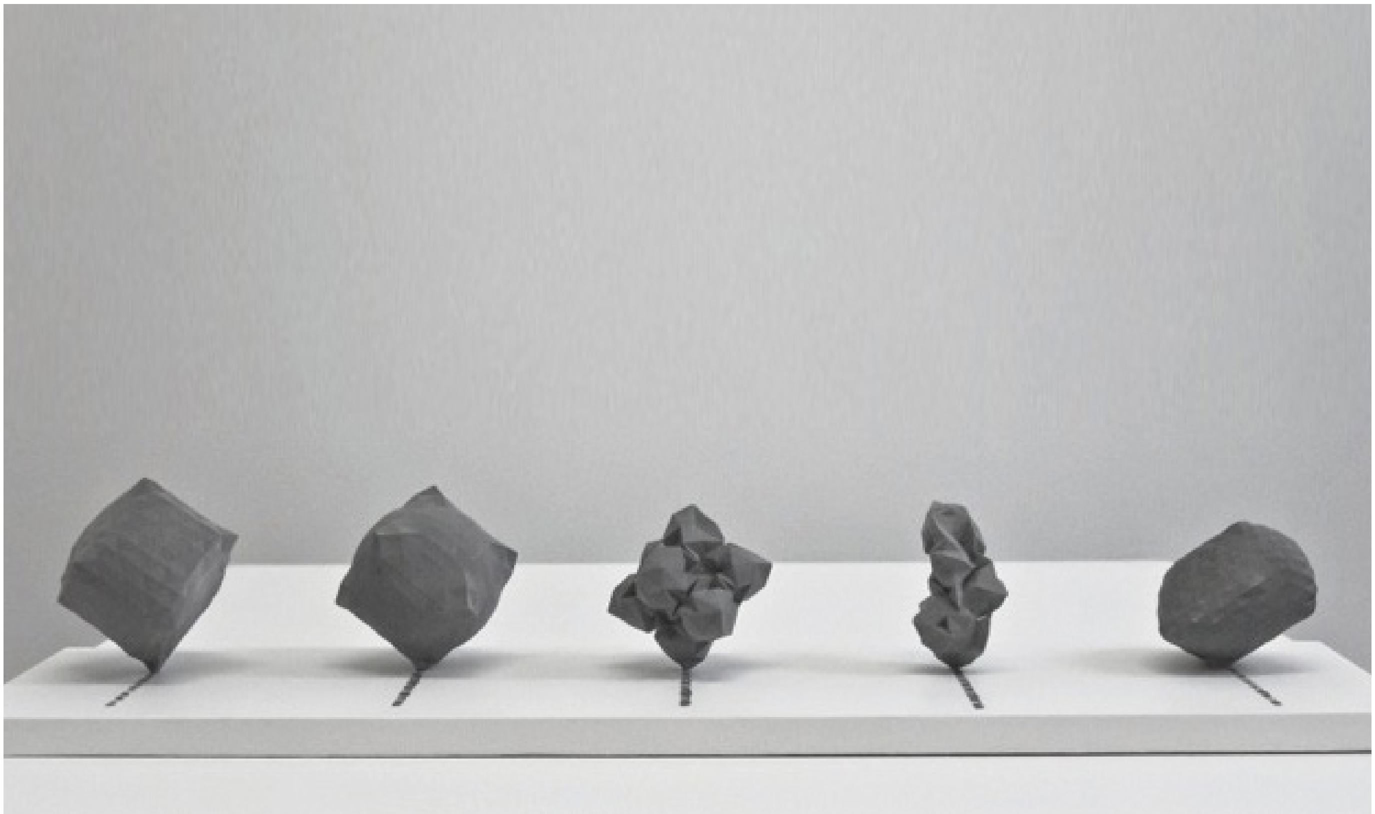
LE CUBE D’APRÈS

INTEGRATED COGNITION FOR ITERATIVE AND GENERATIVE DESIGNS

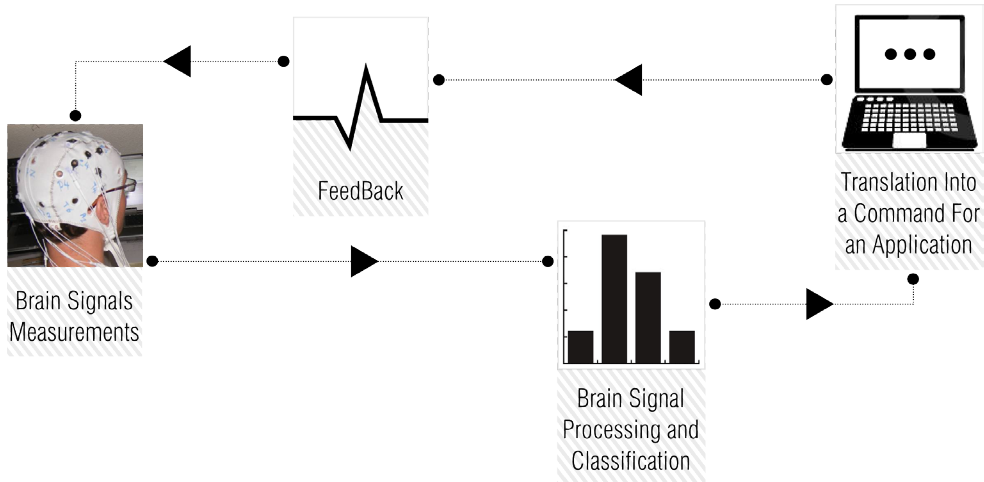
Pierre Cutellic Architect D.P.L.G.



1 Le Cube d’Après

ABSTRACT

This paper describes the work in progress of a research on *Neurodesign* and a previously described process entitled *Augmented Iterations* (Cutellic and Lotte 2013). Within this broader field of research and design explorations, we will focus on describing and commenting on results obtained in the neuro-selection of shapes among a continuously varying flow of visual stimuli. Eventually, these results will lead to the identification of a non-linear and non-convergent potential for the *Human-Based Computation* of iterative and generative designs.



2 BCI Loop. Simplification of a BCI system in four phases and creating an iterative loop. See also (Lotte et al. 2007, 2008, 2010)

INTRODUCTION

By 2023, most of the biologically extendable senses are likely to be scientifically viable and financially reachable. Since neuro-technologies and cognitive technologies have expanded beyond the sole medical purposes (Van Erp et al. 2012), around a dozen current technological trends have been identified as actively developed within miscellaneous applications. Among these are predictive crime prevention, predictive group sentiment analysis, neural network image recognition, emotion tracking, proactive software agents, neuro-prosthetics, neuropharmacology, ultrasonic transducers, neural biofeedback, brain-computer interfaces, brain-to-brain interfaces, optogenetic implants and many others.

