Concurrent Complexity — Possible Development Steps

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At this stage in the development of multi-agent BCI in the arts, it may be productive to approach biofeedback and related pursuits as interactions among complex systems. This begins with placing boundaries around two (or more) systems with internally networked parts that exhibit *interaction states* with each other. For example, in interactive music, one system might encompass a brain with proprioceptive agencies and another might be an instrument with self-organizing affordances. These interaction states, considered as *musical states*, become differentiable interactions located along scales for comparison, just as if they were musical *notes*.

Following extensive work over several decades in applying biofeedback models, using various methods to analyze EEG data from individuals participating in brainwave music performances, resulting in emergent, self-organizing musical forms, it is proposed to extend this paradigm in a new way, called *concurrent complexity*. This would involve developing means to measure complexity in multimodal stimulus environments and correlate those with measures of complexity in brain and/or neural signals from perceiving, interacting entities. It is hypothesized that complexity measures could potentially deepen and broaden what can be learned and created with this bio-cybernetic model, beyond what has already been achieved.

Evidence from preliminary, previous work by others investigating what was called the nonlinear resonance hypothesis of music perception is encouraging, in that relationships have been drawn between the complexity of music stimuli, the complexity of observed EEG waveforms, levels of musical training and experience, and the presumed activation of neural assemblies necessary to process rich associations.

The new concurrent complexity concept would also be embedded in a feedback paradigm in which aspects of the stimulus environment would change according to qualities measured in brain and/or neural signals, to investigate possibly emergent meta-forms, adaptation, learning, and bio-cybernetic affordances. In one form, the perceiving, interacting entities could be individuals, wherein EEG complexity analysis would be pertinent. In another form, the perceiving, interacting entities could be networks of individual neuron groups cultured in vitro, from which complexity analysis of neuron spike signals could be pertinent. In both cases, with feedback, possible behaviors of emergent meta-agents could be studied. In addition, meaningfully engaging aesthetic experiences could also result from this concurrent complexity approach. Developing useful complexity measures of a multimodal stimulus environment is a challenge, and could, in itself, produce potentially powerful new tools for both analysis and aesthetic creation.

It is proposed that the concurrent complexity paradigm be studied in several steps.

1. Determine appropriate and effective measures of complexity to apply to both multimodal stimulus environments and to EEG and neuron spike signals.
2. Following an already successful demonstration of musically sonifying neuron spike signals and many previous projects in brainwave music, experiments employing feedback to neuron cultures would be undertaken.
3. A series of practical demonstrations that could be shared with the public in some kind of interactive exhibition setting would then be developed.
4. Further work extending the concurrent complexity paradigm—possibly in wider, networked information environments—would be developed, following the results of the demonstrations and exhibition.

Possible implications:

* Broaden understanding of the computation modalities of neurons in vitro and possible adaptive learning behavior.
* Learn more about how measures of complexity might relate to human information processing and biofeedback control.
* Open new avenues for interdisciplinary, artistic creation in the ever-expanding field of brain art.
* Expand thinking and encourage dialogue in emerging art-science convergence, including theoretical, practical, and philosophical concepts.