Perspective

Sentiomics: the identification and analysis of dynamical patterns that characterize sentience

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DOI: https://doi.org/10.56280/1531632254

Received 15 January 2022; Accepted: 10 April 2022 Published: 28 May 2022

Abstract

Sentience, defined as the *capacity of feeling*, for example, to experience basic sensations such as hunger, thirst and other types of qualitative mental states, is a psychobiological phenomenon that involves dynamic patterns of electrochemical (below 1Hz) and electromagnetic (above 1Hz) waves in living systems. The science we have called *Sentiomics* studies unconscious dynamic patterns in the brain that define the capacity for feeling. This paper discusses the explanation of creative processes based on unconscious patterns that combine and constructively interfere, generating a conscious output experienced in the living system's first-person perspective. We claim that the *Sentiomics* approach to wave interferences helps to explain creative intuition, artistic creativity, the formation of dreams, and related phenomena. We raise a hypothesis – based on available evidence, to be experimentally tested – that the dominance of slower synchronized oscillatory frequencies (such as Delta, Theta and Alpha bands) in scalp electroencephalogram spectra makes more room for constructive electrochemical interferences supporting creativity. This research points to the dynamism of the unconscious mind, since such interferences happen without the need of conscious control but are influenced by the degree of attention focusing. Once those dynamic processes are understood, they can be used to enrich mental life, boost creativity in general, and improve decision-making processes.

Keywords*:* Sentiomics, feeling capacity, unconscious processes, dynamic patterns, wave interference.

1. Introduction

How is it possible for any one of us to wake up in the morning with the solution to a difficult problem that was not grasped the day before? How can musicians suddenly write down a composition, words and music, with 'holistic' properties such as harmonic structure and rhymes, without explicitly thinking of each part beforehand? How can a speaker improvise in front of an audience, constructing sentences they never thought of before? Our working hypothesis is that all these processes involve dynamism of the unconscious mind, based on constructive interference of electrochemical waves interacting with oscillatory rhythms, implicitly operating with systems of signs and languages without these signs and languages being explicitly represented consciously. Now, while this hypothesis *per se* is not exactly new[1], in this paper, we introduce and describe a novel perspective to further develop it theoretically and empirically.

Sentiomics, the study of the unconscious dynamic patterns in the brain that define the capacity of feeling, may be useful to understand creative processes that generate conscious outputs without an explicit representation of the logical and cognitive processes that make the outputs possible. The combinatorial process involved in generating the outputs is possibly also a dynamic one, containing wave interferences, positive and negative. The dynamic patterns operate as a self-organizing system [3].

[1] The bibliography on creativity is full of references to the role of the unconscious mind in the creative process. For example, in the groundbreaking work of the cognitive scientist Margaret Boden [1], the author makes reference to Coleridge's notion of associative memory, Poincaré's famous description of creativity as first and foremost a process of combination of unconscious ideas, and the role of the unconscious in what Arthur Koestler named "bisociation", i.e. the unexpected synthesis of two difference conceptual matrices ([1], pp. 29-34). Another example is the classic book on the psychology of creativity by Runco [2], where one can find several references to the unconscious in various psychological theories of creativity.

The capacity for feeling, also known as *sentience*, recently emerged as a subject of great interest, having ethical and practical implications for human life and the planet's ecological crisis. In the philosophical and scientific literature (e.g., [4]), sentience is related to consciousness in at least two aspects: (i) As the capacity of/for being sensitively aware and (ii) As part of higher cognitive processes, namely in the form of *qualia*.

Moreover, according to Pereira Jr. [5], it is possible to distinguish three domains in which consciousness, or subjective qualia accompanying consciousness, depends on sentience. They are: (i) Affects, which corresponds to sensations, moods, and emotions; (ii) Cognition, which corresponds to perception, attention, thinking, and memory; and (iii) Action, which corresponds to desires directed to an external object, the will, generation and monitoring of body movements and self-control.

Therefore, the study of sentience can be vital to enlighten a diversity of issues in the philosophy of mind, cognitive and medical sciences. In the study of sentience, one can identify two main approaches with their respective sub-methods. One approach is centered on the first-person perspective (e.g., descriptive psychology; phenomenology). Another one is centered on the third-person perspective (e.g., neuroscience).

