Brain: the ultimate enactive interface[1]?

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Abstract. *Eshofuni@TheAbyss* is a multidisciplinary project and performance, proposing real-time representations of brain phenomena using a brain-computer interface. It implements novel representational approaches to action/perception/reaction processes, specifically, to the contextual balance ratio between reason and emotion. It is an *ecological* approach based on a theoretical framework that implies that behavior and evolution depend on environmental synergies and are a consequence of enactive dynamics, be they physically or symbolically based. This paper discusses the project within the context of live interfaces while also introducing a transdisciplinary approach to brain phenomena, addressing a multiplicity of aspects that are fundamental to its understanding and, consequently, to the project. We discuss the definition of interface, then introduce the brain complex neuro-physical electrical system with pre- and experience-independent, built-in *possibilities*, but which is also *moldable* by interaction, and propose that it is a candidate for the ultimate dynamic interface; we then *correlate* this system with the performative art event(s) and respective environmental synergies; next we explain the representational, conceptual approach and strategy of *Eshofuni@TheAbyss* and finally, we discuss the implications of this approach and propose some insights on the matter.

Keywords: Brain, Interface, Environment, Enaction, Brain-Computer Interface, Art.

1 Introduction

On writing about the seminal book *Endophysics: The World As An Interface* by Otto Rössler, Ichiro Tsuda (2002, 213-214) proposes in his conclusions that "Endophysics tells us that reality only exists at interfaces. By perturbing the interface slightly, we can have different senses of reality". Interestingly, Peter Weibel (1996, 343) raises questions about the same theme saying "The world changes as our interfaces do. The boundaries of the world are the boundaries of our interface. We do not interact with the world — only with the interface to the world." Finally, Manovich (n/a) in his essay *The Interface as a New Aeshetic Category* postulates that "Content and interface merge into one entity, and no longer can be taken apart".

2 The interface dilemma

Is there a proper definition for interface? Definitions may reference functionalities and/or characteristics, they may be considered iconic, symbolic or ecological. In *Computers as Theatre*, Laurel writes (1991, p.4) "interface is not simply the means whereby a person and a computer represent themselves to one another; rather it is a shared context for action in which both are agents". An interface based on the perception-action loop paradigm — integrating multiple modalities (e.g., vision, sense of touch, sound) — can be considered as enactive (Fukuda, 2011, p.77).

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[1] The use of certain expressions within specific contexts tends to be interpreted as signs belonging to those contexts. In this case, the *enactive interface* has a potential relationship with the theory of interfaces. But the choice of those two words in this paper has a (simultaneous) purpose that goes beyond the former framework. The aim is to explore embedded implicit meanings in the text related to the two words — enaction + interface — qua indexical and/or symbolic signs, *per se* and/or as a full expression.

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Reference dictionaries define interface with variations of a common denominator which can be taken as the definition itself — (Interface is) ": the place or area at which different things meet and communicate with or affect each other" (www.merriam-webster.com); "A point where two systems, subjects, organizations, etc. meet and interact:" (www.oxforddictionaries.com).

We propose that: *Interface is whatever, whenever or wherever entities of different systems establish contact that opens and promotes the possibility of data transduction and transfer between them*.[2]

3 Brain basics

The human brain is a complex multi-system whose architecture is based on multiple layers and systems (e.g., groups of neurons devoted to certain routines or functions, such the auditory system) that are networked and permanently communicating with each other (e.g., through electrical phenomena) (Sporns, 2011).

It is a system of sets of circuits that is able to detect and evaluate the relevance of myriads of physical energies in the environment, and plans and executes appropriate reactions to them. It provides us with numerous functional schemas such as basic senses[3] and basic integrated postural and locomotor movement sequences (Buzsáki, 2006). Through sensing, perception and cognition, it allows us to be aware of the environment and of ourselves (Buzsáki, 2006; Wilson and Foglia, 2011).

