A Young Person's Guide to Brainwave Music

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This is a great article from the now defunct Canadian magazine 'HorizonZero'. The zine was a multimedia web magazine about digital art and culture in Canada. This article is from issue 15 published in 2004 - but this is the first time I've seen it. This article was written by Andrew Brouse.

You can check out the other issues at http://www.horizonzero.ca

A Young Person's Guide to Brainwave Music
Forty years of audio from the human EEG
by Andrew Brouse

It is mid-August 2003. In the midst of a sweltering heat wave, James Fung and other students of University of Toronto "Cyberman" professor Steve Mann are hectically preparing sophisticated electronic and computer technology for a unique sonic and visual event: an improvised collective musical piece created interactively from the brainwaves of audience participants. REGEN3: Regenerative Brainwave Music will be orchestrated by feeding tiny micro-voltages gathered from forty wired performers into a responsive EEG network: a "cyborg collective" comprising the cybernetic interactions between performers, musicians, electronics, and computing machines. Norbert Wiener, the originator of cybernetics, would be impressed.

Unfortunately, the planned performance coincides with the largest blackout in North America's history. Major cities from New York to Toronto are effectively shut down. Pre-empted by the failure of a far more massive network - the North American power grid - this networked performance of music and minds has to wait for another day.

Music of the Mind

Two weeks later on August 30, 2003, Steve Mann and James Fung do manage to gather together the needed human energies to present REGEN3 / Regenerative Brainwave Music. [http://regen.eyetap.org Using hardware from Thought Technology [www.thoughttechnology.com and the PD interactive programming environment, [www.crca.ucsd.edu/~msp/software the brainwaves of the audience-performers are channelled into the creation of an interactive sonic and visual environment, where the participants' brainwave patterns create the music and lighting effects for the evening.

Readers having sensations of déjà-vu are not entirely mistaken: this event was only the most recent salient example in the history of brainwave music in which diligent visionary individuals, artists and scientists, have worked together to synthesize hybrid works of art-science. Since 1965, when Alvin Lucier composed the first piece of music using human brainwaves as a generative source, brainwave music has undergone a fascinating evolution. To fully appreciate the directions this music is taking today, it is helpful to reflect upon the history of bioelectricity, brainwaves, and the context in which brainwave music has evolved.

Bioelectricity

Brainwaves are a form of "bioelectricity", or electrical phenomena in animals or plants. The history of research into bioelectricity began around 1780 with Luigi Galvani, who discovered that he could cause muscles in a frog's leg to contract by applying an electrical current to exposed nerves. This work was followed by that of Emil Heinrich Du Bois-Reymond, considered the founder of modern electrophysiology, who in the 1840s began to measure biological currents in electric fish and later in humans via electrodes embedded directly in his own arm.

In 1875 the British neurophysiologist Richard Caton succeeded in measuring brain electrical activity using electrodes implanted directly in the brain tissue of rabbits and monkeys. At the time, it was not believed to be possible to extract meaningful data by measuring more non-invasively, with electrodes placed on the human scalp. (Electrical implants directly into the brain were not widely used on humans for obvious ethical reasons.)

History of Brainwaves

Human brainwaves were first measured in 1924 by Hans Berger, at the time an unknown German psychiatrist. He termed these electrical measurements the "electroencephalogram" (EEG), which literally means "brain electricity writing". Berger published his brainwave results in 1929 as Über das Elektrenkephalogramm des Menschen ("On the Electroencephalogram of Man"). The English translation did not appear until 1969.

Berger is a complex and enigmatic figure in the history of medical science. He had a lifelong obsession with finding scientific proof of a causal linkage between the psychical world of human consciousness and the physiological world of neurological electrical signals. He pursued this quest in the most methodical, disciplined scientific manner possible, determined to explain observed telepathic phenomena in terms of theories of the conservation of energy. Yet Berger's belief in this hypothesis stemmed not from his research itself, but from a personal subjective experience. Berger had almost died in an accident in his youth. The very same day he received a sudden unexpected telegram from his family inquiring into his health. Berger believed that his family had received some sort of telepathic communication from him at his moment of near-death.

