument of this Neuro-ART-Game as a probable situation in the real life and a low percentage of users, that would prefer different final for the game.

CONCLUSION

The proliferating tendency of the EEG technology into the artistic practice visibly demonstrates its creative potential. We



Fig.5. “Robot & Robotnik” user wearing Oculus Rift2, Ovrvision stereoscopic camera and NeuroSky MindWave EEG device.

highlighted some interesting examples in the field of sound art, video art, and augmented reality. The brainwaves data input proves its creative force as an element capable to transform the moods and emotions into the sound or visual composition, as occurs in the art installations “Eunoia I-II”, “Neurodisco” and “NeuroKnitting”. EEG is a valuable tool which can be use to affect the flow of video art by rendering different video layers according to the spectator's moods, as shown in “Environmental Disturbances”.

Incorporating the EEG to augmented and virtual reality environment, strengthen the immersive experiences and the sense of presence in the virtual worlds. The quality from which can benefits the games and art-games. In our “Robot & Robotnik” Neuro-ART-Game, we employ the novel combination of EEG and AR technology by using Oculus Rift HMD and stereoscopic camera to achieve a high grade of immersion. This Neuro-ART-Game features human and robot characters which actuate accordingly to the users' mental states and have influence over the course and narrative of the story, creating an unique final for each player. The user modifies the course of the game and the events within the game affect the users' mental state. In this manner the relationship between the user and artwork creates the mutual influence, establishing a new form of communication for art.

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