Neurophysiology-based art in immersive virtual reality

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Abstract: Virtual reality (VR) art often deals with issues of embodied interaction vs. the fantasy of disembodiment: on the one hand, unlike traditional desktop computers, VR allows full-body interaction; on the other hand, VR allows one to experience disembodied presence in an immaterial, abstract space. Our recent research projects allowed us to reach a new extreme of such disembodied VR experiences, where participants affected their virtual surrounding using their emotional state and, to a limited extent, using their 'thoughts'. This scientific research gave rise to two science–art collaborations. In the first, a visual artist navigated in a virtual maze that he created, using only his 'thoughts'; this experience inspired a set of art shows. The second project included floating inside an immersive VR environment, where the motion was based on electrodermal activity ('sweat response'), and the content of the virtual environment was based on dreams purchased and modelled by the artist.

Keywords: VR; virtual reality; immersive; cave; neurophysiology; brain–computer interface; electroencephalogram; EDA; electrodermal activity; Osmose; Char Davies; affective computing; utopia; dystopia; embodiment.

Reference to this paper should be made as follows: Friedman, D., Donenfeld, A. and Zafran, E. (2009) 'Neurophysiology-based art in immersive virtual reality', *Int. J. Arts and Technology*, Vol. 2, No. 4, pp.331–347.

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1 Introduction

Davies (2004) and her virtual reality (VR) installation art projects, Osmose and Ephemere, have been highly influential in VR art. One of her main drives is to challenge what she refers to as the 'disembodied techno-utopian fantasy'. She further states: "I believe such desires to escape the confines of the body and the physical world is symptomatic of an almost pathological denial of our embodied embeddedness in the living world".

As part of EU-funded research projects PRESENCIA and PRESENCCIA we were able to further pursue disembodiment in VR, by using interfaces based on physiological responses and even 'thoughts', or brain activity. As part of these projects we have issued a call for recent alumni of the Slade Art School of University College, London, to propose art projects based on these brain-and-body interfaces to VR. Two art projects resulted out of this collaboration. In what follows we will describe these works, discuss some of the issues they raise, and eventually revisit warnings of Davies (2004).

The main justification for immersive VR is, arguably, that it allows for an unprecedented sense of presence inside an artificially generated content. This sense of presence is sometimes referred to as the 'illusion of non-mediation' (Lombard and Ditton, 1997). Scientists of VR typically study this illusion as reality substitution (Sanchez-Vives and Slater, 2005): the VR experience would be successful if reality substitution is achieved, that is, if the participant would feel and behave as if they were in a real-world situation that is equivalent to the virtual one. While these scientists are aware that VR can be used to study alternative, non-realistic realities, it is expected that even in such cases the sense of being in the VR will be equivalent to the sense of being in the world in our everyday lives.

Interestingly, Heim (1998) sees the potential of VR art in that it allows for a sense of non-mediation that is even stronger than the sense of immediate contact with reality. In everyday life, we are often aware of ourselves as separate from the surrounding world. Heim (1998) suggests that VR art can allow the participant a sense of non-mediation that precedes the Cartesian object–subject division, in the sense of being-in-the-world as first characterised by Heidegger. This is evident in the interpretation of Osmose by Heim (1998), as well as in the writings of Osmose' artist (Davies, 2004; Davies and Harrison, 1996).

In this paper, we discuss the paradigm of neurophysiology-based immersive VR, as furthering the discussion of using VR art as a metaphysical or phenomenological lab. Writings about VR, most notably science-fiction novels, frequently portray future mediated experiences as integrated directly into our nervous system, and such future interfaces are also expected to allow for a total sensory-replacement experience. While such total immersion and direct brain communication scenarios are often the content of dystopian novels, they are also commensurate with the artist's fantasy to communicate her meaning completely, minimising audience interpretation. Today, an intermediate step is made possible in which the VR experience is dependent upon the participants' neuro-physiological state.

In Section 2, we provide an overview of the scientific research in which we have integrated online recording and analysis of neuro-physiological signals with highly-immersive VR. Two art projects spun out of this research, and they are described in Sections 3 and 4. Finally, in Section 5, we provide some reflections and revisit the issue of disembodiment in VR.

