Creative Thinking: A Brain Computer Inter-Face of Art

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Abstract. The artistic expressions are universally recognized as creative. It might be considered a window on the mind since an artwork implies a blend of implicit and explicit thinking processes and results in behaviors mediated by some media or epistemic instruments. In this sense, art may be seen as creativity enacted, since the mind/brain must interact with the surroundings so to close the cognitive loop open by inspiration.
We can state that creativity is a part of every human daily activity, so that, to understand individuals' behavior, abilities, and the mechanisms of the mind, we must start from the creative process, as, in general, the search of a different (innovative) solution to a problem.
In this paper, we will treat the cognitive aspect of the creative process and we describe an example of creativity enacted by the use of a Brain Computer Interface: the mind the chair project.

Keywords. Creativity; Brain Computer Interface; Cognitive Science; EEG.

Scientific Investigation On Creativity

Scientific investigation through new technological tools, such as Brain Imaging and Artificial Intelligence (A.I.), opens a wide scenario on the opportunity in studying relationships among Art, Technology and brain, and, consequently, creativity. Brain Imaging techniques allow notable improvement in the analysis of the brain "in action", that is the study of the individuals' reactions and brain mechanisms involved in motor, cognitive or perceptive tasks. Thanks to devices and methods, such as fMRI (functional Magnetic Resonance), MEG (Magnetic Electroencephalography), PET (Positron Emission Tomography), EEG (Electroencephalography), it is possible, in fact, to verify in real time the response of an individual to specific stimuli. Because of its low invasivity and high time resolution, EEG is the most used technique to investigate mechanisms such as creativity. Intuitively and experimentally, it is possible to state that Art is a creation of the brain (Cela-Conde, et al., 2004). The study of the neuronal mechanisms that underpin the artwork as well as the aesthetic experience represents the base of the experimental discipline named Neuroaesthetic, officially born in 2001. Founder and pioneer of Neuroaesthetic is Semir Zeki, known neurobiologist who, in the '90s, begun to study to the links between Art and brain, using psychological tests and electroencephalography. Zeki compares artists to a neuroscientist (Lumer and Zeki, 2011; Kawabata, Hideaki, and Zeki, 2004; Zeki and Nash, 1999) "*exploring potentiality and the ability of the brain, even if with different tools"* and, even with a different language "states" an idea discovered or intuited. However, differently from scientific knowledge, artistic ideas are not completely overt. The aesthetic experience of an artwork integrates and transforms the individual perception of reality in a lived experience with regard to the subject: the artwork disturbs, excites, and soothes the individual. Finally, Aage Brandt (2006) proposes to consider neuro-aesthetics as the study of the neuronal process of perception and mental organization of cognitive activity stimulated by the artwork, following both a cognitive and evolutionary approach.

Particularly suited for the described research, the B.C.I. (Brain Computer Interface) headsets are a simplification of the medical equipment for EEG (Allison, Wolpaw and Wolpaw, 2007), and allow to record cerebral rhythms and the direct brain-computer interaction. BCI devices are widely used in research, for the registration completely comparable to the medical EEG, but also for their low cost and high portability. They present, moreover, the advantage to keep in comfort the individual wearing them as they allow a wide movement freedom in the experimental environment. BCI devices collect several brain frequencies, grouped in rhythms: the alpha rhythm (8 Hz – 12 Hz), related to relaxation, meditation, contemplation; the beta band (12 Hz – 30 Hz), associated with active thinking, attention, problem solving (Lucchiari and Pravettoni, 2012); the delta rhythm (0.5 Hz – 4 Hz), a sleep-related rhythm also associated with arousing stimuli (Lucchiari and Pravettoni, 2010); the theta rhythm (4 Hz – 8 Hz), generally related to emotional engagement; the gamma signal (30 Hz – 40 Hz), usually related to the focused attention and cognitive interpretation of multi-sensory signals. BCIs allow investigating the mechanisms of creativity both from the point of view of the artist while creating a work, and from the point of view of the public while observing the final result.

