PANEL: Bio-medical Signals in Media Art

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Abstract

This panel undertakes a deep and critical reflection about the general usage of biomedical signals from the mid 1960s to nowadays and their inclusion in artistic work, in regard both to the artistic application of these signals as well as the consequent theoretical implications. The members of this panel discuss concrete applications of biomedical signals in dance, performance and installation, the role of the enacting self embodied in these systems and the implications interactive installations have for the self-perception through technology. They focus on the complex and hybrid relationships between body, technology and environment, the perceptual qualities emerging from it, as well as the ethical implications of employing these systems.

Keywords

Bio-data, Bio-feedback, BCI, HCI, New Media, DYI, Machine ethics.

Introduction

The use of bio signals was introduced in the arts and music in the mid 1960s after it had been pioneered by psychologists using biofeedback methods in order, for example, to reduce stress and therefore with the intention of creating a certain degree of internal peace. One of the first works was the famous composition using brainwaves by Alvin Lucier: „Music for Solo Performer, for Enormously Amplified Brain Waves and Percussion“ (1965) that used an EEG (electroencephalogram) interface. Nowadays, other composers and media artists such as Eduardo Miranda, Joel Eaton, Kiyoshi Furukawa, China Blue and Claudia Robles-Angel continue to develop new works using EEG data, employing a variety of scientific methods and artistic strategies. The usage of biomedical signals in art is not limited, however, to EEG only, but it also extends to a wide range of biological data, such as ECG (electrocardiogram) and EMG (electromyogram), the latter with well known examples by the Palindrome German dance company and Atau Tanaka at the start of the XXI century. After more than 50 years of successful use of bio signals in diverse art practices, it is now time to discuss the numerous methodological, aesthetic and epistemic implications of these developments.

Topics of the Panel

The panel will address diverse questions with regard to how artists use biomedical signals as well as its theoretical implications, focusing on the impact of scientific developments in the field, the question of access, and the aesthetic and epistemic implications of art using biomedical signals.

Scientific developments. In science and engineering the use of biomedical signals during the past decades has gradually moved from diagnostic investigation towards real-time assessment of mental states and affect, spawning emerging fields like Brain-Computer Interfaces and Affective Computing. With these developments, novel ways of offering objective access to subjective experience are created. How does the use of bio signals in the arts reflect these developments?

DIY access to biomedical signals. Most developments in the field historically have been tied to research facilities and expensive equipment, raising the question of the accessibility of biomedical signals for artistic inquiry and public debate. However, since the early days of biofeedback, numerous DIY (Do-It-Yourself) approaches have accompanied scientific research and informed artistic practice. In regard to this topic, the panel will address questions such as, for example: how can artists access the equipment and methods necessary to produce meaningful work with biomedical signals? Does the advent of EEG game controllers and bio-signal monitoring apps mark a democratization of these methods or will we only have access to our own bio-data via the opaque interfaces of apps and games?

Aesthetic and epistemic implications. By integrating biomedical signals into artistic work, the reception of art and the participation in art by an observer goes beyond the usual “channels” art is communicated through. This raises the question if there is an aesthetic of bio-data and biofeedback. In addition, the development of new forms of access to affective and mental states puts in question the

nature of these very states. How does our notion of, for instance, affect change if it is reformulated through experimental systems? How can artists critically reflect on these methods and their implications? Does the use of biomedical signals enhance or change our concept and perception of self? How do we interact with our own bio-signals?

Contributions to the Panel

Johannes Birringer: "Somatic Gestures in Mixed Reality/Virtual Reality Immersive Choreographies".

Recent danceworks created by DAP-Lab feature immersive mixed-reality environments or *metakimospheres*, offering multi-sensorial and intimate spatiotemporal experiences. Dancers and audiences enter into a deeper awareness of what we consider a form of somatic and tactile choreography. In my presentation, approaches to intra-active flows between human and technical beings are examined through attention to gestural choreographies in a bio-sensorial framework. At the same time, if the framework is considered an engineered atmosphere or environment, its affects and resonances need to be studied in order to articulate the processes that conjoin bodies, materials, and technologies in the becoming of sensory embodiment. The notion of becoming is necessarily contingent on the relational, dynamic and metastable states of the atmosphere.

