DIGITALmusic online tutorials on conputer music
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Essay in 12 Paragraphs: Sounds of the Brain

Sounds of the brain

“Before you can be fitted with your Braincap, you have to be completely bald. … A faint drumming sound accelerated until it became the lowest of audible Cs, then raced up the musical scale until it disappeared beyond the range of the human hearing … He presumed that his neuromuscular control was being tested…” (3001 – The Final Odyssey, Arthur Clarke 1997).

1. The Braincap, as described in Arthur C. Clarke’s science fiction classic, 3001: The Final Odyssey, is the ultimate human-computer interface: it connects the brain to a system that is able to read our thoughts and upload new information. It is the educational machine of the third millennium, where the wearer can acquire new skills in minutes that would otherwise take years to master. As far as our current state of technology is concerned, a system that uploads information into our brain cannot exist outside the realm of science fiction. However, machines that can read our thoughts are becoming present reality.

2. Traditionally, electronic music is composed and played using controllers that resemble standard musical instruments, such as piano-like keyboards. In the past five years or so, there has been a growing interest in devising new controllers for music. A number of innovative ideas have been proposed and tested, ranging from video cameras that translate the movement of body gestures into sound, to wearable musical controllers, such as gloves that translate the movement of the hands into musical notes. However interesting, these ideas still are based upon two conventional notions: stable control and gesture. Such electronic instruments are stable in the sense that they normally foster a one-to-one mapping between a physical controller and a specific output. As in the case of traditional instruments, these controllers often associate specific switches or sensors with the production of definite sounds. Indeed, the notion that a certain key of the piano must always produce the very same note makes the piano a very stable instrument. Moreover, such controllers force musicians to rely upon physical gestures to produce specific sounds. For example, a video camera-based controller would produce a rising pitch if the performer moved his or her arm upwards, and so forth. I am interested in challenging these notions by composing music with systems that are unstable and non-gestural. To this end, I built the Musical Braincap, an unstable and non-gestural musical instrument, used for the first time in the premiere of Wegh, at The First Free International Forum, in Bolognano, Italy, 2003.

3. The electrical activity of masses of neurones acting in the human brain produces electric fields that can be detected using electrodes placed on the scalp, and measured using electroencephalogram technology (EEG). My Musical Braincap uses EEG to track the electric field resulting from the activity of the brain. This electrical activity is then converted into information that can be used to control sound processing software and digital synthesisers. In Wegh, the EEG information generated by my brain during the performance of the piece, controlled software that manipulated the spectrum of the sounds of the flute, played by Emanuel Dimas de Melo Pimenta.

4. Music calls upon widely dispersed areas of the brain, many of which lie beyond our usual consciousness. Music is a profoundly integrating activity: it requires the ability to recognise and imagine patterns of sounds. Music requires sophisticated memory mechanisms, involving both the conscious manipulation of concepts and subconscious access to millions of networked neurological bonds.

5. There are many examples in both musical and non-musical research fields confirming that the EEG provides a rich source of information about our musical thought processes. EEG technology has been particularly useful for demonstrating that the brain expects sequences of stimuli that conform to established circumstances. As a crude example, if you hear the sentence "A musician composes the music", the electrical activity of your brain will tend to run fairly steadily. But if you hear the sentence "A musician composes the dog", the activity of your brain will display significant electrical response immediately after the word "dog". The human brain seems to respond similarly to musical events. Biomedical technology allows scientists to look into our brains and see the specific activity of the musical mind. My Neuroscience of Music research team at the University of Plymouth in England is measuring musical brain activity, using EEG scans that reveal the areas of the brain that experience or create music.

6. Composers develop different ways of bridging together verbal and non-verbal experiences of the world. Whilst it is undoubtedly verbal language that has allowed the human species to evolve culture and social conventions, I believe that music has played an even more important role in our evolution.

