DECONCERT: BATHING IN THE LIGHT, SOUND, AND WATERS OF THE MUSICAL BRAINBATHS

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ABSTRACT

We describe a series of performances, events, and water-based brainwave concerts beginning with an event we called DECONcert ("decontamination concert"). These events explore the combined role of water waves, brainwaves, and radio waves in the production, regeneration, or experience of sound waves (music and musical performance). Water served three roles: (1) water has been the medium for our continued exploration of water-based music (sounds generated by water waves, vortex shedding, and the like); (2) water served a cleansing role, both in actuality as well as metaphorically, to wash away individuality prior to a collective participatory brainwave experience; and (3) as a physical and metaphoric medium for binding participants in a collective consiousness. Various groups of participants at different geographical locations were processed through decontamination and then joined together by EEG (electroencephelograph) electrodes in a common group collective (group of groups). This combination of brainwaves and washing ("brainwashing") formed a common brainwave-based audiovisual feedback space, across cyberspace. Some of the groups were underwater, or immersed in water, and in the process of shedding their shoes, clothes, and other personal belongings, DECONcert participants were cleansed of their individual "cyborg" selves, and re-integrated into a collective consciousness shared by various groups of participants, including Parkinson's patients, in different geographical locations across the World Wide Web. One of the things that we learned is that there is a tremendous willingness for individuals to shed their individuality and become part of a larger collective.

(a)

(b) (c)

Figure 1: DECONcert events allowed participants to explore issues of DECONtamination, music, water, and brainwave. (a) Participants being prepared with electrode paste for EEG readings. (b,c) A separate spotlight on each participant responds to their individual level of visual arousal, thus turning participants into performers who are on stage in the bath.

1. INTRODUCTION

This paper presents a series of performances, art exhibits, and underwater/water-themed concerts, that explored the relationships between water waves, sound waves, and brainwaves (see figure 1). These events merged a custom built EEG (brainwave) computational system with music generation, immersive aquatic spaces, and groups of immersively engaged performers and participatory audiences. Participatory performances explored collective consciousness by creating both physically shared spaces (connecting various groups of participants across distant geographical boundaries) and shared human-computational networks.

The resulting collective immersive experiences were created using the mediums of a shared immersive audio environment, and an aquatic immersive environment where, in some events, groups of participants were actually immersed, in whole, or in part, in water. These media are explorations of waves: in one medium, acoustic waves; in another, aqueous waves (various performances and studies of caustics and wavefronts, as well as water-induced sounds); and, of course, brainwaves.

This theme of waves not only occurred at the observational (output) side of the performance but also at the input: both the environments were generated by directly

measuring and interpreting the brainwaves of the participants. This paper discusses various performance art events together with the philosophical implications and artistic narratives developed in the various events.

2. CREATING IMMERSIVE EXPERIENCES WITH HUMANISTIC INTELLIGENCE

Humanistic Intelligence (HI) is defined [8] as a signal processing framework in which the processing apparatus is inextricably intertwined with the natural capabilities of our human body and mind. Within the processing framework of HI, the computational apparatus and user, in being intertwined as such, are considered as a signal processing block, interacting as one with the outside world. Within this block, the human and computer work together in a tight feedback loop, with each accepting information and outputs from and providing information and inputs to each other. In contrast to AI, which seeks to recreate human intelligence on the machine, HI seeks to utilize the abilities of both the human and machine to their fullest.

HI forms the structural framework in our explorations. In each of our exploratory performances, exhibits, and concerts, water, music and brainwaves become the mediums to express Humanistic Intelligence. Though at first inspection the HI framework may appear to express an individual's relationship to computational apparatus, our events demonstrate the collective nature of HI, where groups of participants are *all* connected to the computational system and thus to each other: a collective consciousness.