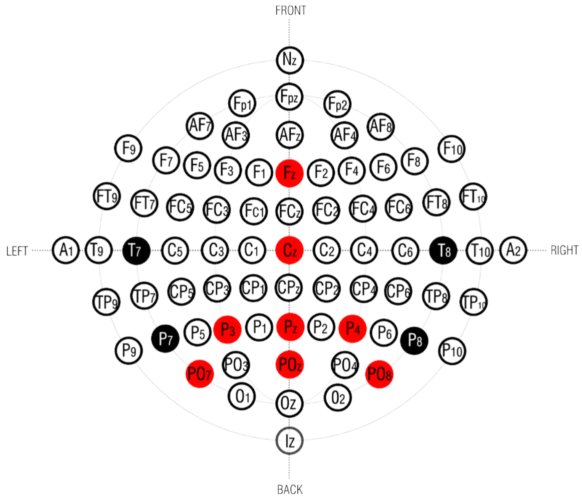
Most of these developments could be grouped in two main streams: one oriented toward the augmentation of human bodily performances and controls (neuro-prosthetics, neuropharmacology, ultrasonic transducers); and the other toward the augmentation of mechanistic processes (neural biofeedback, brain-computer interfaces), the latter being actively related to a wide field of computer science known as *Human-Based Computation* (*HBC*).

We tend to base our research on the latter for investigating the elaboration of some of these main technological developments along with their integration and impacts on generative design. In a previously published paper (Cutellic and Lotte 2013), we described the appearance of neuro-technologies in architecture as an opening toward a sensitive aspect of integration and simulation for computational design. These observations led us to establish a bond between the computation of human cognition and the evolution of design aggregates by exploiting brain-computer interfaces (BCI) for the cognitive selection, at fast pace, of a series of visual stimuli. We called such a framework Neuro-design and defined a process for acquiring, treating and integrating peculiar neuro-signals produced by the human brain when a specific recognition is made and named it Augmented Iterations.

