

Coming from the heart: heart rate synchronization through sound

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Abstract

This paper encompasses recent art works of the first author, where the use of biometrics, more precise EKG, was explored in the context of interactive installation art. The paper also introduces a series of ongoing experiments, in which the effects of audio stimuli on heart rate is studied. These experiments aim to study if and how the human body copes with attuning to rhythmic stimuli. The used stimuli are derived from peoples heart rate, creating a feedback loop to be used in artistic interactive work.

Keywords

interaction, biometric, embodiment, heart rate, sound, art

Theoretical Background

New media vs the mapping problem

Art has consistently dealt with mapping problems, although in traditional art they are more related to senses as to sensors. Meaning within an art piece can be regarded as being embedded in the combination of a given sociocultural context, the artist's concept and the public's interpretation. How meaning is constructed is a much debated topic in formal and new media art. However in new media art the discussion becomes even more complex when the incorporation of sensor technology and participation of the public is included as valued parameters in the construction of meaning. In sum it can even be argued that the mapping problem (or more appropriate, how artists handle this) is one of the main topics of new media art. Dealing with the creative or artistic way in which meaning is communicated through form or sound might well be the essence of 'creating art'.

In interactive art, this mapping problem becomes increasingly complex, seeing that the public is invited to become an equal partner in the construction of meaning. This role is far more than merely fulfilling a role as an interpreter of (artistically) implied meaning. Media theorist Andy Cameron addressed the public's role in interactive media in his presentation 'Dissimulations, The illusion of interactivity' [Cameron, 1998][1], he states that "*Interactivity is the ability to intervene in a meaningful way within the representation itself,*

not to read it differently." [sic].

Furthermore, in his book '*The Language of New Media*' [Manovich,2001][2] Lev Manovich differentiates between '*open interactivity*' and '*closed interactivity*', the latter referring to a fixed branching structure where the choices of the user define the path they follow. This is to a great extent what Cameron refers to as 'to read it [the representation] differently'. In contrast, open interactivity refers to the use of artificial intelligence, artificial life and neural networks coded into software. At the same time, Manovich warns about using the term 'interactive media' when addressing the post- modern shift towards a physical interaction between the user and a media object. He states that this occurs "*...at the expense of psychological interaction.*".

Therefore, the development of sensor technology and implementation of this technology in interactive art works should be guided away from the object (or interface) towards the experience. Focus should be on humanizing the objects rather than objectifying humans. As a result the author presents a strategy towards 'natural' mapping which can guide future research.

Interactivity in music and sound art

Within music research, interactivity is a well established concept. The process of interactivity is a cyclic process, described as an action-reaction cycle (fig.1) in Marc Leman's book '*Embodied Music Cognition and Mediation Technology*'. [Leman,2008] [3]

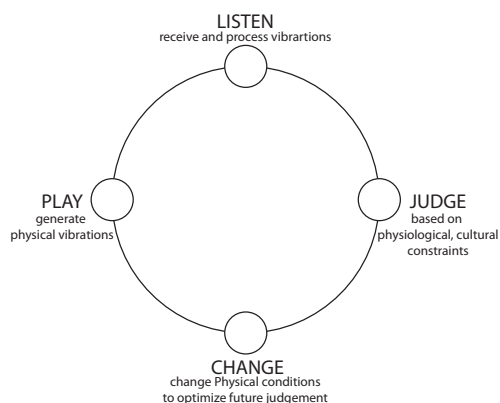


fig. 1 action-reaction cycle

Interaction is made apparent by using the metaphor of how an instrument is built. While playing the instrument, the resulting sound is processed by the human auditory system. A perception is built up in the mind and judged, by undertaking an action the instrument can be changed. This results in a change of the conditions of the instrument and as a consequence this changes the sound produced by the instrument when it is played.

Leman extends this idea in his model of musical communication, with the purpose of communicating musical intentionality between listener and performer. This is realized through corporeal articulations, transformed through the use of a mediator. This mediation technology can ideally be perceived as an extension of the body, capable of interpreting the intent of the performer and distinguishing between various sets of actions. This implies that the mediation technology should be considered no longer merely as an object to which the performer needs to focus his energy, but as an agent, that is on its own capable of interpreting this energy.

Interactivity in new media art

In new media art, which can include multi sensory aspects and is not only sound-related, the action-reaction cycle or model for musical communication may be less apparent. In his introduction on multimedia environments, Leman proposes to “create an autonomous virtual social agent that is able to communicate...” [sic], such agents should be able to deal with capabilities of both synthesis and analysis. In order to do so, it is necessary to have a mapping strategy that is deduced from objective measurements, ideally cross-referenced with an analysis of subjective experience. This mapping strategy should also have a more universal nature than a mapping available to the public based solely on the artist’s decisions.