We can interpret the results of those two approaches as relating to different aspects of the same systems. The first-person perspective methods seek to describe the qualitative states of the conscious experience. In contrast, the third-person perspective aims at describing the measurable patterns that support those subjective qualities. These approaches do not reflect an ontological difference but an epistemological one. Based on that, one of us [6] raises the hypothesis that we can further develop two epistemological approaches to study sentience, as in the common distinction made in the biological sciences between *genotype* and *phenotype* and in linguistics, between generative grammar and the morphology of sentences. So we have methodologically speaking divided the study of feeling into two modalities:
(i) *Sentiomics*: The identification and analysis of dynamical patterns that characterize Sentience;
(ii) *Qualiomics*: The identification and linguistic report of various *qualitative conscious experiences* in the first-person perspective.

The latter is a challenge to conventional science, as stated in the "hard problem of consciousness" [7]. The first-person perspective is not accessible to the conventional scientific measurement methods and explanations. While *Qualiomics* remains a challenge to scientific methods, *Sentiomics* is more suited to third-person perspectives and can be further developed by relying on actual scientific methods and technologies.

Sentiomics can follow the same scientific strategy as corresponding "-omic" disciplines such as gen*omics* and prote*omics*, i.e., disciplines whose target is "*the collective characterization and quantification of pools of biological molecules that translate into the structure, function, and dynamics of an organism or organisms*."[2] By focusing particularly on the temporal dynamics of various structures (e.g., brain networks), the scientific agenda of *Sentiomics* would not be the localization of areas nor the description of static mechanisms (as physical fields) that underpin sentience in a certain biological system, but rather the quantitative register and analysis, with mathematical tools, of temporal unconscious dynamic patterns that support conscious experiences.

2. Basics of Sentiomics

The study of dynamic vibrational states, such as Chladni patterns, has been made since antiquity, inspiring an area of study called *Cymatics*, based on the work of Rudolf Steiner. He, in turn, was inspired by Goethe (see [8]).

Radio transmission through electromagnetic (EM) waves and acoustic engineering are possibly the first contemporary scientific approaches that can contribute to *Sentiomics*. The engineers developed concepts and methods that became very useful in studying living systems, as in the case of the electroencephalogram (EEG). Other antecedents of *Sentiomics* include Manfred Clynes' theory of *Sentics* [9]. The whole living body is approached as a sentient system with temporal patterns in the brain.

Non-linear waves in the study of the brain [10] and the growing area of *Sonification*, in which sounds are used to represent the dynamic patterns of nature in time (see [11,12]). Pereira Jr and de Aguiar [13] have also acknowledged the relevance of gesture studies, bio semiotics, and the philosophy of feeling of Susanne Langer as important sources of inspiration. Still, the list of related research remains open for now. Since

[2] https://en.wikipedia.org/wiki/Omics

Sentiomics is a research approach conducted in the third-person perspective to register and analyze temporal dynamic patterns, we should stress that electrochemical and electromagnetic waves, as e,g. measured into EEG patterns, when correlated with conscious experiences, compose the knowledge database of *Sentiomics*.

Below, we shall present some key notions borrowed from radio transmission, acoustics and EEG, useful for *Sentiomics*. First, let us start with the notions of carrier and modulation waves. We can define a carrier wave like the one that contains the energy necessary to propagate the signal in space (e.g., as in radio transmission, the wave has the AM or FM frequency in which the signal is transmitted across space and that is selected by the listener using the receiver's dial); it is outside the audible frequency and is redundant, which means it carries little information. The modulation wave, in its turn, is the one that generates differences in the carrier wave. A modulation wave "harmonizes" the carrier wave, and by doing so, it "sculpts" a temporal waveform. There can be amplitude (see Fig 1), frequency or phase modulations. Phase modulation is particularly important when the signal is transmitted through multiple channels that might or might not synchronize.