Metakimospheres are kinetic atmospheres staged for visitors that pass through them, listen to them and feel them, unconsciously, attentively, distractedly, blindly, kinaesthetically. Performers are also present and embedded in the kimospheres, exploring the tactile and sonic interfaces, as well as the visual moisture, that animate the growth, slowness, scale and direction, the breath of their movement, their gauzeous entanglement. Some of the performers wear sensors built into their costumes or attached to their bodies. Their behaviours are sensorialised, yet the emergent immersive choreographies are not focused on control-based mapping of data derived from body-worn sensors or biosensors but are always already entangled with spatialised stimulations. Kathleen Stewart (2011, p. 448) argues that: "the senses sharpen on the surface of things taking form. They pick up texture and density as they move in and through bodies and spaces, rhythms and tempi, possibilities likely or not. They establish trajectories that shroud and punctuate the significance of sounds, textures, and movements". The intra-actions between human and technical systems are not pre-programmed or determined.

These stimulations interconnect vibrations of the body with vibrations of the world, creating an intermingling, which is of course also related to energy (and electrical) tangencies and transductions. The performers are conductors, and I mean this in a double sense of guiding visitors through the "score" of the *metakimosphere*, as well as engaging visitors through totemic sounding objects and conductive costumes. The visitors can touch these conductive fabrics and become aware of the sonic ripples, the noises that emanate from porous membranes.

The performers' incubating presence is felt and their transceiving role can be grasped when one realizes their costumes are sensortised and signal-generating. What distinguishes our work from other advanced research in music technology or dance technology/somatic practices is our focus on both the atmospheric architecture and what we call the "tactile narratives" that can evolve in temporal relationships between wearable performance and mediated environments. For a discussion of such biorelational frameworks, see Naccarato and MacCallum (2016).

The performers in the *metakimospheres* are a part of the real-time engineering of the atmosphere, especially of the sound that emanates (in localized intimate circumstances as well as through the spatialised and dispersed sonic gestures).

The dancers do not always invite looking, as their role is not necessarily one to be looked at. When they offer their costumes to be touched or hand one of the sonic objects to a visitor to invite listening to its electro-acoustic sound, the materials or objects also act, transmit, vibrate and resonate. Yet their bodily presence, and what I imagine to be the *expanded choreographic*, is affecting the body of the architecture in-between or beyond the thereness (*meta* referring to such "between" and "beyond" notions of presence/atmospheric space) – in the duration and circulation of space-time. The architecture's thereness can also be a wave, a flutter, touching bodies; there are suspended elements in the architecture that have movement capacities and can react to motion in proximal space. In the first two prototypes of the *metakimosphere*, the dancers' motion or stillness animates the elastic veil-like gauze draperies that are suspended from the ceiling and slouch down on the floor. In turn, they are also animated by the behavior of the pro-active, dynamic and interactive architecture (for example the *{/S}caring-ami* polypropylene prototype created by Hyperbody [TU Delft] for *metakimosphere no. 2,* featuring a computationally generated origami pattern based surface with integrated lighting, motion capture and robotic actuation based on proximity-sensing).

In the expanded choreographic there is no real stillness, not even when there is only breath. Breath not only moves space – inhaling/exhaling, expanding/contracting – but also is audible. In all *metakimosphere* installations the biophysical, etheric sound is amplified. The elemental thereness of the environmental atmosphere includes the audience as experiencers who are "inside" the atmosphere, and the atmosphere is in them. *Meta*: through them. Both, so to speak, reciprocally make up the materialities of the interaction merger. There is black porous gauze on the perimeter, and soft white veil net inside, and these insides-outsides – or "interskins" as Haein Song, one of our dancers, called them – are housed inside a darkened gallery space (circa 10 by 12 meters wide). This first envelope, for a test performance in London (March 2015), was small and intimate. The second envelope was a huge auditorium in the Medialab Prado (Madrid, July 2015), and here the perimeters expanded as an architectural skin with its own properties and behaviours. The third instalment was multi-layered and a more complex dynamic spherical environment that included separate enclosures for intimate listening. The German philosopher Peter Sloterdijk (2004) has

devised a philosophy of *spheres* and *envelopes* which contributes to the current interest in atmospheres, much as Philippopoulos-Mihalopoulos's critical study of "lawscapes" as atmospheres draws attention to embodied social and political norms in the conflict between bodies "moved by a desire to occupy the same space at the same time" (2015: 179). For the tactile narratives, see Birringer, (2016).