We use music and water and brainwaves as mediums to create group immersion to allow participants to experience and become a collective consciousness. We explore collective consciousness through: (1) collective consciousness (i.e. using multiple participant brainwave inputs to drive an artistic process); (2) re-presenting these brainwave signals in a shared multimedia environment where audiovisual experiences, such as sound and visuals, are collectively experienced; and (3) using water as a physical agent to bring participants into a shared space that is truly, and literally immersive (in the sense of a communal bathing experience). These media explore issues of privacy and personal space.

3. THE EVENTS

Starting in July 2001 [1] we had a series of events addressing issues of contamination and biological warfare. The authors created a number of events, performances, and concerts that dealt with issues surrounding **decon**tamination. These events were named DECONference, DECONversation, DECONsortium, DECONtrol, DECONcert, and the like, making reference to DECONtamination. For example, a series of DECONcerts were presented as DECONtamination concerts in which participants were washed down with water prior to being connected to EEG (brainwave) instrumentation. This work builds on our artistic practice of aquatic-based music, such as the hydraulophone (underwater flute) as a self-cleaning musical instrument [9].

Our DECONcert series explored a regenerative feedback loop between brainwaves and music, as the collective consciousness of a large audience either generated music or modified music generated by other performers. In many of our DECONcerts, groups of people from around the world were connected, over the Internet, from various different communal baths or aquatic spaces. For example, in one DECONcert, we had groups of six bathers, at a time, in one rooftop tub, each outfitted with EEG electrodes, connected to bathers, three-at-a-time, in another distant tub that was located on the sidewalk of a busy downtown street. Situating the bath on a busy sidewalk established a juxtaposition of public and private, while inviting passers-by to stop, doff their duds, put on the EEG electrodes, and join in. The different group baths were connected audiovisually, as well as electroencephalically, across the World Wide Web, also by way of web cameras, microphones, and various physiological sensors such as EEG and ECG electrodes.

In another concert, we invited a number of Parkinson's patients to participate remotely from their hospital beds using equipment we sent out on loan. What was remarkable about this form of participation, was the fact that the DECONcerts were inclusive for people of any physical ability. In this form of cyborg space, a person of lesser physical ability is still a full participant, since the primary experimental control modality is brainwaves. All that is needed to be a full participant is a functioning brain.

An important artistic narrative was the juxtaposition of this corporeal transcendence, combined with the physicality of passers-by in their disrobed and electrified bodies, situated in a bath on a busy street.

One set of mini-concerts within the DECONcert series was called "Telematic Tubs Against Terror". This was a series of events in which groups of individuals were immersed in tubs of water and connected by way of EEG to form a collective consciousness. This emerged as participants projected a sub-collective from each tub (each "wash node"). These events explored a collective and distributed consciousness as people's brainwaves were made public, in concert with the collectively shared experience of water and music.

3.1. DECONcert: Collaborative Music in the Key of EEG

DECONcerts were a form of audience-participatory concert in which the participants' brainwaves determined the music they were experiencing.

The first DECONcert was, to the authors' knowledge, the first exploration of music generated by collective consciousness (i.e. more than one person generating music with their brainwaves together).

Our first collectively created concert, DECONcert 1, attracted enough interest to require three separate sessions in the same evening, each for a different group of participants. For each session, we connected 48 people by way

[1] Our first event took place prior to the anthrax scare that came shortly after the September 11th 2001 terrorist attacks.

(a)

(b)

Figure 2: DECONcert Performance: This group of 48 participants simultaneously and collectively adjusted the musical environment with their brainwaves while remotely connected to groups in other countries.

of their EEG signals, which were collectively used to affect the audiovisual environment.

Using six 8-person EEG machines, donated by manufacturer Thought Technologies Limited, we were able to obtain connections from 48 people at the same time.

In order to have the greatest flexibility we wrote our own GNU/Linux device drivers for these machines, and we developed and implemented our own signal processing algorithms. We developed a system to utilize multiple EEG signals to clean the signal and look for collective Alpha synchronization (which occurs, for instance, when people close their eyes). Figure 2 shows images taken of the first DECONcert performance.