In this framework, BCI devices are particularly useful in research, either to register the response to visual and musical stimuli and recognize the emotions valence (Banzi and Folgieri, 2012) and to reveal the mechanisms of the visual creativity (Folgieri, Lucchiari, Granato and Grechi, 2014). The objective of the studies, past and *in fieri*, is to evaluate the emotive and the cognitive response to stimuli, with the aim of understanding what are the mechanisms triggering creativity or characterizing the creative process (the insight). In some experiments, the objective is to evaluate the emotive and cognitive response to visual-perceptive stimuli (Allison and Pineda, 2003; Wiggs and Martin, 1998), based on the concept of *priming* (Banzi and Folgieri, 2012). Other studies, investigate the mechanisms of response to colors (Folgieri, Lucchiari, and Cameli, 2015), or to stereoscopy and monoscopy (Calore, Folgieri, Gadia, Marini, 2013). The obtained results show interesting correspondences among some cerebral rhythms and the creative activity.

Currently, the research focuses on the comprehension of the cognitive mechanisms at the basis of creativity, of emotional intelligence and expression, but the technological cognitive tools at disposition today show, evidently, an enormous potentiality, in giving the possibility to verify, as Vygotskij stated, how the human ontogenesis is strongly influenced by cultural (technological, in our Era) tools at disposition in the historical and social context.

Creativity enacted: Mind the chair

Art might be seen as a window on the mind. It allows probing implicit and explicit thinking processes since artworks are able to give a tangible shape to a complex and covert brainwork. To do so artists generally use some kind of media that we call epistemic instruments. Even artists' body may be used as an epistemic instrument and in some case either thoughts or apparently simple movements. In this sense, art may be considered as creativity enacted, since the mind/brain interacting with the surroundings try to close the cognitive loop open by intuition by translating it in a shareable matter.

This is the reason why cognitive scientists are interested in Art. In fact, they study artificial and natural intelligence, and creativity is one of the most investigated fields. Among the questions to which cognitive scientists try to answer, we wish to recall the following:

- Creativity is innate or can be acquired?

- Could we strengthen it, stimulate it?

- Is there any area of the brain where it resides?

- Is it a prerogative of natural intelligence or also of the artificial systems?

Creativity may be defined as the ability to generate novel and valuable ideas and artifacts. From a cognitive point of view, creativity is a complex cognitive, process resulting from the search of a balance between conscious and unconscious processes. Indeed, creativity may be considered a borderline state of mind, in which the thought seems to fluctuate in a fluid cognitive state. When a new idea arises to the consciousness, and then a balance is achieved, the mind turns back to a "creative-off" state and divergent thinking is replaced by canonical thinking.

Taking an external perspective, we can see creativity as the process that gives rise to these new items (ideas and artifacts) and then we can define three kinds of creativity since new ideas may derive from the combination, exploration or transformation (Boden, 2004). This perspective allows scholars not only to analyze human's productions but also to investigate if computers may show some kind of creativity and which computational mechanisms could underpin this process.

However, we are interested here in how the human brain may interact with epistemic instruments to shape intuitive ideas. We can find a theoretical foundation in the work of Piaget (1970) and Vygotskij (1925) who underlined as the interaction between subjects and objects stimulates the constitution of superior psychic processes. Nevertheless, Vygotskij expresses an interesting point of view, strongly related to the consideration of the links between creativity and means (also technological ones) at disposition. In fact, he underlines how the human ontogenesis is determined also by the contribution of the cultural instruments available in the social context.

The experience we have of the world is made up of details and information, but is also rich in complex forms that interact each other not only to shape concepts and meanings, but also to evoke emotions, memories, thoughts, which are not directly matched with some physical features of a given stimulus detected by the senses. Consequently, creativity is a basic cognitive process which mechanisms are hard-wired in our brains so to give rise to a whole experience of the world, even when we see it for the first time. Hence, these processes allow the human brain to enrich our experience, shaping the deeper motivations that guide our cognition well beyond contextual needs. This is the cognitive core of creativity. As Ramachandran and Hirstein (2011) pointed out, creativity is not magic at all but is the consequence of the way our brain works. In fact, we continually learn and use heuristic rules that guide use in our exploration of the world and these rules allow easy (sometimes, creative) generalizations.