2 Neuro-physiological interfaces to VR

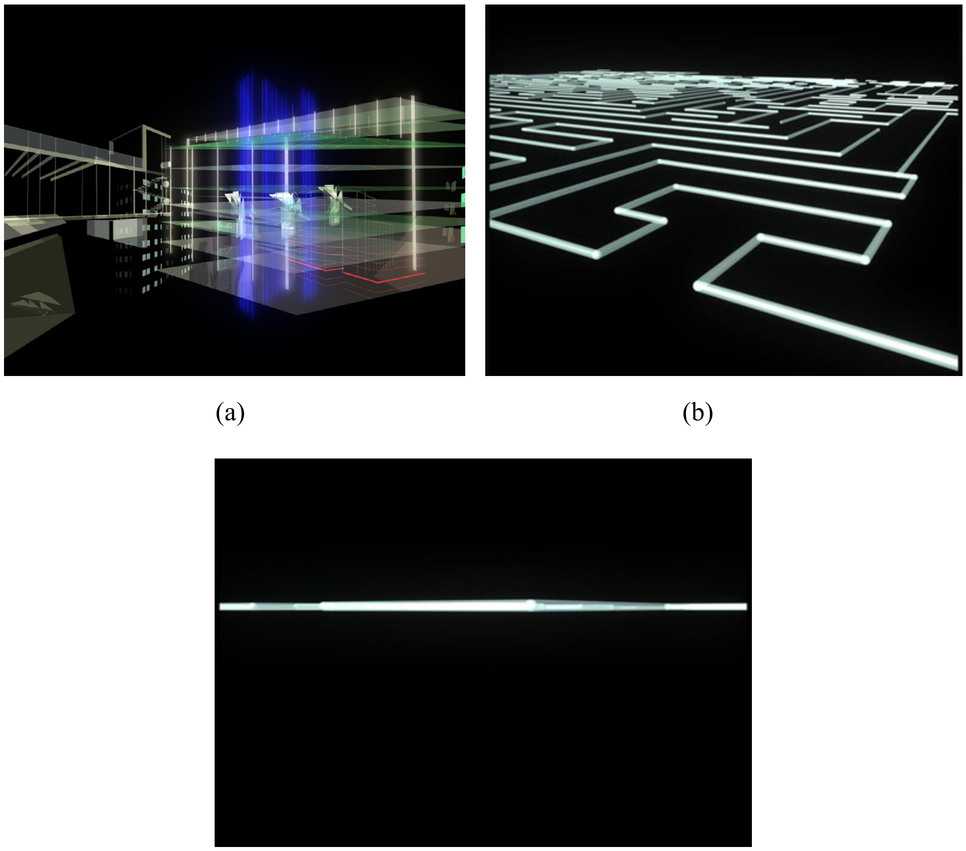
As part of EU projects, PRESENCIA (2003–2005) and PRESENCCIA (2006–2009), we have been able to construct highly-immersive VR experiences that are based on information extracted online from neuro-physiological signals. The VR experiences took part in a four-walled Cave-like system (see Figures 3 and 4b). This is an approximately 3 m cubed area, with projection screens on the floor and three walls (but not the ceiling) providing a stereo view. We use the term 'Cave' in this paper to refer to the generic type of system described in Cruz-Neira et al. (1993). The particular system used was a Reactor system, together with Intersense IS900 head-tracking.

These neuro-physiological signals were extracted from both the autonomous nervous system (ANS) and the central nervous system (CNS, i.e. the brain). In the first case, we refer to responses such as changes in heart rate (HR) and sweat, which indicate levels of stress and arousal. The latter is known as brain-computer interface (BCI): such electroencephalogram (EEG)-based BCI research is aimed at helping individuals with severe motor deficits to become more independent (Wolpaw et al., 2002). It has been shown that it is possible to identify a few mental processes using electrodes attached to the scalp (Pfurtscheller and Neuper, 2001), that is, the imagination of various pre-defined movements, from online EEG signals. Such thought-related EEG changes have been transformed into a control signal and associated to simple computer commands (i.e. cursor movements). The Graz-BCI paradigm (Pfurtscheller et al., 2003) is based on motor imagery, which makes it a natural candidate for 'thought-based navigation' in VR.

We have set up a system that connects the Graz-BCI to a highly-immersive four-sided Cave-like system (see Figure 3). We have carried out several studies with this setting; results include navigating 'by thought' in a virtual street by healthy subjects (Friedman et al., 2007b; Leeb et al., 2006, 2007b; Pfurtshceller et al., 2006) and by a tetraplegic patient (Leeb et al., 2007a) and controlling a virtual avatar 'by thought' (Friedman et al., 2007a, to appear). For technical details of the BCI-VR system see Friedman et al. (2007b).

