NEURAL GHOSTS AND THE FOCUS OF ATTENTION

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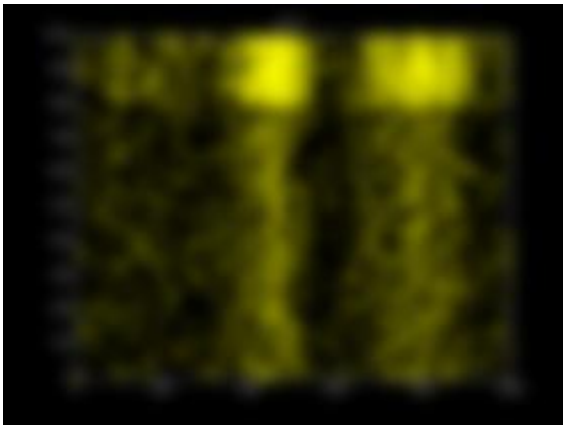
In this paper I will discuss the phenomena of cortical sonic hallucination in conjunction with the new artwork *Ghost*.



Ghost, Raster Plot, Jane Grant, 2011.

Consciousness as attention to memory is a term that neuroscientist Eugene Izhikevich uses to describe a phenomenon in which the cortex re-lives or re-visits a specific pattern of neural activity in the absence of sensory information. The model brain or cortex, deprived of stimulation, journeys around its own temporal architectures conjuring past 'experiences' or 'memories', pulling them into the present. Evidence that these pathways continue to be re-visited once stimulation occurs again is compelling.

Referring to recent research in developing the sonic artwork *Ghost*, and an earlier work: *The Fragmented Orchestra*, all of which have at their core the Spike Neuronal Network model of Eugene Izhikevich, I will discuss the phenomena of 'sonic ghosts', a term I have used to describe the buffering up of the neural past within the neural present.

What we experience as consciousness occurs at many different cortical locations and timescales. In the paper 'Polychronization: Computation with Spikes', [1] Izhikevich discusses one of the simulated, anatomically realistic models of 100,000 cortical spiking neurons that he and his team have created. These networks of spiking neurons form polychronous (multiple or many times) groups, which fire with 'millisecond precision'. The connection strength between pairs and groups of neurons is intricately dependent upon the difference between spike arrival times, the phenomenon known as Spike Timing Dependent Plasticity (STDP). The groups of firing neurons are 'time locked but not synchronous' [1] and that it is the destination of the spiking and not the activation that gives rise to the complexity of the model. Izhikevich states that these time-based clusters or groups across the cortex, give rise to the beginning of 'simple thought and memory.'

These groups are interesting as they form as a result of STDP, not as a consequence of anatomical clustering, emerging from the 'dynamics of the connectivity between the neurons'. The polychronous

groups, because of this continual formation, grow and then disappear, although some 'live' and become more permanent in the neuronal model.

Izhikevich likens the network of polychronous groups to the immune system in which we appear to have antibodies for all possible antigens, 'even those that do not exist on earth'. He also proposes that these groups contain all possible variation of both thought that is, and thought that is to come – all potential manifestation of human cognition.

A major significance of polychronous groups is that they may represent memories or experience. The neuronal model becomes autonomous, self-activating once a certain threshold is achieved. The model devoid of any stimulation or articulate input generates random memories or experiences not associated with any previous input. The network has exceptional capacity for memory and it is this memory that is re-visited when external stimulus is not present. Once the network exceeds a particular threshold, an activation of groups occurs. These groups represent an external stimulus which go on to trigger other groups so that the number of internally stimulated groups are equivalent to the number of groups activated when externally stimulated. Izhikevich calls this 'the focus of attention.' [1] Therefore when external stimulus is not present, the neuronal model, driven by noisy currents, re-visits some of these firing clusters, following the formation of pathways previously established through external and internal stimulation. In a sense it could be said, that the cortex re-lives previous experiences.

"If the size of the network exceeds a certain threshold, a random activation of a few groups representing a previously seen stimulus may activate other groups representing the same stimulus so that he total number of activated groups is comparable to the number of activated groups that occurs when the stimulus is actually present and it is the focus of attention." [1]

"One can say that the network 'thinks' of the stimulus, that is, it pays attention to the memory of the stimulus. Such 'thinking' resembles 'experiencing' the stimulus. A sequence of spontaneous activations corresponding to one stimulus, then another, and so on may be related to the stream of primary (perceptual or sensory) consciousness." [1]

These streams of primary, perceptual and sensory consciousness are the temporal architectures of the brain, fleeting structures built of time. The structures are remarkable, as the neuronal firing events that the stimulus triggers remain, albeit temporarily, despite that they are no longer being physically, sensorially activated.

The aim of my research is to sonify the events that occur within the cortical structures. Their temporality and complexity are fascinating, in terms of time, the precise, but very fleeting nature of these events, are coupled with the exactitude of the millisecond. Furthermore, each firing event has the potential of infinite dimensionality, complexity in process, thought in the moment of becoming.