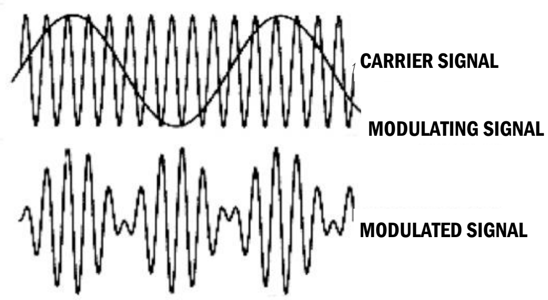

Figure 1: Wave harmonization These differences in amplitude are temporal phenomena that can cancel or add when two or more waves interact.

Going beyond these basic notions, we hypothesize that examples of *musical forms* in different degrees of complexity can also be useful to analyze dynamic patterns that might underpin Sentience in different systems, including the brain.[3] What makes music particularly relevant to *Sentiomics* is the fact that it is built on waveforms, but the patterns it builds (e.g., interval; timbre; rhythm; counterpoint; melody; harmony) are much more complex both in terms of acoustics as well as in terms of the feelings they can communicate to or elicit in the listeners. Therefore, such patterns can be used as sources of stimuli and/or potential models to analyze data on brain activity related to Sentience, consciousness, or other mental processes.

The shift from spatiality to temporality proposed by *Sentiomics* is in agreement with the hypothesis of the "music of thought" proposed by Lloyd [14,15] as a counterpoint to the famous hypothesis of the "language of thought" [16]. According to Lloyd, sparse signals of brain activity collected via functional magnetic resonance imaging (fMRI) do not necessarily imply a language-like structure. Instead, they can also be interpreted as a music-like structure. One can approach them, for instance, as rhythms, motifs, themes, harmonies, and modulations. While [15] has based his initial and promising analyses on fMRI data, we believe that high temporal resolution data would make the link between brain activity and music-like structure even more evident.

Moreover, we believe that music can offer insightful analogies to *Sentiomics*, but it can also be a source of stimuli for potential medical applications. The philosophical and scientific success of *Sentiomics* per se would help explain *how* it is that music can influence the human mind so strongly. But there is more: in the context of *Sentiomics*, we can hypothesize that it is possible to identify specific wave patterns related to specific sentient conscious experiences (e.g., a type of pain experienced by a certain individual); then, we could map the way different musical patterns,

[3] About the use of musicology as a toolkit to analyze measurements of brain activity and the hypothesis of the "music of thought", see [14,15].

instead of simple frequencies, could modulate that experience by modulating the brain waves.[4] This hypothesis could also be useful in the recent debate on music and medicine. It introduces the role of *dynamic patterns* in a discussion that is still pretty much focused on how brain networks are stimulated by music.[5] Let us elaborate on this in the next sections.

3. Brain waves may be electromagnetic or electrochemical

Until recently, neuroscientific studies of patterns related to Sentience have been called "neural correlates of consciousness" [17,18,19]. However, there is a tendency to privilege brain areas and circuits. The neurosciences have mainly focused on identifying *spatial patterns* in the brain, while the role of *temporal dynamic patterns* has been significantly overlooked. This tendency to focus on spatial patterns is what philosopher Bechtel [20] called "localizationism". However, analyzing the temporal functioning of the brain might be particularly fruitful when what is being studied is Sentience and consciousness. *Sentiomics* aims at providing a method to address this issue.

The role of time in the neuroscience of affects, cognition and action is largely ignored [21,22]. Bearing this in mind, *Sentiomics* highlights a shift from a spatial "paradigm" in the neurosciences toward a temporal one in which *dynamics patterns* [23] compose *temporal processes* that underlie different aspects of mental life. From this perspective, *Sentiomics* in the neurosciences has the task of identifying and formalizing the waveforms that characterize affective, cognitive, and/or enactive processes.

The role of time is also central in Microstate Theory (Fig 2), in which micro temporal states registered with scalp EEG are taken into consideration and analyzed: "*For a given EEG wave shape recording, the power spectrum describes how the energy of the time series (the EEG recording) is distributed with wave frequency […] Since wave-shape-based analyses always must analyze a certain extent of time to assess waveforms, for example, like frequencies, these approaches are termed "macrostate" analyses by our group. […] In contrast, "microstate analyses", as reviewed later, analyze single moments. […] A potential distribution map can be constructed for each time point by measuring the brain's electric potential values from many locations on the head surface. Each map is a snapshot of the momentary functional state of the brain as reflected by its electric field. At each moment, there is a single functional state, however, complex the organization of the system […]*" ([24], pp 202-4).