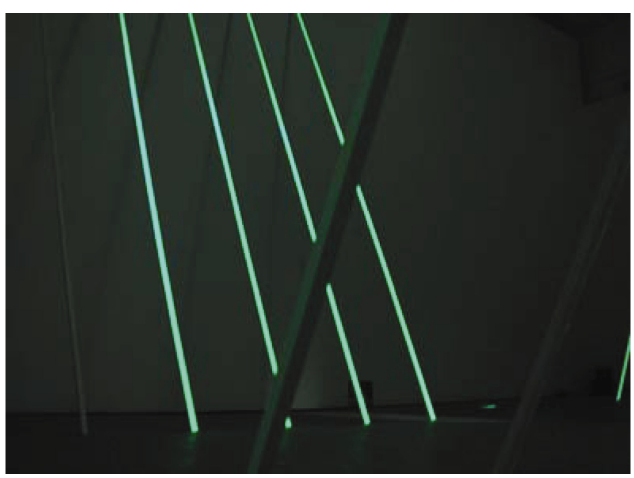
The Graz-BCI makes it possible to distinguish imagination of different body parts; most often used are left hand, right hand and feet. This can be made into a relatively intuitive interface. For example, in a typical navigation task in our experiments the subject would have to imagine moving her feet in order to walk forward in the environment, and to imagine moving her right hand for stopping.

Figure 1 Snapshots of the virtual maze, which was navigated by the artist in the VR cave (see online version for colours)



(a) (b) (c)

Figure 2 An image from Framed; an exhibition inspired by the VR-BCI navigation



One of the questions we tried to address in our studies is the nature of mapping thought processes to external events in the (virtual) world. Application designers would typically try to achieve a natural and intuitive mapping. However, BCI also allows us to ask: what happens when the mapping is not intuitive, maybe even deliberately made counter-intuitive. We have performed such a scientific study, where we allowed participants to control a virtual character (possibly their own avatar) in the Cave. In the 'intuitive' condition feet imagery caused the avatar to start walking, and hand imagery caused the avatar to wave its hand. In a second condition, this mapping was reversed: feet imagination caused the avatar to wave its hand, and hand imagery caused the avatar to walk. We then evaluated both the BCI accuracy performance and the subjective experience. The results were mixed: one subject performed better in the inverse condition, one subject performed better in the normal condition and one subject performed equally well in both cases. Full details and an analysis of the subjective responses are reported in Friedman et al. (2007a). Here, we stress the importance of mapping between internal states, such as thoughts and emotions, to external events in the environment; we will return to this issue in the discussion.

In our studies, in addition to BCI, we have also recorded and analysed ANS activity, specifically HR and its derivatives, respiration and electrodermal activity (EDA) (Friedman et al., 2006; Slater et al., 2006). Information extracted from these signals can be related to the participant's psychological state, mostly stress and/or arousal levels. The latter was used for online control of an experience and is further explained in Section 4.

3 The BCI-inspired art projects

Eli Zafran, a London-based artist, tried to navigate in a virtual maze using his 'thoughts' alone, using the Graz-BCI in the UCL Cave. The artist uses the term a mind-specific art in order to describe an art piece that is completed only inside the participant's head and can only be experienced inside the participant's mind. This notion by the artist resembles Davies (2004), who testified her art projects, Osmose and Ephemeral, to be 'intimate' and 'solitary'.

It is possible to capture the experience of the participant with the VR, for example, by video, and then present it to a larger audience. In fact, this has been done with Osmose and also by Zafran as we describe below. However, it is clear that such replication of the experience relieves it of its essential traits. This is always true for VR art, as well as for other types of interactive art, but it is especially true if the art is supposed to be a statement about the subjective experience of being in the world, as is the case for Davies and Zafran.

The work consists of an installation that deals with the basic notion of mapping a space and reduces this act into a millimetre-wide structure of expanding rays of light, thereby creating a space where images of light and mirrored surfaces intervene. It subsequently developed into three major works:

The first is 'labyrinth' as it looks from the location of the participant, that is, a line that encapsulates the entire labyrinth structure. It was realised in 2005 as a set of digital prints. The second was 'split reality'/a mapping of a space (2005). This project developed the idea further into a structure of glass and a composition of 1 mm lines of mirror. The third part that concludes this project was realised through Node London in 2006 (networked, open and distributed event) as part of *Framed* and it analysed the perception of a three dimensional space in different viewing conditions (Figures 1,2).

The promise of these works lies in its low-key presence, verging on the lack of substance, drawing some fine lines, exposing vantage points, revealing the usually unseen factors of the viewing process, while obscuring materialistic stances. The attempts to concentrate the visual into vision through sight processes require the actual physical experience of the viewer. This is done with minimum material presence in order to avoid diversion into any specific object oriented experience.