The Ganzfeld 'entire or total field' experiment sought to explore extra-sensory perception using mild sensory deprivation, white light and noise, in order to negate defined external stimulation. Regardless of the controversial findings in the field of parapsychology, what became apparent, was that the un-stimulated or sensorially deprived visual cortex begins to conjure vague images or impressions of scenes.

Age related macular degeneration consists of loss of vision occurring at the centre of the visual field. This lack of visual information causes blurred vision and eventually the loss of vision itself. In many

cases it also results in the phenomenon of hallucination ranging from mild to impressively articulate. These hallucinations are thought to be caused by the absence of continual visual information relayed from the retina through to the brain, the brain 'filling in' for the sensory information it lacks. In Ganzfeld, whist every care is taken to deprive the brain of any stimulus; sound, vision and, of course, movement, the brain is never silent. Another more recent study in short-term sensory deprivation found that people not normally prone to hallucination experienced delusions and apparitions during the short period of deprivation. The researchers, from University College, London believe that the hallucinations are produced by a phenomenon called 'faulty source monitoring;' in that 'the brain misidentifies the source of it's own thoughts as arising outside the body.' [2]

The brain, as we have seen from Izhikevich's model, despite the stimulus being removed, creates its own activity, re-visits past experiences, pulling them into the context of the present.

In *Ghost,* eight speakers, eight microphones and a computer are connected to form a 'memory embedded' network of neurons. Sounds have been implanted into the cortex beforehand to provide the system with a buffer or 'memory'. Once installed, live, ambient or performed sounds in the gallery will stimulate artificial neurons, modelled in the computer to fire, sending tiny fragments of sound from the eight microphones to the speakers. When these sounds fail to reach a certain threshold the cortex will journey around its own architecture, re-visiting older, established pathways, using its 'memory' as buoyancy when external stimulus dies away. This memory is its own internal noise, its earliest and primary stimulation. These sounds will be heard as 'sonic ghosts,' a term I have used to describe internal or endogenous noise embedded in the cortex, which reoccurs when the external stimulation is low or not present in the gallery space.

Ghost will reconfigure internal and external sounds causing a temporal and sonic overlapping of the neural past within the neural present, a rupture in the flow of sensory and endogenous information. As the external sonic events occur these will be drawn in to the cortex building an ever-increasing bed of experiences from which to compose.

One of the initial phases of this model was *The Fragmented Orchestra*, where groups of spiking neurons formed polychronous groups allowing a rich and dynamic model of firing activity in the cortex.

"The Fragmented Orchestra is a vast distributed sonic structure created by Jane Grant, John Matthias and Nick Ryan. It was installed in the United Kingdom between December 2008 and February 2009. It consisted of 24 fixed geographical locations, including FACT, Liverpool, University of Plymouth, Landscove Primary School, Devon, The National Portrait Gallery, London, Millennium Stadium, Cardiff and Kielder Observatory, Northumberland. At each of the locations, a 'soundbox' was installed, which consisted of a microphone, a small computer connected to the internet and a Feonic 'drive', a device that transmits audio through resonating architectural surfaces. Sound made in the spaces was transmitted across the internet to a server computer in the FACT gallery. In this computer, we ran an artificial neuronal network, an adaptation of the Izhikevich's recently developed non-linear integrate and fire model that incorporates spatial 'axonal delays' between synapses and a spike-timing-dependent plasticity algorithm, which causes the synaptic strengths between neurons to become updated as a function of the differences in signal arrival times." [3]

In *Ghost*, temporal and topological memories within the cortex, in conjunction with the phenomena of cortical, sonic hallucination are explored. Further research is needed to monitor the buffering up of the

neural past within the neural present in conjunction with STDP. A computer model that creates statistical data and visualization of what exactly is taking place will be developed over the coming year to explore what might be called the thickening of experience. The infinite complexity of how this cortex might perceive what we call experience is extraordinary, a folding in of external and internal articulation, double looped, networks of earlier stimulation extending into the now, sensory architectures building into an endogenous cortical construction of time, the 'sonic ghosts' being the hallucination that the audience hears in the absence of stimulation. It is the crossing of the threshold of the internal to the external and back again which translates milliseconds of neuronal activity into moments of sound dispersed across timescales and geographies and the minute spaces of the brain.

References and Notes:

1. *Eugene Izhikevich, "Polychronization: Computation With Spikes," Neural Computation, 2006 18:245282, http://www.izhikevich.org/publications/spnet.pdf (accessed May 24, 2008),*
2. *Oliver Mason, Francesca Brady, "The Psychotomimetic Effects of Short-Term Sensory Deprivation," in Journal of Nervous and Mental Disease Issue 10 (October 2009): 783-785.*
3. *Jane Grant, John Matthias, "Shifting Topographies: sound and The Fragmented Orchestra," in Spatialities: The Geographies of Art and Architecture, eds. Judith Rugg and Craig Martin (Bristol: Intellect, 2011).*