This *kimosphere* featured various sonorous qualities and vibratory intensities, voices, intonations and choral elements, a meta-language structured like music and gestural, tonal extrapolations in rhythm and timbre: the somatic here expanding outward into a spatial acoustic instrument or "polytope" (Xenakis).

This choreography and the dancers' (and the system's) gestures envelop spectators physically in the particular kinetic atmosphere or directly solicit and engage it as part of its very functioning. In the future version of this presentation, the signal processes, audio-visual interactions and tactile dimensions of the wearables created for the *kimospheres* will continue to be examined, in order to raise questions about what we mean by embodied, embedded, durational and attentionally rich environments (augmented reality/virtual reality) that can act as new conceptual frameworks for cognitive and biological/technological processes.

Furthermore, the notion of immersion will also be scrutinized in order to draw attention to interactive and participatory potentials of dance environments that allow visitors to have concrete tactile and auditory experiences while at the same time being challenged into somatic (inner) bodily sensations afforded by the new kinetics of VR. The DAP-lab is currently exploring narratives that can be composed through choreographic process derived from biophysical data (registering intimate bodily states of arousal, excitation, listening, breathing, moving etc.) in conjunction with interface architects and fashion designers rescripting the data mathematically to generate wearable objects with 3D printers and as avatars inside virtual worlds that are accessed through (HIVE) goggles. We plan to use "choreographic objects" (miniature 3D printed creatures) that become scaled-up avatars in immersive virtual landscapes where they can be encountered to develop sensorial dramaturgies.

The next instalment, *metakimosphere no. 4*, therefore combines two atmospheres, a real architectural space and a virtual (computational) space, both actuated through the same tactile narrative. The crucial aspect for us is the immersant's sensory participation: the resonances of the real and the virtual spaces are to be rhythmically entwined, and the occurrent gestures are envisioned to become reciprocal – pushing the kinaesthetic into a perceptual virtuality (VR) that so far is largely contained in the visual (the ergonomic challenges with virtual reality headsets are well known: the more powerful headsets must be tethered by thick cables to computers or consoles, which can tangle up immersants' legs when these rigs occlude their view of the real world). The kinematic, then, is the challenge for a social VR choreography, which does not insulate/isolate the immersant but allow for an expanded (virtual) synasthetic perspective and embodiment.

This will require a process where the virtualizing instrument is not perceived as an enclosure- object or prosthesis but as a wearable that becomes a part of the body as a metamorphic changeable and emerging process and hyperobject. Given the precarious experience of a technological body or technical being that is mutable and relational, movement becomes a vector of affect. The immersant can enact, or fail to enact, specific bodily gestures or movements, and there is no correct way of executing a particular movement but only actualized potentials derived from resonant (narrative) stimulation. Performances in such augmented reality can let movement emerge from the rhythm of sound, vibration, graphics and light produced by the machinic.

Figure 1. *Metakimosphere no. 3.* Hongye Deng and visitor performing with soundobjects (left), Vanessa Michielon in OrigamiDress (right). Design by Michèle Danjoux. DAP-Lab, Artaud Performance Center, 2016 © DAP-Lab

Thus, the way the somatic is performed, compromised, interpreted or created anew is crafted by the performer, the instrument and the relational context. The objective is to explore a certain level of entrainment, which enables movement and sensual intensity to arise. If the immersant's intentions are constrained, in regard to physical performance or kinaesthetic experience, it is still vital to come to a realization of the biorelational feedback, the continual flow and fluid relations between the enacting self, the coupling with technical system and atmospheric environment. The embodiment in augmented/virtual reality, I propose, is always subject to such a mingled or torn multiplicity, a hybrid octopus-like creature that must push its limits further.