This paper will focus on the development of this definition through experiments made for observing, more specifically design potentials of neuro- selection in generating aggregates of a higher complexity and applied to a design project called *Le Cube d'Après*. The name and scope of this project goes beyond the one of this paper and is related to the work of Catherine Malabou on the notions of generation, inheritance and iteration (Malabou 2005). In order to explain and document the new hypothesis of this paper, we will focus only on the experiment itself and its results. The process of iterative shape selection and the results obtained from this experiment will be first described before we comment and conclude on the properties of non-linearity and non-convergence found in this applied neuro-selection system.

LE CUBE D'APRÈS: PROCESS

Prior to starting on fully applying the principle of augmented iterations on the creation of shapes of progressively higher complexity and the use of evolutionary algorithms, we studied a preliminary step of fast neuronal selection of shapes among several possible designs. More precisely, the aim was to implement the previously defined BCI system (Figure 2) to observe and determine if, under a predefined criteria and narrowed visual context, the neuro-selection of shapes would converge in a noticeable optimum of relevance.



3 P300 Map, top view of the cranium. Locations of sensors that are relevant to identify a P300 in EEG signals. Based on the 10-20 international system (Homan et al. 1987)

4 Le Cube d'Après, Implemented BCI from previously defined system, installation for the MiniMax Exhibition, Lebenson Gallery, Paris 2013. Curated by Leslie Ware

For this system, as for our previous work, since we aim at recognizing an event related and endogeneous potential called the *P300* and involved in the manifestation of the cognitive decision process, the sensor locations on the cranium would be Fz, Cz, P3, Pz, P4, PO7, PO8 and Oz (Figure 3). We then combined a pre-developed software ecosystem composed of OpenVIBE[2] for BCI design, Processing[3] for shape generation, display and iteration as well as a data transfer protocol called VRPN.[4] Concerning the Electro-Encephalographic signals acquired from the neural activity of the brain (EEG signals), we relied on post-treatment algorithms already available such as xDawn and learning systems which go beyond the scope of this paper (Congedo et al. 2011; Rivet et al. 2009; Bashashanti et al. 2007; Blankertz et al. 2008). In this experiment, we did not discriminate the automatic detection of novelty (a P3a signal) from the volitional target detection (a p3b signal), both being considered here as the P300 signal. A custom adjustment has been made as well on the acquisition device which was carrying fourteen eeg channels (standard eMotiv headset) (Figure 4) but had default positions on the cranium which needed to be rerouted to reach the occipital region of the brain where the spatial amplitude distribution of the signal is the strongest and is symmetrical around the central location Cz (Figure 3). The classification training and detection method used for the treatment and analysis of the signal was the "oddball paradigm" (Squires et al. 1975).

Since the overall aim of this research is to implement a closer loop to real-time responses with intricate visual contexts for generative designs, we chose first to study a short time period (one month) and test on a single person the evolution of the neuro-selection of a culturally and scientifically well defined and simple shape: a cube. The visual stimuli system was designed as follows: a cube, which vertices were constantly highlighted and graphically differentiated, was centered in the computer screen and discretized into a closed triangular mesh of uniform resolution supporting a uniform particle spring system (Figure 5). This mesh was then subjected to a sinusoidal cycle of radial forces, inflating and deflating the mesh. Along this continuous cycle, the eight vertices were randomly moved to provide a random deformation of the preliminary cube in opposition to the redundant cycle of inflation (Figure 6).

FIRST RESULTS

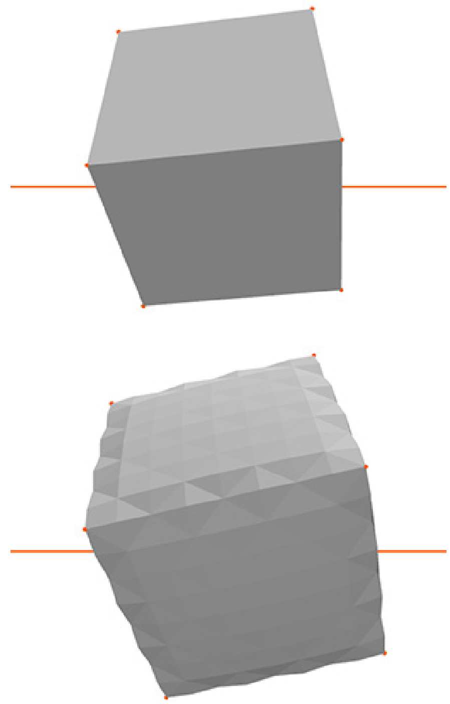
Subjected to a rapid flow of variations, a single and recurrent user (with whom preliminary training and fine-tuning of neuro-signals post-treatment has been made) was asked to focus on the single task of identifying a moment, in this deformation cycle, the appearance of a "relevant" cube; the notion of relevance being left to the appreciation of the user and its eventual evolution through the progression of this experiment. After a few minutes of letting the user get comfortable with the process, and as soon as a P300 (P3a or P3b) signal was detected from the EEG signals, the corresponding deformed shape was frozen and stored for later observation and comparison. At the end of the total acquisition process, all selected shapes were gathered in a grid for mutual comparisons (Figure 7).