Sonification of Brainwaves

Initially, Berger's work was largely ignored. It was not until five years after his first paper was published (when E.D. Adrian and B.H.C. Mathews verified Berger's results) that his discovery began to draw attention. In their 1934 article in the journal Brain [http://brain.oupjournals.org , Adrian and Matthews also reported successfully audifying and listening to human brainwaves which they had recorded according to Berger's methods. This was the first example of the "sonification" of human brainwaves for auditory display.

Music from Brainwaves

If we accept that the perception of an act as art is what makes it art, then the first instance of the use of brainwaves to generate music did not occur until 1965. Alvin Lucier [http://alucier.web.wesleyan.edu/ had begun working with physicist Edmond Dewan in 1964, performing experiments that used brainwaves to create sound. The next year, he was inspired to compose a piece of music using brainwaves as the sole generative source. Music for Solo Performer was presented, with encouragement from John Cage, at the Rose Art Museum of Brandeis University in 1965. Lucier performed this piece several more times over the next few years, but did not continue to use EEG in his own compositions.

Spacecraft

In the late 1960s, Richard Teitelbaum [http://inside.bard.edu/teitelbaum was a member of the innovative Rome-based live electronic music group Musica Elettronica Viva (MEV). In performances of Spacecraft (1967) he used various biological signals including brain (EEG) and cardiac (EKG) signals as control sources for electronic synthesizers. Over the next few years, Teitelbaum continued to use EEG and other biological signals in his compositions and experiments as triggers for nascent Moog electronic synthesizers.

Ecology of the Skin

Then in the late 1960s, another composer, David Rosenboom [http://music.calarts.edu/~david/ , began to use EEG signals to generate music. In 1970-71 Rosenboom composed and performed Ecology of the Skin, in which ten live EEG performer-participants interactively generated immersive sonic/visual environments using custom-made electronic circuits. Around the same time, Rosenboom founded the Laboratory of Experimental Aesthetics at York University in Toronto, which encouraged pioneering collaborations between scientists and artists. For the better part of the 1970s, the laboratory undertook experimentation and research into the artistic possibilities of brainwaves and other biological signals in cybernetic biofeedback artistic systems. Many artists and musicians visited and worked at the facility during this time including John Cage, David Behrman, LaMonte Young, and Marian Zazeela. Some of the results of the work at this lab were published in the book Biofeedback and the Arts (Aesthetic Research Centre of Canada, 1976). A more recent 1990 monograph by Rosenboom, Extended Musical Interface with the Human Nervous System [http://mitpress2.mit.edu/e-journals/LEA/MONOGRAPHS/ROSENBOOM/rosenboom.html , remains the definitive theoretical document in this area.

Simultaneously, Manford Eaton was also building electronic circuits to experiment with biological signals at Orcus Research in Kansas City. He initially published an article titled Biopotentials as Control Data for Spontaneous Music (Orcus) in 1968. Then, in 1971, Eaton first published his manifesto Bio-Music: Biological Feedback Experiential Music Systems (Orcus; republished in 1974 by Something Else Press), arguing for completely new biologically generated forms of music and experience.

Corticalart

In France, scientist Roger Lafosse was doing research into brainwave systems and proposed, along with musique concrète pioneer Pierre Henry, a sophisticated live performance system known as Corticalart (art from the cerebral cortex). In a series of free performances done in 1971, along with generated electronic sounds, one saw a television image of Henry in dark sunglasses with electrodes hanging from his head, projected so that the content of his brainwaves changed the colour of the image according to his brainwave patterns.

Brain-Computer Interface

Unbeknownst to these various composers, Jacques Vidal, a computer science researcher at UCLA, was working to develop the first direct brain-computer interface (BCI) using a batch-processing IBM computer. In 1973, he published Toward Direct Brain-Computer Communication (Annual Review of Biophysics and Bioengineering Vol. 2). Incidentally, the computer used in Vidal's research was one of the nodes on the nascent Arpanet, precursor to the Internet. Vidal has recently revisited this field in his speculative 1998 article Cyberspace Bionics. [www.cs.ucla.edu/~vidal/bionics.html

Burst of Alpha

Throughout most of the 1970s there was a burst of activity in brainwave music and art. Parallel to the work in Toronto, the Montréal group SONDE, along with Charles de Mestral, did some brainwave performances. At Logos in Ghent, Belgium, real-time brainwave triggered concerts were presented in 1972 and 1973. In Baltimore the Peabody Electronic Music Consort did performances. Rosenboom and others continued their work at Mills College.