3.1 A priori versus a posteriori

As a system, the brain is by itself a universe with a priori characteristics, i.e., congenital *possibilities* (not only structural, but also functional) with ongoing intrinsic spontaneous activity (Raichle, 2010) capable of wandering in the absence of external demands (Malia et al, 2008).

According to scientific evidence, a brain can live in isolation (Llinás and Paré, 1991) — and be kept alive as an isolated system as long as proper energy (e.g., glucose) feeds its basic functions (Bohlen and Halbach, 1999). However, many of the same empirical findings also postulate that although a brain may "live" in isolation, it does not produce useful constituents (e.g., data) for itself without environmental interactivity (Buzsáki, 2006). Most interestingly, it does not produce them for itself nor for the entity(ies) that could have a relationship with it (e.g., the human-body that hosts it or other entities that interact with it, e.g., other humans). Or, more accurately, it may not fully develop if isolated from a dynamic context (Buzsáki, 2006; Wilson and Foglia, 2011). Tsakiris et al. postulate that: "coherent experience (…) depends on the integration of efferent information with afferent information in action contexts."(2006).

3.2 Remarks on quantitative brain phenomena

Brains generate electromagnetic oscillations — i.e., rhythmic activity —, which have been being recorded in the form of waves (Electroencephalography). A scientific consensus divided this rhythmic activity into bands by frequency (delta, 0.5–4 Hz; theta, 4–8 Hz; alpha, 8–13 Hz; beta, 13–30 Hz; gamma, >30 Hz[4]). Beyond mere taxonomy, this nomenclature arose because specific bands could denote specific biological significance. Certain characteristics of the brain's electric phenomena[5] may denote emotional processes (Trochidis and Bigand, 2012), while others[6] may denote a voluntary self-initiation of movement, or a kind of preparatory processing that precedes the actual action (Jo et al., 2014). Brain electric phenomena could, as such, be seen as a kind of

[2] Data here should be understood in a broad sense, i.e., from physical to conceptual, e.g., electric energy, a virus, words in the mind, a graphic form.
[3] I.e., sensing, detecting features of the external and internal environments — olfaction, sight, touch, hearing, taste, etc. — supported by and interacting with the multiple body sensors.
[4] The precision of the segmentation of the EEG frequency bands is not absolutely consensual among science communities.
[5] E.g., inter-hemispheric asymmetry of certain bands such as alpha — 8-13 Hz — within the frontal lobes.
[6] E.g., progression of spectral power before onset of a movement.

global mirror of its functions, namely in temporal frameworks, that could denote aspects such as environmental interaction.

3.3 Am I speaking to myself?

Damásio (2010) proposes that the brain has the ability to create the self, which emerges from sensing our own physiology, but also the consciousness, which is based on a self-referential layer — where autobiographical phenomena are one of the most important aspects — that allows us to build a complex sense of ourselves in relation to ourselves, in relation to others and in relation to the environment. It could have arisen as a consequence of a layered evolution according to its necessities and strategies, and has a very peculiar characteristic: conceptualizing the future, besides reasoning about the present and retrieving the past.

Consciousness is, however, a puzzling concept and is not consensual among either philosophers or scientists, or indeed among themselves. There are approaches that reduce it to mechanistic ontological models (Zeman, 2001) while others (one of which is Cartesian *dualism*) "regard at least some aspects of consciousness as falling outside the realm of the physical". (Gulick, 2014)

4 Interfacing

From this framework of theories, we can propose that the brain is, in a broad sense, a point of contact – an interface – between the *I* as a matter-less entity that is aware of its bodiless existence (at least conceptually), and the *Am* as a physical object empowered with mechanisms that can impact reality (by means of efferent data sent to the host mechanic system). Or between *I* and *Do*[7], whereby I, through my will, will behave based on afferent information conveyed by body sensors – e.g., the skin, – and the central nervous system (CNS) to the brain, where it is processed.