DECONcert utilized electroencephalogram (EEG) sensors which sensed electrical activity produced in the brains of the participants. The signals from the brainwaves of the 48 participants were used as signals to dynamically alter a computationally controlled soundscape. DECONcert allowed the participants to form a feedback loop with the computational process of musical composition. The soundscape being generated was in response to the participants: the collective response from the group of participants is sensed by the computer, which then alters the music based upon this response. Again, the participants hear the music, and again respond, and again the computer senses and further alters the sound. In this way, collaborative biofeedback is being used in conjunction with an intelligent signal processing system to continually regenerate the music on the fly.

A total of 3 DECONcerts were held with different configurations exploring different methods of audience interaction. In each of the 3 DECONcerts that were held, up to 48 audience members sat in front of the stage in 6 groups. On stage, jazz musicians improvised on some combination of electric keyboard, electric clarinet, trumpet, saxophone, drums, and/ or electric bass guitar. As audience members listened to the concert, each member's brainstate determined the modulation of the output of the musicians' synthesized instruments. Some acoustic qualities that the audience was able to modulate included pitch, volume, FM oscillation, chorus, and distortion. Figure 3 shows images from DECONcerts 2 and 3.

The participant's raw EEG signal, and frequency distribution, were plotted and projected onto a screen, so the participant could determine if he or she was in an Alpha brain state or a Beta state. When all of the participants in a single group reached Alpha frequency (as determined by an averaging process), the acoustic quality controlled by that group was modulated accordingly.

In this way, the participants' brainwaves collectively and continuously affect music that was being heard. This process was both fluid and regenerative, in that participants' brain states influenced the musical output, which in turn was received (heard) by the participant's brain, which then influenced the participant's brainstate which influenced the music output.

(a) (b)

Figure 3: Regenerative Jazz Performance (a) DECONcert 2: Audience brainwaves modulate the sounds of a trio of performers. (b) DECONcet 3: A Jazz ensemble is affected by audience brainwaves, with acoustic instruments modulated via sound filter.

3.2. Telematic Tubs Against Terror

The second set of events we held, Telematic Tubs Against Terror, also explored the creation of a collective and communal consconsious, this time using the mediums of water and brainwaves, rather than music and brainwaves. Figure 4 shows images taken from these events. Two tubs of water were set up in different locations, one on a main street, and one indoors 1.5 miles away. Eight EEG leads and several EKG leads were suspended over the tubs.Two screens abutted the tubs. Each location received the EEG and EKG information of the sister tub and projected it on one screen, as well as receiving live video feed from the sister location projected onto the second screen. Up to 8 (and sometimes more) participants at a time entered the tub together, and connected themselves to the EEG and EKG leads. In this way the participants were sharing not only physical space, but mental space as well.

3.3. Differentiating Brainstates to Create Control Interfaces

In DECONcert 1, we hooked up 48 people's EEG signals, which were collectively used to affect the audio environment. Each audience member had a single EEG lead held against the back of his or her head with comfortable headband, at the location of the occipital lobe. As well, a wire was clipped to each ear for grounding. The collective signals from groups of eight participants were cleaned, and collective Alpha synchronization (which occurs, for instance, when people close their eyes) was detected.

The Alpha-wave intensity increases when a person approaches a calm meditative state of concentration and it is inversely proportional to the amount of visual stimulant the person receives [4]. Experiments have shown that there exists a correlation between the mental activity of a person and their respective EEG spectrum [2]. Lusted and Knapp explored brainwave interfaces [7]. An early musical brainwave implementation was conducted by Lucier [5, 6], also employing Alpha waves as a sonic device. Rosenboom [10] worked with Alpha waves for music production. The music of this work extends the group dynamic of brain wave music to 48 simultaneous participants, and explores both light and water as additional mediums for immersive experiences.