When individually observed, none of the selected shapes would make sense in terms of identifiable similarities to a cube, for example, its geometrical properties (congruence, isometry, etc). But as they were gathered, a recognizable pattern could be observed in the recurrence of approximating symmetrical arrangements and low angular deformations of the mesh. Far from trying to follow trends of neuropsychology and the gestalt in an eventual reordering or grouping of form recognitions and shape grammars, we rather pursued on a more critical aspect that these results demonstrated: the non-linearity and non-convergent properties of human cognition submitted to a rapid flow of varying visual stimuli under short periods (Figure 8) and when both cognitive capacities of novelty detection and discrimination of odd events were tracked in the neural activity (Polich 2007; Soltni et al. 2000).

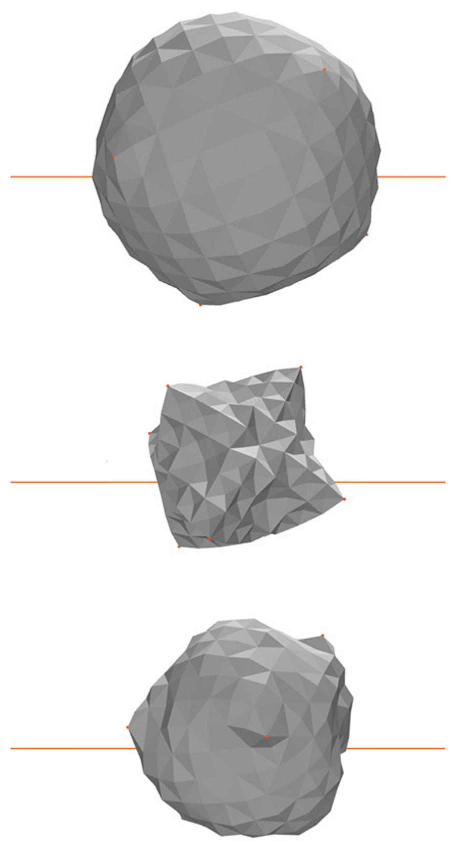
A CONCLUSION, NEW HYPOTHESIS

As mentioned previously, such an integrative approach allows for merging both human and computer performances for cognition and calculus. But its impact on a generative design process and the linearity dilemma it carries through iterations, whether or not an ordering model is used (bottom-up, top-to-bottom, middle-out) are critical aspects of this research. Since we considered the brain as the primary synthesis center of human cognition of physio-psychological and cultural phenomena, its implementation in an iterative selection process carries a higher degree of multi-criteria selection than a usual mechanic optimization and/or learning system. Therefore, such a process can neither complete a deterministic nor stochastic model in terms of an optimization or prediction process. The unquantifiable amount of criteria gathered by the human brain for cognitive tasks, as well as the cognitive process itself and its performances being different from one individual to the other, cannot take part in a converging or predictive design process and leads to potentials of open adaptation in design simulation and integration of complex models and shapes.