Claudia Robles-Angel: "Using Bio-signals in Interactive Installations: Revealing the Hidden Side of the System".

The following contribution to the panel consists of an artistic approach to the main topic of usage of bio-signals in media art by introducing a selection of interactive works of my authorship using diverse types of bio-interfaces and software – from open source to commercial devices – and therefore discusses methodological, aesthetic and epistemic implications of such developments. These works have been conceived aesthetically as art-works, although frequent exchanges with scientists were necessary as well as essential to their creation. Their main characteristic lies in the fact that they were created as installations, with the main intention focusing on the participation and reaction of visitors. My contribution hereby concentrates on installations instead of on performances, because installations provide for a direct contact of audiences with these technologies and their interaction with their own bio-signals. Hence, while performances with bio-signals raise epistem-

ic questions such as for example about the credibility about the data used or questions about what is really happening between performer and visuals/sound, installations such as those introduced in this paper were conceived to reveal to the audience the hidden side of this type of works, inviting them to experience with their own inner emotional states, eliminating those doubts about the accuracy of many performance works in the field.

This raises questions about methods to be implemented in those installations, namely:

(i) which bio-signal and which interface should be used in order to invite participants to create an audiovisual environment with their own bio-signals?;

(ii) which are the advantages/disadvantages of the selected interfaces and their respective physiological parameters in each particular situation/art-work?

Two Bio-signal Installations: SKIN and WEB-MINDSCAPE.

My experimentation with bio-signals started in 2004 for the composition and production of multimedia interactive performances and installations creating immersive spaces that invite visitors and audiences to dip into an audiovisual environment shaped by imperceptible physiological manifestations. This was driven by the idea of *how to perceive the imperceptible*, particularly related to the human body and those internal signs that are usually imperceptible in our daily life. Those afore-mentioned bio-signals can be of diverse nature, for example brainwaves, heartbeats, muscular tension and many others.

As described in the Proceedings of the NIME 2011 (Robles-Angel, 2011, p. 422), my first work using bio-signals was the performance/installation *Seed/Tree,* which was developed at ZKM – Karlsruhe, Germany, and which consists of a Butoh performance combined with the usage of an EMG (Electromyogram) interface for one of the dancers, whilst microphones were used to amplify the breathing and the heartbeat of the other two. The strong connection achieved in *Seed/Tree* between sound and performers was an experience, which revealed to me the potential for further experimentation of the impact of bio-signals in my work, which could be made extensive also to audiovisual environments made by internal emotional states.

In the following years, I continued my research and practice using other interfaces such as for example EEG (Electroencephalogram) and GSR (Galvanic Skin Response), creating interactive multimedia works such as INsideOUT, SKIN and the recent WEB-MINDSCAPE, all of these with the intention not only to make *perceptible the imperceptible* but also to raise awareness about the human body and its internal subtle signs and the possibility to control them in a conscious way, inviting visitors to create audiovisual environments from their own emotional and physiological parameters.

Thanks to the accessibility of several devices/software such as, for example, the Arduino project, I was able to create in 2009 an interactive biofeedback performance called INsideOUT, where the performer uses an EEG interface in order to influence both images and sound surrounding him/her via real-time data stemming from the conversion of Alpha and Beta brainwaves. The EEG interface in this occasion was an open source board from *Olimex*, assembled without the need of expensive and difficult-to-access hardware.

Due to the increasing interest of audiences to experiment with both the interfaces and their effects by themselves, in the past few years I started to create installations in which visitors are able to use the interfaces. One of the problems with this approach is that the interfaces afore-mentioned (e.g. the EMG and EEG interfaces from *Olimex*) require complicated methods to attach the devices to the user (for example, gel for each electrode, utmost precision in positioning electrodes, etc.), all of which are difficult to implement with large audiences of participants in interactive installations. In order to avoid these complications, I started to experiment with the GSR2, a Galvanic Skin Response or electrodermal bio-interface developed by the Canadian firm Thought Technology Ltd., specialised in biofeedback instruments. The advantages of using this commercial interface were, its ease of handling, its data accuracy and seemly direct understanding of the results. The interface measures the skin's conductance, which similar to other physiological parameters, is directly connected to the nervous system and the variations of these values indicate physiological arousal, such as for example the appearance of stress or relaxation. The GSR is very sensitive to diverse emotions such as for example anger, anxiety or relaxation.