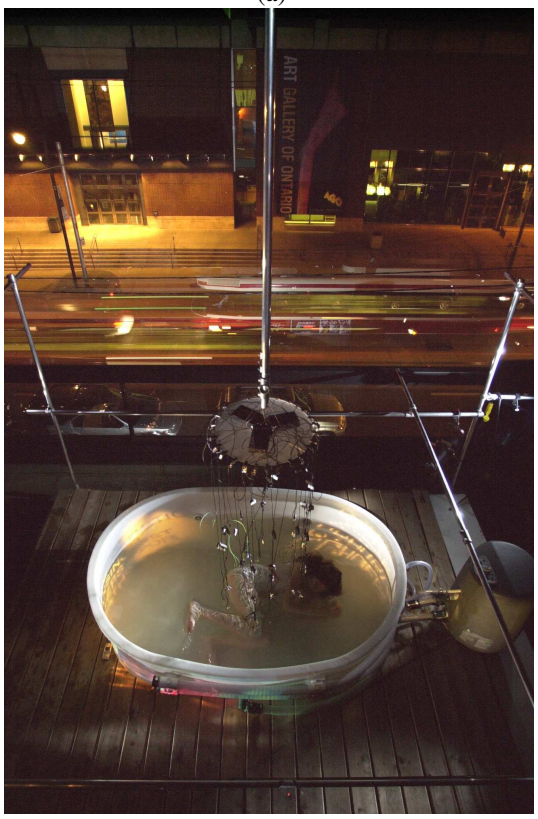
Humans are generally described as being in one of 5 brain states, Alpha, a calm creative state that is described by brainwave activity of 8-12 Hz, Delta, slow brainwave less than 2 Hz, is associated with deep sleep. Theta, a state achieved by those in deep meditation or earlier stages of sleep, are classed as 4-8 Hz. Most individuals spend most of their day in Beta waves, classified as any wave activity over 12 Hz. [1] For our purposes, we tracked whether participants were in Alpha state (8-12 Hz) or another state

3.3.1. System Configuration

The basic configuration of the system is shown in Figure 5. To digitize brainwave activity for analysis, a Thought Technology FlexComp A/D encoder and ISA DSP2 Data Acquisition Card (DAC) were used. These devices provided up to a 2kHz brainwave sampling rate, and measured brainwave activity down to a maximum of 5% error and 1V accuracy.

A set of custom programs were written to utilize the hardware for music generation. Additionally a Linux device driver was written to interface with the ISA data acquisition card. A server program communicated with the DAC, placed on the ISA bus of a Linux system, and optically connected to the FlexComp encoder hardware thereby making raw EEG data available over TCP/IP. A client system connected to the server via TCP/IP and received the EEG data, upon which it performed the filtering and processing of brainwave data. Both programs ran on a single Linux PC using the loopback address (127.0.0.1), when the PC was sufficiently fast. Similarly the TCP/IP interface was exploited to allow communication between remote locations, as in the implementation of the Telematic Tubes exhibit, and the remote Parkinson's patients event.

(a)



(b)

Figure 4: Telematic Tubs Performance. (a) and (b) show two different "wash nodes" where participants' EEGs and ECGs were read and shared between sites. A video link connected each wash node with the others as well, and brainwave data was displayed and re-presented remotely.

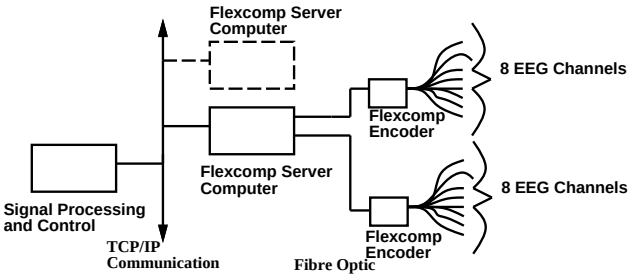


Figure 5: EEG Multimedia Control System. The system is expandable to accommodate a number of EEG channels, which may be connected to multiple participants. Additionally, the TCP/IP connection allows the possibility of remote and wireless data analysis and storage.