5 Synergy of interaction dynamics

An artistic performative live act, with performer(s) and audience (as the entities that share the act), is a participatory event, where both parts share and construct a simultaneous set of interlinked circumstances. It is an event where modal constituents — e.g., visual, sonic, olfactive — trigger interactive processes of analysis, perception, appreciation, feedback and co-processing between the entities involved, creating a dynamic and complex process of aesthetic experience, reasoning and emotion. Interestingly, art forms such as music are so powerful that they can activate nearly every known area of the brain and the deepest systems generators of emotions (Levitin, 2007), as well as elicit involuntary behaviors perhaps even by coercion (Sacks, 2006). However most of us can only guess what is going on inside the performer's mind, i.e., in the dynamics of this complex relationship, we are not able to *see* possible inner constituents of a *reality* not *visible* by immediate mechanisms.

6 Transcoding and translating the brain phenomena

Both sciences and arts have been using technological apparatus and procedures which can record the brain's continuous electric activity and transcode it into discrete objects (Vidal, 1973) and representational models to denote and characterize the constituents of brain phenomena. For example, EEG topographic visualization uses (pseudo)colors-coding schemas to represent

[7] To avoid going into a deep Aristotelian or Kantian discussion, we can formulate the *I* and *Am* qua being — i.e., as a consciousness conundrum — and the *I* and *Do* qua agent — i.e., as a physical behaviorism conundrum.

specific occurrences within specific regions of the brain's geography[8] (Shankar and Ramakrishnan, 1998; Teplan, 2002).

There are many electroencephalography approaches — both representational and technological — but many are restricted by auto-regulation paradigms, i.e., although they may allow reconceptualization and evolution, they replicate the conventions and theoretical frameworks on which they depend. They also embrace laboratory presettings and aseptic paradigms in detriment of ecological contexts.

7 *Eshofuni*

Eshofuni[9] (Tomé-Marques et al., 2014) is a multidisciplinary project embracing art, communication design and programming, that proposes an approach to the real-time representation of brain data using a virtual physics engine — built fundamentally in the Max programming environment — and real-time Emotiv EEG BCI signal on performative contexts. *Eshofuni* invokes a conceptual parallelism inspired by Newton's laws of motion and equilibrium — a body continues in its state of rest, or in uniform motion, unless external forces compel it to change that state — and the theory that the brain has a default mode where it develops as a self-organized or spontaneous state without external input, but for which external perturbations are crucial nevertheless to perform useful computations (Buzsáki 2006). Started in 2013 as a research project to propose and repurpose representational approaches, in real-time and in creative ways, but with objective empirical criteria and support, it evolved to *EshoFuni@TheAbyss*, a step forward in brain data representation relying on a new approach placing it in ecological contexts — now both literally and metaphorically.

7.1 Eshofuni@theabyss

The Abyss is an ecological system inhabited by entities with graphic and sonic forms — inspired by the creatures that constitute plankton such as, for e.g., zoids[10] — that interact among themselves and with the *Eshofuni* qua performer's avatar, thus allowing the set to denote the performer's brain processes that are hence generated and conditioned within this environment.[11] It uses real-time and longitudinal statistics (e.g., real-time retrieval iterated with analysis, segregation and cumulation), applying filtering (band and multiple order) and Fast Fourier Transforms (FFT). It is based on two models: 1) alpha asymmetry to denote emotional processes;[12] 2) Emotiv COG[13] as procedures to support executive functions, i.e., conscious control.

It is an evolutionary system that co-implements behavioural algorithms to allow autogenesis and independent evolution. Entities that inhabit the *Abyss* have their own *independent* and interactive life. Some of them are *connected* with different clusters of the brain metaphor (i.e., *Eshofuni* — which is also an entity inhabiting the *Abyss*). Those clusters are brain sites correlated with the