In the beginning of this project, the artist volunteered to be a subject in an experiment that examined the ability to control movement in a VR environment by using only basic patterns of thought. The outcome from this mind-specific experience took place inside an environment of a labyrinth that was designed using Maya Modelling and resulted in a maze of white light, made of both its actual and reflected manifestations, as seen in Figures 1 and 2.

Because of the intrusive nature of this experience the artist volunteered to be the subject, playing the role of the 'laboratory mouse' that was dropped into its own invented world of the maze. Being the inventor of this world put him in a superior position to the mouse, although he was still the subject of the experiment. Unlike the mouse, by knowing the existence of an endless void outside this maze, Zafran never had any desire to leave it or did not have any task to complete whilst within it. This maze became his temporary residence albeit a conceptual one. This all-encompassing experience within this virtual world was in contrast to the constant feeling of the electrodes connected to his scalp and the endless wires that were connected to him during the experiments. This necessitated a physical effort to maintain a set posture whilst freeing the mind to navigate.

Figure 3 A cave participant controlling a virtual bar room using BCI

Figure 4 (a) A screenshot of an industrial area from a dream, as viewed online. (b) A participant in the VR Cave experiencing the same industrial area in SuperDreamCity (see online version for colours)

(a) (b)

Note: This image is for illustration: in the actual experience the participant would not be holding the navigation wand (as they navigate based on EDA) and the image would be stereoscopic.

In order to emphasise these issues Zafran based the construction of maze on the lack of choice encapsulated in urban society. Although one can think, on an aimless walk through a city, that one has unlimited route options, in fact one is subject to constrictions that control one's movements at any single moment. This lack is a reasonable outcome of the reduction and enclosure of private spaces in enormous metropolises. Immediate examples in this context would be the marking of private and public boundaries and territories.

The marking of boundaries was the starting point of this project since these have a specific visual form that are the result of accepted social codes. This is closely related to common fears such as that of trespassing and breaking and entering of property and violation of objects. It seems that the only line of retreat is inside one's own mind. However, as the speed of communications increases constantly the concept of direct non-verbal ability to communicate is already a border that had been crossed by using technology such as the one demonstrated in this project. This fits perfectly with the paranoia of logging into one's mind but at the same time it reflects the need for direct communication.

4 SuperDreamCity

4.1 Overview

London-based artist Suji's SuperDreamCity allowed visitors of the London Node Festival (2006) to navigate a VR landscape, made of Suji's dreams, based on their level of EDA. This study is part of a research that assumes an experimental paradigm where a person is exposed to stimuli that systematically induce physiological changes (such as changes in HR, heart rate variability (HRV), EDA and similar autonomous responses). A computer program monitors how the physiology changes over time and in response to sequences of visual stimuli. The automated decisions related to the presentation of the visual stimuli are planned to have some desired impact on the participant's physiological state.

Such research could be considered complementary to traditional biofeedback. ‘Classic’ biofeedback involves measuring a subject’s bodily processes such as blood pressure or EDA, and using a machine to convey this information to her in real-time, in order to allow her to gain control over physical processes previously considered automatic (Blanchard and Young, 1974; Gaarder and Montgomery, 1981). Biofeedback has a number of therapeutic uses in helping people learn how to achieve and control positive mental states such as concentration or relaxation, and has been used with people with anxiety, depression and attention problems (Schwartz and Andrasik, 1995). We can now revisit traditional biofeedback taking into account advances in online signal processing, intelligent computation and various types of feedback, such as, in this case, highly-immersive VR. Our approach is almost the inverse of ‘classic biofeedback’: in our case the machine is the one supposed to do the adaptation, and not the person.

While this was not a scientifically controlled experiment, we show how the results can be systematically analysed. This raises the possibility that such science–art collaborations will have scientific value, yet illustrates many of the potential methodological problems (as mentioned in Section 4.8).

4.2 Background

During the last 10 years there has been research on computer applications based on emotional feedback loops. Picard (1997) coined the term affective computing: this includes computers that both recognise and exhibit emotions. Picard (1997), as well as others in this area of research, has demonstrated devices based on real-time analysis of autonomic responses, such as affective jewellery and accessories, affective toys, affective tutoring systems, computer responses to user frustration and visualisation of the user’s emotional state. Recognition of emotions is addressed by several means, physiological responses being one of them.

Bersak et al. (2001) coined the term affective feedback, which means that ‘the computer is an active intelligent participant in the biofeedback loop’. Prendinger and his colleagues have developed and evaluated a closed-loop virtual agent that responds to users’ emotions. The valence and intensity of emotions are recognised based on skin-conductance level and electromyography (Prendinger and Ishizuka, 2005; Prendinger et al., 2005, 2006). The so-called affective loop has also been described by Hook and colleagues; see for example, Sundstrom et al. (2007). It has been shown in systems like SenToy (Paiva et al., 2003), eMoto (Sundstrom et al., 2005), Affective Diary (Lindstrom et al., 2006) and Brainball (Hjelm et al., 2000) that it is indeed possible to involve users in affective loops, but that the design needs to be carefully crafted to the specific demands of the application functionality in order for the application to work.