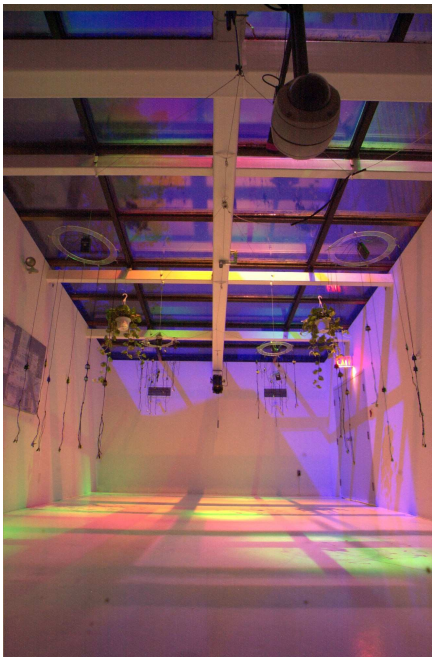
Additionally, control of standard AC room lighting was achieved using a DMX-512 dimmer system. DMX-512 is a simple packet-based digital protocol for controlling stage lighting and other devices using an RS-485 serial interface at 250kbaud connecting to a LanBox LCX DMX-512 Controller over a TCP/IP socket which sends a single text command to change room lighting levels. This change was transmitted via the DMX protocol to a set of DMX dimmers, which changed the light intensities in the room as required. Figure 6 shows the EEG controlled lighting environments used in the exhibits.

3.4. Screening out unusable signals

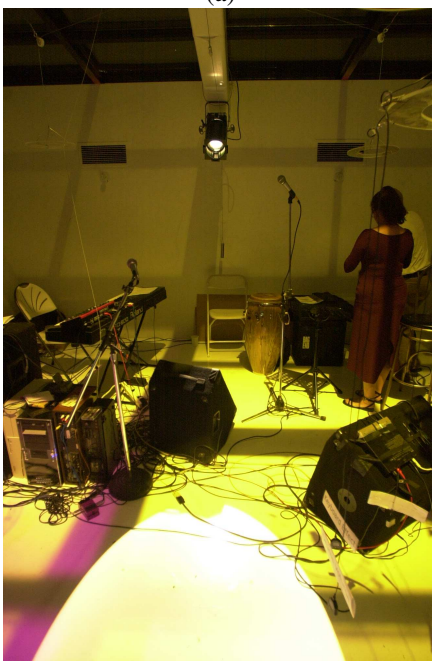
EEG signals are typically orders of magnitude weaker than muscular signals. Consequently, if the participant is moving their head, or their muscles are not sufficiently relaxed, the EEG signal signal strength is weak in comparison to the muscular electrical activity, which we consider noise. In this situation, we cannot rely upon the analyzed EEG bands to produce a usable signal. In order to detect these cases, we calculated the power of the received signal, and rejected the signal above a certain threshold, which could be calibrated as the system was in use.

3.5. Real-Time control of live musical input

Because the system is used for real-time control, latency between the onset of a desired EEG trend, and response of the system was found to be of interest. We implemented several approaches to control. The first approach was to use a variable counter which incremented so long as the participant's Alpha waveband strength was above a threshold. The counter decremented when the Alpha waveband strength was below a threshold. Sound effects were triggered when the counter was above a certain threshold. The advantage of this method was that only sustained periods of high Alpha activity triggered a sound response from the system, making it quite robust with respect to "false positive" Alpha strength events. Additionally, this method allowed us to verify the efficacy of our system at detecting Alpha activity. However, the requirement for sustained periods of Alpha activity meant that the sound effects would only occur at typically longer than 10–15 seconds after the onset of the Alpha activity state. This latency made it difficult for a casual participant to perceive



(a)



(b)