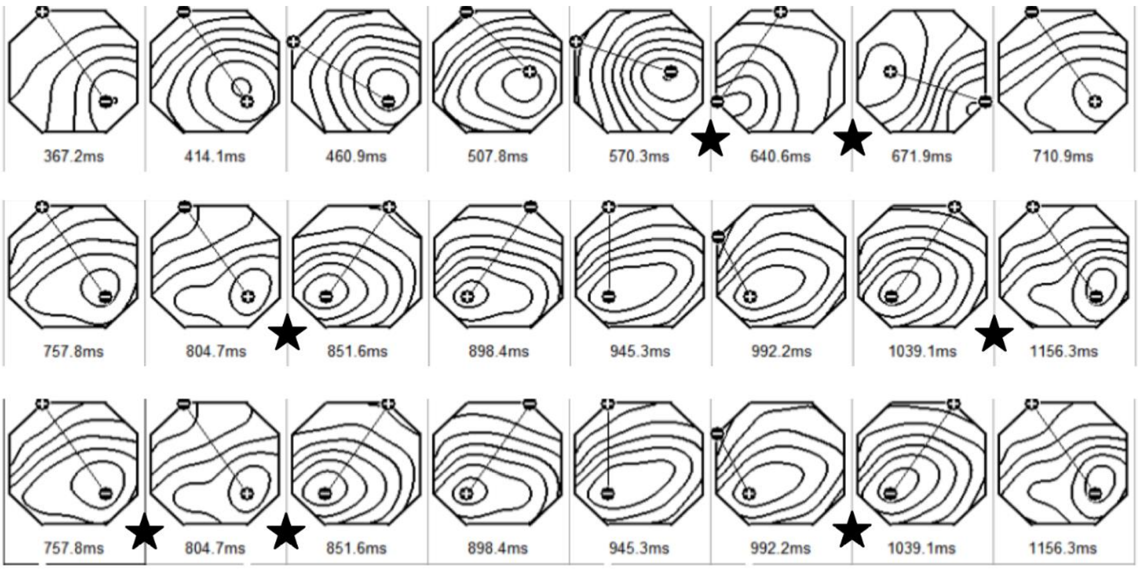

Figure 2: Dietrich Lehmann's Illustration of Brain Microstates (Lehmann, 2013, p.205). The time when each microstate occurs is indicated in the respective box, and the direction of current relative to a reference electrode is indicated by (+) and (-) symbols. According to Lehmann, "the mapped landscapes show brief periods of quasi-stable spatial configurations that are concatenated by very rapid changes of landscape […] Data-driven analysis approaches for electric brain data can parse the series of momentary maps into temporal segments of quasi-stable map landscapes […] Their mean duration during no–task resting is in the range of about 100 ms." ([24], p.204).

[4] For more on this hypothesis, see [12].
[5] See, for instance, the summary of findings in [17].

Research on dynamic patterns in neural (neuronal and glial) tissue requires high temporal resolution registers. Skull surface electrodes can measure some of these patterns but are limited to the more superficial layers of the cortex. Internal electrodes used during brain surgery, and arrays of invasive electrodes implanted in rodents, have been used to detect high temporal resolution dynamics patterns in the brain. These findings cannot be obtained with fMRI because of its low temporal resolution.

Electromagnetic (EM) waves generated by the oscillatory dynamics of neuron dendritic fields, activated by external and internal signaling, prompting extracellular ion movements that build the local field potential (LFP), are the main source of the scalp EEG register [25]. From current neuroscientific approaches, the type of register of brain activity most relevant to *Sentiomics* is the high-resolution EEG, which registers electromagnetic waves' frequency, amplitude, and phase modulations. In the awakened person's brain, rhythmic activity is dominated by medium to faster-synchronized waves in the theta, alpha, beta and gamma ranges [25]. In slow-wave sleep, delta waves take over the whole system in such a way (alternating long hyperpolarized *downstates* with long depolarizing *upstates*) that information patterns registered during the awaken circadian period tend to be erased or selectively consolidated, resetting the system for another day full of new experiences. It should be mentioned that EEG activity measures potential differences or electric field interactions. Still, an electric field is not EM because it is not (necessarily) accompanied by a magnetic component. Yet, from a multiscale approach, EM waves do from the EM resonance phenomena.

