Silent Barrage: Interactive Neurobiological Art

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ABSTRACT
Here we present Silent Barrage, a closed loop system in which a culture of rat brain cells is given a new body in the form of a small 'forest' of robotic poles located within an art space. This system allows us to study the relationship between brain and body in both scientific and artistic contexts.

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In vitro Learning, Biological Art, Neuroengineering

ACM Classification Keywords
J.5 [Arts and Humanities]: Arts, fine and performing

General Terms
Experimentation, Human Factors

INTRODUCTION
The concept of 'embodiment,' how intelligent agents use bodies, raises questions in both the arts and sciences. These questions range from philosophical investigations of what defines the boundary between mind and body, to the engineering task of designing artificial 'brains' to optimize the function of huge, highly complicated power systems [1]. We address these issues from the perspectives of Neuroengineering and Bioart.

Within the neurosciences, questions of how networks of neurons process information and learn have remained difficult to study. This is partially due to the difficulty of recording all the information necessary to characterize a network of neurons in a learning organism. One neuroengineering approach to further understanding of the learning process at this level has been to isolate networks of neurons and provide them an artificial body [2].

Within the arts, one main aim is to get the viewer to question their environment. By its very nature Silent Barrage allows the viewer to contemplate the existence of life from an ontological point of view. What does it mean to be alive and are accepted notions of 'living' and 'non-living' absolute or are there some levels that can fit in between? Silent Barrage raises these questions and many more. It is a semi-living entity that is unique in that it is both artistically and scientifically meaningful.

To address these questions, we provide a remote robotic 'body' to a culture of rat neural tissue. The body consists of 32 robotic poles located within a public art space. Each pole is 3 meters in height and spaced such that the audience can walk through the field of poles. Audience movements are captured through four overhead cameras, which form the sensory system of body. Data from these cameras is preprocessed on site in the exhibit, and then sent back to the neural culture through a MultiElectrode Array (MEA). Communication between the culture and electrophysiology (stimulating/recording) equipment in Altanta and the robotic (sensory/ motor) machinery in the exhibit is accomplished through a custom webserver. This embodiment shows a progression from previous work with similar technology [3], in that the audience interacts directly with the embodied culture by entering its 'field of view' and responding to its neural activity.

The primary form of activity of neural cultures that don't receive sensory input is a seizure-like barrage of electrophysiological activity [4]. These barrages are silent while inside the dish, but the robotic body allows the audience to experience the barrages as bursts of movement and sound, lending the piece its name.

METHODS
In order to produce this elaborate system, a variety of subsystems had to come together- the culture itself, the electrophysiology software and hardware used to communicate with the culture, the robotic body and sensory system, software to translate the neural data into movements of the robotic body and translate the movements of the audience into neural stimuli, and a webserver to allow two way communication between the robotic 'body' and living 'brain.'

Neural culture
Tissue from embryonic rat neocortex is dissociated to break down prior structure in the tissue, allowing the tissue to re-grow as a two dimensional monolayer of roughly 50,000 cells [5]. Neurons within this living network communicate with each other using short spikes in cell membrane voltage. This electrical activity can be recorded using electrodes spaced throughout the glass multielectrode array (MEA) that the neurons live on. This forms the 'read-out' or motor part of the electrical communication with the culture. By electrically stimulating these same electrodes, neural activity can be induced in select populations of neurons. This forms the 'write' part of the communication, i.e., sensory input from cameras to neurons.

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Electrophysiology

Both neural activity and electrical stimulation occur on sub-millisecond time scales. To process neural data and stimulation tasks in real time, we created NeuroRighter, a free open source program available online. NeuroRighter uses National Instruments Data Acquisition hardware to record and stimulate the electrodes, and allows neural electrode data to be recorded, filtered, and displayed in real time through a graphical user interface. It also has the ability to stimulate the MEA electrodes using a custom multichannel stimulating circuit, and to control arbitrary additional hardware through a digital TTL signal. Lastly, the recording and stimulation capabilities can be used simultaneously through custom closed-loop 'plugin' programs. [6] This 'plugin' program has been changed for each exhibition of Silent Barrage, allowing for different scientific questions to be asked by changing the way sensory information (optical flow of the overhead cameras in the exhibit) is used to generate stimulation patterns and changing how motor commands (directions for when and how much the poles should move) are generated from network activity.

Exhibit

The webserver provides a constant connection to the exhibit, which has been be shown in USA (New York), Spain (Madrid), Brazil (São Paulo), Ireland (Dublin), and Beijing (China). On the exhibit side, a computer running MAX/MSP is used to connect to the webserver in Atlanta. The MAX module then normalizes the incoming data and relays this information to PICAXE® microcontrollers which serve as a central hub to communicate with and monitor each of the 32 poles.

Each pole, made from 80mm (3½ in.) PVC wastewater pipe, is wrapped in paper. Motors control a printhead, which moves up and down the pole, and the rotating pen for drawing on the paper. Each pole has its own microcontroller, allowing autonomous control of the head positioning as instructed by the master controller.

To attain the level of movement accuracy required, each pole controller has software which allows it to 'learn' the characteristics of its pole. Once 'learned', the response characteristics are stored in non-volatile memory and are constantly referred to as occurs in other living systems.

Over time during an exhibition, a series of lines are drawn on the paper covering the poles. The lines represent a simple graphic memory of past activity around each electrode in the neural network. Stimulus for the neurons around each electrode in the multielectrode array comes from audience activity in the area immediately around the robotic pole. The resulting drawings are "simple but beautiful data visualizations"[7], acting artistically as traces or documents the interaction between the viewers and the neurons. Audience members have reported that while walking through the poles "the feeling of physically travelling through an active brain is impossible to escape" [8] and that Silent Barrage "provides an immersive and somewhat overwhelming sensorial manifestation of questions that are at the core of our understanding of the stuff that make us think." [9]

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