This interface was used in SKIN, an audiovisual interactive installation for three video channels and octophonic sound (creating an immersive space), in which visitors use the GSR interface, where the values received from the GSR are transmitted to a computer in order to interact with sound and images. Visitors are therefore invited to sit in the middle of the surround sound space and use the hand-held interface in order to transform the audiovisual environment with their own emotions, basically projecting either levels of stress or relaxation. The visual part of the environment consists of two basic textures: one orange and the other blue, which correspond to the two mainly inner states: relaxation and anxiety/stress. Users are normally confronted at the beginning with the normal tension state, with rare exceptions of people normally unstressed at the start. This tension state is reflected in the visual part as an unstable surface, which moves chaotically according to the level of stress, the pre-recorded image is infinitely multiplied in small images or screens that move randomly within the large screen. After some minutes sitting quiet in the middle of the audiovisual environment, concentrated into their own breathing and being aware of their own inner states, visitors start getting relaxed. In this first step of calming down, a blue line appears, getting bigger, helping people to realise, that they are relaxing: the more the screen turns blue, the more signs of relaxation. A full state of relaxation is achieved, once the entire visual space is blue. The sonic part of the installation consists of a sound produced by the GSR2 and which becomes high-pitched when the user reached high levels of tension/anxiety and low pitched when they reach relaxation levels. This sound is further sent to the computer in which a granular synthesis process is applied and spatialised in eight audio channels, creating a surround immersive space. Both, image and sound were programmed with the *Max* software.

After using a commercial and ease of handling interface with SKIN, I turned again my attention to the use of brainwaves in a new work: WEB-MINDSCAPE. Having already experienced a DIY interface (*Olimex*) in INsideOUT, and aware of the disadvantages this interface

could produce in an installation situation, I decided to explore a commercial and seemly accurate interface by the firm *EMOTIV*. There are two versions of this interface, one for scientific research purposes (*EMOTIV Epoc*), which consists of 16 electrodes that must be previously wetted, and which – due to the long process of setting up – was not appropriate for usage in installations, and a light version, the *EMOTIV Insight*, developed for health and well-being purposes. The latter consists of only 5 polymer sensors that absorb the humidity from the atmosphere, thus it does not require the application of gel or saline solutions and is therefore appropriate for usage in art installations. After exploring several possibilities, I used the software *MindYourOsc* together with the *EMOTIV Insight*, which makes its own interpretation of the EEG data divided in five basic emotions: Engagement/Boredom, Frustration, Meditation, Excitement and Excitement Long Term. Although these five emotions were used at the start of the development, participants could not fully understand how their brain activity was influencing the audiovisual environment. As an important aspect of my work is that participants are invited to control the interactive space and experiment with their own internal emotions, I decided to reduce the set to only two emotions: Meditation and Excitement, which helped users to be more participative, understanding how to control these two opposite emotional states.

The audiovisual installation WEB-MINDSCAPE concentrates on my exploration of the influence of external inputs in our daily life and particularly on the current and profuse usage of social media. The goal is to make visual and audible unconscious internal reactions that are produced in the subject in front of a well-known social network inviting people to reflect about and how this outside input is reflected inside their own self. In the installation, visitors are confronted to Twitter messages while the computer measures their brain waves and analyses their emotional reactions. The visual part is created by a light structure made by electroluminescent wire (EL wire), which glare when applied to an alternating current (AC). Hence, once the AC has been activated, the data of the subject's brain waves from the EEG interface is utilised in order to turn on/off different cables in different tempos. The subject is immersed in this luminous structure, surrounded by light cables and sound, the latter diffused in 8 audio channels, creating an immersive audiovisual environment. Visitors (one at a time) are connected to the EEG interface, which is continuously measuring their brain activity whilst listening to messages via Twitter from all over the world. Simultaneously, a community is invited worldwide to joint a Twitter account.