Interactivity and biometrics

The availability of a large range of bio sensors at a reasonable cost is fairly new for artists and it is imperative that new mapping strategies are researched. The choice for using a heart rate sensor is very much related to the belief that change in heart rate is an involuntary corporeal function, and thus it should behave on a more subliminal level than responses induced by cognition.

Artistic Background

Artistic background

The experiments are founded on two existing art-installations of the first author, the first being “LiebesLektion”, an (unintentional) responsive work dating from 2003. While the second is an interactive sound-installation called “the Heart as

an Ocean”[Coussement, 2008][4](fig.3).

For “LiebesLektion” a specially designed contact microphone was used to record the heart rate of two lovers while embracing each other. Every recording made, showed that after approximately 15 minutes the heart rate and phase of the two persons grew very close to each other. Whether or not this was due to the fact that they were physically touching was not investigated further. However, when exhibiting the piece, the public’s response to “LiebesLektion” was striking. Everyone but one who stayed near the installation left the exhibition space relaxed. The one exception being a man with a pacemaker implanted.

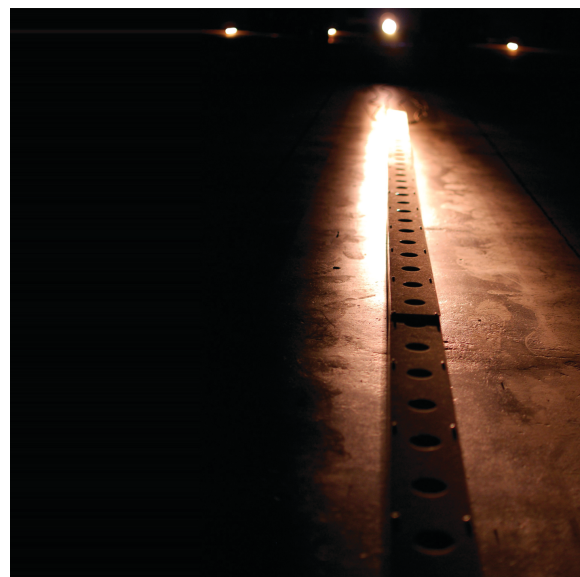


fig. 3 the Heart as an Ocean, exhibited at the new media festival PLUTO, 2009

These findings led the first author to the second installation “The Heart as an Ocean” in which the heart rate of a participant is transformed into a sounding ocean, thus binding the heart rate and rhythm more subtly to sound. Here also, people had a feeling of getting more relaxed while interacting with the installation. The goal of ‘The Heart as an Ocean’, is to generate a natural flow of communication, and the installation was developed to be easily comprehensible as a more complex technical interface could obtrude the intended interaction. The interaction functions more as an affordance [5]. Where objects refer to just those action possibilities which are readily perceivable by a participant. On that account sophisticated explanations should be unnecessary to begin interaction, and user feedback should be based on a strong homogeneity in ‘experiencing’.

The experience would originate out of a reflection of the state of mind of the person interacting with the installation. For this reflection, a synthesized

ocean wave is created every third heartbeat. the total of consecutive waves imitates the sound of an ocean breaking on an imaginary shore. The intensity, level, duration and amplitude of each wave are all derived from the heart rate, detected by a Suunto comfort belt, of the person interacting with the installation. Musical parameters are altered in direct relation to heart rate: an agitated person, with a strong and fast heart rate, would generate strong loud and fast waves; a calm person, with a slow heart rate, would generate slow and gentle waves.