However, this process does not give rise to an illusionary world: simply, it extends mind possibilities, opening new frontiers and unblocking landscapes and options, thanks to an “as if” experience. Furthermore, this view of the brain working through "as if" processes may be integrated with the theoretical perspective by Changeux (1994). This author argues that we should always consider the perception as a creative process. For instance, when someone observes something (e.g. an artwork) in his/her brain a sort of re-creation is “in march”, so to find a meaning but also to attribute mental states, emotions, intentions to the “source” of that object, thus mentally tracing the path from the creator to the observer.

Creativity may also be described in relation to problem-solving since it allows to think “out of the box” to find a solution. Problem-solving is a one the function of thinking and is a basic issue in cognitive psychology. It refers to the activity performed by a living organism or by an artificial intelligence device to achieve a status starting from one or more given condition. It is, so, the set of processes allowing analyze, organize and combine information to solve given problematic situations. In its work “The Act of Creation”, Arthur Koestler (1964) explains creativity through the bi-section mechanism that is “means to join unrelated, often conflicting, information in a new way”. In fact, if in our daily life we associate elements belonging to the same reference system (book-sheet, cooking-food, etc.), in the artistic, humoristic or scientific creation we realize a connection among heterogeneous reference systems, usually considered incompatible. Problem-solving and creativity are correlated cognitive processes and can be analyzed through Brain Imaging methods, and it is evident that we can measure, also quantitatively, the activation level of a brain, analyzing the electric signal produced (Zeki, 2001).

Consequently, we can state that the more and more cognitive scientists now consider the creativity as a basic field to explore in order to better understand how our brain works and hot it shape our mental processes. We argue that in this investigation we cannot rely only on traditional methods and techniques. We also need creative methods. For instance, new technologies are now available to be used outside psychological labs so to implement creative experiments. Artworks investigation might become a relevant field in a near future.

In particular, the links among Art and Technology, creativity and the study of its mechanisms are several:

- the opportunity for the preservation of the artistic heritage;
- the potentiality provided by new instruments for the artistic expression;

- the possibility to study the links among Art, brain and Technology and, jointly,
- the creative processes, allowed by the progress of Artificial Intelligence, *Brain Imaging,* and technological devices.

In this introductory paper, we will focus on the last point of the list. In the next paragraph, we will introduce why and how scholars perform scientific investigations on creativity. In the following, we present the use of technology to express creativity and an experimental example of it, concluding with our considerations.

With the aim to show how creativity is related to brain activation, we wish to introduce "Mind the Chair" (or "La sedia del Pensatore"), an interactive installation focused on a real time audio/visual representation of the activity of the brain, providing the possibility to control it. The performance allows visualizing the level of concentration of an individual, through an audio/visual answer (LED lights and sound generation/manipulation). While using a BCI headset, a person is able to understand how 'control' own brain activity and therefore to increment the level of concentration, modifying the intensity of the light or filtering the associated sounds. The interactive performance aims to give awareness about how our brain works and what 'concentration' means, therefore, how much brain energy is required to perform a specific task (for example, to increase the lighting), and how it can be difficult to keep our brain working for a certain amount of time.

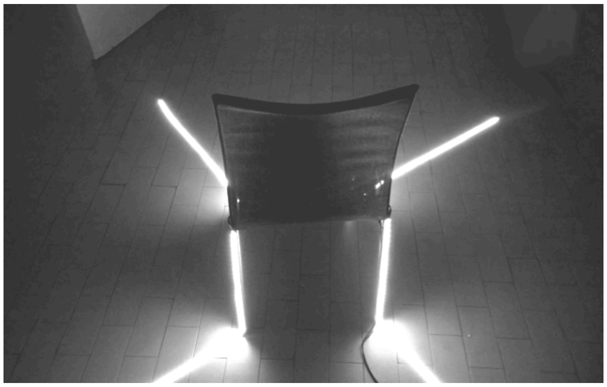

Figure 1: "Mind the chair", Francesco Soave. The performance installation in action, as exhibited in the artistic event " Terni Festival", 18-27 Sept 2015, Terni, Italy.