Electrochemical waves are slow (under 1 Hz) and generated mostly inside astrocytes when calcium cations are released from the endoplasmic reticulum and move along astroglial compartments (called "astroglial processes"), under the action of the Coulomb force of repulsion [26]. These slow waves have a low impact on the EEG and are usually filtered to increase the signals from the faster waves. Recently they have been registered using invasive optical imaging methods in rodents, such as two-photon microscopy.

Astroglial hydro-ionic waves, which contain calcium and other cations in movement, form dynamic dipoles with negative water [26] and are amplitude-modulated in time. At the same time, neuron firing is mostly not amplitude-modulated (all spikes have approximately the same amplitude). Ionic *currents* inside the neurons also present rich temporal dynamics [27]. Changes in amplitude in time putatively generate meaningful sensations and feelings for the biological system in the first-person perspective [4].

Pereira Jr. and colleagues have extensively analyzed the role of neuro-astroglial interactions and hydro-ionic waves in the constitution of sentient cognition (e.g., [26,28]). According to the proposed model, "*there are two types of signal processing in the brain: one based on continuous hydro-ionic waves in living nervous tissue, corresponding to feelings, and the other based on discrete electrical pulses through axons isolated by a myelin layer, corresponding to the processes of sensory transmission, mental representation, logical thinking and motor control. Ionic waves in nervous tissues and axonal pulses in the neural networks interact intimately; graded neuronal potentials generate waves, which modulate synapses, reinforcing or depressing the frequency of action potentials*." ([5], p. 201).

As a theoretical hypothesis, we assume that hydro-ionic waves in neural tissues (or similar) make a living (or similar) system sentient. Plants do not have neurons and glia but display calcium waves within their structures [29]. Each biological species, of course, has proper ways of feeling; plants do not have animal feelings, but possibly some sensing of heat, water, light, etc. For instance, *Mimosa* displays calcium waves following a touch on their leaves. In comparison, ions in water (like acid batteries) are not sentient like biological systems because their dynamics do not display the required temporal structure. The scientific task of *Sentiomics* is to distinguish both types of phenomena, namely, *sentient* and *non-sentient* ionic waves and currents.

Maybe there is some 'proto-sentience' when a battery reacts to electric input during charging or changes in weather (heating or cooling). Still, *Sentiomics* is not about hypothetical rudimentary processes. Based on available experimental evidence, hydro-ionic waves in plants and animals can generate feelings since the experience of feeling somehow impacts their measurable 'covert' or 'overt' behavior in humans and other animal species, making possible a *report* of the qualitative experience. Science still cannot treat the experienced qualities (this would be a task for *Qualiomics*) but can identify the dynamic patterns related to the experienced qualities.

This branch of science heavily depends on empirical registers and mathematical analysis. A proper mathematical model is central to *Sentiomics*. Therefore, the studied dynamic patterns are temporal and should be mathematically represented, not as static structures, but as *processes in time* (e.g., time *derivatives*). A biophysical description of these processes without formalization can be found in another publication by one of us [30].

4. The role of constructive interferences of electrochemical waves

Now we would like to propose a *Sentiomics* approach to the phenomenon of mental creativity. Just like the neuroscience of sentience and consciousness could profit from a *Sentiomics* approach, as was presented above, so could the neuroscience of creativity. The study of creativity requires an approach to *unconscious processes* that may complement psychoanalysis (as discussed in [31]). Without accounting for sentience, the neuroscience of *creativity* could hardly succeed; we suggest that *Sentiomics* provides much-needed conceptual tools to advance the neuroscience of creativity.

Explaining creativity is still a big challenge for psychologists, computer scientists and neuroscientists, despite the growing body of research on that topic.[6] In comparison to other cognitive functions, creativity seems particularly hard to define. It is difficult to agree on what counts as a paradigmatic example of creativity, distinguishing it from other mental functions such as perception, imagination or memory.