Figure 6: Brainwave Controlled Immersive Lighting and System Sculpture. (a) The DECONcert theatre. Six stations of EEG Electrodes hang from the ceiling. Gelled lighting systems shining from above the skylights of the space use light to create a collective immersive environment. The custom designed circular discs form EEG nodes for eight participants, reflecting the "neuron" like design of the system where multiple branches of input flow to a signal processing machine. (b) In turning the audience into a participant, DECONcerts invert the relationship between audience and performer, bringing the two together. A brainwave controlled spotlight shines on the participants with the intensity controlled by their concentration state.

their effect on the sound. Similarly the window size used for the frequency analysis is related to the latency in the system. Longer windows allow for more reliable detection of sustained mental state. However, this increased overall latency of the produced control signal. Additionally, high, but short lived Alpha activity is not well detected in this case. Short windows allow for faster system response, but were affected by noise.

3.6. EEG Based Music Composition

Our approach to EEG based musical composition was that of creating a general programming framework, whose variables were continuously controlled by the EEG signals of the participants.

There was a simple sequenced bassline (randomly choosing from 4 note progressions), and a simple sequenced drum track (the complexity of the track altered by the person's Alpha), which utilized a sequencer. We used the counter method described above. However, instead of only a single event above a preset threshold, different ranges of the time-integrated Alpha-wave envelope were used to control the complexity of the tracks.

For the bassline, several sets of notes' on and off toggles were under control of the EEG. Thus, for higher activity, more notes were turned on and this made the sound of the bassline appear more busy and complex. For the sequenced drum track, the EEG was used to toggle different rhythm tracks on and off. When more instruments were triggered on, the rhythm appeared more complex. Again, these were turned on and off with respect to current Alpha counter range. Additionally pad and background sounds were randomly triggered by the amount of Alpha activity of the participant.

To maintain a musical consistency the tones (notes) were chosen from a predetermined scale (aeolian mode) so as minimize the disonnance which would occur if completely random notes were used. For these effects, however, the primary contribution of EEG control was to affect the filter frequencies of the tones, which dramatically affected their quality. The control was achieved via sending MIDI control signals to synthesizers.

Typically observed minimum and maximum Alpha waveband strengths were mapped to the range $[0, 127]$ used by MIDI. This method represented a continuous form of mapping Alpha strength to control variables as no thresholding was used. Additionally, however, we found that the most effective sound effects were those which changed dramatically over their MIDI controlled range. In some instances, we restricted the MIDI controller value into a range which produced dramatic changes instead of the full $[0, 127]$.

We found that this approach allowed the system to emulate the complexity and richness of sweeps and pads and to create those events under the control of the Alpha portion of the spectral distribution of brainwaves. Similarly, the kick drum or delay effects on a drum track are additionally triggered on and of under the control of Alpha waves.

Overall, we found that these approaches allowed for different parts to fade in and out. For instance, the kick sometimes provided a beat, and would then fall out, giving way to a more open segments and so on. The participants were able to learn and control the system well by listening to the music feedback, over the 30 minutes they had to use it. At the end of the performance, the participants understood their control of the music well.

3.7. Affecting Live Performance with EEG Signals

DECONcerts 2 & 3 used participant brainwaves to alter the sound qualities of instruments being played by live musicians. Both acoustic and electronic instruments were affected. Electronic instrument sound qualities were affected by varying MIDI parameters using the system of DECONcert 1. An electronic keyboard, electronic wind instrument and electronic drum pad were used.

To achieve variation on acoustic instruments, a digital mixer was used. For acoustic instruments such as an amplified bass [2] , two audio channels were fed into the mixer. One channel was the unaltered audio channel, and the second was the same input run through a filter. The filter was either a pedal filter, or a digital filter applied internally: a feature of the mixer equipment. Brain wave signals drove the system to, via MIDI, crossfade between the unfiltered and filtered channels. In this way the brainwaves altered the sound quality of the acoustic instruments used at the event.