4.3 Scientific objective

In SuperDreamCity we have tried to achieve the dual goal of an art installation that is also a scientific experiment, with well-defined research questions. The objective of the study is to test whether the physiological state of a VR participant may be manipulated systematically over time, during a VR experience. In addition, we suggest methods for analysing the data and inspecting whether the manipulation was achieved. Such intelligent systems for physiological manipulation may be based on several computation paradigms. Our approach here is based on reinforcement loops – such an approach would try to deploy positive and negative feedback loops; these were investigated as early as the middle of the 20th century (Wiener, 1961). Positive loops may be used to drive an existing trend to an extreme, and negative loops may be used to extinguish existing trends.

Specifically, our assumption is that we can induce positive feedback loops by leading participants into two types of spaces with different affects: into 'good' places when they are relaxed and into 'bad' places when they are stressed (or aroused). (We use the terms 'good' and 'bad' as not to confuse with the technical term positive and negative feedback loops.). If the system is successful, we would see two types of patterns: in one case participants will mostly visit the 'good' places and their overall EDA levels would remain flat or even decrease. In the other case, participants would mostly visit the 'bad' places and their overall EDA level will increase significantly during the experience.

This assumption can be broken into two hypotheses:

1 'Bad' places would have a significantly different impact on EDA tonal level than 'good' places – specifically, the EDA level would increase after 'bad' places and decrease after 'good' places.

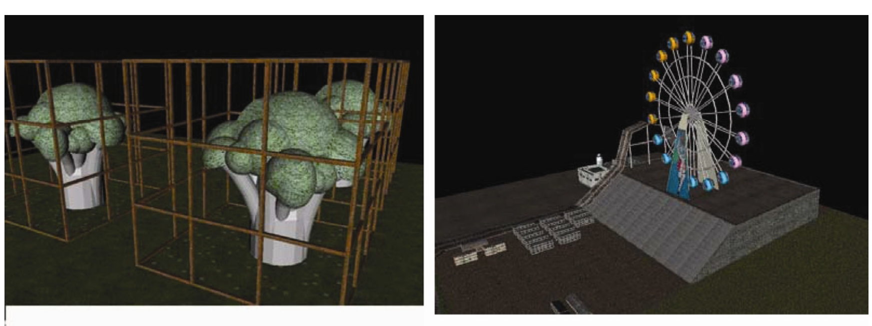
2 An analysis of the dynamics of transitions between 'good' and 'bad' places would reveal the existence of positive feedback loops.

4.4 The virtual environment (VE)

The content of the VE is based on work by Suji, a London-based artist, who is in the (fictional) business of buying dreams: she pays people 1 Great British Pound each so that they tell her about their night dreams. Then she models the dreams in 3D, and adds them into DreamCity – an online version, where people are able to browse among other people's dreamscapes. For the London Node media-art festival, March 2006, we decided to create a unique version of DreamCity called SuperDreamCity. Firstly, rather than displaying the models on a desktop computer, we adapted DreamCity for the Cave. Secondly, we decided that the participants will explore the dreamscape using their physiological responses.

For SuperDreamCity the artist selected several 'dreams' into one VE where all the dreamscapes were randomly scattered around (see Figures 4 and 5); we have only used static models in this version. Most of the dream sites include sound clips that played when the participant was in the site vicinity. The VE included a low-volume background music playing in a loop – this was a dream-like electronic music.

Figure 5 Screenshots from SuperDreamCity (see online version for colours)



4.5 Physiological input

We wanted to allow the participants to explore the VE in a way that would depend on their internal bodily responses to the environment, as reflected in their autonomous nervous-system responses. We have selected EDA as a single measurement, since this is easily measured by a small sensor placed on two fingers, which is easy and quick to fit; this was important as we were attempting a quick turnover of visitors.

EDA is measured by passing a small current through a pair of electrodes placed on the surface of the skin and measuring the conductivity level. Skin conductance is considered to be a function of the sweat gland activity and the skin's pore size. The real-time variation in conductance, which is the inverse of the resistance, is calculated. As a person becomes either less or more stressed, the skin's conductance decreases or increases proportionally (Andreassi, 2000). There are two measures associated with EDA: one is overall level, called the tonal level, which gives the overall level of arousal, and the other is skin conductance response (SCR), which gives the level of arousal in response to specific events (or unknown random internal events). In our study, we have used the tonal level.