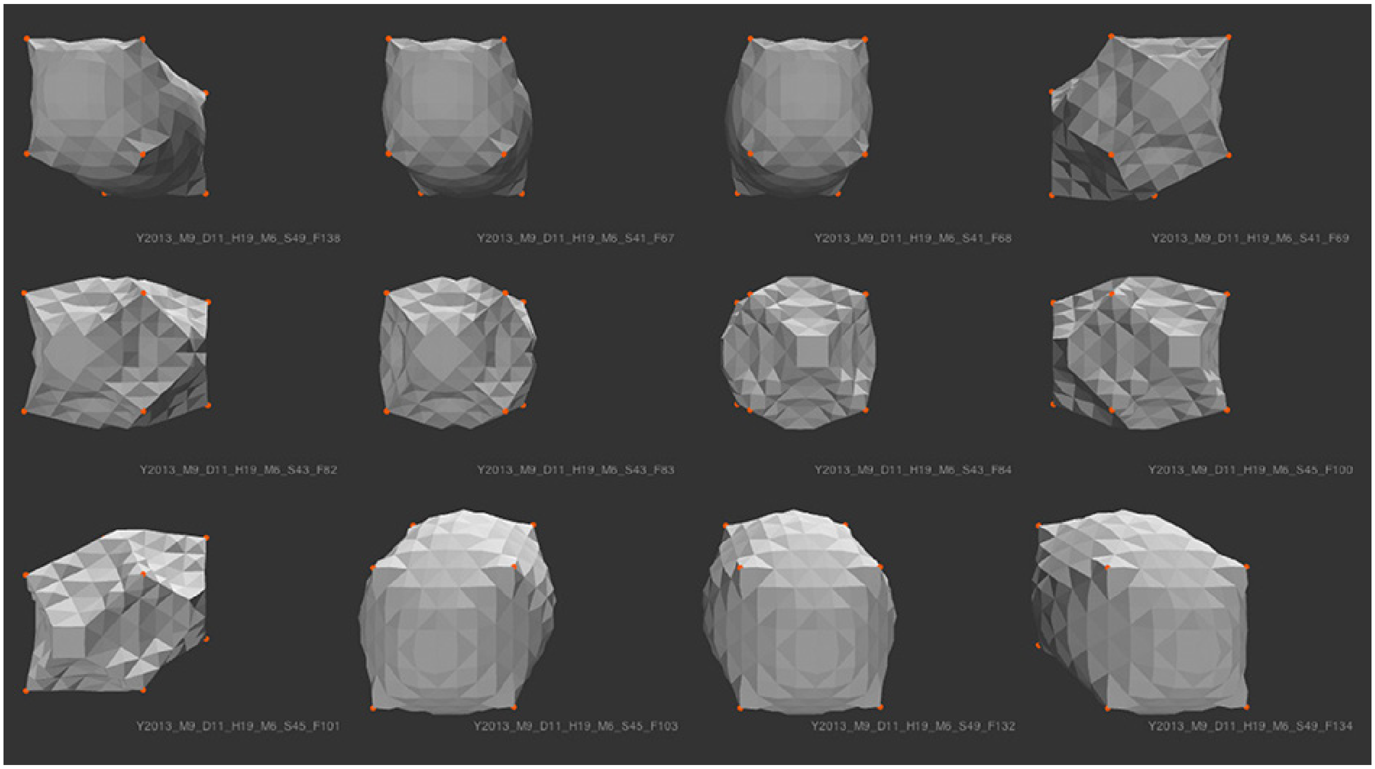
Broader studies in neuroscience have proven that the plasticity and learning capacities of the human brain can be used for convergent and optimization systems, as long as a training period can be implemented on a longer term (Vidal 1973). But this non-converging principle is a hypothesis of research, which will be actively exploited during the next study for collective human computation and distribution of generative designs. Another important aspect of the aforementioned process is its lack of scalar and formal foundation. Working as a heuristic and non-totalistic graft within any generative designs involving an iterative process which could be graphically expressed and conditioned as a fluent flow of visual stimuli, the integrated cognition for generative design would suspend the model itself in a synchronous rearrangement with the constant evolution of the human brain and its technological artifacts.



5 Le Cube d'Après, the cube in its primary state (left) and its discretization in a spring-particle system (right)



6 Le Cube d'Après, the mesh, inflating (left) and deflating (center), combined with random deformations led by the cube vertices (right)



7 Le Cube d'Après, comparative animated grid of some of the neuro-selected shapes relevant to the recognition of a cube over a month period

ACKNOWLEDGEMENTS

We particularly would like to emphasize that this paper can only take place in, and be understood as, a broad and transdisciplinary collaboration. In that aspect, we would like to particularly thank Fabien Lotte and Aurelien Van Langenhove for their scientific and technical collaborations, Leslie Ware for her active support in promoting innovative design approaches and Christian Girard and Philippe Morel for constantly encouraging such initiatives.

NOTES

1. Horizons GE 2014, "Metascan 3." http://www.horizons.gc.ca/

2. Openvibe Software. http://openvibe.inria.fr/

3. Processing Software. http://processing.org/

4. VRPN. http://www.cs.unc.edu/Research/vrpn/index/html

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8 Le Cube d'Après, from left to right, five selected shapes from the neuro-selected ones equally picked over the month period of acquisition and demonstrating the non-linearity or non-convergence of the human cognition under the defined process. 3D printed alumide and plywood

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IMAGE CREDITS

Figure 1–8. The Computational Monkeys (2013–2014) Le Cube d'Après.

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