The sound section of the work consists of a soundscape which changes depending on the information coming from the EEG: when the subject is in a relaxation state, the sound creates a balanced and subtle soundscape composed with frequencies received from the brain waves; when, on the other hand, the subject's relaxed condition is altered by the messages received from the outside, the sound combines words coming from the instant tweets in real-time, creating a sonic environment made of words as whispers, and which increasingly becomes more chaotic according to the data received from the brain activity.

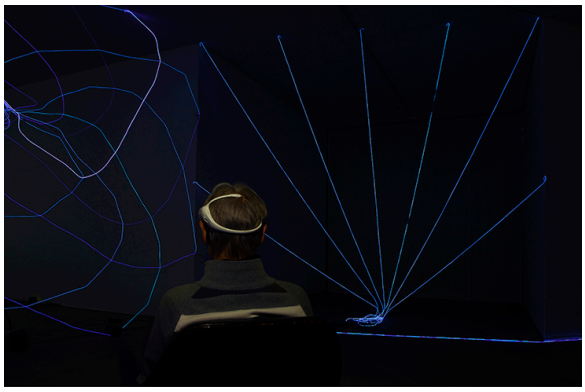

Figure 2. WEB-MINDSCAPE at IK, Vlissingen, The Netherlands. Photo by Michiel Vermet. © 2016

The installation WEB-MINDSCAPE is at this point still a work-in-progress with two important aspects needing revision: firstly, to be in a position to manipulate the *EMOTIV Insight*'s raw data, in order to further develop the visual and sound aspects of the piece, due to the limited information available from the software *MyndYourOsc*; secondly, the idea of seeing and hearing internal reactions in front of a social network needs further research in order to extract the exact information from the EEG for which I have the support of the department of musicology at Cologne University.

To finalise and with regard to some of the questions addressed by this panel, as an artist I consider highly relevant the intersection between art and science, as it opens the possibility of working with scientists, not only to have access to professional equipment (with possible impact on the scientific research within the area), but also to produce meaningful artworks applying both the professional equipment and the scientific knowledge related to bio-signals. One of the main difficulties of making art pieces with bio-signals, is the fine line between either having a scientific result rather than an artistic one at the end, or, given the complexity of the management of the interfaces, that results may not be accurate, and therefore, distorting the very core issue of making art through bio-signals.

Lasse Scherffig: "Interacting with Bio-signals: What do We Enact Here?"

Cybernetic and, more recently, enactive accounts of perception, understand perception as an activity. One implication of this idea is the conclusion that the objects of our perception emerge from the actions we carry out with them (von Foerster, 2003). This may be especially true for virtual objects and environments (Scherffig, 2016). Integrating bio-signals into interactive experiences thus opens a path towards the perception of biological states as objects of experience. Art using bio-signals and other forms of biofeedback hence fundamentally changes the relationship between us and such "hidden" states. The latter used to be defined as "epistemic objects" that are products of research programs, scientific cultures and their material conditions (in terms of apparatuses, experimental procedures, discourses, see Rheinberger, 2006) and that primarily exist within the realm of academic research. Instead, they now become accessible as objects of experience, that are enclosed in a loop of perceiving them and acting on them in real-time. They become subject to sen-

sory substitution (Bach-y-Rita, Collins, Saunders, White & Scadden, 1969) or sensory enhancement (Clark, 2007).

This not only implies the emergence of new objects based on bio-signals. These objects are, moreover, mediated and shaped by the technologies that render them perceivable. Tools such as *Max/MSP*, scientific equipment, gaming gear like the *Emotiv* EEG headset, and self-built DIY solutions all carry their own built-in assumptions about the nature and relevance of (bio-) signals and the possibilities of translating them – assumptions that often are based on the tradition of signal processing. Artistic practice, in turn, brings its own traditions into this mix, as artists working with bio-signals draw from such disparate fields as electroacoustic music, dance, performance, installation, and interactive art. More recently, the use of bio-signals has also surfaced in commercial applications and games, adding game-mechanics and gamification, quantified self, and medical applications to the range of possible strategies.