4.6 Method

For the show, the artist recreated the VE with 20 of her own dreams modelled in 3D, 10 having 'good' associations and 10 having 'bad' associations. As an example, a 'good' dream considers an amusement park, and a 'bad' dream considers industrial areas. The emotions were expressed with choice of colours and sound effects. In this case the emotional interpretation of the dreams was given by the artist or by the dreamer; clearly, in a controlled scientific experiment, this emotional interpretation needs to be validated.

Initially, we have attempted a low-level mapping of EDA into navigation. However, EDA levels are one-dimensional. This could map naturally into navigation speed, but not into navigation in three dimensions of space. Thus, we opted for a high-level mapping. We decided to split the experience into stages. First, all subjects found themselves floating over one of the 'good' dream sites. Then, in each stage of the experience, they started floating from one dream site towards another site. The decision to what site to navigate was based on the trend of the EDA.

For the art exhibition, we decided to explore positive feedback loops, that is, the system would try to reinforce the participant's physiological trend. If the EDA value increased from the previous section, a random 'bad' dream site was targeted. If overall EDA decreased, a random 'good' site was selected. Navigation speed was also modified – for every selection of a 'bad' site the speed was increased by 10% of the baseline speed, and, correspondingly, for every selection of a 'good' site the speed decreased by 10%. Thus, our expectation was that this VE would create a positive feedback loop with the participant – that is, we expected that some participants will keep visiting 'bad' sites, which would increase their EDA, so that overall they would mostly visit 'bad' sites and become increasingly stressed throughout the experience. We expected that for other subjects there would be a relaxation loop, such that their EDA would gradually decrease as they keep visiting 'good' sites and floating in a slower and more relaxed fashion. In the next sections, we explore how this was evaluated scientifically, and report the results.

4.7 Experimental procedure

Our assumption was that, under some conditions, an exhibition open to the public can serve as a scientific experiment (for an example that was highly successful, at least for the science part, see Eng et al., 2003); in the least case, the data collected can serve as useful insight for future research.

The London Node Festival took place over a whole month, included dozens of events in different locations around the city, and advertised online. We have advertised the exhibition, which took place in our VR lab. We announced it would be open to the public for a few hours each day over three consecutive days (over the weekend) and required people to register online in advance. Each registered person received a time slot to show up in the lab (20 min allocated per person).

During the exhibition there were at least three people working in the lab. One person was necessary to fit the EDA device and operate the systems. Another person stayed outside the lab space and managed the queue of people. Finally, the artist greeted each person into the experiment. She was dressed as a businesswoman, handed them her business card, explained to them about her (fictional) business buying dreams and explained to them that they are about to experience a dreamscape that would respond to their physiology.

When participants were led into the Cave room they were fitted with the EDA sensor and goggles, placed inside the dark Cave and were instructed to wait. This was followed by a period of at least 60 sec, after which the VR experience began – this duration was used for measuring EDA baseline. Participants stayed in the Cave for varying durations of 5–15 min, based on the queue outside. Most participants loved the experience and would have stayed more if they were allowed.

4.8 Results

We collected data for all participants, but most of the sessions had to be discarded. Due to the art installation context, participants behaved in quite different ways than subjects would behave in a typical scientific experiment. In general, we believe such settings should be the subject of scientific studies; in fact, one could claim that such settings have larger ecological validity than a typical laboratory study. However, this behaviour does introduce a myriad of methodological problems: some of the visitors talked a lot, moved a lot, tried to jump or even, in one case, lie down on the Cave floor. In some cases we had a long queue outside and had to allow more than one person into the Cave. All these sessions were discarded from the scientific analysis. Out of the remaining sessions, 15 sessions included valid EDA data, and these were analysed as described below.

Each session is characterised by a number of events – an event is the point in time when the system decided to navigate into another dream site, either 'bad' or 'good'. The duration elapsing between two events varies, as it depends on varying navigation speeds and on variable distances among the pairs of dream sites. The duration between events was always at least 20 sec, sometimes up to 1 min. Thus each session included a different number of events ranging from 7 to 35.

First, in order to test whether 'good' dreamscapes affect EDA in a different way than 'bad' dreamscapes, we examined the trends in EDA tonal level around the events. This is tested using an analysis of covariance (ANOCOVA). We take the time around the events (from 20 sec before the event to 20 sec after the event) to be the predictor x, the EDA level to be the response variable *y* and a binary variable *c* for the dream category. If our hypothesis is correct then we expect the coefficient of the 'good' dreams to be significant with a negative slope, the coefficient of the 'bad' dreams to be significant with a positive slope and the Anova value for *xc* to be significant.