Creativity is characterized by two main components: originality and effectiveness [32]. According to different authors, those two notions have undergone many variations. Thus, creativity is strongly associated with novelty, surprise, usefulness, fit, and appropriateness. That pinpointing the elements that characterize creativity brings with it the question of who is to judge when these elements are taking place or not.

Bearing in mind the complexity of the topic, in this article, we assume that creativity involves (i) a process in which novelty is generated as well as (ii) a wider process of evaluation in which the adequacy, value, fitness, etc. of that novelty will be tested. The first element is easier to quantify or determine with a certain degree of precision. Here, the novelty can be compared to a more or less stable frame of reference (e.g., objects of the same type). However, the second element implies a more complex evaluative framework, including philosophical, sociological, historical and economic variables.[7]

Approach to creativity starts with certain presuppositions that narrow, in some direction or another, the search from processes that lead to pure novelty to those that support creativity, i.e., a novelty that is also useful, adequate, surprising, valuable, etc

Sentiomics can address that "neural" complexity. The perspective that results is a holistic conceptual and empirical approach capable of clarifying the 'differences that make a difference' in the brain processes that underpin novelties and creativity (in one sense or another). More specifically, this research points to the dynamism of the unconscious mind as a repository of dynamic wave patterns that influence each other, as - making an analogy - the fluxes of water that interfere with each other in the ocean. In that sense, the study of unconscious dynamic patterns in the brain could be an interesting addition to the neuroeconomic approach to creativity, as presented in [35], since both approaches are concerned with *dynamic interactions* in the brain as the basis of processes of "computing" and "evaluating" the value of novel findings, to use their jargon.

As long as creativity is a type of intuition based on feeling, we raise the hypothesis that it is based on the (temporal) dynamics of tissue waves; not from EM waves alone, because these are defined by the frequencies, but by the temporal 'sculpting' of these waves by underlying electrochemical processes and their emerging interference patterns. The specification of a frequency alone (e.g., a sine wave) is not informative but redundant: it corresponds to the carrier wave alone, without the information sculpted by the modulating wave! As Atlan [36] pointed out, a self-organizing system needs a degree of *redundancy* together with an informational *variety* [37]. For instance, consciousness cannot be explained only based on the specification of synchronized frequencies, such as in a raw version of the "40Hz hypothesis" [38]. Therefore, we should look to understand how the slower, electrochemical tissue waves amplitude-modulate the EM carrier waves. In this case, creativity is expected to rest on the interplay between electrochemical tissue waves (below 1 Hz) and electromagnetic tissue waves (above 1Hz) in the spectrum of brain rhythms. This reasoning leads to a hypothesis that slower dominant frequencies (in Delta, Theta and Alpha bands) may "give more room" for electrochemical tissue waves to constructively interfere, as discussed in the next section.

[6] In a recent paper, specialist Arne Dietrich provides the following summary: "Imagine the impact if we were to understand, and thus could reliably enhance, something – anything – about how creativity works in the brain. The fact that this prospect is not anywhere in sight makes it clear that no reliable progress has been made on the mechanisms underlying creativity over the last half century. Indeed, with the divergent thinking paradigm shown to be theoretically incoherent for neuroscience, there currently is no viable experimental approach to tackle the problem." ([33], p. 1).

[7] More on this complexity, see [34].

5. The Interplay of Brain Electrochemical and Electromagnetic Waves

Pereira Jr. and colleagues [39] have argued, based on several experimental results, that conscious experiences involve a spectrum of brain rhythms, from those lower than 1 HZ, related to tissue waves, to faster ones related to attention to fast-moving stimuli and make the conjecture of a Fibonacci-like proportion of brain rhythms during conscious experiences: "The progression of frequencies during the 2s time when a conscious episode is formed can be covered by the recursive equation Y = 2X + 0.5. Beginning with a frequency of 1 Hz (corresponding to…the formation of calcium waves in brain tissue), we have the series for the first six recursions: 2,5; 5,5; 11,5; 23,5; 47,5 and 95,5 Hz, which roughly corresponds to brain rhythms involved in conscious processing. Kozma and Freeman [40] and Buszáki [25] anticipated this approach. They have suggested that a recursive operation underlies the brain self-organizing oscillatory activity necessary for conscious experience" ([40], p. 239).