Artists working with bio-signals thus navigate a territory in which the various dispositives of the production and mediation of these signals are confronted with artistic and commercial strategies and traditions and together shape the experience of new objects of perception. We can therefore ask: How, in the light of this, do these objects look and feel? Or: what is the phenomenology of these objects? In the panel, this question is discussed as a conversation between scientific and artistic experience.

Uwe Seifert: "Brain-Computer Interfaces, Mobile EEG and Robotic Systems: New Media Art and Entertainment in Need for Machine Ethics and Android Epistemology?"

Not only digitally advanced societies such as Japan, Korea and the USA but also other societies relying heavily on information technology are now increasingly introducing (autonomous) machines – i.e. artificial computational systems – with capacities for learning and decision making in social domains such as warfare, healthcare, education, and economy. In new media art and entertainment artificial computational systems with learning and decision making capabilities acting to some extent autonomously are also rapidly increasing. In particular interactive installations using brain-computer interfaces and robotic and mobile EEG-systems come to mind. At the same time there is a strong tendency to conceive art as research or science and bring together scientific research and art. For example, the Synthetic, Perceptive, Emotive and Cognitive Systems group led by cognitive scientist Paul Verschure is one the most advanced scientific research groups exploring the human mind/brain as a computational system by combining robotics, new media art, and experimental research using bio-signals (Verschure & Manzolli, 2013).

In general, the use of artificial computational systems with learning and decision-making capabilities in connection with brain-computer interfaces, robotics and mobile EEG-systems in art, entertainment, warfare, healthcare and education raises ethical questions, which need urgently be addressed. The United Nations Educational, Scientific and Cultural Organization (UNESCO) has already undertaken first steps to deal with an ethics for robotics. In August 2016 UNESCO's World Commission of the Ethics of Scientific Knowledge and Technology (COMEST) released a "Preliminary Draft Report of COMEST on Robotics Ethics." The point to be kept in mind is that this report deals with ethics for researchers. This must be carefully distinguished from machine ethics, i.e. an ethics for machines (Moor 2005; Anderson & Anderson, 2011), in particular for robotic systems in warfare, healthcare, and education. For example, Anderson and Anderson (2010) claimed to have implemented for the first time ethical principles on a NAO robot. Both issues, i.e. an ethic for researchers and an ethic for machines, are barely addressed for art and entertainment. For example, the article by Veruggio and Operto (2008) about roboethics touches only briefly upon robots in art and entertainment.

So, in this context some main future challenges arise for new media art and entertainment:

1) Do we need an ethics for new media artists parallel to an ethics for e.g. roboticists? How would such an ethic look like? What then about artistic freedom?

2) Do we need a machine ethics, i.e. an ethics implemented in computationally bounded artificial artistic agents? What kind of rules might be implemented in a feasible manner? In general: Does new media art need an android epistemology for computationally bounded artificial artistic agents?

Let us deal first with questions concerning an ethics for artists. Given that an ethics should be grounded in human rationality the question pops up whether we have some kind of normative theories on which a rational ethics might be grounded. If we are interested in such an ethics first-order languages, subjective probability theory and decision theory provide a core for the best normative theory of rationality we have to date (Glymour, 2015). According to Clark Glymour (2015) first-order languages tell what an agent ought to believe if he wants to believe all and only the necessary implications of what he believes. Subjective probability tells the agent how his degrees of beliefs ought to be distributed. Decision theory, then, tells an agent what to do under given degrees of beliefs and specification of his preferences and utilities.