7. 7. EEG signals can be categorised into four main components: a random-seeming background; long-term coherent waves; short-term transient waves; and complex ongoing waves. The random-seeming background, about which little is known, is the residue observed after all known methods of waveform decomposition are exhausted. Long-term coherent waves are commonly classified according to their frequency into four bandwidths: Theta (4 – 7 Hertz), Alpha (8 – 12 Hertz), Beta (13 – 25 Hertz) and Gamma (25 – 40 Hertz). They are often associated with certain states of consciousness, such as alertness and sleep. Short-term transient waves reflect neural activity associated with an external stimulus. Finally, non-random complex components seem to exist emanating from the build up of baseline activations from the vast neuronal masses within the brain. This pattern is taken to be the result of the ongoing, self-organisation of information during one's experience of life. If these patterns could successfully be measured, and sense made of them, we might witness the mechanisms of higher level thought processes. Nobody has managed to track these complex ongoing waves yet. The Musical Braincap focuses mainly on long-term coherent waves because there is already a significant amount of knowledge about them in the scientific literature, and the technology for dealing with these signals is fairly well developed. Long-term coherent waves can be measured with EEG technology, and it is possible to train the brain to produce these frequencies using neurofeedback.

8. We hear even within the womb, and we cannot shut our ears as we can our eyes. All sound at all times has to be interpreted by our brains and to do this we have evolved very complex neural systems. As early as six months old, babies display highly developed abilities to recognise musical structures. Music and language sound very similar early on because babies simply hear the intonation of the voice. Newborn babies clearly respond to particular voices and the tonal and rhythmic qualities of stories with which they are familiar, suggesting that musical significance precedes verbal.

9. Neurofeedback is a form of biofeedback system. Any system that helps us to monitor and/or control the functioning of the body can be regarded as a biofeedback system. Biofeedback is often used for medical monitoring purposes but it has also been used to increase the awareness of those functions of our body that would normally be taken for granted, such as variations in our body temperature or pulse rate. As an example, imagine a biofeedback system composed of a thermometer and drugs for lowering body temperature. The thermometer is used to read and analyse your body temperature. If the temperature is higher than a specific threshold, then you take the drugs to bring the temperature down; the effect of the drugs can be monitored by taking your temperature again. An important aspect of biofeedback is that the analysis of the information extracted from our body can prompt us to take an action in order to achieve a certain physiological goal. Analysis and action thus feed information back to each other. Neurofeedback is aimed at the activities of the brain. It uses electrodes placed on the scalp in order to read EEG signals. These signals are then fed into a computer for analysis and the results are given back to the subject, either visually or aurally. With some practice, it is possible to guide the brain to produce specific EEG patterns. For example, people can train themselves to achieve altered states of mind by controlling their alpha waves. Alpha waves are frequencies between 8 and 12 Hz that are often associated with a state of meditation. Through the use of a neurofeedback system, one can learn to recognise and eventually gain some control of the burst of alpha waves and enter a state of heightened awareness.

10. Listening to music has often been regarded as a passive activity. Yet neuroscience teaches us that every moment of consciousness also includes reaction in addition to sensation. Consciousness is driven by massive amounts of neural activity involving sensory and motor organs, and the brain, whose main purpose is to turn sensation into behaviour. It is hard to picture in this scenario why nature would have evolved the ability to sit back and watch the world pass by, or simply enjoy listening to music. I am a stronger believer, however, that watching the world pass by and listening to music are not, in fact, a passive activities at all

11. From a fundamentally neurological point of view, our natural response to music is to move our body; hence our tendency to involuntarily nod our head and tap our feet to the sound of music. We can, however, suppress this neural predisposition at will, because the brain can choose to not activate the behaviours that were supposed to be set in motion by incoming sensations. But even then, it is likely that at its most fundamental levels, the brain still processes music in terms of movement.

12. The amount of information that flows in the brain is immense, but we have evolved pretty good strategies to react to sensations as quickly as possible. The bottom line is that we cannot afford the time that it would take to wire from scratch billions of neurones for every leap of consciousness. One of the strategies that the brain has evolved to deal with huge amounts of information flow and reaction delays is to make predictions. Scientists generally agree that the brain knows how it will react prior to actually processing the whole range of incoming sensory information. The brain formulates an image of what is expected, and weighs it against the properties of the external world as reported by the sensory organs. The matching between the internal and the external worlds generates behaviour. The internal representation is then upgraded and the next prediction is formed, and so on. Thus, a lapse of consciousness cannot exist without a context; there is always something about what has just happened that prompts the brain to predict what is likely or unlikely to happen next. This is music. The brain is musical and music is our soul.