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[8] It is therefore a method that serves to simultaneously denote and characterize event(s) and place(s) / location(s) of a phenomenon.
[9] Eshō-funi is a Japanese Buddhist term: esho is a compound of shoho, meaning life or a living being, and eho, its environment. Funi, meaning "not two," indicates oneness or non-duality. It is short for nini-funi, which means "two (in phenomena) but not two (in essence)." Ho of shoho and eho means reward or effect. At the most fundamental level of life itself, there is no separation between ourselves and the environment.
[10] Zoids are the beings that constitute the Siphonophores - the longest animals on the planet.
[11] The *EshoFuni@TheAbyss* approach is highly inspired in the "Plankton Chronicles" project (www.planktonchronicles.org), a documentary series based on very short videos about the life and characteristics of planktonic organisms — errant, from Greek planktos.
[12] Alpha asymmetry is a theory that proposes that the frontal inter-hemispheric brain EEG differential on this specific band could be correlated with emotional processes. The purpose of this paper is not, however, to discuss the theory.
[13] Emotiv COG (Cognitive suite) is a *machine learning* proprietary algorithm by Emotiv Inc that enables volitional control of software functions after training.

EEG 10/20 system.[14] Evolution happens when specific clusters of the brain — e.g., F3 — are triggered by events that happen in this ecosystem. That is, when spectral and oscillation patterns related to complex brain specific processes — e.g., volition, emotions — are detected, the system denotes these phenomena as changes in the representations (the *all* metaphor). This evolution can be characterized by the recodification of color, changes (complexification) in forms, sounds, or whatever inventive representation we can think of insofar as it fulfills our purpose and criteria. This means that a time-frame of longitudinal cumulative changes in a site could be denoted by the consequentially changed character of the constituents related (*connected*) to the respective site.

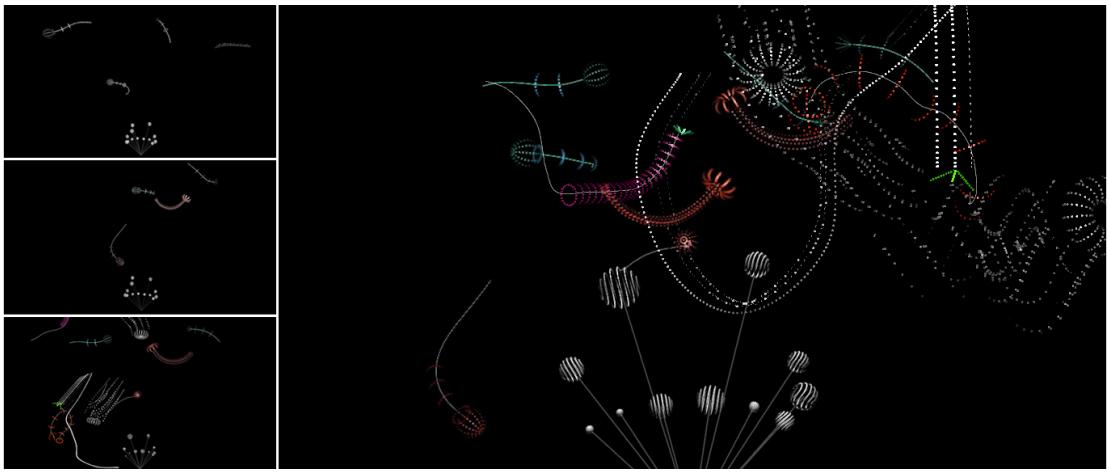

Fig. 1. *Eshofuni@theabyss*, four frames of the system.

8 Discussion, purpose and strategies of an novel approach

When science proposes that the brain has the ability to create the self from sensing one's physiology, maybe we should see this as a kind of low-level computation that deals with hardware parts and details, and the consciousness as a kind of high-level computation that deals with abstractions and pure concepts.

We accept that the brain can have a conscious endo-reality, one that may only communicate with the exo-reality (the environment) via non-haptic abstract interfacing, disassociated from any specific corporeal instance , but which is however embodied in our hardware (i.e., human physical constitutive element). This embodiment has created a complex organism with multiple sensors and sub-systems that are interdependent and fundamental to the procedures it has to operate in order to live. A kind of enactive simultaneity where the entity is dependent on the system and is conditioned by it, but at the same time, has a personal perspective and understanding of the system, its icons and symbols, and acts on it according to this understanding. This means that the complexities of both the environment and the entities are bi-directional and impact each other. We are also empowered with the notion of ourselves as agents that can act in coherence with the available options (*affordances*) derived from the dynamics of the entity-environment relationship, but which can also refuse to act with respect to incoherent deliberations.