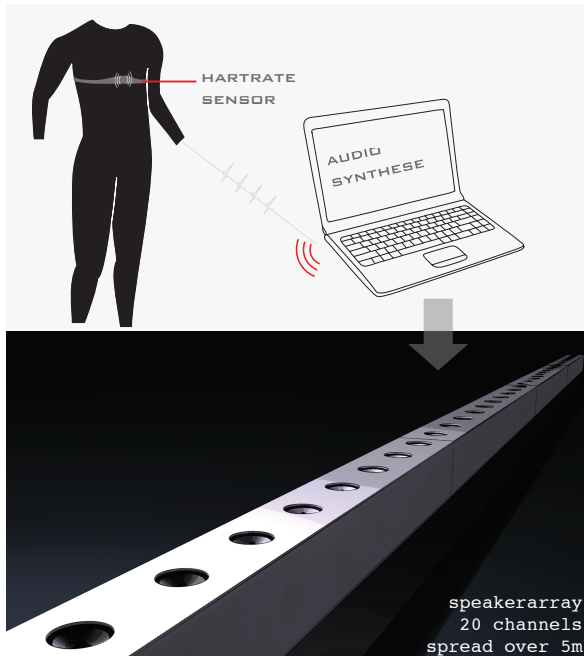


fig. 4 the Heart as an Ocean, diagram

The effect of a sea breaking on a shore is emphasized by the spatial movement of each wave in a setup with twenty speakers. Each wave starts its cycle randomly at one position and moves through the auditory space using the other speakers. The sound of the sea was initially chosen because of its soothing effect. Water has also played an important role in the spiritual, psychological and physical ablation throughout history. Moreover, the sound of the sea contains all frequency bands and therefore, can be conceived as a type of a white noise signal in space. As a result, surrounding sounds are numbered out, resulting in a very personal auditory space. Throughout the first five to ten minutes the mean heart rate is calculated and delta times between heart beats are compared (to detect if people where straining to affect the installation more by, for example, running). After which the software gently lowers the presented heartbeat and makes a prediction on when the following beat will occur. When the trend of the following heartbeats is as predicted this process is repeated, further lowering the tempo. If not the installation adapts to the

participants heart rate again.

The installation imposes a different rhythm upon the participant in an attempt to lower that participants heartbeat, relaxing him/her without causing any strain on the body.

Previous research

Previous research studies in music therapy [Knight et al.,2001][6] report on the impact of 'sedative' music on anxiety. Wendy E.J. Knight et al. executed a lab experiment with eighty-nine participants, in which the goal was to see whether 'sedative music' prevents stress-induced increases in subjective anxiety, systolic blood pressure and heart rate. The piece selected for the experiment was Pachelbel's *Canon in D major*. Previous studies reported that the piece induced relaxation in many participants. The results of this study suggests that music indeed largely prevents increase of subjective anxiety and heart rate. In fact, in most cases there seemed to be a slight reduction in stress levels. However, whether or not music is classified as being 'sedative' or 'stimulating' has been argued to be an oversimplification [Hodges,1980][7]. Furthermore, Repp and Penel (2003) [8] found evidence that synchronization of movement with auditory rhythms is more common than synchronization with purely visual rhythms. Synchronization can be conceived of as a type of sensorimotor mechanism and is, in principle, possible without paying to much attention to the physical stimulation.

The aim of the experiments described in this paper is to investigate if this synchronization is also reflected in heart rate, and investigate if evidence can be found of the soothing effects of sound with non-musical stimuli. The experiments forgo the term music, due to its cultural references, and investigate to what extent sound can induce or effectuate a connections with biological responses. These experiments investigate the physiological responses to sound stimuli and are targeted towards implementation in artistic projects.

Experimental Setup

Relaxing music is, in general, characterized by slow tempo, repetitive rhythmic patterns and gentle contours. Based on this categorization, we opted to concentrate on the element of repetition in conjunction with slow tempo, and designed a synthetic heartbeat from a sine wave oscillator with both amplitude as frequency modulation.

The stimulus is produced as follows. The ADSR envelope shaping the frequency, set at 102.4 Hz, has a sharp attack and a sustain of half of the attack value. Thus keeping the tail of the presented sound at 51.2Hz. The amplitude modulation has an

identical attack but has a more gradual decreasing tail. Combining two sounds results in the easily recognizable sound of a heartbeat (fig.2).

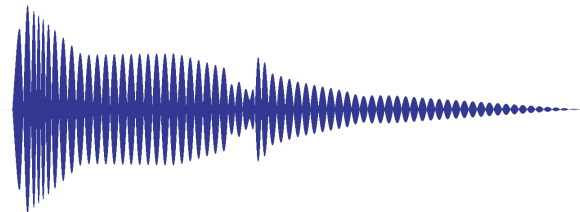


fig. 2 example of synthesized heart beat

The experiment consists out of 3 consecutive stages of five minutes each. In the course of the first stage, the test subject is listening to the synthesized heart beat, synchronized to his or her own heart rate. Throughout this first stage, the average heart rate of the participant is calculated. In the second stage, twenty beats per minute are deducted from this average over a period of one and a half minutes, after which the heart rate presented normalizes to a slow pulsating rhythm. During the third stage the rhythm increases until it is synchronized with the heart rate of the test subject.

An icubeX wi-microSystem, from the company infusionsystems, is used for sending the data to the computer. Both a BioEmo and a BioBeat are connected to the ADC in order to measure GSR (BioEmo) and the full EKG (BioBeat). The heart rate is derived from the EKG signal, after which it is sent to a pulse train to trigger the audio-synthesis. The BPM that is detected is simultaneously recorded with the EKG and GSR values for further analysis. All the data recording and the sound synthesis is handled by a MAX/MSP patch.

After the experiment each subject is asked to comment on their experience in a short interview.

Results

The study took place in a quiet room where the 10 subjects were tested individually. The task at hand for them is to sit back in a comfortable sofa and relax while concentrating on the sound. They were told that they would be listening to their heartbeat and that this stimulus would change its rhythm twice.

subjective data

Each of the participants was asked to respond to the following questions:

- Could you identify the heartbeat you heard as being a part of you?
- Did you feel like you had to change anything during the experiment to cope with what you heard?