A case-by-case study reveals that the hypothesis was correct for only 5 out of the 15 subjects: cases where the slope was significantly different between the two events, and the trend for 'bad' dreams was higher than for 'good' dreams. For nine subjects the results were not significant, and for one subject the results were significant, but they were the opposite of our prediction: the 'good' dreams resulted in an increase in EDA and the 'bad' dreams in a decrease.

The dynamics of the experience can be further analysed using hidden Markov models, by modelling each session as a stochastic process over state transitions. The complete details of this analysis are provided elsewhere (Friedman et al., 2007c). Here we provide a non-technical explanation: by modelling the experience as a sequence of transitions between dreams, we can compute the probability of navigating from 'good' dreams to 'bad' dreams and vice versa. This allows us to compare the actual scenarios as experiences by the participants with the expected probabilities under the assumption of positive feedback loops. In our case the analysis shows that, overall, the state transitions of the participant-environment as a system were random; this would not have been the case had the environment been able to manipulate the participant's physiological state.

5 Discussion

For the art community, the possibility for constructing 'total' experiences, which combine highly immersive VR with brain- and body-based interfaces, is a cause for great fascination, regardless of whether it is utopian (as is possibly the case of SuperDreamCity) or dystopian (as is clearly the case of Zafran's work). From the scientific point of view, there is interest in constructing VR experiences that meaningfully adapt to the participant's neurophysiology, rather than just experiences that leverage the excitement caused by the multitude of esoteric devices.

One of our main lessons from the SuperDreamCity study is that while it is now feasible to create this type of biofeedback application, using highly-immersive VR, it is not easy to create a meaningful experience that fully exploits the possibilities of biofeedback in highly-immersive VR. Our analysis revealed that the feedback loop did not take place as expected (unless, possibly, for 5 out of 15 subjects whose data was analysed). Thus, for most participants the biofeedback part of the experience was probably meaningless, in the sense that the experience had no systematic effect on the participant's physiology. Unfortunately, similar art projects often fail to report and analyse the data.

Neuro-physiological feedback loops allow for a new type of experience, arguably a new kind of quale, or in more phenomenological terminology – new modes of being characterised by different moods, where the world around us responds directly to our inner thoughts or emotions, without us taking any physical action. VR is the perfect complimentary technology for such interfaces, although it is also possible to conceive of mixed reality or pervasive computing scenarios in which the environment is affected by internal states.

It seems that VR art can teach us metaphysics by experience. We have seen two very different possibilities for VR art based on neurophysiology. One was based on intentional voluntary control, using cognitive processes, and the other was based on involuntary emotional state. Thus, while these two art projects are both instances of the same paradigm, that is, neurophysiology-based VR, they can also be considered as two examples of two opposed theories about art's function.

Shklovski (1917) claims that art is intended to alienate things – to make us see everyday reality in new, surprising ways: "The purpose of art is to impart the sensation of things as they are perceived and not as they are known. The technique of art is to make objects 'unfamiliar'". BCI-based navigation of the maze can serve as an example of this, which is also what Davies (2004) refers to as 'de-automatisation' – taking the everyday experience of walking inside a large city and experiencing it in a completely new way.

On the other hand, Schopenhauer (1819) claims that art should get the audience 'carried away' in the art piece "Only through the pure contemplation... which becomes absorbed entirely in the object, are the ideas comprehended; and the nature of *genius* consists precisely in the preeminent ability for such contemplation... (T)his demands a complete forgetting of our own person". A similar view is also taken by Wittgenstein (1916, p.83):

> "If I have been contemplating the stove, and then am told: but now all you know is the stove, my result does indeed seem trivial. For this represents the matter as if I had studied the stove as one among the many things in the world. But if I was contemplating the stove it was my world, and everything else colourless by contrast with it."

SuperDreamCity may be considered an attempt to use the possibilities of physiological loops in order to lure the participant deep into the dreamscape.

We suggest that there is a spectrum of VR experiences: on one extreme we have BCI, in which the interaction is based on voluntary, intentional control, and on the other extreme we have the unconscious control, such as that based on the ANS. Interestingly, Osmose is right in the middle, being based mostly on breathing, which is semi-volitional (and probably modulates the ANS); this has been a deliberate decision made by Davies. However, we note that Osmose was based, in addition to breathing, on external actions: gaze, position and speed of motion. Neurophysiology-based VR experiences can be based on internal states, both cognitive and affective. A major means of artistic expression in such art work is the mapping from the internal states to actions and events in the VE.