Another important aspect related to the brain is that there are brains — millions of them — not only *one* brain. This means that there are millions of endo-realities, and consequently millions of perspectives about the environment in which each one operates, i.e., there are also multiple exo-

[14] A standardized physical method to describe and apply the location of electrodes on the scalp, adopted in 1955 by the International Federation in Electroencephalography and Clinical Neurophysiology (Teplan 2002) where brain sites and hemispheres are designated by letters and numbers — e.g., F3, denotes a site on left frontal lobe.

realities. All these aspects raise huge problems concerning the ultimate objectiveness of any representational recipe.

Brain phenomena are extraordinarily complex and can be approached, studied and represented from many perspectives, involving multiple methodologies and strategies, but this complexity raises indisputable problems to their decoding. Even within contexts of quantitative empirical approaches, although science has uncovered certain consensual patterns that denote brain specific processes, the findings are far from being secure.

No less important, given that the artistic performative live act is an environmentally-dependent, participatory and multi-contributive event, where the parts share and build a set of interlinked events — as proposed, a dynamic process of aesthetic experience, reasoning and emotions — one can only infer and assess certain phenomena within the context in which they arise, while still running the risk that the complexities inherited from their related environment could compromise the understanding of the data.

As suggested, there are specialized apparatuses and software procedures (e.g., brain-computer interfaces, algorithms) that could transcode brain phenomena into discrete, discernible data, but the fact is that most of the solutions are far from being capable of decoding the immense complexities of the brain's phenomena, comprising thus one of their most important limitations.

As such, this project is, beyond the quantifiable criterion, relevantly inspired by and anchored in holistic ecological concepts where particles (e.g., humans, entities, agents) and the environment interact and develop in an inclusive and integrated manner, where the all is more than the mere sum of the particles — like a super-organism, but one constituted by heterogeneous parts, i.e., entities that have agency and personality that can impact the course of the events in unexpected and uncontrollable ways. We strategically use metaphor, because only through metaphor are we (slightly) capable of suggesting the behavior, characteristics, intricacies, complexities and synergies of the endo-exo *reality* simultaneity and the entities that operate it and within it.

According to our research, this is the first real-time statistical system that is multimodal and which is used as a strategy and methodology to process multiple operations in order to simultaneously access, use and denote (or connote) multiple brain phenomena, namely volition and emotions (in this particular case), as well as *independent* environmental occurrences (i.e., those derived from the interactive behavior of the system constituents other than those that could denote any brain specific phenomenon) and the consequences of all processes (i.e., evolution of the entire system along a timeframe). Therefore, this project becomes a real-time, chronological documentary system.

Finally, among the most important aspects in this context — and for us as artists —, is the urgent need to break rules and abolish assumptions postulated and commited by reductionist and restrictive theories, assuming that breaking rules (and assuming risks) is crucial to opening other and novel hypotheses for the same problems addressed in the respective theories and, consequently, find new answers. Even in science nothing should be taken for granted.

9 Future research

This does not mean that we do not subscribe to scientific quantitative criteria to process data based on proven and consensual methods. On the contrary, this project is grounded on scientific EEG methodologies and this alignment also makes us highly aware that our approach is far from being perfect. For example, the use of independent component analysis is very *primitive*. Future work will focus on in reviewing, updating and/or applying new methods of real-time analysis and artifact removal in order to achieve a more rigorous data interpretation. We are also working on alternative algorithms such as Hidden Markov Models[15] to help to devise new ways of

[15] Hidden Markov Models are statistical models that have been used for the classification of sequential pattern problems.

implementing iterative evolutionary learning (machine learning), as an alternative to the Emotiv COG paradigm (proprietary algorithms).

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