This created a challenging playing environment for the musician. The sound quality of the musician's instrument changed in ways that were not under the conscious, direct control of the musician. As the sound quality changed, the musician needed to adapt his or her playing style to match. For instance, the decay of the note would change. With a short decay, the musician could perform quick, staccato phrases, while with longer decays, phrases incorporating sustained notes were more appropriate. In this way, participants affected the overall qualities of the music despite the fact that the musicians were playing the instruments themselves.

4. PHILOSOPHICAL IMPLICATIONS/ DISCUSSION

4.1. Human/Computer Feedback Interaction (HI)

Both Telematic Tubs Against Terror and DECONcert create a Humanistic Intelligence feed-back loop using the elements of music, water and brain. As discussed, Humanistic Intelligence is defined as intelligence that arises from the human being in the feedback loop of a computational process in which the human and computer are inextricably intertwined, in other words, it is a regenerative feedback loop. In DECONcert, regenerative music is the expression of HI in music. In regenerative music the computer, instead of taking only active cues from the musician, reads physiological signals from the musician/performer. The music which the regenerative algorithm then creates will be heard by the musician/performer. It is hoped that the music will in turn generate an emotional response on the part of the musician/performer, and that this emotional response will be detectable by the computer, which can then alter the music in some way in response. Continuing in this fashion, it is clear that there is a well defined feedback loop occurring between the human and the computer.

[2] for the moment, we consider the analog nature of the amplification of the vibration of the strings of an electric bass guitar as "acoustic"

4.2. Regenerative Music

Jazz, the musical genre of the DECONcert performances, is a natural non-computational example of regenerative music. Jazz is a free flowing style of musical improvisation in which the performers intuitively read one another's states, mood, and musical intention based on both the performer's sonic output as well as conscious and subconscious communication between players. The players, in a sense, create an immersive, responsive environment. Immersed in the music that surrounds them, in the musical and collective 'zone', they respond to one another's output. The response of the audience, also encourages or discourages the musicians' particular output. DECONcert takes this intuitive process and turns it inside out.

Regenerative Music looks not only at the audience-musician interaction, but also the musician-instrument response. It brings in the problem of how a musician can learn to respond to this new physiologically driven instrument, as well as how the instrument can learn to infer the wishes of the musician through their physiological signals, in addition to the normal playing of the instrument. In a sense, the musician and instrument each play off of each other, and together, both can be viewed as an "instrument". The choice of how to map from physiological signals into instrument behavior would be an artistic one, under the control of the musician.

4.3. Collective Unconsciousness

Creating regenerative music then becomes a distributed process, where no one individual has conscious control over the sound. In a sense, all individuals enter a collective state in which no single individual is aware of or has conscious control over the outcome. Collectively and communally, the audience determines what will be heard musically, using the interface of their brains. The audience has no determination over what the final outcome of the music will be, nor do the musicians. Thus, with brains physically connected to one another through EEG leads, the audience enters both physically and metaphorically into a collective unconsciousness.

In Telematic Tubs Against Terror, collective unconsciousness was explored not through music as its medium of expression, but through water. Sitting together in a pool of water collecting and sharing brainwave information, participants were brought into the same collective DECONsciousness as DECONcert. In Telematic Tubs, both the physical and metaphoric aspects collective consciousness are strengthened. In Jungian tradition, water is the strongest metaphor for the unconscious. "Water," Jung

says, "is the commonest symbol for the unconscious" [3]. Analytical psychology views the sea (ocean, water) as the symbolic realm of a collective unconscious.

4.4. Water and Electricity

Telematic tubs invites participants to enter the waters of the unconscious. Engaging in communal activity in a post 9/11 world, particularly during the SARS crisis during which these events were held, poses risks. Entering a collective unconscious also poses risks, as below the surface of the waters of the unconscious float any number of dangers. Telematic Tubs highlighted these dangers in a novel way. Popular wisdom would have it that water and electricity don't mix. The "dangerous" (in perception) although perfectly safe pairing of EEG leads hanging over a large pool of water and having an individual connected by wires to the EEG machine while submersed in a tub is profoundly counter intuitive. It highlights the danger that occurs when on enters the waters of the unconscious a place fraught with symbols that can seem threatening or taboo, but when faced, prove rewarding.