The dominant frequency band in the EEG spectrum is likely to be relevant to creativity. Based on experiences in the first-person perspective, we find positive evidence for the hypothesis that slower dominant frequency bands give "more room" to the interference of tissue waves that support creativity. This hypothesis would explain why it is possible to be creative while sleeping. On the other hand, faster frequency bands dominating the EEG would not "make room" for the constructive interference of tissue waves that support creativity. Being creative while paying attention to a fast-moving ball is very rare. For instance, the talents of Pelé and Maradona in football (soccer) imply making room for constructive interferences of tissue waves while controlling the movements of the body targeted to a fast-moving ball.

Based on the above conjectures, we propose that creativity is based on the *constructive interference of electrochemical waves below 1 Hz, boosted by the dominance of slower synchronized oscillatory frequencies* ("brain EM waves") registered by scalp EEG. While faster frequencies presumably do not "make room" for the constructive electrochemical interferences to reach consciousness, because of the types of mathematical ratios (to be discovered) in which both combine, the slower dominant frequencies of the EEG ("brain EM waves") allow the electrochemical waves to interact for longer periods. Then creativity arises through their constructive interferences.

The hypothesis is currently not fully confirmed by the evidence, and for this reason, it stands as inspirational for an open research program in *Sentiomics*. There are some pieces of evidence for the hypothesis, such as: (1) We are creative during unconscious, dreamless sleep (under Delta dominance). The phenomenological evidence is that we often wake up with new ideas; (2) Theta waves (7 Hz) correlate with creativity [41]; (3) Broad attention and creativity are correlated with increases in the Alpha band, e.g., during mindfulness meditation [42], "focused attention" and "open monitoring" mindfulness practices [43]. A generally broader spatial attentional focus has also been linked through individual differences approaches to higher posterior alpha wave [44]; then, "it's of course not an accident that alpha power increases still further with the eyes closed" (Karina Linnell, *personal communication*); (4) If Gamma bands (from 30 to 100Hz) have not been correlated with creativity, this is positive for the hypothesis; a systematic review is necessary to check this issue; (5) People are more creative under the action of alcohol and other drugs, or when emotionally taken, etc. Assuming that these conditions impair the default distribution of frequencies of the EEG spectrum, then we can speculate that this perturbation makes room for more (constructive or destructive) interference of the electrochemical waves.

In the whole spectrum of brain rhythms composing the EEG of a conscious person, there may be the dominance of one of the frequency bands, depending on what she is doing at the moment. For instance, while in dreamless sleep, there is a dominance of Delta waves (centered around 3 Hz), paying attention to the internal states of the person, as in meditation, may increase the Alpha band (centered on 11, 5 Hz), and paying attention to a fast-moving stimulus, as the ball in ball games, leads to a dominance of the Gamma band (above 40 Hz).

As a consequence of the hypothesis, when arousal reduces, so does the mean frequency in the EEG [45], fostering broad attention and creativity. One of the accounts that seem to encapsulate the diverse nature of attention is the adaptive gain of Aston-Jones and Cohen [46]. According to this account, attentional states can vary dynamically between exploitative/focused states and explorative/diffuse states, mediated by shifts in arousal levels. In this sense, creativity is unlike to arise while a person is attending to a narrow attentional focus (e.g., while scratching an itch); on the other hand, during a broad attention focus (e.g., in *mindfulness* meditation), there would be more room for creativity. Relating these phenomena to the theoretical concept of *global gain*, Eldar and colleagues [47] state that: "*A large body of psychological research in humans suggests that stress.*

(which is associated with high levels of norepinephrine) reduces the breadth of attention Another line of studies shows that stress and norepinephrine shift rat and human behavior from a flexible mode of behavior to a more rigid habitual mode in which previously established stimulus-response associations are followed. Stress and norepinephrine have also been linked to diminished performance in cognitive flexibility tasks. Our findings suggest an explanation of these previously observed phenomena in terms of the influence of the LC-NE system in globally modulating neural gain. Increased gain narrows attention by strengthening already strong neural representations at the expense of competing for weaker representations. This, in turn, favors previously established patterns of behavior, which are subserved by well-established neural circuits and thus tend to form stronger representations".