This mapping can serve to replicate real-world situations, but, possibly, they can also serve to create new modes of being, experienced as novel moods (new qualia). Thus, VR art, and specifically neurophysiology-based VR art, can further advance into a phenomenological lab. For example, in the case advocated by the SuperDreamCity project, if the world (real or virtual) starts responding to our feelings in meaningful ways, we may develop the sense that the world surrounding us is alive; this is not unlike the sentient planet Solaris (Lem, 1961).

Our research may be considered a manifestation of what Davies comes up against as the 'disembodied techno-utopian fantasy'. One of the artists responding to the technology indeed presented a very dystopian interpretation, and as such would probably be in line with Davies. The interpretation of SuperDreamCity is not clear, and the artist does not provide comments about her art. It is probably a mixture of irony (see e.g. the logo in

Figure 6), a dystopia where our dreams are being cannibalised by capitalism, and some genuine fascination with VR and BCI technologies.

We provide a few responses to Davies' concerns. First, as Hakim Bey (1985) noted, the desire for getting rid of the flesh is not unique to our culture: "Humanity has always invested heavily in any scheme that offers escape from the body. And why not? materiality is such a mess".

Moreover, we wish to distinguish among several senses of embodiment. One is, a cognitive claim, expounded by Lakoff and Johnson (1999) that all concepts are derived from the interaction of the body with the world. According to this view, even if we have such desire to leave the body, it is futile.

Another sense is that an intrinsic and important conception of ourselves has to do with the 'dirty' aspects of the body as flesh-bodily excrement, bodily odours and bodily feelings. This is important in reminding us of our being part of the world, which is essential to the possibility of authenticity in the Heideggerian sense – the awareness of our own finitude. In that sense some neurophysiology-based interfaces are also a form of embodied interaction, since stress and relaxation are essentially bodily feelings.

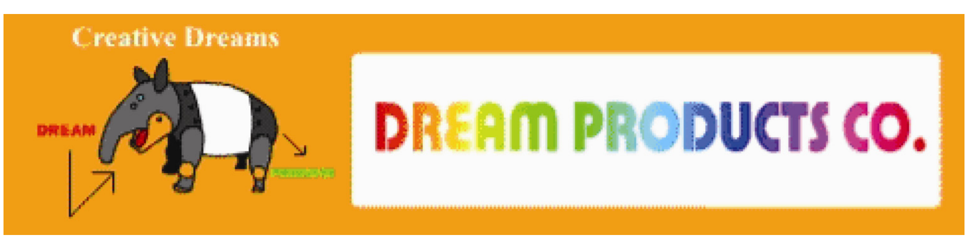
In a third sense, the flight from the body is the flight from individuality and the individual body, with all its small and great flaws, from displeasing appearance to invalidity (see Leeb et al. (2007a) for an account of a tetraplegic patient navigating the Cave by 'thought'). The previous sense of embodiment is conflated with this sense in the depiction of Socrates by Plato. Socrates was portrayed as both of an ugly bodily appearance and a beautiful individual soul, and of the soul being beautiful as it achieved the greatest separateness from bodily existence.

Davies does not distinguish between these three senses of embodiment. In fact, if her main project is of bringing awareness to the non-Cartesian, non-controlling nature of perception, then physiological feedback loops are a form of less control than the respiration control in her works. The authors are closest in ideology to Hakim Bey (1985) that

> "Certainly spirit has lost its ontological solidity (since Nietzsche, anyway) while body's claim to 'reality' has been undermined by modern science to the point of vanishing in a cloud of 'pure energy'. So why not assume that spirit and body are one, after all, and that they are twin (or dyadic) aspects of the same underlying and inexpressible real?"

Or as he plastically describes it: "We experience 'spirit' when we dream or create; we experience 'body' when we eat or shit (or maybe vice versa); we experience both at once when we make love".

Figure 6 Logo on the DreamProducts 'company' website (see online version for colours)



Neuro-physiological interface technology is developing rapidly. It is important to be aware that it is 'not neutral' in the same way as VR is not (Davies, 2004). At the current state of technology the authors of this paper are not ready to give up their body, but they do not rule out considering this option in the future.

Acknowledgements

We wish to thank Robert Leeb, Gert Pfurtscheller and Mel Slater, who were behind the scientific part of the BCI-VR projects. We also wish to thank David Swapp and Anthony Steed for their support in using the UCL Cave, and to Kana Suji for her collaboration on SuperDreamCity. These projects were partially supported by EU projects PRESENCIA, IST-2001-37927 and PRESENCCIA, IST-2006-27731.

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