The concept comes from the idea of 'the chair of the thinker' where a person sits on a chair, and its own thought starting from the mind, flows through its body, along the chair and then in the surrounding space as light.

During the performance, the visitors are not given physical objects to concentrate on. They are only asked to 'concentrate' in terms of 'focusing' on something close to their attitudes. The visitor is required to not distract too much from feeling his/her brain activity, or the purpose of the installation would fail. During the performance, the word 'concentration' is, then, used as the simplest way to describe the aim of the interactive installation that is testing the power of the brain. For instance, many visitors tried to relax doing some yoga exercises, but even if they were expecting a deep fall of the lights, this didn't always happen as, in fact, whatever action you perform requires brain activity, even the act of relaxing and 'freeing' the mind.

The ability to control the brain rhythms and the concentration level, depends on, of course, by the experience of an individual: solving a simple equation can be an easy task for a mathematician, but can be a really difficult task for a non-mathematical mind. To make the installation react is, then, necessary to find a specific, personal task that makes our brain work, which, of course, can be different for different people. Also, the ability to control the brain changes depending on the psychophysical status of the person: if the user is really tired, he/she will experience difficulties in controlling the performance. Interesting enough, when the brain activity is peaking, individuals show more difficulties in losing focus and slowing down the level than actually increase it.

To realize the project a Neurosky Mindwave BCI interface and specific Java code were used to detect the brain activity through the analysis of the collected brain waves. In detail, as the installation involves concentration, Beta rhythms play a key role in identifying the level of brain activity. To make the representation consistent with the real brain activity, the interactive installation does not have a 0 level (in terms of 'lights off'): this is because our brain is working at all times and what makes the difference is the amount of work required to perform a task. Then, when the level of concentration is close to zero, a random blinking will appear, to represent the floor noise which is, in fact, a random signal existing in every kind of impulse and therefore even in the EEG brain rhythms.

Conclusions

Cognitive Science as well as neuroscience study creativity and artistic inspiration to discover their cognitive mechanisms. At the same time, non-invasive and wearable new brain technologies (e.g. BCI devices) may be used to new artistic expressions (i.e. as epistemic instruments) allowing researchers to investigate how the brain creates and understand Art in real-time and in an ecological setting. In cognitive science, the functioning of the brain and the achievements of Art are considered together to explain our aesthetic experience. The application of the Cognitive Science approach to Art, entertainment, and educational fields also represents a promising field. In fact, the importance of a BCI-based performance like “Mind the chair” is not limited in creativity studies. We argue that the use of BCIs and similar tools, such as, for example, eye trackers, should also be useful within a pedagogical program in order to contribute improving users’ ability to focus attention on abstract cognitive tasks and in translating abstract thinking in concrete operations. Many people find great difficulties in approaching similar tasks since their attention is easily grabbed by environmental distractions and so they fail in getting important educational achievements. Furthermore, the ability to focus and maintaining attention on mental tasks may contribute to the development of multitasking abilities, now considered particularly important in different contexts. Normally, expressive arts techniques are useful in helping people to increase attention skills, but they are limited by individuals’ technical competencies (e.g. drawing) or by personality traits. BCI-based tools, such as BrainArt (Folgieri, Lucchiari, Granato and Grechi, 2014) or BCI-based performances, may instead be enjoyed by everyone, without any prerequisite both in stand-alone and in group settings. Future research will test if BCIs are concretely able to increase attention-based skills and creativity, potentially increasing the penetration of art within the realm of the neuro-cognitive approach to individual empowerment both in normal and pathological conditions.

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