4.5. Sousveillance

Surveillance pervades our society, ostensibly to mitigate danger. As a collective of individuals whose information is being shared amongst one another, we are engaging in a "sousveillance" [11] of sorts. Whereas traditional surveillance is a top-down affair, where some hierarchically superior "Big Brother" is watching the movements of the general populace, in Telematic Tubs Against Terror and DECONcert, the distributed sharing of private information creates a sousveillance situation in which the subjects themselves are recording and sharing their own information with one another. In an interesting twist, this sousveillance creates a feedback loop between the audience and the recording device, particularly evident in the complex feedback loop of Telematic Tubs Against Terror between the video cameras and 2 separate wash nodes. In being recorded, particularly while in the vulnerable situation of bathing, one's behavior changes. In Telematic Tubs, one realizes one is being recorded, and ones actions are affected as such. Those different reactions are broadcast to the sister tub, who in seeing the actions of their fellow bathers at a separate location, act differently. The reactions of the participants in the second tub are then recorded as video and projected on a screen visible from the first tub, to further affect the behavior of the participants there, who cannot directly view on a screen their own behavior, only that of the second tub. Thus a self-conscious distributed self-surveillance feedback loop is created.

5. CONCLUSION

DECONcert and Telematic Tubs Against Terror speak of the interconnected relationships between water, music and the brain. Using an intelligent signal processing system to control musical output we created a collective consciousness by highlighting both the humanistic intelligence human-computational feedback loop as well as the physical shared immersive environment. In creating what we refer to as a collective DECONsciousness, issues of privacy, contamination, and control become significant. Participants become performers who are on stage in the bath, self powering a distributed immersive experience with the pooling of their brainwaves.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

[1] J. Brankack and S. F. M. Stewart. Current source density analysis of the hippocampal theta rhythm: Associated sustained potentials and candidate synaptic generators. *Brain Research*, 615(2):310–327, 1993.

[2] L. Cromwell, F. J. Weibell, E. A. Pfeiffer, and L. B. Usselman. *Biomedical Instrumentation and Measurements*. Prentice Hall, Inc., Englewood Cliffs, New Jersey, 1973.

[3] C. G. Jung. Collected works. 9(1).

[4] H. Legewie, O. Simonova, and O. D. Crutzfeldt. *EEG Changes During Performance of Various Tasks Under Open- and Closed-eyed Conditions*. Elsevier Publishing Company, Amsterdam, Netherlands, 1969.

[5] A. Lucier. *Music for Solo Performer (1965), for enormously amplified brain waves and percussion*. Lovely Music, Ltd., 1982.

[6] A. Lucier. Music for alpha waves, assorted percussion, and automated coded relays, on "imaginary landscapes". *Elektra/Nonesuch 79235-2*, 1989.

[7] H. S. Lusted and R. B. Knapp. Controlling computers with neural signals. *Scientific American Magazine*, pages 82–88, October 1996.

[8] S. Mann. Humanistic intelligence/humanistic computing: 'wearcomp' as a new framework for intelligent signal processing. *Proceedings of the IEEE*, 86(11):2123–2151+cover, Nov 1998. http://wearcam.org/procieee.htm.

[9] S. Mann, R. Janzen, and M. Post. Hydraulophone design considerations: Absement, displacement, and velocity-sensitive music keyboard in which each key is a water jet. In *Proceedings of the 14th annual ACM international conference on Multimedia, October 23-27, Santa Barbara, USA.*, pages 519–528, 2006.

[10] D. Rosenboom. Method of producing sounds or light flashes with alpha brain waves for artistic purposes. *Leonardo*, 5(1), 1972.

[11] M. F. Steve Mann, James Fung and G. Baccanico. Panopdecon: deconstructing, decontaminating, and decontextualizing panopticism in the postcyborg era. *Surveillance & Society*, 1(3):375–398, 2003.