Toward the end of the 1970s, biofeedback and brainwave research fell into a period of quiescence due to many factors, primarily a lack of funding and of sufficiently powerful computers. Almost nothing happened in the field for about ten years.

BioMuse

Then in 1990 two scientists, Benjamin Knapp and Hugh Lusted, began working on a computer interface called the BioMuse. [www.biocontrol.com/biomuse.html It permitted a human to control certain computer functions via bioelectric signals including EEG and EMG (electromyogram: a measure of muscle-related bioelectricity). In 1992, Atau Tanaka [www.sensorband.com/atau/ was commissioned by Knapp and Lusted to compose and perform music using the BioMuse as a controller. Tanaka continued to use the BioMuse, primarily as an EMG controller, in live performances throughout the 1990s. In 1996, Knapp and Lusted wrote an article for Scientific American about the BioMuse called Controlling Computers with Neural Signals. [www.absoluterealtime.com/resume/SciAmBioCtl.pdf

Current Work

During the past five years or so there has been a renewed interest in brainwave music and a resurgence in its performance. Much of this new work is naive in the sense that the musicians are not fully cognisant of the rich history of brainwave music and research which has preceded them. There has also been something of a bifurcation between those using hobbyist "biofeedback" equipment or techniques and those preferring to take a more rigorous "scientific" approach. Nonetheless, current advances in Brain-Computer Interface technology, along with advanced digital signal processing and more sophisticated aesthetic theoretical foundations, will inevitably drive the field forward into a new era of

possibilities and music not yet imagined.

Below is a sampling of some of the new and promising projects currently underway.

Music and Art

Artist/musician Neam Cathode showed Cyber Mondrian [www.oboro.net/archive/exhib0001/neam/neam.html at Montreal's Oboro Gallery in 2001. This work incorporated Mondrian-like generated images with synthesized sound that was controlled using the Interactive Brainwave Visual Analyzer or IBVA system. [www.ibva.com

New York improviser David First created OPERATION: KRACPOT [http://davidfirst.com/krac.html in 2002 using "brainwave entrainement" and the phenomenon of the Schumann resonances [www.innerx.net/personal/tsmith/Schumann.html to create haunting music.

Paras Kaul, the so-called "Brain Wave Chick", [www.brainwavechick.com/ has been using the IBVA system in her own brainwave music at George Mason University for many years.

Adam Overton, a student of David Rosenboom at CalArts, has very recently performed his series of works entitled Sitting.Breathing.Series and Other Biometric Work. [http://www.calarts.edu/~aoverton/projects/Sitting.Breathing/

Andrew Brouse, the author of this article, created his InterHarmonium [www.music.mcgill.ca/~brouse/interharmonium in 2001. This Internet-enabled brainwave performance system uses Max/MSP [www.cycling74.com/products/maxmsp.html and OpenSoundControl [http://cnmat.cnmat.berkeley.edu/OpenSoundControl/ software.

BCI Research

Jessica Bayliss has a background in music technology, and has been working on Brain-Computer Interfaces for real-time control of computers at the Rochester Institute of Technology. [www.cs.rit.edu/~jdb/research/bci.sigproc.html

Eduardo Miranda runs the Neuromusic lab at the University of Plymouth, [http://neuromusic.soc.plymouth.ac.uk/neuromusic.html where researchers are trying to further earlier research into brainwave music using the latest advances in Brain-Computer Interfaces.

There are other active BCI research projects at universities around the world, including the University of British Columbia, [www.ece.ubc.ca/~garyb/BCI.htm the Wadsworth Centre [www.bciresearch.org in Albany, the University of Tubingen, [www.uni-tuebingen.de/uni/tci/ and the University of Technology Graz. [www.dpmi.tu-graz.ac.at/bci.htm

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