If cognitive science is correct and the human mind and especially human reason are computational bounded systems – and at least it seems that cognitive science offers the best approach today to investigate the mind-brain scientifically – then a theory of rationality based on these theories does not provide a guide for human actions, i.e. for an ethics, that applies to humans. Computability and complexity theory impose limits on the capacities of computationally bounded agents. According to Glymour (2015) evaluation of human behaviour and beliefs can be thought of as functions to be evaluated and according to his computational thesis these functions are Turing-computable. So, computability and complexity theory impose – as for any computational system – limits on the evaluation of human beliefs and actions: thus, humans are computationally bounded agents. For computationally bounded systems, there is – assuming in addition the Church-Turing thesis –theoretically and in principle only a "small" class of functions that is effectively computable. Therefore, for such agents there exists an epistemological limit of what can be known and formulated in an explicit and communicable way. Moreover, practically, there are time and space restrictions on computations, e.g. computations of functions without polynomial-time algorithms are not tractable or feasible and it is also not possible to keep

all the parameters needed to represent an arbitrary probability distribution over a state description, i.e. over all possible logically non-equivalent conjunctions of n (two-valued) atomic sentences, in the "head". Such a state description consists of 2^n possible states. In the worst case the space requirement for representing a probability distribution increases exponentially with the number of atomic sentences. Which means for realistic situations the computationally bounded human mind-brain is not capable to represent such a distribution. What does all this mean? Briefly, there are normative theories of rationality but computationally bounded agents cannot act as required by them. This applies to humans conceived of as computationally bounded agent and a fortiori for artificial computationally bounded agents. So, how can humans cope with the challenge to develop an ethics for certain special areas such as for researchers in robotics or artists? Is an ethics for artists in new media art especially whose who are dealing with art as science necessary? How could it look like given such odd situation?

Assuming that cognitive science is not correct and humans are not computationally bounded agents, then still, questions remain whether a machine ethics, i.e. an ethics for computationally bounded artificial agents, and android epistemology are needed for interactive works of new media art which integrate artificial agents with capacities for learning and decision making.

Unfortunately, as already indicated, the odd situation transfers to this situation: computationally bounded artificial agents are not capable to fulfil requirements set by current normative theories of rationality.

At stake are not only a machine ethics but also (artistic) creativity and learning capabilities of computationally bounded agents in new media art environments: in general, an android epistemology for new media art. Why is an android epistemology for media art necessary?

Imagine the simple case that a learning and decision making interactive installation might cause some harm to its visitors. Will the artist be responsible? The artist did not pre-specify the actions of the system, the system learned through interacting with visitors. In addition, the system evaluated and decided to choose some action sequences by itself. Think of another case, a system might – because of its learning functions – become capable to create aesthetically more interesting products than the artist or user it is supposed to support in creating art works. Should it be allowed to do so? How could this be implemented? Here android epistemology is needed to clarify the epistemological, ethical, and esthetical limits of computationally bounded artificial artistic agents. The main question android epistemology asks are (Glymour 2015, p. 370):

1. What might be normative principles of rationality for a computationally bounded agent?;

2. How can a computationally bounded agent possibly do what humans do?

Thus, being aware of these epistemological questions and questions and problems raised by cognitive science new media art – especially conceived of as "art as science" – will reflect on and cope with questions concerning the human condition and participate in forming human's future socio-cultural as well as economic environments.

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Prof Dr Uwe Seifert studied Musicology, Computer Science and Philosophy at the University of Hamburg, from which he received the »Magister Artium«, the »Promotion« (PhD) and the »Venia Legendi« or »Habilitation« (postdoctoral qualification) in Systematic Musicology. Since 1999 he has held a professorship in Musicology at the University of Cologne. He has been a member of the Collaborative Research Centre SFB/FK 427 "Media and Cultural Communication" since 2002, in which he has been leader of the research projects "Electronic Music Transformation since 1950 – Transcriptive Interaction" (2002-2004) and "Artistic Interactivity in Hybrid Networks" (2005-2008). From 2006 till 2014 he has been partner of the International Summer School in Systematic Musicology funded by the European Union. Currently he is a member of the research group »Schlüsselthemen musikalischer Grundlagenforschung: Interdisziplinäre Musikforschung und Musikphilosophie heute« at the Institute for Advanced Study »Hanse-Wissenschaftskolleg«, Delmenhorst.