Is creativity "related to broadening attention, *and* reducing the global gain, not favoring previously established behavior patterns?" (Karina Linnell, *personal communication*). We suggest that this may be the case and that - if correct - the conjecture may help to understand several types of phenomena related to creativity, such as: why does the consumption of psychoactive substances (e.g., ethanol) perturb the orchestration of brain rhythms may have a positive effect on creativity? This is because if the faster rhythms dominate the EEG and entrain themselves in a perfectly mathematical proportion, the neural systems operate in such a way that favors the linear activation of cortical columns and activates habitual behavior, reducing the interferences of tissue waves to a minimum. On the other hand, when this proportion is perturbed – of course, in a dose-dependent manner (if the perturbation is too high, the person will lose consciousness and, ultimately, will enter a coma and die) – there is more room for constructive interferences that may result in creative mental processes.

Although not a case of a constructive, creative process, experimentation with the Stroop test - in which there is interference between the neural correlates of colors and meanings of words - may also be interpreted according to our hypothesis. Focused attention may be a filter or restriction on the interaction and interference of slow electrochemical waves. When paying attention correctly, the subjects can give the correct answers. If not attending correctly to the task, e.g., the word "red" written in blue color may be reported as "blue" because of an unconscious interference between the neural correlates. These unconscious, non-attended interactions may be responsible for creativity and intuition, both the constructive and mistaken ones.

6. Concluding Remarks

Dynamical patterns of Sentience – the slow electro-chemical waves - interact unconsciously. We do not perceive these interacting patterns but only the processes' results, depending on the dominant spectrum of EEG frequencies. These results may, in some cases, appear as intuitive or creative outputs, in which we do not represent each logical step that leads to the output but only the final result. We *are* our conscious experience and several unconscious processes, some of which endows us with the capacity of feeling (Sentience) and many others just having the function of keeping us alive. Our body/brain receives signals from stimuli and then builds an image (embedded on a complete scene) projected to the signal source. We see the result of the projective operation [5]. The structured world we perceive is a construction that involves our affective, cognitive and enactive dispositions. However, this does not mean that the object that signals itself to the perceiver does not have its structure and that we, as perceivers, do not at least partially capture the structure of the object itself.

Sentiomics is one attempt to scientifically register, identify and analyze the dynamic patterns that compose the objects of conscious perception and the processes in neural tissues that support the experience of these objects. These processes, which happen on multiple spatio-temporal scales, begin unconsciously and become partially conscious. There is an "overflow" [48] of content beyond our limited capacity [49] of consciously representing, attending and logically thinking. In this paper, we sketched a possible approach to the interactive process, suggesting the possibility of a science of the dynamic patterns that interact and constructively interfere, generating outputs that we experience as intuition and creativity.

Considering that each frequency band corresponds to a sub-scale of temporal patterning of neural activity in the living brain/body, we state that the multiscale mathematical proportion of rhythms is central to mental processes. Although creativity and consciousness may not happen together, both depend on this type of mathematical proportion. According to the hypothesis we presented here, unconscious creativity is generated by the constructive interference of neural electrochemical tissue waves in frequencies under 1Hz. Therefore, matching these slow frequencies, obeying some mathematical ratios (to be studied by *Sentiomics*) with the dominant EEG rhythm is relevant for the rise of creative processes. When faster rhythms dominate the EEG, there is less room for creativity, especially when attention is narrowly focused on fast-changing stimuli. The talent to be creative in this type of situation is very rare.

There are individual differences in the creative process. This subject is amenable to experimental research once the hypothesis is formulated and good experiments are planned. This paper has the role of inspiring new research on the neuroscience of creativity, departing from the hypothesis we raised - that may be confirmed, corrected or rejected based on experimental results. Along with this proposed research program, *Sentiomics*, the science of the capacity of feeling, has the potential of becoming an important branch of multiscale neuroscience.

Acknowledgment

We are grateful to Karina Linnell (Psychology, Goldsmiths University of London) for language corrections, criticisms, and suggestions to better understand the relationship between attention and creativity.

Conflict of Interest

The authors declare no conflict of interest

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