- Could you clearly differentiate between the consecutive stages
- Could you describe how and what you felt throughout the different stages of the experiment?

All participants except for one reported that the presented stimulus sounded natural. In the first stage of the experiment, they identified with the sound and thought it to be a part of them. The people who identified with the sound also reported that the rhythm was mesmerizing, only one of them reported the experience thus far as being stress inducing. She elaborated on this by explaining that this was because she was very concentrated and overwhelmed by what she heard and was not used to 'sitting still'.

On the second question, there was a wide variety of answers, with reference to the first two stages of the experiment. Most noticeable was the answer of the participant who could not identify with the sound, he reported feeling compelled to adapt his breathing to what he heard to make the experience more tolerable. There were another three subjects that noticed change in how they were breathing, and reported their breathing slowed down in the transition from the first to the second stage of the experiment. The other six didn't notice any immediate change in behavior.

All of the participants outlined the three stages of the experiment without difficulty. In the second stage all participants but one felt detached from the sound, reporting no identification whatsoever, describing the sound as 'just something in the back' or 'noise'. One described the second stage of the experiment as being 'exterior' as opposed to an 'interior' feeling in the first and third stage.

The transition from the first to the second stage felt strange for some (30%), with people thinking things like 'what is wrong with me', or 'what are they doing to me'. The transition from the second to the third stage was more worrying to our participants, with 70% of them reporting an apparent reaction. Four participants started breathing faster to 'calm their heart' while the other three simply reported being stressed. During the third stage, all the subjects that felt initially identified with the sound, felt the same level of identification.

Most of them found the whole experience calming, although none of them could say with certainty if it was the stimulus or the mere fact that they had a 20 minute break in a comfortable sofa.

objective data

When analyzing GSR and EKG no conclusive results were found. Although, with a few of the subjects, it seemed that when the heart rate dropped there was a tendency to follow no significance was found, and the results remain inconclusive. The average heart rate did not

change according to the setup during the experiment. There was hardly any activity measurable in the GSR signal, which leads us to believe there was no significant raise of stress levels.

Discussion

To our knowledge, there are not that many art projects concerned with biometric sensing and biofeedback. The most well known in art history are perhaps the compositions of Alvin Lucier and David Rosenboom. In his *Music for Solo Performer* [Lucier, 1965][9], for example, Alvin Lucier uses EEG electrodes to detect alpha waves to actuate percussive devices like kettle drums and snare drums, among others. However, it was David Rosenboom that has been the most articulate on the role of systematic change in biofeedback music. His own brainwave analysis software, used “for creating self-organizing musical forms” being just one example. In “*On being Invisible*”, which he composed in 1976-77, the software learns the cognitive processes mapped to his listening over time, thus truly envisioning the concept of creating a feedback loop. He describes “*On being Invisible*” as “a self-organizing, dynamical system, rather than a fixed musical composition” [Rosenboom, 2000][10]. A more recent example is Atau Tanaka’s BioMuse instrument [Tanaka, 1995][11], which he plays solo or in Sensorband, an ensemble formed by Edwin van der Heide, Zbigniew Karkowski and Atau Tanaka. The BioMuse is a system that tracks neural signals (EMG), translating electrical signals from the body into digital data and via software to sound.

Our prognosis is, that there will be an increasing amount of projects dealing with biometrics, seeing that biosensors become more commercially available. They have already been widely used to interpret the effects of sound (and vision) in both medicine and psychology. Concerning systematic musicology, and to be more precise our research group, the use of biometric for monitoring is still in its early stages. Using biometrics as a means of creating the aforementioned feedback loop is even more in its infancy. The aim of this paper and the discussed research is to create a framework where the physical influences of sound on the human body are explored and documented, in conjunction with qualitative results. This to increase our knowledge about how we encode what into sound, and if it will affect us humans universally.

The results of this paper are to no extend conclusive and a larger study need to be done. However the sense of identification with a sounding heartbeat and the lack thereof when listening to a very disassociated heartbeat is a trend we would like to explore further. The feeling our participants had of getting more relaxed when concentrating on

the rhythmic pattern of their own heart as opposed to the second transitional stage in which they reported discomfort leads us to believe there is some room to explore this further.

In conclusion we acknowledge that the setup of our experiment could be approved upon. Having people exposed to music only on headphones might be a much to limited experience, seeing that we are responsive to low frequency vibrations with the whole of our bodies and not only with our, specialist, ears. The setup also commenced with people being at rest. There is no clear manner for them to actually direct their actions into getting relaxed, for instance sitting down when being upright or even lying down. The effects should be further quantified in order to make a more firm statement, that is not only of concern in a lab context but is at the same time pointed towards implementations into artistic projects.

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